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Versatile Production in a Variable Climate

28th Annual Conference
of the Grassland Society of NSW Inc.

28th Annual Conference

Inverell 2014

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THE GRASSLAND SOCIETY OF NSW INC.

Versatile Production in a Variable Climate

Proceedings of the 28th Annual Conference of the Grassland Society of NSW Inc.

Inverell RSM Club, Inverell July 22-24 2014

Edited by Carol Harris

28th Annual Conference

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.

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Contents

Preface

On behalf of the Grassland Society of NSW Inc, it gives me great pleasure to extend a very warm welcome to all members and non-members attending this, the 28th Annual Conference, of our society. In 2013, the Grassland Society of NSW Inc decided not to hold its annual conference, as there was an equally significant event being held by the International Grassland Congress in Sydney at a similar time. That conference was a great success, as we are expecting of this years' conference at Inverell.

This is the first time Inverell has hosted our conference and we look forward to enjoying their hospitality and meeting many locals. Our society deems the sharing of our conference locations as a very strong attribute of the society, trying to distribute the current research and extension work as widely as we can. In recent years, the Grassland Society of NSW Inc has been chartered with convening the 'Pasture Updates', an MLA funded extension activity providing similar content in a one day workshop. These too have proven to be a great success, allowing many more participants to be reached on an annual basis.

With NSW having such a diverse range of pasture production systems and regions, it seems inevitable that not everyone is 'getting a season' all at the same time. That is particularly true of this year. Seasonal conditions this year in the south of the state are some of the best seen in many years, while the north and North West are possibly in some of their driest times. Sadly, winter is only just upon us in these less fortunate areas, and hand feeding will be required for many weeks yet. Our thoughts are with those who are doing it tough. Your turn will come, and hopefully new knowledge can assist in production fortunes when things do turn around.

All of us are aware that change happens. Whether it be the seasons, climate, market conditions, whatever, it is critical that we make the effort, however, big that is, to expose ourselves to what researchers, consultants, agronomists and other producers have to offer. Implementing new ideas may not be possible instantly, but just hearing and seeing new things often challenges us. "Would that work at home", or "I wonder if ...", for example, are often questions people ask themselves having seen or heard of what successes others have had.

The conference this year, with its' theme 'Versatile Production in a Variable Climate' will directly challenge us all. Many presentations will cover lots of attributes of the plant / animal production systems, which will then be fully complemented by the bus tours available.

I encourage everyone to ask all the questions they can. Everyone hopefully learns something from everything they do, be it good or bad, and it is only through those learning experiences that others can learn more and improve.

An integral part of our society are our sponsors. They continue to provide great assistance, either financially or in kind, and it is through much of their involvement that many of the society's activities can be conducted. I am fully aware that the commercial world is getting tougher, with the same conditions being experienced by many on their own properties. To those sponsors of our society for the 2014/2015 year, I would sincerely like to thank each and every one of you for your contribution. We continue to pray for good seasons, and hope that you too can benefit when the time comes. I encourage all conference delegates to visit the commercial displays and take to time to talk with the representatives. Their product knowledge and other resources available may just be the key to some improvement you can achieve in your own business.

To the conference organising committee and convenor Carol Harris, thank you. Many hours of voluntary work has come together for all our benefit, and for that, we are grateful. You are to be congratulated on the great conference program, content, and tours you have delivered.

In encouraging any non-member delegates to consider joining our society and reap the year round rewards on offer, I wish all delegates in attendance the best for the conference; it is provided for your learning and enjoyment. Should you have any ideas, comments or concerns, I would encourage you to share them with any of the organising committee. Your feedback is always welcome and our society can only improve on the back of peoples' collective input.

Enjoy your time here,

David Harbison
President

Invited papers

Climate variability: history and future predictions –what are the implications for pasture production and management?

BR Cullen

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Abstract: *Climate variability has a large impact on the productivity, profitability and sustainability of grazing systems across the Australian continent, and projected climate change will present further challenges. Evidence is emerging that currently available management options can better adapt grazing systems to the negative impacts of warmer and drier climates projected for southern Australia. However, projections for changes in the frequency and intensity of extreme climate events, for example increasing drought and extreme daily rainfall, are likely to result in increasing seasonal and inter-annual climate variability. Rainfall scenarios characterised by longer dry periods interspersed with fewer, larger rainfall events highlight several challenges not well covered in previous research, including the impact on plant persistence and possible wet weather damage to pastures. With more climate variability, tactical decision making will be increasingly important to achieve productivity and sustainability goals. In this respect a modelling approach investigating the impact of soil water content on future pasture growth rates at two sites in New South Wales is described, showing some potential to predict pasture growth over future months. In future there is potential to link this approach to seasonal climate forecast systems to provide information on future pasture growth. Further development and evaluation of tools for managing climate variability in grazing systems is required but potential exists to improve the information available to producers.*

Keywords: soil water content, Sustainable Grazing Systems pasture model

Introduction

Climate variability has a large impact on agricultural production, rural livelihoods and sustainability of grazing systems (Ash *et al.* 2007). Farm managers need to make appropriate management decisions that take climate variability into account, in order to both reduce losses in the poor years and make the most of the good years. Seasonal and inter-annual variation in pasture growth rates is characteristic of Australian grazing systems. This poses significant challenges for livestock producers in both meeting the feed requirements of animals and maintaining the pasture in a productive state. These challenges are likely to increase in a changing climate.

In this paper, projections for future climate will be reviewed with an emphasis on projected changes in extreme climate events and climate variability. The implications of these changes in climate variability for pasture management will be discussed, including addressing some limitations of previous analysis and identifying tools to enhance adaptation to climate variability in the grazing industries.

Projections for changes in extreme climate events and climate variability

Climatic change impact analyses of agricultural systems have mainly focussed on the long term changes to average climate of a region (e.g. Cullen *et al.* 2009). Across Australia there is consistency in projections for warmer temperatures, but projections for rainfall change are less certain. In southern Australia a drying trend is projected, but the projections in northern Australia are less clear. However, in addition to these projections for long term changes in average climate, changes in the frequency and intensity of extreme climate events are also considered likely. The 'State of the Climate 2014' (http://www.csiro.au/Outcomes/Climate/Understanding/State-of-the-Climate-2014, accessed 28 June 2014) report lists the following possible changes in extreme climate events:

- Temperatures are projected to increase with more hot days and fewer cool days across the Australian continent.
- Average annual rainfall is projected to decrease in southern Australia, with an increase in drought frequency and severity.
- Average annual rainfall projections for northern Australia are uncertain.
- The frequency and intensity of extreme daily rainfall is projected to increase in most regions across Australia.
- The number of days with extreme fire weather risk is projected to increase, with a longer fire season in southern Australia.
- A potential decrease in number of cyclones is projected, but cyclone intensity is projected to increase.

There is a high degree of certainty about projections for temperature, but projections for rainfall change are less certain. At the current time, it is not possible to be precise about the magnitude of the changes in frequency and intensity of extreme events. Nevertheless, these projections suggest that farmers should expect a greater frequency and intensity of extreme climate events leading to a more variable climate. The implications are potentially large, changes in rainfall patterns to include increased severity of drought occurring with increased frequency means that there will be a higher probability of having poor seasonal conditions in successive years. This will have implications for pasture persistence and recovery of grasslands, as well as for farming business performance more generally. Managing systems to adapt to an increasingly variable climate will clearly be a significant challenge.

Impacts of, and adaptation to, climate change and variability

To date, analysis of climate change impacts on grazing systems have focussed on long term changes to average monthly or seasonal temperature and rainfall without explicitly considering the possible changes in climate variability. This work has shown that in the temperate and Mediterranean regions of southern Australia, warming and drying climate trends will result in higher pasture growth rates in winter and early spring but there will be a contraction of the spring growing season (Cullen *et al*. 2009). This work showed that pasture production in regions with high rainfall, cool temperate climates may benefit from warmer and drier climate scenarios, but warmer temperate and Mediterranean regions are likely to be negatively impacted. More recently, Moore and Ghahramani (2013a) demonstrated that the regions in southern Australian with lower rainfall will be more severely impacted by climatic change than those with higher rainfall. In northern Australia, large uncertainties in rainfall projections make prediction of future trends in rangeland production difficult but it is not likely to be as severely affected as southern Australia (McKeon *et al.* 2009).

Recent work has begun to focus on how grazing systems can adapt to reduce the impact of climate change. Cullen *et al*. (2012) demonstrated that pasture systems which currently contain a mix of C3 and C4 species will be more resistant to projected climate changes than pastures based on C3 species alone. This occurs because the more heat tolerant and water use efficient C4 species extend their growing season in warmer climates. While this aids total dry matter production, forage quality may be negatively impacted. Moore and Ghahramani (2013b) have shown that using combinations of pasture management and livestock improvement options have potential to offset some of the impact of climate change by better adapting the system to future environments. Examples of adaptation options include increasing soil fertility, introducing summer-active pastures (e.g. lucerne, *Medicago sativa*) and continuing genetic gain in livestock. While these results are encouraging, they indicate that there is no single option to manage climate change but that combinations of adaptation options will be required to overcome some of the negative impacts. Two issues that have not been explicitly evaluated in climate change impact analysis are pasture persistence due to drought and wet weather damage to pastures caused by inundation or pugging by livestock. One of the main reasons for this is that the biophysical models used to analyse climate variability and change are not capable of simulating pasture persistence. However, projections for changes in drought and extreme daily rainfall are likely to result in climate patterns with longer dry spells interspersed with larger rainfall events. This suggests that pasture management challenges associated with dry and wet weather may increase.

There is a need to develop processes that better account for persistence and wet weather damage to pastures to better account for these effects in climate change analysis. For example, recent research in a temperate agricultural region in the northern hemisphere demonstrated a relationship between the spring-summer water deficit (rainfall minus potential evapotranspiration (PET)) and tiller survival, with tiller death in temperate cocksfoot (*Dactylis glomerata*) cultivar commencing at a deficit of 400 mm (Poirier *et al*. 2012). The applicability of this cumulative water deficit to estimating persistence of perennial ryegrass (*Lolium perenne*) in dairy regions of south eastern Australia has been examined, showing potential to estimate the effects of climate variability and change on pasture persistence and re-sowing rates. Results highlight that relatively moderate changes in climate may have large effects on persistence of temperate grasses such as perennial ryegrass.

Pasture species selection will need to consider the traits for pastures that will be better adapted in warmer and more variable climates. Persistence will be a key issue, and traits like summer dormancy will be important (Nie and Norton 2009), but the species must also be productive in these conditions. Recent research by Cullen *et al*. (2014) indicates that selecting plants with deeper roots, the ability to grow at higher temperatures, and that can respond more to elevated carbon dioxide concentrations in the atmosphere will help to overcome the negative effects of warmer and drier climates in southern Australia. These results also indicated that different traits are important in different regions, and understanding the genotype by environment interactions will be important to select the appropriate plants for each region.

Approaches to manage climate variability

Variation in rainfall, or more precisely soil water content (SWC), is the major cause of seasonal and inter-annual pasture growth rate variability. Tools and technologies that use SWC to predict future pasture growth rates may be useful to manage variation over coming months by informing decisions about stocking rates, livestock selling policies and/or supplementary feeding requirements. Decision support tools predict pasture growth rates and seasonal climate forecasting systems are two technologies that may be of use in this respect.

Predicting pasture growth rate based on soil water content

In cropping systems, tools like 'Yield Prophet' have been developed to assess seasonal climate risk (Hochman *et al.* 2009). The 'Yield Prophet' tool utilises knowledge of soil moisture and nitrogen status to improve decision making for grain growers, for example in deciding how much nitrogen to apply. There has been little comparable evaluation and tool development for the grazing industries even though the biophysical models, including Grassgro and the Sustainable Grazing Systems (SGS) Pasture model, can offer insights into the relationships between climate and farm management decisions in livestock production systems.

A pilot study by Cullen and Johnson (2012a) demonstrated potential to forecast future pasture growth rates based on SWC using the SGS Pasture model (Johnson *et al*. 2003; 2008). The general approach used in this study was to simulate the influence of low, medium or high SWC on the first day of each month on pasture growth rates over the following 12 months using historical climate data at each site. The three starting SWC starting conditions were prescribed in relation to field capacity and wilting point of the soil, with high SWC equal to field capacity, low SWC equal to wilting point, and medium SWC at the mid-point between field capacity and wilting point. The pasture growth projections based on SWC were assessed in terms of their effects on monthly average pasture growth rates, how many months the effect persists for, and the reliability of the projections. In this case reliability was calculated as the percentage of years that the pasture growth rate projection was above the long-term median monthly pasture growth rate for the site was used, with 70% accuracy deemed to indicate a useful level of reliability. Further details of the method used are available in Cullen and Johnson (2012a, b).

Simulations were conducted at 12 sites across southern Australia. Overall results indicated that knowledge of SWC can, at least for some times in the year, give valuable information about future pasture growth. For example, considering a mixed native grass pasture at Moree in northern New South Wales, high SWC in the months autumn (April) indicated above median pasture growth rates during the following 4 months (Fig 1a). High SWC in September indicated above median pasture growth rates for the following two months (Fig 1b). Similar results were modelled for a phalaris (Phalaris aquatica) based pasture at Wagga Wagga (Fig 2). Both of these examples highlight that pasture growth rates can be very different to the median growth rate for the region based on the availability of soil moisture.

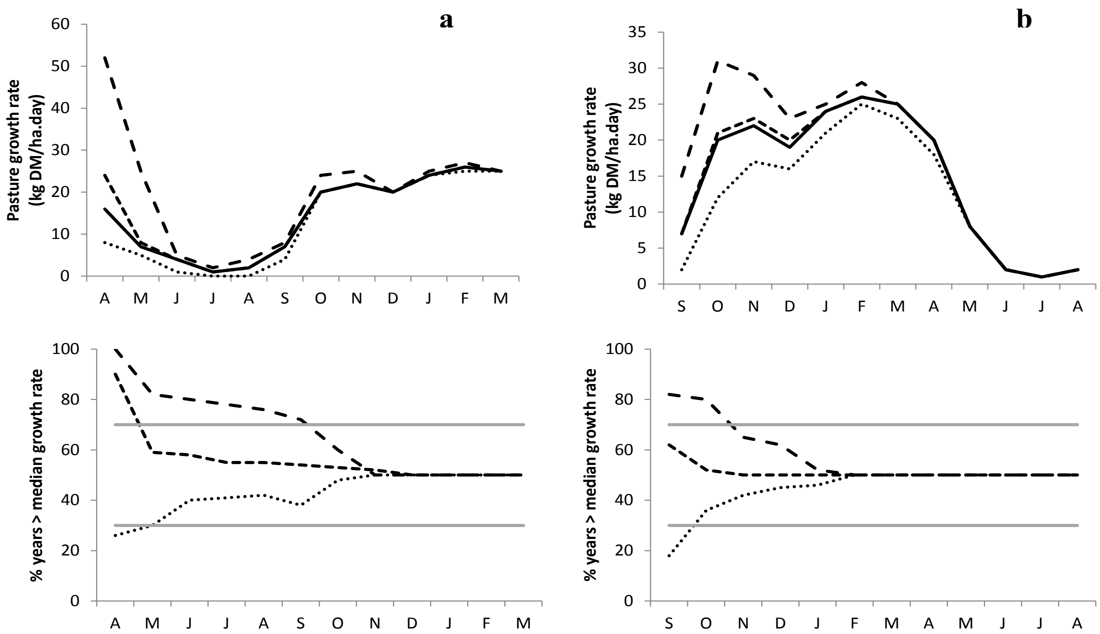

Figure 1. Effect of High (long dashed line), Mid (short dashed line) and Low (dotted line) SWC at the beginning of (a) April and (b) September on simulated average monthly pasture growth rate (kg DM/ha.day) compared to the long-term median growth rate (solid line; top panel), and the percentage of years in each SWC category predicted above the long-term median (bottom panel) for a mixed native pasture containing both C3 and C4 native grasses at Moree, New South Wales.

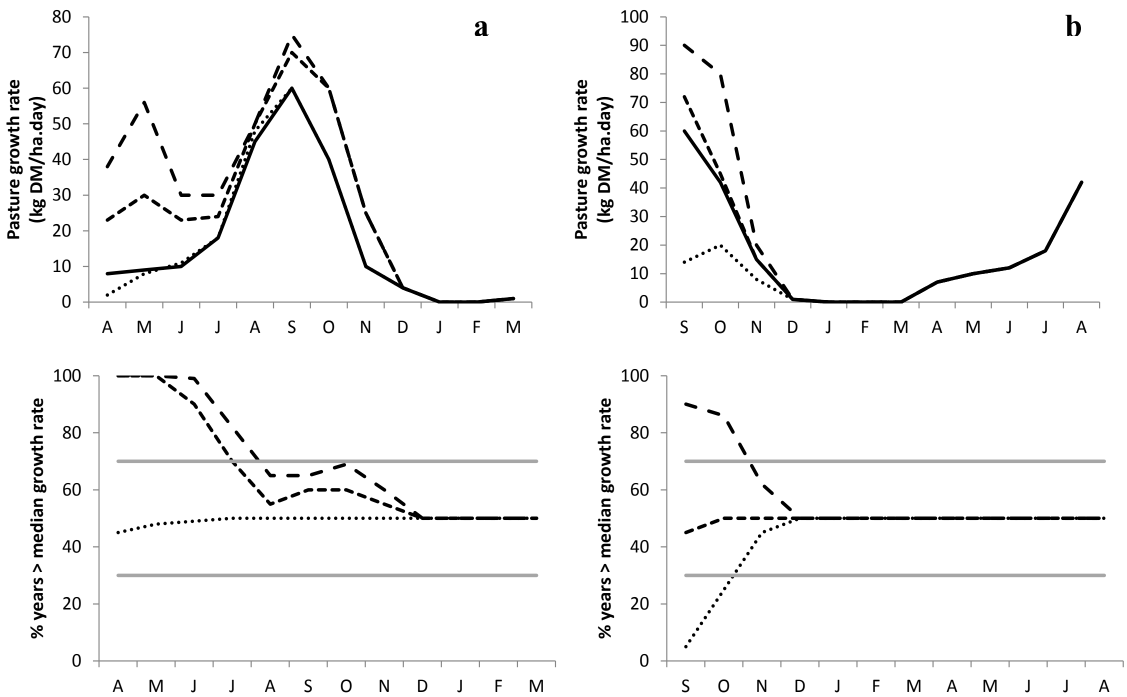

Figure 2. Effect of High (long dashed line), Mid (short dashed line) and Low (dotted line) SWC at the beginning of (a) April and (b) September on simulated average monthly pasture growth rate (kg DM/ha.day) compared to the long-term median growth rate (solid line; top panel), and the percentage of years in each SWC category predicted above the long-term median (bottom panel) for a phalaris and subterranean clover pasture at Wagga Wagga, New South Wales.

Across the other sites modelled in southern Australia, there were considerable differences between sites and pasture systems in the times of year when pasture growth projections based on SWC were useful (Cullen and Johnson 2012a). The results need to be interpreted on a case-by-case basis and an understanding of the seasonal pattern of pasture growth variability is integral to making use of these projections. Despite this, some general patterns were observed for regions and pasture types:

1. At the winter-dominant rainfall sites with temperate pasture types (i.e. ryegrass or phalaris pastures) there was potential to predict pasture growth rates in autumn and spring which are the two times of highest variability. In particular, high SWC in March or April indicates above median pasture growth rates over the following 1-5 months, while low or high SWC in spring indicates below or above average pasture growth rates for 1-2 months. These effects were more pronounced at the lower rainfall sites than at the higher rainfall sites.

2. At the summer-dominant rainfall sites with summer-growing pasture types (i.e. native, kikuyu or Rhodes grass pastures) at most times of year, high, and to a lesser extent medium, SWC indicates higher pasture growth rates for up to 9 months. Again, these effects were more pronounced at the lower rainfall sites than at the higher rainfall sites.

3. At the summer-dominant rainfall sites with winter-growing pasture types (i.e. ryegrass or tall fescue pastures) there was less influence of SWC compared to the summer-growing pastures types.

Taken together these results indicate potential to predict pasture growth rates based on knowledge of the SWC at key times of variation in pasture production across southern Australia. Further research is needed to define the value of these forecasts in farm management.

Seasonal climate forecast

Future increases in skill of seasonal forecasting systems are likely to come from dynamic modelling of climate rather than statistical approaches such as the Southern Oscillation Index (Ash et al. 2007). POAMA (Predictive Ocean Atmosphere Model for Australia) is a dynamic climate model developed by the Bureau of Meteorology that provides seasonal climate forecasts for Australia. The skill of POAMA seasonal rainfall forecasts varies by region and time of year. Analyses of the accuracy of POAMA seasonal forecast for rainfall indicate that accuracy is generally better in the south-east of Australia as compared to south-west of the continent. Forecast skill is better in autumn and spring, as compared to winter and summer. However, the seasonal forecast skill does not regularly exceed the threshold of 70% accuracy, generally accepted as the minimum skill required before farmers will make a decision based on a forecast. However POAMA forecast skill is being improved and further investigation of its role will likely be warranted in the future. Pasture growth rate predictions should utilise both knowledge of current SWC and seasonal forecast information.

Conclusions

Climate variability has a substantial impact on grazing systems and climate projections for increasing frequency and intensity of extreme weather events are likely to make the climate more variable. Of particular importance are projections for increases in droughts and in extreme daily rainfall events. Tactical management of climate variability in grazing systems will be increasingly important. Potential exists to use knowledge of soil water content to predict future pasture growth rates to reduce the uncertainty associated to variation in pasture production over coming months, and improve decision making. Future research priorities must also consider climate variability and change in association with other sources of variation for farm businesses, including cost and prices, to develop strategies that will be more resilient in the future.

Acknowledgements

The work in this paper detailing the pasture growth forecasting based on soil water content was funded by Meat and Livestock Australia.

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Key messages from EverGraze research in northern NSW

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Abstract: *Field research was conducted during 2006−14 to find solutions to a range of issues identified as being important to the profitability and natural resource outcomes of grazing enterprises in northern NSW, where the climate is highly variable. On-farm monitoring showed all native perennial grass-based pastures had available green herbage mass below the minimum benchmark levels in the critical period for spring lambing ewes of June to September. High weaning percentages (increase from 70 to >110%) were achieved by integrating forage sources such as oats, lucerne or tropical grasses into the forage base, or providing protein and energy supplements at key times. Adjusting stocking rates on at least a seasonal or monthly basis in relation to available pasture increased pasture utilisation and reduced requirements for supplementary feed. Pastures with a mixture of lucerne and tropical perennial grass increased total dry matter production and spread its distribution more evenly through the year, compared with pure native grass swards, thereby reducing feed gaps and providing greater resilience in variable seasons, while helping to conserve natural resources on farm. Opportunities for improved natural resources outcomes were identified by documenting that conservation of Box–Gum grassy woodlands in this area is likely to be best achieved through on-farm management of high quality remnant patches. Considerations were discussed for putting these key messages into practice on-farm.*

Key words: tropical perennial grass, legume, ground cover, runoff, erosion, biodiversity.

Introduction

EverGraze was a national research, development and extension program conducted in northern NSW during the period 2006–14. The program developed grazing systems based on perennial species, which aimed to increase profitability of livestock enterprises and at the same time improve natural resource capital in the high rainfall zone of southern Australia. There were six regional research sites stretching from Western Australia, through Victoria to New South Wales (NSW) (Friend *et al.* 2007).

To achieve this goal in northern NSW, a multi-disciplinary research team tackled the problem of how best to integrate the on-farm use of native and sown pasture species, forage crops and supplements to get higher levels of sheep production (Lodge *et al.* 2008). Livestock producers are faced with the challenge of growing sufficient quantity and quality of forage for their livestock enterprise in a landscape that has a variable climate and rainfall pattern. The program operated at the whole-farm level and undertook a wide variety of studies that focused on; developing strategies for graziers to manage the variable climate and its associated impacts on forage supply to meet animal requirements; the development and potential of lucerne-grass mixtures for improving ground cover and spreading feed supply throughout the year; and the options for improving on-farm conservation of plant species diversity.

Findings from individual studies were reported previously, including; benchmarks for livestock production (Lodge 2011*a*), on-farm monitoring of pasture and livestock condition (Lodge *et al.* 2011), integrating forage sources to achieve year-round feed supply (Murphy *et al.* 2010*b*), impact of climate variability on forage supply and animal performance (Lodge and McCormick 2010), development of lucerne-grass mixtures (Boschma *et al.* 2010), field testing of lucerne-grass mixtures (Murphy *et al.* 2014), and on-farm studies of biodiversity (Schultz 2013, Schultz *et al.* 2014*a* and *b*). The intent of this paper is to synthesize the conclusions of these studies into a set of key messages useful for graziers in northern NSW and further afield, to improve the productivity and natural resource capital of their enterprises and farms.

Background

Region

The northern NSW EverGraze region was a diverse agricultural area with a summer dominant rainfall distribution. The region comprised the North-West Slopes and Northern Tablelands areas, bounded to the east by the crest of the Great Dividing Range and to the west by the Newell Highway with a combined area of 74,125 km^2.

Typical farms in this region averaged around 1140 ha with unimproved native grass and timbered country occupying around one third (34%) of property area (Lodge 2011*b*). Surveys of graziers and agronomists revealed that major limitations to increasing farm profitability and natural resource capital were a variable feed supply, drought and climate variability. Common on-farm practices to improve profitability were to increase legume content, sow perennial grasses, and apply additional fertilizer (Lodge 2011*b*). However, on-farm challenges common to many producers included maintaining ground cover, lack of perennial species and soil erosion (Lodge 2011*b*). Lucerne (*Medicago sativa*), while being the most commonly sown temperate perennial legume in our region (~5% of farm area on average, Lodge 2011*a*), can develop low ground cover thereby increasing risk of runoff and soil erosion, and expose cattle producers to risk of livestock losses through bloat.

The wheat–sheep belt of NSW is a productive agricultural region, however, it is also a region in which native vegetation has been fragmented, degraded or lost. Appropriate management of the remaining native vegetation on farms, while still maintaining the most productive areas for driving profitability, is vital for the conservation of biodiversity in these landscapes. A challenge is to assist producers to identify on-farm areas that may be suitable for conservation.

Variable climate

Climatically, the area was classified as subhumid with a summer dominant rainfall distribution. The wettest months are December and January and the driest, April, May and August (Figure 1). Sixty-percent of total rainfall occurs from November to March, but rainfall effectiveness during that period is low due to high evaporation rates and losses through surface runoff (Murphy *et al.* 2010*a*). Rainfall effectiveness is greater during winter (50-55% of rainfall is stored) compared with summer (25% is stored), which means winter rainfall is important for replenishment of reserves of stored soil water (Figure 1, Murphy *et al.* 2010*a*).

Average rainfall values are useful for explaining the general limits on pasture production and livestock enterprises, but variability of rainfall both between seasons and between years is a key feature of this region. Production levels in rain fed pasture systems are directly correlated with the timing and amount of available soil water and the efficiency of its use. Therefore, rainfall variability is a fundamental risk, which producers need to understand and include in their management.

Analyses of short- and long-term monthly and annual rainfall data for sites in northern NSW (Warialda, Barraba, and Tamworth) indicated that since 2000, rainfall in autumn has been substantially lower, and spring-early summer has been substantially wetter compared with the long-term mean (Lodge and McCormick 2010). These weather patterns have profound implications for livestock production, since adequate May rainfall is required for the germination of annual, winter-growing legumes and late sown cereal forage crops, while November–December is a critical period for seed production of annual legumes, sowing and establishing tropical perennial grass pastures and the growth of summer-growing native perennial grasses. However, there is little documented information in this region on past climate variability and its likely effect on animal production.

Native perennial grass pastures

Native pastures in the region are dominated by summer-growing perennial grasses (e.g. redgrass *Bothriochloa macra*, Queensland bluegrass *Dichanthium sericeum* and wiregrass *Aristida ramosa*) and much has been written on their forage value and their limitations in meeting animal requirements (e.g. Lodge *et al.* 1991). In most years, the summer-growing perennials provide mainly low quality feed, suitable for stock maintenance rather than fattening. Summer growing grasses can produce 6-8 t DM/ha of feed in their growing season, but with frosting and low stocking rates, much of this carries over from autumn to winter to spring as dead standing material (Lodge and Roberts 1979). The main value of this dead standing material is as a 'paddock haystack' that can be utilised

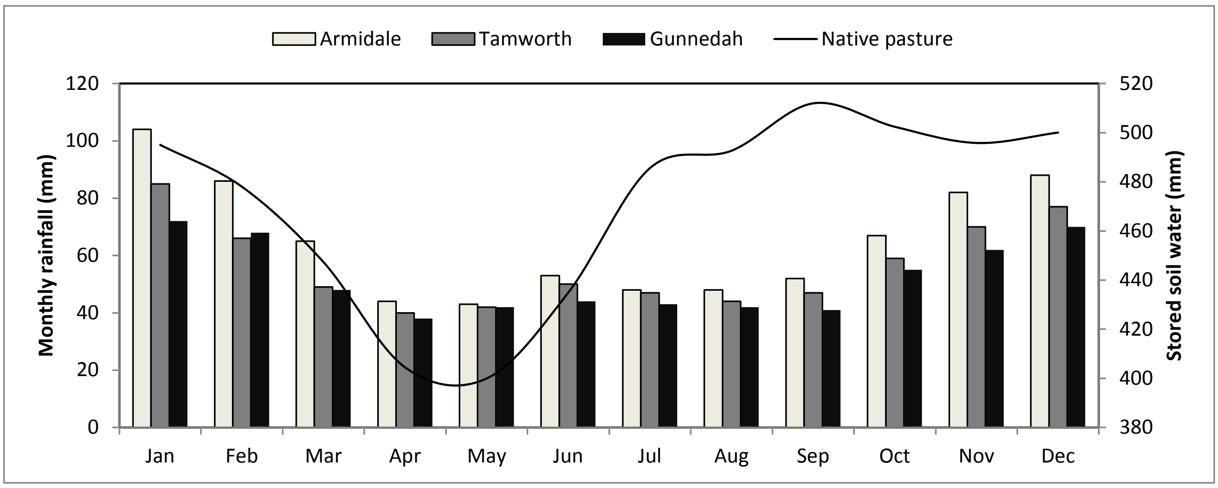

Figure 1. Distribution of monthly rainfall for three centres on the Tablelands and North-West Slopes and trend in total stored soil water for native pasture at Gowrie, near Tamworth.

with supplementation in drought and dry times, however, in the following spring it can reduce regrowth. This limits both stocking rate and the stock type that can be grazed on these pastures with dry sheep for wool production and store cattle being the most common enterprises. Current management of native pastures tends to be *ad-hoc*. Many producers in the region are seeking answers about how to best manage their native pastures and how to integrate their use with other forage sources in order to raise weaning percentages.

Livestock systems

A wide range of livestock enterprises (both cattle and sheep) are run on properties with breeding programs timed to take advantage of the increasing feed supply in spring and summer. Average stocking rates are 3.3 dry sheep equivalents (DSE) per ha, ranging from 1-2 DSE/ha on unfertilised country to 6-8 DSE/ha for fertilised native pasture oversown with subterranean clover (*Trifolium subterraneum)* and 10-12 DSE/ha for lucerne (*Medicago sativa*) and sown perennial grass-based pastures. Many properties have small areas sown to other forage sources such as improved pastures (tropical or temperate grasses), lucerne and forage crops (winter or summer).

Native pastures are generally not suited to livestock enterprises that involve fattening or breeding, yet about one-third of surveyed graziers produced lambs solely from native perennial grass-based pastures that did not receive any fertiliser or legume inputs with little or no supplementation provided (Lodge 2011*b*). However, it is known that animal demand is not likely to be fulfilled by this feed supply in terms of either quantity or quality. Based on forage quality and seasonal growth rates for both winter and summer growing native perennial grasses, most native pastures cannot meet the digestibility, protein and energy requirements of breeding livestock.

Further, ProGraze pasture benchmarks (Graham 2011) for the minimum green herbage mass (68% digestibility) required to maintain satisfactory production levels in a spring-lambing self-replacing Merino enterprise clearly indicate that most native perennial grass pastures fail to supply the required metabolisable energy (ME, MJ/kg DM), particularly in winter-early spring. By integrating native pastures with a variety of other forages, total ME supplied can be increased to be greater than that required by livestock for all months. For a productive self-replacing Merino enterprise the target values are 600 kg of green dry matter (DM)/ha for dry sheep, 700 kg DM/ha for ewes in mid-pregnancy, 1200 kg DM/ha for those in the last month of pregnancy and 1700 kg DM/ha for lactating ewes. For these benchmarks, pastures are assumed to have 500 kg DM/ha of dead material (47% digestibility) and a legume content of 15%. However, when green herbage drops to 60% digestibility it is not suitable for ewes in late pregnancy or for lactation.

Key Message 1 – Integrate native pastures

"*High weaning percentages for spring lambing ewes grazing native perennial grass based pastures on the North-West Slopes of NSW can be achieved by integrating forage sources such as oats, lucerne or tropical grasses into the forage base, or providing protein and energy supplements at key times*."

On-farm monitoring of pasture and livestock conditions

In both 2008 and 2009, sheep flocks on up to 15 commercial properties (18 properties over 2 years) on the North-West Slopes were monitored to gather on-farm data related to ewe production and pasture/forage systems (Lodge *et al.* 2011). The on-farm data were used to examine the relationship between green feed availability, ewe fat score and sheep enterprise performance. All sites were grazed by spring-lambing Merino ewes joined to either Merino or terminal sires. The composition of the feedbase varied from farm to farm, but for specific analyses was categorised into four key groups:

- poor native pasture (unfertilised, predominantly summer growing grasses such as redgrass and wiregrass, no supplementation used),
- good native pasture (a mixture of winter growing species, Wallaby grass *Rytidosperma* spp. and summer grasses, redgrass and Queensland bluegrass, fertiliser applied and legume oversown and/or supplementation used),
- poor native pasture, but with supplementation and lucerne available, and
- good native pasture, but with forage oats (*Avena fatua*) and lucerne available.

Pasture or forage paddocks that were grazed by a sheep flock were assessed every time the flock entered or was removed from the paddock. If animals remained in a paddock for an extended period, then samples were taken at 6 weekly intervals. At these times total herbage mass, the proportion of green (green herbage mass), the proportion of sown species, litter mass and ground cover were assessed (Lodge *et al*. 2011). Since native perennial grass pastures were the focus of the EverGraze project, these were the dominant pasture types sampled, together with lucerne and forage oats.

Data collected from individual sheep flocks (23 in 2008 and 21 in 2009) included weaning percentage (the number of lambs weaned as a proportion of the total number of ewes joined) and mean ewe fat score at critical reproductive stages (*vis*. joining, 100 days of pregnancy, pre-lambing, marking, and weaning). Fat scoring is a simple, objective measure to assess livestock condition and can be aligned with potential reproductive performance (White and Holst 2006).

Results and Findings

Native grass pastures did not meet benchmark levels of green dry matter for ewes during late pregnancy or during lactation. Ewes require adequate levels of green dry matter during late pregnancy to maximise lamb survival, ensuring adequate lamb birth-weight, and the ewe remains at the birth-site at lambing. During lactation, adequate green feed is required to meet lamb growth and development targets of the lamb while maintaining ewe condition prior to joining.

Poor native pastures failed to meet available green herbage mass benchmarks both in 2008 and 2009 (Lodge *et al.* 2011). The dry conditions combined with low temperatures in winter reduced the available green herbage mass of native pastures dominated by frost-sensitive summer growing grasses to generally <300 kg DM/ha in the critical June to September period. The resulting ewe fat scores were below the required benchmarks throughout these two years (e.g. Figure 2). Further examination of the data indicated that the required benchmark levels for green herbage mass for ewes in late pregnancy and lactation were never met by either the poor or good native grass pastures, and were only met by lucerne and forage oat paddocks on a few properties.

Ewes on native pastures had lower weaning percentages. Fat score data at each reproductive stage was compared against targets for flocks of ewes grazing pastures grouped into the four feedbase categories, illustrating increased weaning percentages when higher quality forages or supplementation were available. As a result of the inadequate green herbage mass, fat scores of ewes grazing poor native pastures were below minimum benchmarks for the entire duration of the reproductive cycle, and ewes grazing good native pastures were below benchmarks at joining and lambing. Those flocks recorded very poor lamb weaning percentages (70–82%, Figure 2). Where native pastures were integrated with lucerne, forage oats and/or adequate supplements, condition targets were met and flocks recorded higher weaning percentages (109–115%, Figure 2).

Achieving these targets requires that producers:

- are aware of the critical benchmarks for fat score, at critical reproductive stages,
- are aware of the Prograze critical benchmarks for green herbage mass,
- monitor fat score at each of the critical reproductive stages,
- monitor green herbage mass, and
- use fodder budgets to make decisions ahead of time for purchase of supplements, moving stock to a new paddock, trading stock or conserving fodder.

Putting the key message into practice

Results from the monitoring sites indicate that productivity gains can be made by meeting ewe fat score and green herbage mass targets throughout the reproduction cycle. A range of observations were made of management decisions taken by graziers across the on-farm monitoring program (Lodge 2011*b*). Leading producers with profitable enterprises tended to:

- have higher proportions of lucerne, forage oats (sown in late summer rather than autumn) and native pastures over-sown with subterranean clover and achieved up to 20% higher lambing and weaning percentages,
- restrict joining to a 6–8 week period,
- scan ewes at 80–90 days pregnancy to detect dry, single and multiple lamb bearing ewes, using this knowledge to make informed management decisions, and
- sell trade quality lambs (~45 kg liveweight) using contracts.

Key Message 2 – Variable climate needs a flexible approach

"*Adjusting stocking rates on at least a seasonal or monthly basis in response to available pasture will increase pasture utilisation and will reduce requirements for supplementary feeding.*"

Modelling utilisation and animal requirements

Climate variability and drought are common events in northern NSW and need to be considered in routine stocking rate decisions. In a native perennial grass-based pasture system, the effects of a variable climate can be managed with flexible grazing, and by integrating alternate forages (e.g. oats and lucerne) or providing adequate protein and energy supplements. The SGS Pasture Model (Johnson *et al.* 2003) was used in simulation studies of three different pasture and livestock systems to illustrate strategies that may be used to better handle climate variability in northern NSW and so provide insight for different pastures and livestock enterprises to increase profitability.

As northern NSW grazing systems commonly utilise a range of forage options, the animal types, grazing management practices, and forage options available within the SGS Pasture Model made it ideal to explore the likely impact of climate variability on animal production. In the model, animals were provided with supplementary feed if their ME intake from pasture declined to below levels that met 60% of their daily requirement for wethers or below 95% for lactating animals. Supplement was taken to be any other feed source, including pastures, forages, or feed mixes that provided the required amount of ME.

Results and findings

Flexible stocking reduces supplementary feeding.

Increasing the continuous grazed stocking rate from 2 to 4 to 8 wethers/ha caused the mean annual pasture intake

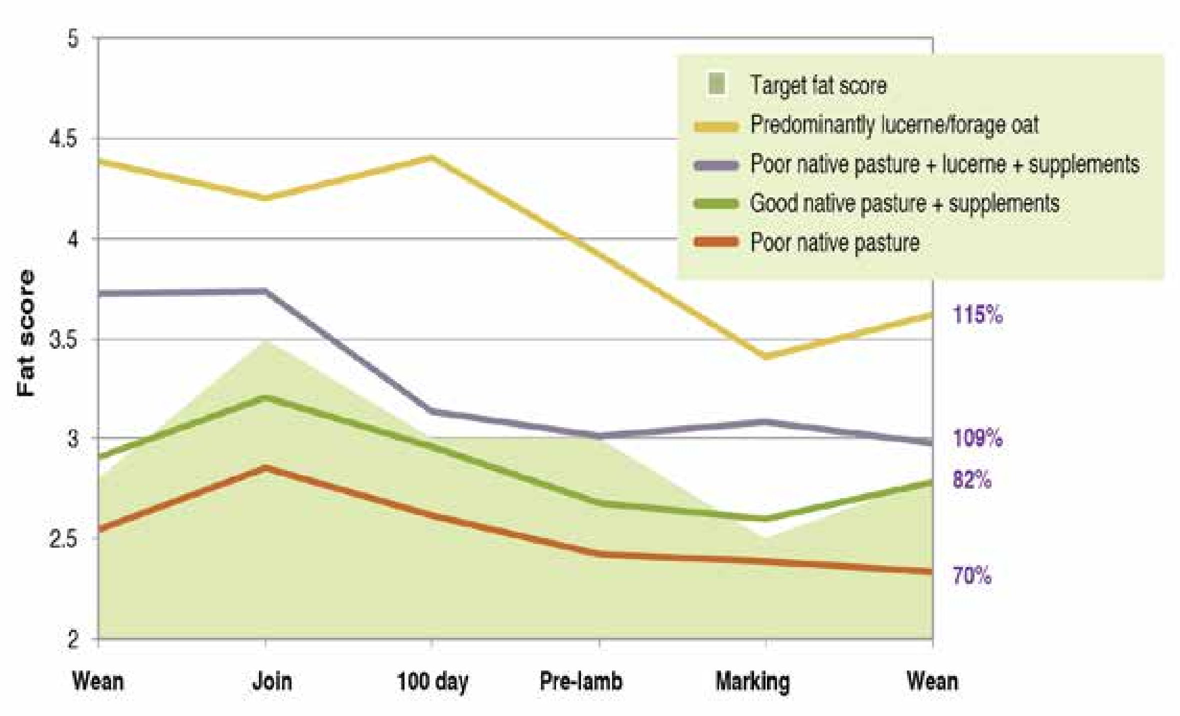

Figure 2. Actual (lines) and target fat score (FS grey shaded) of autumn-joined ewes over a 12 month period from weaning, grazing a range of pasture types on-farm in 2009. Final weaning percentage (%, RHS) is shown for each grouping.

to firstly increase from 0.69 to 0.82 t DM/ha/yr and then decline to 0.60 t DM/ha/yr. This caused the amount of supplement that was needed to almost exponentially increase from 0.05 to 2.0 t DM/ha/yr (Lodge and Johnson 2008). At the higher stocking rate, the percentage of total intake provided by the pasture was just 23% of total requirement, indicating that higher stocking rates are likely to be unsustainable.

Importantly, the simulation studies show that if stocking rates were adjusted monthly or seasonally in relation to available pasture, predicted pasture utilisation increased and supplementary feed requirements declined. These time-frames for adjusting stocking rate are feasible in practice and indicate that simple variable stocking rate strategies may be of considerable long-term benefit (Lodge and Johnson 2008).

Within a variable climate, a pasture with a broad mix of seasonal growth habits and perennial and annual species best met daily intake requirements of Merino ewes and lambs. The three pasture types modelled had markedly different production distributions for the proportion of total animal intake that was contributed by each pasture type (Lodge and McCormick 2010). This was related to the different growth habits of the species, that is:

- a perennial species monoculture – lucerne,
- a native perennial grass pasture – with summer and winter active grasses, and
- a fertilised mixture of perennial and annual species – native pasture plus subterranean clover.

The single pasture that best met the intake requirements of the Merino ewes rotationally grazing over a 100-year period of variable climate was the fertilised mixture of native pasture plus subterranean clover. With a variable climate this broad mix of seasonal growth habits and perennial and annual species, probably allowed different environmental niches, such as summer and winter growth, to be best exploited.

The lucerne monoculture was worst at fulfilling animal intake requirements, although lucerne is reputed to be a productive perennial legume in this environment. Its predicted poor performance was associated with a high proportion of years with below average rainfall (50 years in the 100-year record) and over 30% of years with rainfall being more than 100 mm below the average. Although lucerne is relatively drought tolerant because of its deep root system, most of these dry years tended to occur consecutively, thereby exacerbating the effect of the dry conditions.

On 'real' farms, it is important to integrate a range of different pasture types and forages to both take advantage of climate variability in good seasons and minimise its impact in poor seasons, because no single forage type is best in all types of years.

Pasture utilisation – a key driver for profitable grazing, but increased utilisation comes at a cost of increased supplementation. Daily pasture growth rates were simulated for a native perennial grass pasture and then the effects were examined on pasture utilisation by increasing stocking rate of Merino wethers under continuous grazing or adjusting stock density at regular intervals (Lodge *et al.* 2012). The site on which simulations were based was growing a mixed summer and winter active native perennial grass pasture at Glen Innes (29° 42'S; 151° 42'E) on the Northern Tablelands of NSW (Lodge *et al*. 2012).

Mean monthly predicted pasture growth ranged from 2.6 to 36.2 kg DM/ha/day in winter and summer, respectively, reflecting both the frost sensitivity of the summer growing native perennial grass and its ability to respond to summer rainfall and high temperatures. In terms of being able to rapidly change stock densities, these large seasonal differences in growth rates are a challenge and indicate short timeframes for increasing stocking rates or buying and selling options, and at the whole-farm level the need to fill the winter-early spring 'feed gap' if breeding enterprises are being considered.

Under continuous grazing, increasing stock density from 1 to 10 wethers/ha increased mean annual predicted pasture intake from 0.5 to 2.9 t DM/ha/yr and increased predicted pasture utilisation from 10 to 49%. However, at stock densities above 5 wethers/ha the intake of supplements, as a proportion of total intake, rapidly increased indicating that total intake exceeded pasture growth in some years. At the low stocking rate, pasture utilisation was higher in the dry years and lower in the wet years. Utilisation at the high stocking rate tended to be low in the dry years reflecting the need for supplementary feeding, and high in the wet years reflecting a better match between intake and pasture growth and quality (Lodge *et al*. 2012).

Varying stock density either daily, monthly or every two or three months according to feed availability allowed higher stock density in summer, but had little effect in winter, highlighting the temperature restrictions on pasture growth in the winter months. Maximum monthly stock densities in summer ranged from 30 wethers/ha for the daily adjustment to 22 wethers/ha for the monthly and 17 wethers/ha for both the two and three month adjustments and were lowest in July (~3 wethers/ha for all variable stocking rates).

While a short time interval of one day may not be practical for adjusting stock densities, the results illustrate that more regular adjustment of stock density in response to pasture growth in individual paddocks is likely to improve utlilisation and intake over time.

For these simulations, a 20% increase in predicted pasture utilisation of a native pasture stocked at 3 wethers/ha (the winter carrying capacity) could be achieved in two main ways;

- increase the continuous stocking rate to 10 wethers/ha (pasture utilisation increased from 29 to 49%), but at the higher stocking rate about 20% of the total intake will need to be met from supplementary feed (mean predicted intake of 0.7 t DM/ha/yr), occurring mostly in the drier years, and
- maintain a stocking rate of 3 wethers/ha and also opportunistically trading lambs in summer–autumn to utilise the extra feed grown in most years and adjust overall stock density every three months based on feed availability.

Putting the key message into practice

In southern Australia, utilisation of pasture is typically 25-30% and an increase of up to 20% could double farm profit (MLA 2011*a*). On-farm, increasing pasture utilisation involves increasing the animal intake of green pasture. While intake is influenced by pasture height, density, total herbage mass and digestibility the aim is to maximise the stock density that a pasture can sustain without restricting its regrowth and long-term sustainability (MLA 2011*b*). However, within a grazing system if intake exceeds pasture growth then different animal enterprises may need to be considered, or alternatively higher growth rate pastures/fodder crops may need to be used.

Tactical management to tackle climate variability.

Climate variability and drought are common events so should be considered as part of day-to-day management. On Red Chromosol soils of northern NSW, drought is effectively never more than 6 weeks away, because in this time stored soil water reserves can be depleted and pasture growth will cease. The modelling undertaken in this study showed that under these variable conditions, flexible stocking rates provide opportunities for higher pasture utilisation and can reduce the reliance on supplementation. Flexibility can be achieved by making effective stock buying/selling, stock movement, supplementary feeding or other tactical decisions through a good understanding of:

- pasture growth curves and when rainfall is required to drive production of the forage base,
- the current stocking rate profile, and
- fat score targets and energy requirements of each animal class in the livestock enterprises.

With this understanding, timely decisions can be made by:

- regularly assessing pasture availability and quality in regard to meeting livestock requirements for reproduction and growth,
- devising trigger points (e.g. forage oats need to be sown by the end of February) for both climate variability and availability of green feed,
- scanning ewes at 80–90 days pregnancy to detect

dry, single and multiple lamb bearing ewes and to use this knowledge to make informed management decisions, and
- using a simple spreadsheet to calculate target livestock numbers.

Strategic changes for increasing utilisation and managing variability. In a variable climate, such as northern NSW, the pasture base needs to incorporate a proportion of both winter and summer active forages in order to fill the winter-early spring feed gap for green feed and to take advantage of rainfall in whatever season it occurs. This can be done by determining the proportion of paddocks with native perennial grasses, sown grasses and legumes, and forage crops required according to the livestock enterprise being run. Again, a simple spreadsheet calculator can be used to compute changes in required pasture types/areas, timing of reproduction and stocking rates.

Key Message 3 – Lucerne-grass mixtures are an option for northern NSW

"*Pastures with a mixture of lucerne and a tropical perennial grass have potential to increase total dry matter production and spread its distribution more evenly through the year, thereby reducing feed gaps and providing greater resilience in variable seasons, while helping to conserve natural resources on farm*."

A lucerne-grass mix has long been held as an attractive pasture option, several challenges were encountered when attempting to establish mixes, including: competition among seedlings; sowing configuration, sowing time and sowing rate; persistence of species; and total herbage production. Little knowledge was available on recommended sowing rate, time and configuration to best establish a productive lucerne-grass mix and with lucerne's demand for soil water, it was not known whether a temperate or tropical grass would best persist and be productive in a mix. Lucerne's poor performances in variable rainfall years, low growth in winter, and potential for bloat in cattle are also issues of concern.

A series of field experiments was conducted on a Brown Vertosol soil at Tamworth Agricultural Institute from spring 2008 to spring 2012 to investigate competition among seedlings, sowing (configuration, timing and rate), persistence (plant frequency), herbage production, soil water storage and water use efficiency, ground cover and control of surface runoff and erosion from lucerne-grass mixes. The mixes sown including lucerne cv. Venus; Digit grass (*Digitaria eriantha)* cv. Premier; tall fescue (*Festuca arundinacea)* cv. Demeter; and cocksfoot (*Dactylis glomerata)* cv. Kasbah, were chosen in an attempt to extend the growing season by generating growth from rainfall in both the cool and warm seasons and so reduce the dependence of livestock systems on annual forage crops.

Results and Findings

Sowing rate and configuration. Plant frequency of lucerne sown in spring in mixtures at 0.5 kg/ha began to decline 18 months after sowing. This highlighted the risk of establishing lucerne in spring in our environment unless rainfall conditions are ideal, and by the end of monitoring these pastures had low lucerne densities in both pure swards (18%) and mixtures (11%). Plant frequency of digit grass increased over time in all treatments, but by the end of monitoring had higher average plant frequency as a single species sward (84%) than in mixtures (74%).

Sowing time of year for pure swards. Lucerne seedling density (measured ~4-weeks after sowing) was higher when sown in autumn compared with spring (39 *vs.* 4 plants/m^2), so that spring sowings resulted in lower plant frequencies and herbage mass. While lucerne can be sown in spring on the North-West Slopes, this commonly occurs under irrigation. There is a high risk of failure in dryland spring sowings due to high temperatures and variable ineffective summer rainfall that often occurs in high intensity storms.

Digit grass sown in spring (November) had a seedling density of 26 plants/m^2. When sown in autumn, digit grass did not emerge until September and had a seedling density of 6 plants/m^2. It is important to note that rainfall in the winter following autumn sowing was below average, which reduced microbial activity and seed losses allowing some plants to establish, but is not a recommended method. When plant densities were low, individual digit grass plant crowns grew large, resulting in high plant frequency, similar to swards with higher plant populations. However, the disadvantage is that large crowns tend to be raised forming 'humps' and there is a tendency for the plants to produce more stem compared with swards that have high plant densities.

Sowing time of year for a lucerne-grass mix. Lucerne sown in autumn established well with 30-34 plants/m^2, but lucerne sown in spring was very poor with only 3-4 plants/m^2. Digit grass sown together with lucerne in autumn established in September, but in low plant numbers (12 plants/m^2) and only in sections of the plot where there was no lucerne. Lucerne and digit grass sown together in spring established with low lucerne density (11 plants/m^2) and moderate grass density (24 plants/m^2). However, when digit grass was sown in spring (November), in rows adjacent to autumn sown lucerne, the grass established (15 plants/m^2), but only where there was no lucerne. By spring when soil temperatures are sufficient for digit grass to germinate, lucerne was actively growing and produced a full canopy within about 4 weeks of grazing and by November most of the plant available soil water had been used.

To overcome this competition, the grass and lucerne may need to be separated by more than sowing in alternate rows, for example alternate strips 1 m or more wide. Also, autumn sowing of tropical perennial grasses is not recommended because up to 100% of tropical grass seed sown in autumn can be lost during an 'average' winter due to microbial activity. Establishment of a lucerne and tropical grass mixture can be improved by sowing the tropical grass in spring and the lucerne in the following autumn.

Herbage production. Sowing configuration did not affect herbage production of mixtures (Figure 3). For the period 2009–11, total herbage production for single species swards ranged from 11.5 to 24.5 t DM/ha for digit and lucerne sown at 2 kg/ha, respectively. Herbage produced by the single species and mixed swards with lucerne at each sowing rate were similar, varying only 1.5–2.7 t DM/ha. Interestingly herbage production of digit grass was similar irrespective of the lucerne sowing rate, indicating that (a) the difference in total production was due to lucerne and (b) the grass was not greatly affected by the different quantities of lucerne present. Production of digit in mixtures was only 2 t DM/ha less than the single species sward. Averaged over the three sowing configurations, the lucerne percentage of production in mixtures sown with 0.5, 1 and 2 kg/ha of lucerne seed were 42 (6.9 t DM/ha), 55 (10.9 t DM/ha) and 59 % (13.6 t DM/ha), respectively.

While sowing configuration did not affect overall dry matter production, the sowing rate of lucerne was important with production from higher sowing rates being close to that of a pure lucerne stand. Therefore, lucerne should be sown at a rate of at least 1 kg/ha to achieve a productive mixed stand.

Putting the key message into practice

In northern NSW, pastures of lucerne-grass mixtures offer significant ground cover benefits (Murphy *et al*. 2014) over pure swards of lucerne and significant production benefits over pure swards of grass. Forage production of the combined lucerne and perennial grass pasture was significantly higher than the grass grown alone and the pasture could take advantage of rainfall at more times of year meaning livestock were better able to access green feed. When making decisions on pasture improvement, consideration must also be made to utilising the additional feed; producers need to ask 'Will I have enough livestock to utilise the additional feed?' Establishment costs for lucerne-grass mixtures will vary with species and varieties selected. Split sowings of tropical grasses with lucerne will not only incur another pass with sowing equipment, but might also require herbicide control for annual weeds before sowing lucerne. Infrastructure planning is also necessary, additional fencing and watering points may be required to adequately use the additional feed and manage increased stock numbers.

When planning to establish lucerne-grass pasture mixes in northern NSW we suggest to:

- ensure good weed control (both grass and broadleaf weeds) in seasons leading up to sowing a mixture, because of reduced herbicide control options once the mixture is sown,
- avoid dryland spring sowing of lucerne as it is risky and poor establishment often results,
- improve establishment by sowing the tropical grass in spring and the lucerne in the following autumn,
- sow lucerne seed at a minimum of 1 kg/ha, and
- manage to achieve lucerne persistence by using recommended grazing strategies, or it may only be a short-term legume.

Key Message 4 – Conservation of Box–Gum Grassy Woodlands on the North-West Slopes of NSW is best achieved through on-farm management of high quality remnant patches.

"*Native vegetation on farms, particularly woodlands and little disturbed grasslands on gently sloping country, can be important for biodiversity conservation and for providing ecosystem services. Conservation of Box–Gum Grassy Woodlands on the North-West Slopes of NSW is best achieved through on-farm management of high quality remnant patches*."

Studies of grass-woodland conservation value.

Native vegetation on-farm, particularly woodlands and little disturbed grasslands on gently sloping country, can be important for biodiversity conservation and for providing ecosystem services. While on-farm areas managed for biodiversity may contribute to conservation objectives at farm and landscape scales, these areas will also contribute to outcomes of ground cover management, reduced soil erosion and whole-farm water balance.

A series of studies (i.e. analysis of flora databases, flora survey of sites, and paired site studies, Schultz 2013, Schultz *et al.* 2014*a*, Schultz *et al.* 2014*b*) were undertaken between 2008 and 2011 to determine the plant conservation value of vegetation on farms grazed by both sheep and cattle. The studies aimed to:

- provide new information on the diversity, phenology and ecology of native perennial pastures,
- investigate the biophysical and management determinants of grassy vegetation composition in the region,
- evaluate the likely economic impact of implementing different plant conservation strategies, and
- provide region-specific plant conservation recommendations, including on-farm options.

Results and findings

Owing to their occurrence on productive agricultural

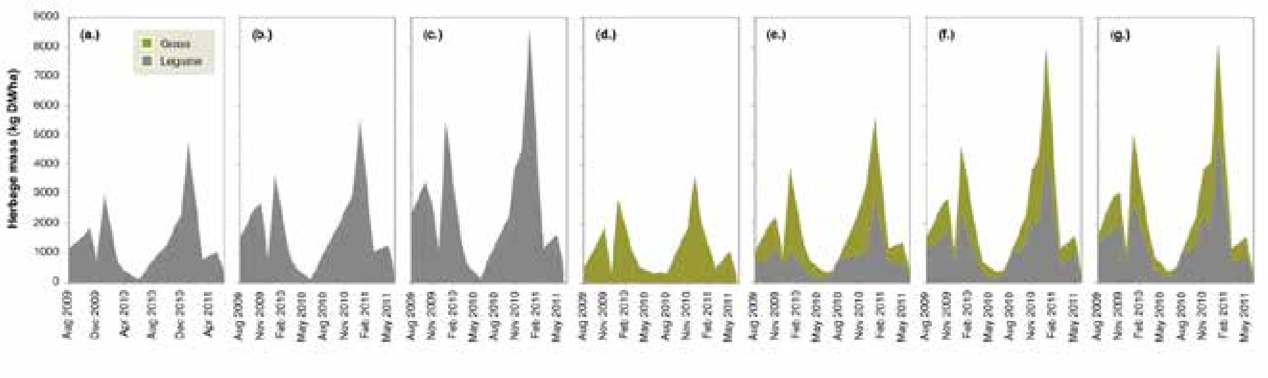

Figure 3. Herbage mass (kg DM/ha) of single species swards of lucerne (cv. Genesis) sown at three rates (a) 0.5, (b) 1 and (c) 2 kg/ha and (d) digit grass (cv. Premier) and mixtures of lucerne and digit grass sown in 1:1 alternate rows with lucerne sown at (e) 0.5, (f) 1 and (g) 2 kg/ha between August 2009 to June 2011.

soils, Box–Gum Grassy Woodlands are the region's most extensively cleared and modified ecological community, and are under-represented in the region's national parks and nature reserves. Most of the gently sloping or flat land on which Box–Gum Grassy Woodlands once occurred is now farmland. For this reason, on-farm management has the greatest potential for conservation of Box–Gum Grassy Woodlands, through protection of remnants and management of derived grasslands for understorey species diversity and natural recruitment of woodland trees.

Furthermore, the region's conservation reserves are predominantly located in hilly terrain at higher elevation, with few reserves in gently sloping areas at lower elevation. Hence, as farmland occupies the majority of low sloping fertile land, on-farm conservation management has a vital role in plant conservation in the region. To allow for the conservation of plant diversity at a regional scale, agricultural lands must successfully integrate biodiversity conservation, or a suite of reserves will be needed in areas of low relief, or preferably both.

The survey of 143 sites across four land-use categories (previously cultivated native pastures, never cultivated native pastures, grazed woodlands and ungrazed woodlands) revealed that livestock grazing, fertiliser application and tree cover were poorly correlated with total species densities (i.e. the number of ground layer species in a 20 × 20 m area), but were correlated with native and exotic species densities.

Overall, this study showed that pastoral management had a consistent influence on vegetation composition that was not conducive to the conservation of rare or infrequent native vascular plant species in the region. Woodland vegetation that was not grazed by livestock made a large contribution to regional plant diversity, despite its very limited extent in the landscape.

Native pastures regenerating after cultivation re-establish total species densities comparable with those of uncultivated native pastures 10–25 years after the last cultivation, and re-establish comparable native species densities 15–30 years after the last cultivation. Vegetation composition in paired grazed and ungrazed plots was monitored in native pastures over 2.5 years. Exclusion of livestock grazing did not influence composition over this period.

Putting the key message into practice

The studies conducted supported the concept that conservation of Box–Gum grassy woodland on-farm will make a valuable contribution to the national reserve system and assist to maintain biodiversity at the landscape scale. If producers think they have an area on their farm that is suitable for on-farm conservation, then a set of questions can quickly determine the next course of action (Schulz *et al*. 2013). If the answer is yes to each of the following series of questions, then it is highly likely that the farm has an area worth conserving:

- Are you interested in identifying and conserving areas of high conservation value on your farm?
- Do you have native vegetation that is (or was once) Box–Gum grassy woodland (e.g. grazed woodland, native pasture)?
- Do you have areas of vegetation with no history of cultivation or fertiliser, and no disturbance other than by grazing or fire?
- Are any of these areas on flat or low sloping country?

Do you have areas with some key indicator species (Figure 4)?

What do the EverGraze Key Messages mean on-farm?

A major achievement of the EverGraze project in northern NSW was to demonstrate the role of monitoring seasonal rainfall, pasture availability, pasture quality, livestock condition and conservation value in order to achieve both production and sustainability outcomes on-farm. The axiom "*If you don't measure it you can't manage it*" is appropriate in all of these areas and EverGraze provided producers with the capability to self-measure and understand why certain production levels were achieved and so identify possible ways to make improvements.

In a variable climate, such as northern NSW, the forage base needs to include species that can respond to available soil water at different times of the year, in whatever the season that rainfall occurs. On-farm, native perennial grass-based pastures are likely to be the dominant forage and can be integrated with other forage and feed sources such as over-sown subterranean clover, lucerne, sown temperate or tropical perennial grass-based pastures, forage oats, and or other forms of supplementation. The exact proportion of the farm that each of these forage types occupies will vary from farm to farm in relation to land capability and grazing enterprise being considered and the specific needs that match forage availability to livestock requirements. For those producers who have an interest in identifying and managing Box–Gum grassy woodland, an associated guide (Schultz *et al.* 2013) is an ideal starting point. The key messages discussed here will be useful for graziers in northern NSW and further afield, wanting to improve the productivity and natural resource capital of their enterprises and farms.

Acknowledgments

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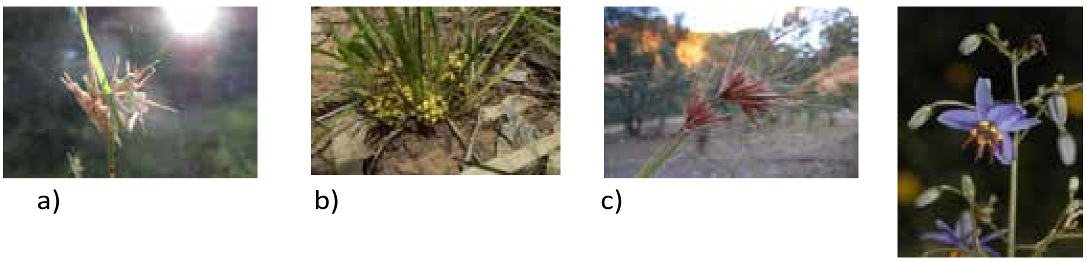

a) b) c) d)

Figure 4. Key biodiversity indicator species a) Barbed-wire grass (*Cymbopogon refractus*), b) Mat-rushes (*Lomandra* spp.), c) Kangaroo grass (*Themeda australis*), and d) Flax-lily (*Dianella* spp.).

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Managing nutrition and utilisation of tropical perennial grass pastures

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Abstract: *Tropical perennial grasses are productive and persistent and are becoming an important component of grazing systems in northern NSW. To maintain productivity and quality, tropical pastures need to be fertilised with nitrogen being a key nutrient. Companion legumes are an alternative and sustainable method of supplying nitrogen and current research is investigating a range of temperate annual and perennial, and tropical legumes. Grazing management is important to maintain the quality of the pasture at its optimum for animal production. During periods of peak growth pasture production can exceed animal requirements and alternative strategies need to be employed to utilise the surplus dry matter. These strategies are outlined and offered he potential for flexibility and enterprise diversity.*

Key words: fodder conservation, hay, silage, supplements, soil water, water use efficiency

Introduction

Northern New South Wales (NSW) has a highly variable, summer dominant rainfall distribution with about 60% of annual rainfall falling during the period November to March. Summer rainfall tends to be relatively ineffective as it can occur as high intensity storms, which often results in runoff, and soil water is quickly lost through evapotranspiration due to high temperatures (Murphy *et al*. 2004). Rainfall received during the winter period is most effective for replenishing soil moisture reserves (Murphy *et al*. 2010). As a result of this, a wide range of pastures and forages are commonly sown to utilise actual and effective rainfall – namely temperate and tropical grasses, lucerne (*Medicago sativa*), temperate annual legumes, forage oats (*Avena sativa*) and forage sorghum (*Sorghum bicolor*). However, extended periods of below average rainfall, broken by short periods of good rainfall or storms, represent an ongoing challenge to producers to maintain a quality forage base year-round in order to meet the demands of livestock and leads to a miscellany of forage sources being used (Lodge *et al.* 2011; Lodge and Johnson 2008; Murphy *et al*. 2014a).

Analyses of short- and long-term monthly and annual rainfall data for sites in northern NSW (Warialda, Barraba and Tamworth) indicate that since 2000, rainfall in autumn has been substantially lower, and spring–early summer has been substantially wetter compared with the long-term mean (Lodge and McCormick 2010). These weather patterns have profound implications for livestock production, since adequate autumn rainfall is required for the germination of annual, winter-growing legumes, while spring–early summer is a critical period for seed production of annual legumes, and the sowing and establishment of tropical perennial grasses.

Tropical perennial grasses have increased in popularity in recent years, with about 400,000 ha now estimated to have been sown across northern NSW (Harris *et al.* 2014). The production potential (Boschma *et al*. 2009), persistence (McCormick *et al.* 1998; Boschma *et al*. 2009), responsiveness to summer storms and fertiliser (Boschma *et al*. 2014*b*), deep rootedness (Murphy *et al*. 2008*a*), high ground cover and water use efficiency (Murphy *et al*. 2008*b*) are all favourable attributes of these grasses meaning that they have important roles in providing flexibility and sustainability to grazing systems (Teitzel *et al.* 1991; Boschma *et al.* 2010*b*).

Nitrogen (N) is a key, but often limiting nutrient for perennial grasses and is critical for optimum pasture performance. While seasonal growth of tropical perennial grass pastures can be impressive, making best use of this production by increasing utilisation while also maintaining forage quality can be difficult. Variable rainfall often leads to seasonal growth that is ‘stop-start’ in nature (Boschma *et al*. 2014*b*) with periods of high growth followed by dry periods with low growth. Managing the erratic production cycle to achieve year-round production and making the most of peak production periods of tropical grass pastures is a focus of research by NSW Department of Primary Industries (DPI). This paper reviews progress made to date in determining the response of tropical perennial grass pastures to N, options for companion legumes in mixed pastures, and discusses management to achieve high levels of utilisation to sustain animal production.

Response to nitrogen nutrition

Daily growth rates of tropical perennial grasses vary among species, and also with stored soil moisture and fertility status. With adequate soil moisture during summer an unfertilised tropical grass pasture can produce on average 34 kg dry matter (DM)/ha/day compared to 78 kg DM/ha/day for a pasture fertilised with 100 kg N/ha (SP Boschma, unpublished data). However, with highly variable rainfall, production can range from 150 kg DM/ha/day during periods with good soil moisture to less than 10 kg DM/ha/day when soil moisture reserves are depleted.

Fertiliser that has been applied but not utilised by pastures during dry periods are not necessarily lost, but remain in the soil allowing the pasture to respond quickly following rainfall, providing large quantities of forage in a short period of time (Boschma *et al*. 2009, 2014*b*). In addition, strategic use of N fertiliser has been shown to extend seasonal productivity (Kemp 1975) and improve drought survival. Nutrients that are not used during one season can carry over for plant use in another season whether by temperate species (weeds, grasses or legumes) in winter or tropical species the following spring. In wet winters N can move down the soil profile, and during extremely wet winters it could move below the rooting zone of the tropical grasses (Boschma *et al*. 2014*b*).

Good plant nutrition is essential for tropical pastures to achieve optimum growth and quality. When a pasture is first established, following ideal preparation, it is likely to have high soil moisture and nutrient reserves to draw upon and production is commonly high. However, this will not be sustained unless the pasture is adequately fertilised (e.g. Robbins *et al.* 1987; Meyers and Robbins 1991; Murphy 2014), with productivity decline over time potentially becoming a significant issue. In northern Australia fertility rundown resulting in productivity decline is a widespread issue in sown grass pastures (Meyers and Robbins 1991; Peck *et al.* 2011). It has been estimated that sown pasture production has fallen by about 50% with a farm gate cost to industry of more than $17 billion over the next 30 years. For producers in northern NSW, this issue needs to be considered in long-term planning to prevent it occurring in our grazing systems. N fertiliser and the inclusion of productive persistent legumes in tropical perennial grass pastures are two recommended options to stop further decline and/or to recover productivity (Meyers and Robbins 1991; Peck *et al.* 2011).

Companion legumes – the organic source of nitrogen

Legumes are an attractive option in grazing systems as they can be a cost effective, sustainable and environmentally friendly source of soil N. In addition to N fixation, legumes are also valuable for animal production. Forage with high protein content is important to maintain optimum rumen function, which increases the rate that forage moves through the rumen, allowing animal intake to increase and ultimately animal production. In order for a legume to be an effective component in a pasture it must fix N, be productive, resilient and persistent (Boschma and Harris 2014).

To fix N a legume must be adequately nodulated with the correct, effective strain of rhizobia (Thies *et al.* 1991; Peoples *et al*. 2012). Factors such as low population numbers and ineffective soil rhizobia, soil water stress, high concentrations of soil N and nutrient disorders contribute to poor nodulation and subsequent N fixation (Peoples *et al*. 2012). But ultimately, the amount of N fixed by a legume is proportional to the amount of plant DM it produces and as a rule of thumb, temperate legumes fix about 35–40 kg N/ha/t legume DM produced (taking into account N fixed on a whole plant basis; Peoples *et al*. 2012) and about 13 kg N/ha/t DM of this becomes available to plants in a perennial pasture (Herridge 2004). In northern NSW, the greatest response in DM of tropical grass pastures occurs when 50–100 kg N/ha is applied per growing season (Boschma *et al.* 2014*b*). To fix this much N in a tropical grass pasture, a legume needs to produce about 4–8 t DM/ha annually. Current research is evaluating a range of legumes to identify those that can achieve this reliably.

To fix N year-to-year, a legume must be able to persist in competition with the tropical grass, through highly variable seasons, and respond quickly to rainfall when it falls during its growing season. To achieve this, annual legumes need to be able to establish quickly and set large quantities of hard seed to maintain a seed bank, while perennial legumes need strategies to survive highly variable seasons.

Soil moisture is commonly the most limiting resource affecting pasture growth. In a pure tropical grass sward soil water content is lowest in autumn at the end of their growing season and highest in spring as the pasture recommences growth (Murphy 2014). This is because during the winter period while these grasses are dormant, rainfall is captured and stored in the soil profile and available for use by the pasture in spring. Since these soil water reserves can only be used once, decisions need to be made on how or when the stored water should be used for plant growth for animal production, which have implications for legume choice.

Over the last five years and in ongoing research, NSW DPI scientists have been conducting experiments to determine the type of legumes that might be effective in tropical grass pastures and understand the interaction of species in mixtures so that robust recommendations can be made. Three legume groups that have potential as companion species for tropical perennial grasses include: temperate annual, temperate perennial and tropical. Each group has advantages and disadvantages, which are described below.

a) Temperate annual legumes

Growing season of temperate species is autumn through winter, peaking in spring and therefore almost the opposite of tropical grasses (Fig. 1*a*). Growing a temperate annual legume and a tropical perennial grass in a mix offers the potential to increase the period that forage is available from a paddock from about 8 months (tropical grass only) to 12 months (mixed pasture). While this is advantageous there are two main factors that can significantly affect regeneration, production and seed set of the annual legume – rainfall distribution and grazing management.

Our studies and anecdotal evidence suggest that the plant characteristics required for long-term persistence of temperate annual legumes in northern NSW (excluding the Tablelands) include high seedling vigour so that the legume can establish quickly; deep rootedness allowing the legume to quickly access soil water stored deeper in the soil profile; early flowering with the ability to produce large quantities of hard seed to ensure seed set each year and 'insurance' for those years unsuitable for annual legumes. The ability of the legume to continue growing after flowering if the season is favourable is also a desirable characteristic for maximising the amount of N that can be fixed (Boschma and Harris 2014).

Using production of at least 4 t DM/ha as a guide for satisfactory N fixation, studies conducted at Tamworth in northern NSW have shown woolly pod vetch (*Vicia villosa*) cv. Namoi and arrowleaf clover (*Trifolium vesiculosum*) cv. Cefalu to be productive and persistent, producing 6.6 and 4.8 t DM/ha/yr, respectively, over the three years of the study (Boschma and Harris, unpublished data). In comparison, subterranean clover (*Trifolium subterranean*) cvv. Dalkeith and York averaged less than 1 t DM/ha/yr. At Bingara, northern NSW, purple cover (*Trifolium purpureum*) cv. Electra also had high production (7 t DM/ha/yr)(Harris and Boschma, unpublished data). The addition of a productive temperate annual legume increased total production of the pasture particularly during the late winter–early spring period. It was also noticed that the foliage of digit grass was greener in the plots with productive legumes, indicating likely higher quality.

To encourage good regeneration of annual legumes it is important the grass pasture is well grazed in late summer to remove the bulk of DM and open the grass canopy to allow light penetration. In spring, stocking rates will need to be reduced or the pasture destocked to allow aerial seeding annual legumes to flower and seed set. Subterranean clover will need to be well grazed to stimulate flowering and high seed production.

b) Temperate perennial legumes

This legume group generally have a similar growth pattern to the temperate annual species, growing during the cooler months of the year and potentially offer year-round forage from a single pasture. Perennials have the advantage of being able to survive multiple years and some species can grow year round if sufficient soil moisture is available. These traits mean that perennial legumes have the potential to fix more N than annual species and are not reliant on suitable conditions to regenerate each year. Lucerne is the most productive and persistent temperate perennial legume in northern inland NSW (Boschma *et al*. 2009) and has been the focus temperate perennial legume of research with tropical grasses. It has the ability to grow and fix N under environmental conditions that are unsuitable for either establishment or growth of annual legumes, and therefore legume DM production and N fixation tend to be more consistent than the variation observed with most annual legumes (Peoples and Baldock 2001; Bowman *et al*. 2004; Peoples *et al*. 2012).

Lucerne has greater summer activity than many temperate legumes and in a tropical grass mixed pasture can result in additional growth in some to all months of the year, depending on seasonal conditions and cultivar. The inclusion of lucerne in a tropical grass pasture results in less soil water replenishment during winter and its carry over into spring because lucerne growth commences earlier than the tropical grass and therefore utilises it first (Murphy 2014). Research has shown that lucerne cv. Venus (semi-winter dormant cultivar) in a mixed pasture commenced growth (and water use) in late winter–early spring (Fig. 1*b*) and had used the majority of plant available stored soil water within six weeks, often before the tropical grass commenced growth, thereby dominating growth during spring and early summer. As the mixed stands aged, the proportion of production provided by lucerne with digit grass (*Digitaria eriantha* cv. Premier) increased from 54 to 61% (Murphy *et al*. 2014*b*). However, good summer rainfall in the hotter part of the year would likely favour growth by the tropical

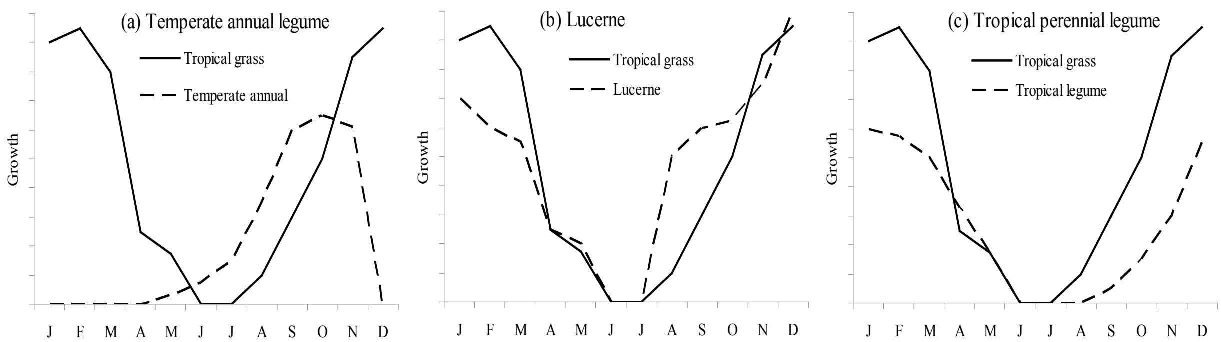

Figure 1. Estimated relative growth curves of tropical grass with a (a) temperate annual legume, (b) lucerne and (c) tropical legume to illustrate overlap in DM production on an annual basis.

grass over lucerne. Since lucerne is a competitive species, it is recommended to sow tropical grass-lucerne mixed pastures on soils with higher water holding capacity (Murphy 2014).

Another hurdle for mixes of temperate and tropical species is successfully establishing both types in the pasture. This can be particularly challenging for perennial species because not all species self-recruit and poor establishment can result in a low plant population with limited opportunity to improve it. Research has shown that establishment is more likely to be successful when each species is sown at its optimum sowing time, although the species that establishes first will tend to monopolise resources, thereby inhibiting establishment of the second species (SP Boschma, pers. comm.). Lucerne seedlings are more competitive than tropical grass seedlings (Boschma *et al*. 2010*a*) and it is recommended to sow and establish the grass first in spring and lucerne the following autumn, ensuring that the bulk of the grass material has been removed to provide light penetration and space for the lucerne to establish.

Studies conducted at Tamworth in northern NSW have shown that lucerne cv. Venus produced 17.6 t DM/ha/yr over the three years of the study. In the same study, production from a digit grass–lucerne mixture (15.2 t DM/ha/yr) outperformed that from a fertilised pure tropical grass (12.2 t DM/ha/yr), which highlights the potential of the mixture (Murphy *et al*. 2014*b*). Lucerne is a highly competitive species so total production of the pasture and proportion of lucerne and grass is dependent firstly on the proportion of lucerne in the established pasture and then seasonal conditions for growth.

c) Tropical legumes

These summer growing legumes are common used in Queensland but have not been widely tested in northern NSW. They are frost susceptible and have a similar growth pattern as tropical grasses; growing during the warmer months of the year from spring until autumn (Fig. 1*c*). Since these legumes have the same period of growth as the tropical grasses it means that soil water reserves can be replenished over the winter for use in spring, however, production from this pasture is limited to the warmer months of the year.

In a review of N fixation in Australian pasture systems, Peoples *et al*. (2012) noted that there have been relatively few studies undertaken with tropical legumes compared to temperate legumes. Published data suggested that N fixation of tropical legumes is less than temperate species, however, reported differences in soil organic N and improvements in N uptake by cereals grown after tropical legume crops suggested that higher inputs of fixed N can occur. Peoples *et al*. (2012) suggested that low N fixation by tropical legumes may have been due to low DM production as a result of low rainfall or semi-arid environments and issues with poor nodulation and high soil N fertility. Nodulation has also been reported as variable in northern Australia due to a combination of small seed size and shallow sowing in hot soils during summer (Peck *et al*. 2011). A study is current underway addressing this issue.

A small number of tropical legumes were evaluated at Tamworth (2009–2012) as a preliminary investigation to identify species that may be adapted to northern NSW. Again, using production of 4 t DM/ha/yr as a guide for satisfactory N fixation, the legumes that showed potential in the initial study were desmanthus (*Desmanthus virgatus*) cv. Marc⁽ᵖ⁾ and leucaena (*Leucaena leucocephala* ssp. *glabrata*) cv. Tarramba⁽ᵖ⁾, which both produced 4.9 t DM/ha/yr. The adaptation of these two species and other tropical legume species are being further evaluated at sites on the North-West Slopes and Central West (2012–17). This research and other component studies funded by Meat and Livestock Australia are ongoing.

Grazing for animal production

Maintaining high feed quality can be difficult in tropical grass pastures, but can be achieved with good plant nutrition and appropriate grazing management strategies.

Although 50–100 kg N/ha/year is recommended, the appropriate rate to apply may vary depending on area of tropical grass pasture to be fertilised, the type of livestock that will be using the pasture and capacity to utilise the additional forage. For example, higher rates of N would be suitable for a small area to be utilised by stock with higher forage quality requirements such as fattening stock or lactating cows. These livestock classes will likely provide a return on the fertiliser investment, while dry cows grazing the same area will not.

The optimum growing 'window' for moderate to high animal production from tropical grass based pastures is narrow and is closely linked to grazing management that maximises herbage quality and quantity (Fig. 2). Data have shown that crude protein and metabolisable energy levels of the green leaf proportion of digit grass plants cut at the 4–leaf growth stage were higher than those cut at stem elongation and flowering. The time for the pasture to reach these growth stages varies with species, nutrition and soil water reserves, but could be about 2 weeks, 3–4 weeks and 4–6 weeks regrowth for 4–leaf, stem elongation and flowering growth stages, respectively.

Tropical perennial grass pastures are often considered to only be suitable for cattle, but they are also suitable for sheep when managed appropriately. The optimum herbage mass to maintain a tropical grass pasture for maximum animal intake (with a digestibility of 65%) is between 1.6–2.5 t DM/ha for cattle and 1.0–1.5 t DM/ha for sheep (Graham 2011). Managing tropical perennial grass pastures at these levels can be difficult, particularly during mid-summer when growth rates are high. During these times regular grazing with high stock densities, and possibly set stocking, may be required to maintain the pasture in a high quality, leafy growth stage. For example, stocking rates of 60 lambs/ha (25 kg liveweight) or 11 steers/ha (about 300 kg liveweight) may be required to utilise the growth of a fertilised tropical grass pasture growing at 100 kg DM/ha/day. Dividing a large paddock into multiple smaller areas allows the stocking rate to be increased and for cattle can be easily achieved with a single wire electric fencing, although shade and water points need to be considered.

Strategies to use surplus forage

During periods of high pasture growth when stock are intensively grazing 1–2 paddocks, other paddocks will be underutilised and quickly move past the high quality stage. At these times other strategies will need to be employed to utilise the surplus DM. These strategies include increasing stock number to use the DM at time of growth during the growing season, making hay or silage to conserve the excess DM, and allowing some of the pasture to mature and senesce, and utilise it as standing DM over winter.

a) Increasing stock number

Additional stock to utilise surplus DM produced during peak periods of growth can be achieved by buying, agisting or backgrounding stock. Increasing stock numbers potentially offers enterprise diversification, although the risk is that if it does not rain, pasture production will decline and could result in a shortage of feed and de-stocking required. This risk can be managed by making decisions based on feed availability and reliable seasonal forecasts. Infrastructure should be considered when planning to increase stock numbers as paddock subdivision and additional watering may be required (Boschma *et al*. 2014*a*).

Buying trade stock when seasonal conditions and feed supplies are favourable can be an effective method to increase stock numbers for a short period while maintaining a core breeding enterprise. In this scenario trade stock could graze tropical grass pastures during summer and be finished on forages such as oats and/or lucerne. This system provides flexibility as the number of stores bought each year can change in relation to the available feed and seasonal weather outlook, and allow easy selling to reduce stock numbers if the season turns unfavourable.

Agistment or backgrounding is also an option for increasing stock numbers as backgrounding or growing stock for producers in other locations is common in the dairy and feedlot industries. These methods have guaranteed fees, however they offer less flexibility if season conditions decline.

b) Fodder conservation

Conserving surplus forage as either silage or hay can be an effective tool to utilise surplus DM and return the pasture to a state of high quality and growth rates for continued animal production. Some producers have baled tropical grasses, but the quality observed has generally been poor because the pasture was cut at flowering, and as described above, the quality declines quickly as the pasture become reproductive and stem elongation commences (Fig. 2).

As a pasture management tool, silage and hay offer the potential to increase productivity, however, it is important to have clear objectives and plan how it will fit into the overall pasture management program. The main objectives when integrating silage or hay making with grazing management are to:

1. Improve pasture utilisation by strategically timing cuts to use surplus pasture,
2. Maximise total forage production, either from grazing or silage and hay making, during the period of peak pasture growth, and
3. Maximise the quality of both the silage/hay and grazed pasture (Kaiser et al. 2004).

An advantage of silage or hay production is the opportunity to store quality forage that can be used as a supplement for 'out of season' production. Fodder conservation can increase drought proofing, enterprise flexibility and create new marketing opportunities. Hay and silage production can be costly so the amount stored needs to reflect the requirements of the enterprise. There will also be additional fertiliser requirements on these paddocks as nutrients are removed in silage or hay (Kaiser *et al*. 2004). Silage often has feed quality and management advantages over hay when used on the farm where it is

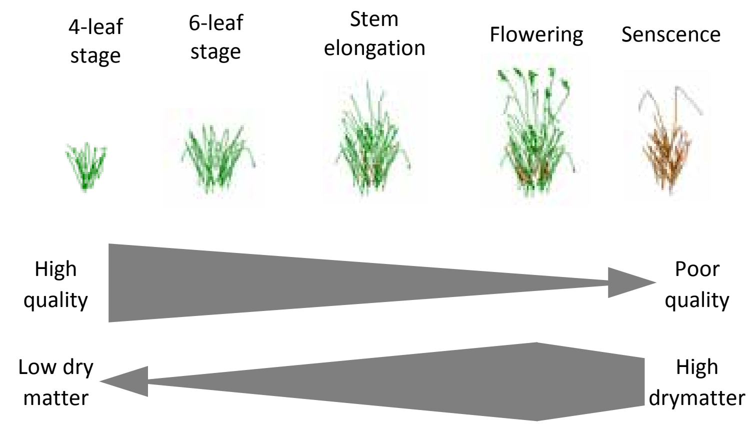

Figure 2. Relationship between plant growth stage and herbage quality and quantity

produced, these advantages include:

1. It can be cut earlier in the growing season, producing a higher quality product,
2. Reduced loss of DM and feed quality during wilting and harvesting operations, and
3. Silage does not require long periods of drying so is easier to make in a wet season when surplus DM is more likely to be available.

Baled silage is convenient to make and feed out, but can be expensive. Bulk, chopped silage stored in a pit or bunker is better suited to long-term storage and can be cheaper for larger enterprises (Kaiser *et al*. 2004).

c) Dry standing feed

In most years, it is not possible to utilise all growth from tropical grass pastures and inevitably there will be a bulk of dry standing matter going into winter. This effectively is a 'standing haystack' which can be utilised during winter and 'shoulder periods' of spring and autumn. This feed will have little or no green leaf and will be of low quality and so livestock will require supplementation to increase pasture utilisation and prevent excessive weight loss (Table 1).

Table 1. Examples of possible supplementary options for cattle utilising tropical perennial grass pastures outside the growing season and characteristics of the pasture at that time (modified from Joshua 2006). For details on the best type, quantity and any associated warnings on supplements for your sheep and cattle, speak with your livestock or veterinary advisor or District Veterinarian at your Local Lands Service office.

Pasture description	Class of stock	Example supplement	Feeding frequency
Plentiful dry feed (e.g. late autumn–winter) Characterised by: 1. Low pasture digestibility limits intake 2. Protein supplements increase pasture intake	Cows and calves, dry adult stock	1. Urea/molasses 2. High–protein grains 3. Protein meals	1. Continuous access 2. Every second day 3. Twice weekly
	Weaners	Supplement and frequency as for other classes of stock, but high protein grains or meals preferred	
Deteriorating dry feed (e.g. late winter) Characterised by: 1. Quantity and digestibility restrict intake 2. Energy/protein supplement mixes required	Cows and calves	1. Molasses/urea/protein meal 2. Grain/protein meal	1. Continuous access 2. Daily or 3 times/ week
	Dry stock	Grain/protein seeds or meals	Daily or 3 times/week
Short green feed (e.g. early spring)[1] Characterised by: 1. Quantity of pasture limits intake 2. Feed energy supplements	Cows and calves	1. Good quality hay/silage 2. Cereal grains	1. Twice weekly 2. Twice weekly
	All dry cattle	1. Hay/silage 2. Cereal grain	1. Once a week 2. Once a week

[1]At this time of year it is recommended to rest the pasture until there is about 1 t green DM/ha before grazing.

The supplement could be grain, concentrates, minerals or conserved forage depending on the deficiency. For a supplement to be effective, it must contain the main dietary requirements to make up for those deficient in the paddock forage. For example, standing DM is often deficient in protein. For efficient use of supplements the following steps should be followed:

1. Identify the components that are most limiting to animal maintenance/production (usually metabolisable energy and protein) and select supplements containing adequate levels of these components.
2. Balance the supplement to ensure efficient rumen function
3. Choose feeding techniques that minimise disruption to the animals' digestive system.
4. Monitor consumption, animal live weight and condition to confirm that the supplementation is working (Joshua 2006).

It is important to understand the requirements of your livestock type to meet production targets and match the appropriate forage type available. For example, a dry standing tropical grass pasture with a protein supplement can be a maintenance feed. If higher weight gains are required, a supplement with additional energy will be required but alternative forage (e.g. lucerne or oats) may be more cost effective.

Leaving the pasture rank to create a 'standing haystack' is best used later in the growing season, and it is recommended that only a small proportion of tropical grass pastures on a property be used this way. Legume regeneration can be reduced through shading by the rank grass, so this strategy should only be used for pastures that do not contain legumes, or just one year at a time so that the legume seedbank is not compromised.

Conclusion

Tropical perennial grasses are a productive forage source for northern NSW grazing systems capable of responding and persisting in a highly variable rainfall environment. Nitrogen fertiliser is important to maintain production and quality of tropical grasses, and current research is investigating a range of temperate and tropical legumes so that robust recommendations can be made. Active grazing management is required to maintain the pasture in a vegetative and high quality state for maximum animal production. During periods of peak growth tropical pastures can grow at high rates and exceed requirements of livestock. This surplus DM can be utilised during the growing season with additional stock or conserved as either hay or silage, or allowed to senesce and grazed during the winter period with supplements.

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Using tropical grasses in a temperate environment

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Abstract: *The paper discusses the benefits and uses of tropical grass based pastures in a temperate climate.*

Introduction

The decision to sow tropical grass based pasture was made after having indifferent success with temperate pastures. I was looking for pastures that would persist in our variable climate and fill an autumn feed gap. Another factor was the establishment cost of temperate pastures compared to the tropical pasture.

Property and grazing business

1. 'Yarroview' is located 35km west of Armidale and 20km north/north west of Uralla on the Northern Tablelands of New South Wales.
2. Elevation is 770m.
3. Average annual rainfall is 750–800mm with predictably dry autumns.
4. Property size is 326 ha, 70% arable.
5. Soils are loamy granite. Country has received approximately 1200 kg/ha of single super over the past twenty years.
6. Pastures are native grasses, annual ryegrasses, sub-clovers and natural clovers. Winter fodder cropping is used to prepare paddocks for sowing pastures.
7. With livestock, our enterprise is Wagyu cross cattle and finishing prime lambs that have been bred on a separate block.

Objectives

There were several factors that influenced my decision to use tropical grass based pastures.

Autumn feed

Feed is not normally an issue in summer for us, however, our predictably dry autumns are a major problem. I have been pleased with the ability of the tropical grasses to stay fresh well into the autumn and much longer than the other pastures on the property. With late summer or early autumn rain, quality feed has been available from the tropical grasses.

Fodder Conservation

The ability of the tropical grasses to grow a large amount of dry matter through the summer has allowed opportunistic fodder conservation as hay and/or silage.

Persistence of Pasture

Another aspect of tropical grasses that attracted me was their persistence. After having indifferent success with temperate pastures that included perennial ryegrass, cocksfoot and tall fescue only lasting approximately four years the establishment cost was hard to justify. Having seen tropical grasses at Baan Baa that were nineteen years old and still very resilient proved to be a big factor in my decision making.

Implementation

Establishment

My first paddock was sown the first week of December 2008. Species that were sown: Premier digit (59%), Bambatsi panic (35%), Katambora Rhodes grass (5%) and Consol lovegrass (1%). The mix was sown at a rate of 4 kg/ha of bare seed at a cost of $13/kg. The paddock was sown with 70 kg/ha of DAP fertilizer. In comparison a temperate pasture typically costs $100 to $130 per ha for the seed. The down side of establishing a tropical grass based pasture is the lead in time, in that you need a very thorough weed control, particularly summer grasses ideally over three seasons.

Production

The growth period for tropical grasses in my area is generally between October and April, however, I have had growth in June following rain and mild weather. During the summer months the tropical grass pastures are capable of producing a large bulk of dry matter. Between the 15th December 2009 and the 2nd February 2010 we experienced very favourable conditions and made silage from a 17.4 ha paddock that produced 377 round bales (approx. 500 kg/bale). I found that these pastures perform better if they can have some degree of bulk left on them. On other occasions I have left standing dry/frosted feed for use in winter. The first paddock I sowed has had quite a lot of annual ryegrass come back in, which has been beneficial for the winter months.

Fertiliser Program

During the following autumn (after sowing) paddocks have been top-dressed with 125 kg/ha of single super and sub-clover has also been broadcast at this time. Arrowleaf clover was broadcast in 2010. In the following October paddocks were top-dressed with urea at 100 kg/ha (~50 kg N/ha) and subsequent years have seen an annual top dressing of single super at 125 kg/ha. I do feel that the pastures would have benefitted from a nitrogen application during their first summer. As with all improved pastures, if conditions permitted, an annual nitrogen application would maximize the growth potential.

Grazing

During recent springs, that have arrived late, the tropical grass pastures have produced more feed early than the other paddocks, providing good grazing conditions. To achieve quality autumn feed I have kept the tropical grasses grazed to a level of 20–30cm through late summer. I have found that by doing this the ability of these pastures to produce quality, early autumn feed has been very good even as drier conditions prevail. These pastures make better use of limited rain in the autumn months. I've used these pastures to graze cross-bred lambs while fodder crops are establishing.

Persistence

I am very pleased, at this point, with the persistence of the tropical grasses. Premier digit has been the best performer of the grasses, both in production and persistence and after five and half years is still a very thick pasture. Katambora Rhodes has not persisted in the low-lying paddocks. Bambatsi panic has thinned and the Consol lovegrass is very persistent and more frost tolerant, however, produces less dry matter.

Conclusion

Overall I am very pleased with the paddocks I've sown to tropical grasses. To this point they are meeting the objectives I set out, particularly the autumn feed gap and persistence. Future planning includes sourcing perennial, temperate pastures that will persist over a long period of time and handle the hot, dry summers that we sometimes get and our consistent dry autumns. I am pursuing this avenue to complement the tropical grass pastures and take advantage of winter rainfall. Traditional temperate pastures, as I have said earlier, do not persist in my area, particularly if grazed by sheep. As a result of this I am currently trialing Uplands, a Spanish cocksfoot .

The role and use of traditional and alternative fertilisers

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Abstract: *The use of traditional and alternative fertilisers, such as topdressing with nitrogen or poultry litter, raise questions about terms used to describe fertilisers and claims of efficacy. A farmer survey is reported showing farmers have a variety of considerations when choosing to use fertilisers. Trials in the Lower Hunter region of New South Wales show that alternative fertilisers such as poultry litter can be effective and good value while other products failed to produce a pasture yield response. Availability, reliability and quality of evidence to support marketing claims for fertilisers and other soil additives in future are identified as an issue.*

Key words: nitrogen topdressing, poultry litter, pseudo-science, pasture

Introduction

Fertilisers are used to overcome a nutrient deficiency which would otherwise reduce or limit plant or animal production, and to maintain soil fertility by replacing nutrients which have been lost when produce is sold. Most farm produce goes to major cities or overseas export taking valuable nutrients with it. If these nutrients are not replaced then soil nutrient depletion will be an increasing problem.

Interest in alternative fertilisers has grown in recent years, but what is an alternative fertiliser and how do we know if it is effective?

In earlier centuries conventional agriculture relied on the use of animal manures, crop rotation, flood sediment, cultivation, wood ash or some form of slash and burn to enhance natural soil fertility. Mined products such as guano, lime, dolomite, gypsum or potash were found to increase production in certain situations. Over time new and more concentrated fertilisers were developed and the definition of conventional farming seemed to change so now what was once conventional is referred to as alternative by some groups. Mainstream agriculture has embraced this evolution to use all the tools, options, innovations and knowledge it can to supply markets with the produce they require at a profit and without degrading farm resources.

Today conventional fertilisers refers to chemical, synthetic or manufactured fertilisers while alternative fertiliser may refer to manures, composts, rock dusts, humic products, organic based liquids, biological products and a myriad of mixtures in both solid and liquid form.

Speakers at previous Grassland Society of NSW conferences have discussed the evolution of thinking on the use of fertilisers and the quality of evidence to support claims of efficacy or cause and effect. Virgona and Daniel (2010) raised concerns about ‘products for which outlandish claims have been made without any demonstrated benefit’ and also non-adoption of technology which has been shown to work. They provided some guidelines for evaluating the quality and reliability of evidence and explain why well conducted experiments should be considered superior to testimonials alone.

Edmeades (2011) also wrote about the quality of evidence in a paper titled ‘Pseudo-science: a threat to agriculture’. He refers to the Green Revolution of the 1960s and the need to produce more food than ever before if we are to feed a predicted 9 billon people on earth by 2050. He writes about a ‘Post-modern philosophy’ where respect for science is being eroded and all opinions are given equal authority irrespective of where the evidence lay. This ‘Pseudo-science’ is anti-science which will only prevail if science is undermined and belittled. He writes ‘pseudo-science uses fear-mongering and conspiracy theories, claims wisdom from the past is now overlooked and calls for a new way of thinking which supports their opinions or products’. He writes about products where ‘the only possible conclusion was that these products are ineffective when used as recommended’.

This theme was continued by Menzies *et al*. (2011) who also discussed the difficulty of assessing biological products in the field where plants growing with microbes is the natural condition. Menzies *et al*. (2011) also expressed concerns when speaking about products where those with a commercial interest may respond by taking legal action against a researcher and/or their employer.

Leech (2012) observed that there is growing producer interest in potential use of alternative fertilisers on pasture, but there was little applied research comparing alternative fertilisers with more conventional products. Landholders from the Bookham and Binalong areas, on the South-West slopes of NSW, were engaged and trials were established comparing animal derived manures, compost and mineral based products with superphosphate and a nil control in low fertility soils. The results showed that products which delivered the highest amounts of phosphorous (P) and sulphur (S) produced the most dry matter (kg DM/ha) of pasture.

Billingham (2012) reported that more than 200 humic products are currently being manufactured and sold as soil amendments in Australia. They are marketed with the promise of enhanced plant growth and improved soil physical, chemical and biological properties. A major problem, possibly due to their cost, is recommended application rates are set too low to have any positive benefit.

It would seem that descriptions of traditional or alternative fertilisers get confused with terms such as conventional, manufactured, new and old, natural, organic and so on. Take the example of organic, in this sense it is not the same as the term used in organic chemistry which means containing carbon, otherwise urea would be considered an organic fertiliser and guano not organic. Humic substances are a natural component of organic matter in soil, but humic products are manufactured by treating brown coal, peat or other sources of carbon with an acid or an alkali (Billingham 2012). Manures and composts, once considered traditional fertilisers are now viewed as alternative.

It is easy to tell a confusing story and be selective on what claims of benefit or problems are reported. As Menzies *et al*. (2011) write, the extremes are relatively easy to accept or reject, it is the middle ground that is difficult and sometimes open to interpretation.

What do farmers think about fertilisers?

A questionnaire distributed at 10 field days and meetings held in the Hunter Valley, North Coast and North-West slopes of NSW, in 2011 was developed to provide insight into what farmers think about using fertilisers.

One hundred and fifty people completed the questionnaire with 94 percent describing themselves as farmers. Seventy six percent had been on their properties more than 10 years and 54 percent of properties were larger than 100ha. The respondents were beef producers (58 percent), dairy farmers (34 percent) with the remainder other enterprises including horses and poultry.

Ninty percent of respondents have used some form of fertiliser or additive. Sixty four percent have used ‘conventional or traditional’ fertilisers and forty percent have used new or alternative methods. A number of the respondents have said no to conventional fertilisers and alternative methods (23 and 40 percent respectively). Lime, gypsum or dolomite have been used by 64 percent of respondents, nitrogen fertilisers by 62 percent, phosphorous fertilisers by 60 percent, and poultry litter by 50 percent. Between five percent and 14 percent replied yes to questions about using organic, mineral, compost, biological or alternative products.

When asked to comment on importance of a range of issues when deciding what fertiliser, or additive to use, the following were rated important or very important: nutrient requirements (84 percent), seeing or measuring a benefit (84 percent), impact on the environment (75 percent), trial results (75 percent), cost (70 percent), professional advice (68 percent), availability (66 percent), risk of runoff and ease of use both (62 percent), feedback from other farmers (61 percent) and organic classification (29 percent). Smell was only considered important by 10 percent of respondents. Only 23 percent of respondents rated advice from sales representatives or neighbours as important.

Although 89 percent said they had used soil tests, interestingly only 33 percent said soil test results were important.

Nitrogen topdressing using traditional and alternative fertilisers

In 2009 trials were established at Tocal, Taree and Berry in response to questions from local dairy farmers interested in a number of topdressing options for high production pastures where soil fertility was high and nitrogen (N) topdressing was thought to be the only fertiliser requirement (Muir *et al.* 2011, Griffiths *et al*. 2012). A range of products were being promoted as cheap, more productive, better for the environment, feed quality, soils, soil biology and clover content and confirmation of these claims was sought. Suppliers active in the area at the time were invited to nominate suitable products and appropriate rate for use in a comparative trial. The range of products included in the trials represented traditional fertilisers (urea), liquid organics, biologicals, plant hormone and poultry litter. Some treatments varied with site. This paper concentrates on the Tocal site - where forage yield, feed quality and limited observations of clover content and soil biology were measured in two trials over a two year period. In Trial 1 treatments were applied after each harvest. In Trial 2 treatments were applied after every third harvest except for poultry litter which was applied annually.

Results

Table 1 shows that a number of the ‘alternate’ fertilisers contained very low N levels and although promoted as an option for topdressing could not be expected to act as a traditional fertiliser. They may act as a growth promotant, but were not replacing the N removed when the pasture was harvested. They also were not necessarily cheaper than traditional fertilisers.

Figures 1 and 2 show that yield increased as the amount of N applied increased. ‘Alternate’ fertilisers yielded approximately the same as the nil fertiliser controls in these trials The exception was gibberellic acid (GA) which enhanced yield when applied with 50 kg/ha urea compared to 50 kg/ha urea alone.

Table1. Tocal topdress Trial 1 and 2 - Nutrient applied per hectare per application

Treatments	Trial	N %	P %	K %	Cost $/ha	Cost $/unit N
Nil	1,2	-				
Urea 50 kg/ha	1,2	23			37.25	1.62
Urea 100 kg/ha	1,2	46			74.50	1.62
Urea 200 kg/ha	2	92			149.00	1.62
Green Urea 50 kg/ha	1,2	23			42.45	1.85
Green Urea 100 kg/ha	1,2	46			84.90	1.85
Green Urea 200 kg/ha	2	92			169.80	1.85
Entec Urea 50 kg/ha	1,2	23			47.30	2.06
Entec Urea 100 kg/ha	1,2	46			94.60	2.06
Entec Urea 200 kg/ha	2	92			189.20	2.06
Polymer coated urea 75 kg/ha	2	34.50			91.50	2.65
Polymer coated urea 150 kg/ha	2	69			183.00	2.65
Biological N fixer	1,2	-			30.00	-
Biological + 50 kg/ha Urea	1,2	23			67.25	2.92
Gibberellic Acid (GA) 20 g/ha	1,2	-			12.80	-
GA 20 g/ha + Urea 50 kg/ha	1,2	23			50.05	2.17
Organic liquid 1 @ 20 L/ha	1	3.54		1.38	73.00	20.62
Organic liquid 1 @ 30 L/ha	2	5.36		2.1	109.50	20.66
Organic liquid 2 @ 10 L/ha	1,2	1.0	0.37	0.74	55.60	55.60
Organic liquid 2 @ 20 L/ha	1,2	2.0	0.74	1.48	111.20	55.60
Organic liquid 3 @10 L/ha	1	1.5	0.5	0.5	69.45	46.30
Poultry Litter 15 m^3/ha	2	160	108	60	300.00	1.88
Poultry Litter 7.5 m^3/ha	2	80	54	30	150.00	1.88

Poultry litter on pastures

In some areas poultry litter is used as an 'alternate fertiliser'. In most traditional poultry production areas, including the Hunter Valley, it is considered a standard fertiliser which can supply major nutrients N, P, potassium (K), S, trace elements and organic matter. In some areas it is considered a N fertiliser which contains other nutrients; I prefer to think of it as a P fertiliser which contains other nutrients. If used repeatedly as a N fertiliser then soil tests show a dramatic increase in soil P over time, to the extent that extra P would not promote extra pasture growth (Griffiths 2000). The surplus P is a cost and a risk to nutrient runoff (Griffiths *et al*. 2004). Poultry litter should only be applied when soil test results show that P would be beneficial.

Standard laboratory test methods can be used to compare different fertilisers and predict likely production results. For example in 2010 poultry litter sampled had an average of 1.1% total P with 0.5% water soluble P, 0.5% citrate soluble P and 0.1% citrate insoluble P (N Griffiths pers. comm.) compared with single superphosphate with 8.8% total P, 8.0% water soluble P, 0.6% citrate soluble P and 0.2% citrate insoluble P and reactive rock phosphate (variations also described as soft rock, composted rock and similar) with total P from 8 to 13% depending on source, with less than 1% available in the water soluble and citrate soluble forms of P and the majority in the non available citrate insoluble form. The combination of immediately available (water soluble) P and slow release (citrate soluble) P in poultry litter could be beneficial to sustained pasture growth compared to the extremes of water soluble P in superphosphate and citrate insoluble (unavailable) P in rock phosphate.

A trial at Tocal has demonstrated the effectiveness of poultry litter as a fertiliser on pastures. This trial has compared pasture growth from poultry litter and fertiliser from 2002 to present. The pasture is irrigated (bike shift) and monitored using pasture cages. The pasture consists of a kikuyu base and is usually oversown with ryegrass in late autumn. The paddock had high soil fertility prior to the trial starting with $pHCaCl_2$ 5.6 and P tests 195 ppm (Colwell) and 53 ppm (Bray).

The trial consisted of three treatments, two replications, plot size 15 m x 100 m, three pasture cages per plot. Pasture production (kg DM/ha) was estimated from the pasture cages. Other measurements included changes in soil fertility and nutrient runoff.

The treatments were applied as follows; Treatment 1- Poultry litter: 15 m^3/ha in December of each year, Treatment 2 - first three years received NPK fertilisers applying the same amount of nutrients estimated to be applied in treatment 1. These fertilisers were applied in split applications every 3 months. From year four to the present this treatment has only received N fertiliser as urea at 100 kg/ ha/month applied when the pasture is actively growing. In years four and five urea was applied in seven months each year. In years six and seven urea was applied every month, and Treatment 3 - poultry litter was applied at 15 m^3/ha/year every second year plus 100 kg/ha urea applied every 3 months except in years one and three when no extra urea was applied. There was also a nil treatment comprising a 20 m nil fertiliser "buffer" located at the bottom of the Treatment 3 plots.

The results presented in Table 2 and 3 indicate that poultry litter can be a cost effective fertiliser.

Figure 3 demonstrate that continuous annual applications of poultry litter at 15m^3/ha can result in excessive Colwell P levels. The urea only treatment (nil P) demonstrates declining Colwell P levels and at this trial site poultry litter every second year maintains soil

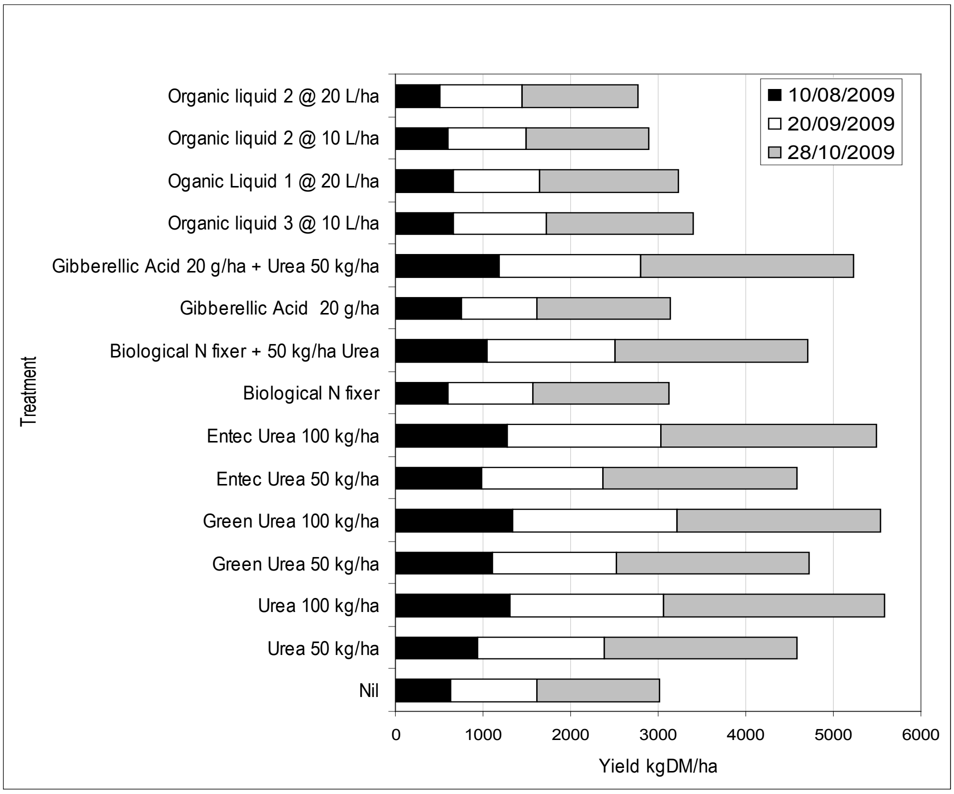

Figure 1 Tocal Trial 1 season 1 dry matter yield

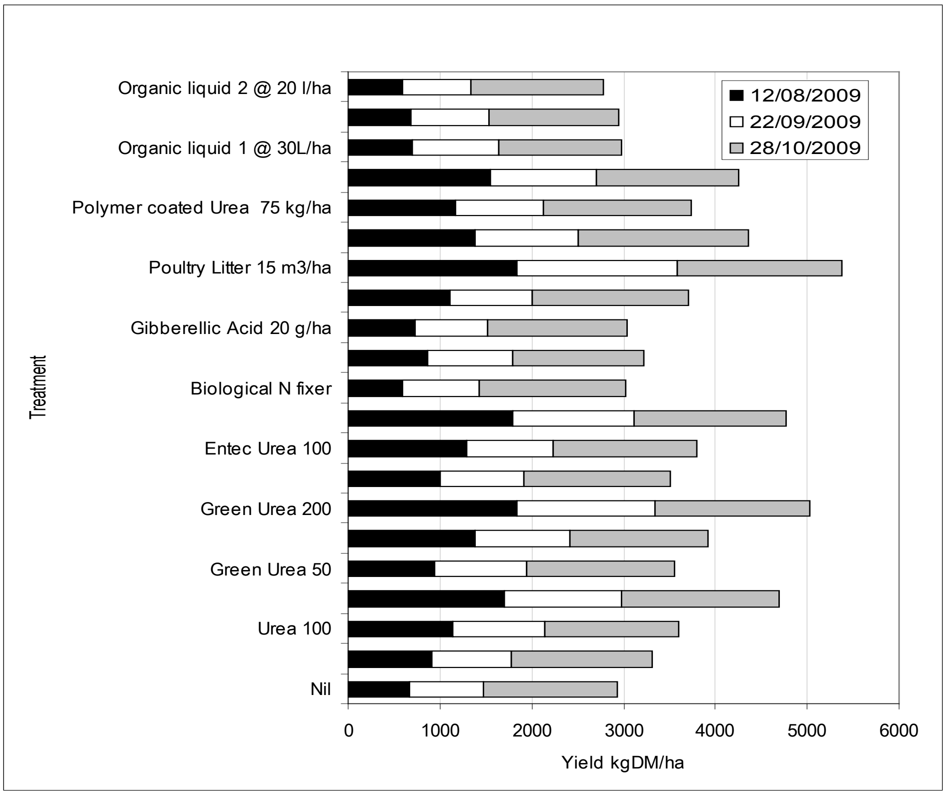

Figure 2. Tocal Trial 2 season 1 dry matter yield

Table 2. Poultry litter trial fertiliser costs

Treatment	Fertiliser applied	Cost	Total cost
1.	Poultry litter 15m^3/year x 7 years	\$20/m^3	\$2,100
2.	DAP 555 kg/ha x 3 years	\$1,080/t	
	Urea 142 kg/ha x 3 years	\$810/t	
	Muriate of Potash 124 kg/ha x 3 years	\$1,370/t	
	Urea 100 kg/ha/month x 7 months x 2 years	\$810/t	
	Urea 100 kg/ha/month x 12 months x 2 years	\$810/t	\$5,794.26
3.	Poultry litter 15 m^3/year x 4 years (years 1, 3, 5, 6)	\$20/m^3	
	Urea 100 kg/ha 4 times per year in years 2, 4, 5, 6, 7)	\$810/t	\$3,200

Note: Price of poultry litter is delivered and spread. Price of fertiliser is delivered only.

Table 3. Cost of pasture produced 2002–2008 (fertiliser cost only)

Treatment	Total pasture produced in 7 years t DM/ha	Total cost of fertiliser \$/ha	Cost of pasture \$/t DM
1. Poultry litter only	108.826	\$2,100	\$19.30
2. Fertiliser only	121.093	\$5,794.26	\$47.85
3. Combination poultry litter plus nitrogen (urea)	120.850	\$3,200	\$26.48

phosphorous levels at current levels of production shown in Table 3. Soil testing is required regularly to ensure poultry litter is applied when pasture production responses can be expected.

Discussion

Any comparison or discussion about traditional or alternative fertilisers is confused by varying definitions and context of the terms used. The reasons for using different types of fertiliser including the expected benefits and the reliability and repeatability of evidence to support the claims made can add to confusion.

Ideally any fertiliser program should be objectively based. That is, based on a need for nutrients confirmed by reliable soil testing and/or nutrient budgeting. When nutrient requirements are known, a range of products which will supply the required nutrients can be compared for cost. Other considerations which may be important include reliability of local supply, odour (if neighbours nearby could be affected), organic certification, form or mode of action such as slow release.

Unfortunately it seems an increasing number of fertiliser decisions are based on belief and misinformation leading to the use of products which may be ineffective or very expensive or both In some cases, products are not used because of concern about side effects which may not be justified, or based on information which is out of context.

It is easy to be confused about the use of fertilisers for pastures because results will depend on seasonal growing conditions and management factors such as; grazing strategy and pasture species as well as the cumulative effects which may be good or bad depending on situation and detail. The studies presented in this paper illustrate these points. Poultry litter may be considered traditional or alternative depending on location and the users' background. It can be effective in increasing soil fertility and pasture production if used in suitable situations, however, it can be expensive and an environmental risk if not used correctly.

The study of nitrogen topdressing alternatives included several products where trial results did not support claims of effectiveness. We cannot conclude that the products do not work, we can only conclude that these products were not effective under the conditions of these trials.

With new products continuously coming onto the market and an increasing range of marketing claims being made, the need for objective trials and comparative studies is greater than ever. Replicated coordinated experiments are expensive and current trends away from public funding toward an increased reliance on industry funding is concerning. Some fertiliser users will be concerned about the dominance and independence of large companies funding research. Small businesses will find it difficult to research and they are increasingly using testimonial "evidence" to support marketing claims. We hear that evidence based recommendations are required, but what is the quality and reliability of such evidence. Will demand for research limit innovation and adequate testing of new products from small operators?

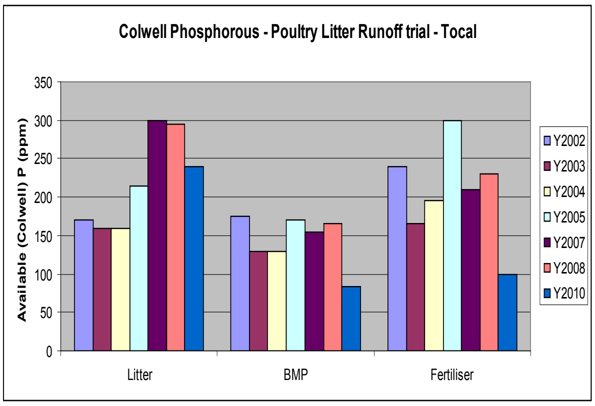

Figure 3. Tocal Poultry litter trial soil phosphorous levels

Conclusion

With a trend towards reduced funding for research and increased use of unsubstantiated claims by some marketers to promote products, it will be more important for producers to have the knowledge and understanding of the basics of soil science and fertiliser use to enable them to correctly interpret information. It will be more important to conduct reliable soil testing programs and to use fertiliser test strips and simple on farm trials to test the beneficial claims of the new products.

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Interspecific hybridisation to improve the adaptation of white clover to soil moisture stress

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Abstract: *A requirement for high soil moisture imposes some limitations on the use of white clover (*Trifolium repens *L.) in New Zealand, and in other parts of the world. Periodic drought can also have severe impacts on white clover production and persistence in higher rainfall areas. The application of interspecific hybridisation is a novel approach to improving the drought resistance of this major legume species. Closely related species within the genus* Trifolium *have been crossed with white clover to introgress new genes and traits from outside its existing genetic variation. In particular, traits or adaptations related to the natural edaphic conditions of these, mostly wild, relatives are of interest. Hybrid combinations relevant to drought resistance include* T. repens × T. uniflorum *L. and* T. repens × T. occidentale *Coombe, in addition to crosses between* T. occidentale *and* T. ambiguum *M Bieb. This paper reviews the research to date on these hybrids, and discusses the potential of interspecific hybridisation to produce more drought resistant, productive clover germplasm. In essentially unselected material, we have found that the effects of soil moisture stress on many morphological and physiological traits were significantly smaller for hybrid families, compared with white clover cultivars. These include smaller reductions in shoot dry matter production and shoot morphological traits, and lower shoot senescence. In addition, the more vigorous root systems and/or the presence of thicker roots observed in the hybrids would be beneficial for water acquisition. Further improvements, above those already seen on average, will be achieved by greater understanding of underlying traits and by utilising variation to develop elite breeding populations.*

Key words: drought, water stress, introgression, plant breeding, interspecific hybrids, forage legumes

Introduction

White clover (*Trifolium repens* L.) is a major pasture legume in New Zealand, particularly in areas of high rainfall or under irrigation. Its stoloniferous growth habit, productivity, feed quality and ability to fix atmospheric nitrogen (N) all contribute to the value it provides to grazing systems. Due to higher feed intakes and efficiency, sheep liveweight gains are higher when grazing white clover compared with perennial ryegrass (*Lolium perenne* L.), the major companion species in New Zealand agriculture (Ulyatt 1981). Castle *et al*. (1983) also found that increasing the proportion of white clover silage versus perennial ryegrass silage increased the intake and milk yield of dairy cows. In 1996 the annual estimated average N fixation by white clover in New Zealand was 1.57 million tonnes, valued at that time at NZ$ 1.49 billion (Caradus *et al*. 1996). Crush (1987) lists rates of 17–380 kg N/ha/yr fixed from studies in grazed pastures, and over 600 kg N/ha/yr in mown plots. The transfer of fixed N from white clover to grasses in grazed swards has been estimated at 60 and 70 kg N/ha/yr for above- and below-ground transfer, respectively, accounting for 50% of grass N (Ledgard 1991).

White clover is a highly heterozygous, outcrossing species which leads to high genetic variation (Williams 1987) and wide adaptation. Considerable variation exists within white clover for numerous characteristics (Caradus 1994). This variation has been exploited through plant breeding to create cultivars adapted to particular environments and farm systems, and also enables the species to adapt naturally to, and thus survive in, a range of conditions. However, the existing genetic variation within white clover does not include characteristics for, or adaptation to, soil moisture stress, and a requirement for high soil moisture currently imposes restrictions on the productivity and use of white clover. The effects of periodic drought events on white clover production can also be significant. Knowles *et al*. (2003) studied the effects of a summer/autumn drought on white clover in five regions throughout New Zealand. They found that 23% of long-term mean rainfall (November-April) in Marlborough reduced white clover presence by 95%, while 80% of long-term mean rainfall in the Wairarapa reduced white clover by only 8%.

The ultimate effects of drought stress on white clover are decreases in dry matter (DM) production and survival (e.g. Brock and Kim 1994; Barbour *et al.* 1996). However, several underlying factors contribute to these effects. White clover has poor control of water loss under dry conditions (Johns 1978; Aparicio-Tejo *et al*. 1980; Hart 1987), which may be due to failure to close the stomata or a low cuticular resistance. Hart (1987) suggested this was the cause of low water use efficiency (WUE) in white clover in dry situations. In moisture limited conditions, Johns and Lazenby (1973a, 1973b) found that although water use of white clover and forage grasses was similar, the clover produced significantly less herbage. Barbour *et al*. (1996) reported no variation in WUE among 10 white clover cultivars. Aparicio-Tejo *et al*. (1980) concluded that subterranean clover (*T. subterraneum* L.) was better adapted to water stress than white clover because of larger decreases in transpiration, higher cuticular resistance, and better recovery of N-fixation after drought.

The senescence of leaves during drought stress is commonly reported in white clover (Johns and Lazenby 1973a; Brock and Kim 1994) and may be a direct consequence of water loss, or a response mechanism to limit dehydration and maintain plant survival. Once the white clover tap root system dies and the plant fragments, 12–18 months after germination, the clonal plants are dependent on smaller nodal root systems which are more vulnerable to factors such as drought and insect pests. Nodal roots of white clover require adequate soil moisture to form (Thomas 1987), so decreased nodal root formation during drought would reduce total root mass for access to available water. In general, the relatively small, shallow root system of white clover limits its ability to access water, especially in competition with companion grasses. Characteristics such as increased root vigour, high root:shoot ratio, and presence of large diameter nodal roots can improve the yield and persistence of white clover under drought (Blaikie and Mason 1990; Caradus and Woodfield 1998), particularly when selecting from dryland ecotypes (van den Bosch *et al*. 1993).

Predictions of future climate indicate that eastern areas of New Zealand, which are classified as dryland environments (summer evapotranspiration > summer rainfall in most years (Brown and Green 2003)), are likely to become drier with a 20–30% increase in potential soil moisture deficit (Salinger 2003). An increasing frequency or severity of drought events may also occur across the country. The summer/autumn drought which affected most of the North Island in 2012–13 was the most severe in 40–70 years, depending on location. Parts of the northern North Island also suffered from drought in the following summer/autumn, with severe effects on pasture growth and survival. We are utilising a novel approach to white clover breeding aimed at improving its adaptation to these future conditions, and expanding its current adaptation into more marginal farming areas. Interspecific hybridisation introduces new genes and characteristics, outside the existing genetic variation of white clover, from its close relatives. These are predominantly wild species, not used in agriculture due to low productivity or poor adaptation to grazing systems. However, they can produce vigorous hybrids with white clover. Our goal is to identify and select hybrid populations which combine the productivity and other desirable traits of white clover with targeted characteristics from its close relatives.

White clover is itself a natural interspecific hybrid. Ellison *et al*. (2006) used molecular techniques to identify the most likely ancestral parents of white clover as *T. pallescens* Schreb. and *T. occidentale* Coombe (western clover). These species are now geographically and ecologically isolated occurring, respectively, in alpine (>1800 m altitude) and coastal European habitats (Williams 2014). The work by Ellison *et al*. (2006) also redefined the species relationships within the genus *Trifolium*, identifying 'new' close relatives of white clover but also 'repositioning' species which had been considered to be closely related based on the previous morphological based phylogeny. From a group of eight closely related species, eleven taxa have now been successfully hybridised with white clover (Williams 2014). Traits of interest include increased flowering, and resistance to pests, diseases and viruses. Several of these species occur naturally in challenging edaphic conditions and may also provide a route to improving the drought resistance of white clover.

Trifolium repens × *Trifolium uniflorum*

Trifolium uniflorum L. (2n=32) is a perennial, autotetraploid species from the Mediterranean region, very closely related to white clover. Little information is published on its edaphic adaptations but it is reported as being tolerant of dry environments (Tela Botanica 2014). It occurs from coastal to inland habitats (Brullo *et al.* 2000) and in Greece has been recorded from sea level to 2400 m altitude (Fotiadis *et al*. 2010). *Trifolium uniflorum* has been considered for use in the dryland wheatbelt of southern Australia, where it ranked highly for persistence but poorly for productivity among the species investigated (Li *et al*. 2008). In addition to the little that is known about its natural habitat, morphological traits such as small, thick waxy leaves; thick, deep roots; and a woody tap root also suggest this species may be a valuable source of genetic variation for drought resistance. Nichols *et al*. (2014a, 2014b) have also identified potential for improved growth at low soil phosphate levels in some *T. repens* × *T. uniflorum* hybrid families.

Hybrids between white clover and *T. uniflorum* were first produced by Pandey (1957) but there has been, until recently, little effort to develop these hybrids further. The two species cross relatively easily, compared with some white clover interspecific crosses. Embryo rescue is needed to produce F_1 progeny, but these are highly fertile and backcross readily to white clover to produce successive backcross generations (Williams 2014; Williams *et al*. 2013). F_1 hybrids have been created using several *T. uniflorum* accessions from the Margot Forde Forage Germplasm Centre (Palmerston North, New Zealand) and backcrossed to a range of commercial white clover cultivars. Backcross hybrids, and some F_1 hybrids, have been screened under a range of conditions to determine the effect of low soil moisture, compared with white clover, and to measure key characteristics related to drought resistance.

Hussain *et al*. (2012) screened seven F_1 hybrid genotypes, 32 first-generation (BC_1) hybrid genotypes and 17 white clover genotypes outdoors in a bed of coarse sand at Palmerston North, New Zealand. Plants were established from stolon tip cuttings and planted in a complete randomised block design with three replicates. The shoot and root dry weight (DW) of the best BC_1 hybrid plants were similar to the best elite white clover plants, and BC_1 hybrids had a higher ratio of thick roots per unit of root DW. Although the F_1 hybrids had a small root DW compared with BC_1 and white clover, they had the highest ratio of thick roots. Pattern analysis identified several BC_1 genotypes with superior vigour for both shoot and root characteristics. Pandey and Petterson (1978) and Pandey *et al*. (1987) both reported transgressive segregation for root traits in *T. repens* × *T. uniflorum* hybrids, describing vigorous hybrids with stronger, deeper root systems than white clover, particularly the presence of thick nodal roots. As well as potential mechanical benefits to drought resistance, thicker roots are considered to penetrate deeper into the soil and would therefore provide access to deeper subsoil moisture in dry environments and drought conditions.

Nichols *et al*. (2014c) conducted a field experiment at Lincoln, New Zealand, to determine whether *T. repens* × *T. uniflorum* hybrids were more drought resistant than white clover, and to identify traits that might be contributing to this. An automatic rain shelter that activated to cover the site was used to exclude rainfall for four months (early December until late March), and soil moisture was controlled using irrigation. Six replicate plots were irrigated once a week to replace potential evapotranspiration +10–20 mm, and a further six replicates received no water through either irrigation or rainfall for the length of the treatment period. A split plot design was used, with watering treatments assigned randomly within replicates. Plants were established from cuttings and the positions of 16 different clover entries were assigned randomly within each plot. Seven BC_1 families, four second-generation (BC_2) families, and five white clover cultivars with a range of leaf sizes were studied – six genotypes of each, clonally replicated between watering treatments. At the end of the treatment period, volumetric soil moisture averaged 10% in the top 20 cm of the stressed treatment and 28% in the watered treatment. Soil moisture at 95 cm depth was similar for both treatments, at 30%.

The response of the BC_2 generation to water stress was similar to that observed for white clover, but the effect on BC_1 hybrids was smaller than white clover for a number of different traits, most importantly for shoot DW. Mean shoot DW of BC_1 decreased by 47% under water stress, compared with almost 70% for BC_2 and white clover. The relative differences, on average, in shoot production between BC_1, BC_2 and white clover in the watered treatment were similar to those observed under standard field conditions in this location (Nichols *et al*. 2014d). Mean shoot DW of BC_2 was 26% higher than BC_1, and white clover was 95% higher than BC_1. However the differential effect of water stress meant that there were no differences in shoot DW among the three clover types in the stressed treatment. Similar results were observed when a wider range of hybrid families (38 BC_1 and 80 BC_2) was screened in a multiyear experiment under dryland conditions near Lincoln, with equal summer growth among hybrids and white clover cultivars (Widdup *et al*. 2014). However, variation among hybrids indicated potential for higher growth relative to white clover in some families. Soil moisture deficit (>75 mm) from November to April in all three years of the experiment was sufficient to cause plant stress.

The smaller effect of drought on shoot DW of BC_1 hybrids was probably influenced by smaller effects on many stolon morphological parameters, compared with white clover (Nichols *et al*. 2014c). In particular, genotypes with a smaller decrease in leaf size under water stress had smaller decreases in shoot DW, and genotypes with a smaller leaf area in the absence of water stress also had smaller decreases in DW. On average, leaf size of BC_1 hybrids was smaller than that of BC_2 and white clover, a general trend also reported by Nichols *et al*. (2014d) and Widdup *et al*. (2014). Changes in senescence were also correlated with effects on DW, with no change in mean senescence under water stress for BC_1, compared with significant increases for BC_2 and white clover. Senescence under water stress was significantly lower in BC_1 hybrids than in BC_2 and white clover. Nichols *et al*. (2014c) and Widdup *et al*. (2014) both also recorded higher stolon densities under water stress for BC_1 hybrids than for white clover, a trait which could affect DM production and may influence persistence under grazing in dry hill country (MacFarlane *et al*. 1990).

Nichols *et al*. (2014c) found that root DW, taken in 100 mm diameter x 100 mm deep soil cores over the centre of each plant in a subset of entries, increased significantly under water stress for the individual BC_1 family which was measured but not in the corresponding, related, BC_2 family or white clover parental cultivar. Increase in root DW during drought is a common response which increases the biomass available to obtain a limiting resource. The cross-sectional area of the largest nodal root in the sample was also higher for the BC_1 family than for the BC_2 family and cultivar, regardless of watering treatment. This is consistent with the observations of thicker, stronger root systems by Hussain *et al*. (2012), Pandey *et al*. (1987) and Pandey and Pettersen (1978). Higher proportions of thicker roots in both *T. uniflorum* and *T. repens* × *T. uniflorum* hybrids, compared with white clover, have been confirmed in both hydroponic and sand culture (S. Nichols, unpublished data). These root traits and responses may have enabled the BC_1 family to maintain water uptake and, therefore, its photosynthetic rate under water stress, whereas photosynthesis decreased by over 40% in the BC_2 family and white clover parent (Nichols 2012).

Chlorophyll fluorescence data indicated there was no physical damage to the photosynthetic apparatus in either white clover or hybrids (Nichols 2012), which is consistent with other reports on the effects of drought stress in white clover (Hofmann *et al*. 2003). Decreases in photosynthesis in the BC_2 family and its white clover parental cultivar, therefore, reflect a response to limit water loss. Similar to the lack of variation found by Barbour *et al.* (1996) among white clover cultivars, there were generally no differences in WUE between hybrids and white clover (Nichols 2012), indicating this may not be a strong trait for selection. However, Nichols (2012) did report evidence for variation in production of protective phenolic compounds, some of which were correlated with changes in shoot DW and senescence under water stress. Other studies have found that these compounds are associated with UV and drought stress in white clover, and accumulate in higher levels in ecotypes than in cultivars (Hofmann *et al*. 2003).

This data indicates that hybridisation with *T. uniflorum* has potential for improving the drought resistance of white clover, especially given the relatively unselected nature of the plant material studied. Most importantly, the effects of drought on DM production and senescence were smaller for BC_1 hybrids than for white clover. This may be mediated by root characteristics or other, physiological, traits. As the contribution of *T. uniflorum* genes is decreased by repeated back crossing to white clover, later generation hybrids may exhibit characteristics and responses more similar to the white clover parent, as observed for some traits in the BC_2 generation. However, given the variation expected among interspecific hybrids and the potential for combination of desirable genes, the performance of individual genotypes and families within such generations may exceed the average.

Trifolium repens × *Trifolium occidentale*

Trifolium occidentale Coombe (2n=16), one of the ancestral parents of white clover, is a perennial, diploid species from coastal environments in Spain, Portugal, France, Great Britain and Ireland. Its habitat on beaches, sand dunes, and cliff tops suggests it has tolerance of dry, saline conditions (Coombe 1961). Hybrids with white clover were first reported by Chou and Gibson (1968) but, as with *T. repens* × *T. uniflorum*, were not developed much further until recently. In its diploid form *T. occidentale* does not cross readily with white clover but, when colchicine-doubled, tetraploid *T. occidentale* plants produce fertile F_1 hybrids (Hussain and Williams 2014). Consequently, a wide range of *T. occidentale* accessions were colchicine doubled, and crossed with white clover for the purposes of introgressing new genes, developing breeding populations, and cytological examination (Hussain and Williams 2014).

Hussain and Williams (2014) compared four *T. repens* × *T. occidentale* BC_1 families with white clover, in 33 cm x 33 cm x 27.5 cm boxes of soil at four soil moisture levels. Shoot DW of white clover was the most affected by decreasing soil moisture from 13 to 36% w/w, declining by 84% compared with 54% for *T. occidentale* and 69% for BC_1 hybrids. In contrast, root DW increased by less than 30% in white clover but approximately doubled in *T. occidentale* and the hybrids. The vigorous root system observed in *T. repens* × *T. occidentale* hybrids is likely to assist with acquisition of water during drought stress. Further screening of this material, and identification of traits contributing to drought resistance, is ongoing. In a field experiment over two years at Lincoln, New Zealand (600 mm annual rainfall, summer dry) the best *T. repens* × *T. uniflorum* and, particularly, *T. repens* × *T. occidentale* hybrid families had equivalent or greater growth scores compared with white clover (K. Widdup, unpublished data).

This data also indicates the potential for improved drought resistance in white clover through interspecific hybridisation with *T. occidentale*. In a similar response to that seen with *T. uniflorum* hybrids, smaller effects of water stress on shoot dry weight are likely facilitated by root characteristics and responses, however the influence of physiological adaptations is currently unknown.

Other interspecific crosses

Discovery that Caucasian clover (*T. ambiguum* M Bieb) can be crossed with *T. occidentale* has opened a number of potential new opportunities to breed hardy forms of clover. *T. ambiguum* has a large underground system of deep roots and rhizomes which confer drought tolerance (Marshall *et al*. 2001). Diploid *T. ambiguum* was crossed with diploid *T. occidentale* to produce an infertile diploid hybrid (Williams *et al*. 2011). When this was chromosome-doubled to form a tetraploid, the resulting hybrid was both vigorous and fertile. Similar hybrids were developed by crossing tetraploid *T. ambiguum* with tetraploid *T. occidentale*. These are similarly vigorous and fertile, with short rhizomes below ground and short stolons above-ground. These hybrids do not occur in nature and may constitute a synthetic new 'species' of agronomic potential, combining the drought tolerances of both parent species. Additionally, these plants can be crossed with white clover (Williams *et al*. 2013) to potentially enable the breeding of white clovers carrying drought tolerances from both *T. ambiguum* and *T. occidentale*.

Conclusion

For all three hybrid combinations discussed here, interspecies chromosome pairing has been observed, indicating the potential for recombination and true introgression of new genes and traits from one species to another. In white clover, the homologous chromosomes of the two sub-genomes (*T. pallescens* and *T. occidentale*) do not pair, however interspecific hybridisation provides potential for 'remixing' the white clover genes to produce new variation within the white clover component of hybrid genomes. Apart from this, differences in the combination of genes from the non-white clover parent mean that high genetic variation can be expected in interspecific hybrids in general. This provides potential for selection and segregating populations, but also requires extensive phenotyping to identify and characterise material of interest.

In both *T. repens* × *T. uniflorum* and *T. repens* × *T. occidentale* crosses, screening of unselected material has proven the potential for developing white clover germplasm with improved drought resistance using interspecific hybridisation. Germplasm screened so far was not previously selected for drought resistance traits, so the average improvement in factors such as growth, senescence, and root system size and form is promising. Focusing these responses into elite material should be possible given the variation that has been observed. The traits contributing to drought resistance in these hybrids are likely to involve factors influencing access to water and persistence, including both morphological and physiological characteristics. More detailed study of root and physiological traits will assist with identifying their relative contributions to drought resistance, and targeting traits for selection. Further improvements could be made through the use of new accessions of wild relatives in existing hybrid combinations, and the potential for combining genes from three or four species (Williams 2014).

Development of drought resistant hybrid germplasm could be accelerated by utilising genomic resources such as linkage maps and microsatellite markers for white clover (Griffiths *et al*. 2013a) and *T. occidentale* (Griffiths *et al*. 2007); and sequenced reference genomes being developed for these species (Griffiths *et al.* 2013b; 2014). Integrating these resources with the advent of low-cost high-density marker systems, such as Genotyping-by-Sequencing (Elshire *et al*. 2011), provides a platform to trace introgression, and to increase the efficiency of hybrid breeding by tracking regions of the donor genome associated with drought resistance.

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Control and management of invasive coarse grasses in the New England and near North-West Slopes of NSW

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Introduction

The author Jim Benton owns and manages a beef cattle breeding and fattening farm on the Northern Tablelands and near North-West Slopes of NSW. The operation consists of a 136 ha granite property near Glen Innes and a 4000 ha basalt and trap breeding property at Strathbogie, 70 km North West of Glen Innes. The Glen Innes property 'Weather Vale' is at an altitude of 1070 m and the Strathbogie property 'Reedy Creek' is at an altitude of 700–800 m.

Over the preceding 10 years, a number of trials have been conducted to investigate various methods of controlling and managing invasive coarse grasses on both 'Weather Vale' and 'Reedy Creek'. The problem grasses have been African lovegrass (*Eragrostis curvula*) at 'Weather Vale' and Coolatai grass (*Hyparrhenia hirta*) at 'Reedy Creek'.

Financial and environmental sustainability

The management strategies developed for the control of both species have had to be both financially and environmentally sustainable.

Factors influencing the financial sustainability were;

1. Cost of control,
2. Cost of establishment of replacement species, and
3. Cost of maintaining replacement species.

Bearing in mind the declining 'terms of trade' in the farm sector cost is a paramount consideration.

African lovegrass trial on 'Weather Vale'

Background

'Weather Vale' is a 136 ha property subdivided into 20 paddocks ranging in size from three to 13 ha. The property is stocked principally with young cattle from April to January each year and is lightly stocked from January to April to allow pasture to build up and set seed. 'Weather Vale' has a long superphosphate history and until 2002 pasture and grazing management followed traditional methods. The results were at best, just satisfactory. Invasive weeds, particularly African lovegrass were becoming dominant.

In early 2002 heavy rain on newly, ploughed ground resulted in severe erosion and the complete failure of new pasture in a couple of paddocks. A conscious decision was made to discontinue traditional ploughing and sowing methods of pasture establishment.

'Weather Vale' pasture management

Following various trials the 'Weather Vale' pasture program has been developed. The program incorporates a system of managed grazing, soil monitoring, strategic fertiliser use and African lovegrass control using a swingwiper (a rotating carpet roll wiper). This leads to a sustainable productive and diverse pasture of both native and introduced species.

Soil health is improved because of deep-rooted plants and increased soil organic matter. The risk of soil erosion is minimal because no ploughing takes place and maximum ground cover is maintained at all times. Rainfall use efficiency is enhanced and runoff is reduced.

The pasture management and grazing system is as follows;

i) Cattle are grazed rotationally year round in one mob (usually 150–200 head) for three to four days per paddock, eating down quality pasture of both native and introduced species.

ii) After grazing paddocks are spelled for six to 10 weeks depending on the seasonal conditions. This allows grazed paddocks to regrow, develop root systems and in spring/summer set seed. New pasture seedlings can germinate in dead mulch when seasonal conditions are favourable.

iii) On selected paddocks perennial pasture seed is broadcast with fertiliser and harrowed.

iv) In selected paddocks the African lovegrass is wiped with the swingwiper immediately after grazing. The rate of glyphosate applied varies depending on the African lovegrass height and density. It is important that the desirable pastures has been eaten down so only the target species have chemical applied to them.

Principles

The principles guiding the 'Weather Vale' pasture system are;

i) Apply a harsher pressure to the coarse grass (African lovegrass) by wiping than the pressure applied to the desirable species by grazing. This will result in a gradual change in the pasture composition – a gradual change is a stable change.

ii) Allow recovery time by managed grazing and periods of rest to allow desirable species to set seed and develop roots.

iii) Maintain maximum ground cover at all times – no ploughing.

iv) Utilise dry matter produced by the introduced and native grasses in the grazing management systems.

v) Control rabbits – these apply a harsher grazing pressure than domestic stock.

Coolatai grass trial at 'Reedy Creek'

Background

Following on the success of the African lovegrass at 'Weather Vale' it was decided to trial a similar control program on Coolatai grass at 'Reedy Creek'.

Trial process and results

The trial was conducted over three years and followed the 'Weather Vale' pasture format and principles. Because of the altitude, (700–800 m) temperate grasses were unsuitable as replacement species. Native grasses supported by legume seed (sub clover, arrowleaf clover and lucerne) were the targeted pasture mix.

The trial was successful, the result was a diverse pasture mix and the Coolatai grass dominance was reduced. However, the cost of the control work was the same as the highly productive Glen Innes area and the difficulty and cost of maintaining a suitable replacement species led to the conclusion that this method of combating Coolatai grass was economically unstainable in the Strathbogie area and that utilisation of the Coolatai grass was the only practical option.

Coolatai grass utilisation methods

Over the past three years, the following methods have been employed to utilise Coolatai grass.

Urea blocks and grazing management: Heavy grazing pressure and urea blocks (urea 11%, crude protein 32%) have resulted in moderate utilisation of Coolatai grass. However, after a relatively short time the cattle went off the blocks and consumption of Coolatai grass and stock performance decreased.

***Spraying molasses water mix and grazing management*:** Heavy grazing pressure coupled with spraying a molasses water mix (molasses 40%, crude protein 32%) over Coolatai grass resulted in increased utilisation and trampling of Coolatai grass. However, this method was discontinued because of time and labour costs as well as the inconvenience of handling molasses.

Spraying with ethanol syrup and grazing management: Heavy grazing pressure coupled with spraying ethanol syrup over Coolatai grass resulted in increased utilisation of Coolatai grass. The cattle did well and ate the Coolatai grass as well as trampling the grass. This method was also discontinued because of the high setup and labour costs. A boomless jet was used to spray the syrup over the grass. Because of the convenience and effectiveness, this method was superior to using molasses, however, the supply of the ethanol syrup is uncertain.

High content molasses and urea blocks and grazing management: This method has been used over the last very dry summer and current winter. The high content molasses blocks (molasses 57%, urea 10%, by-pass protein 4%, salt 4%, calcium 5%, phosphorus 2%) were used to keep the cattle on the on the blocks and keep up a constant supply of urea. The cattle have been both eating the Coolatai grass and trampling it. At a budget cost of $1 per head per week, this is affordable, controllable and manageable. It is the preferred option at this time and we will probably continue to use this method to utilise Coolatai grass over the long-term.

Conclusion

Control of African lovegrass and similar invasive coarse grasses in high rainfall genuine temperate grass zones of the Northern Tablelands is achievable and both environmentally and financially sustainable.

Control of Coolatai grass on the western side of the Northern Tablelands is achievable, but not financially sustainable. Utilisation of Coolatai grass is the best option.

Coolatai Grass- Management and utilisation

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Abstract: *Coolatai grass is a highly persistant and aggresssive grass species encroaching on vast areas of the Northern Slopes and Plains of NSW and Southern Queensland. Its spread has been greatly assisted by shire council roadside maintenance and repairs along with routine agricultural activities. In many areas and situations eradication is not a realistic or economical option and so we must learn to live with and utilise it. It produces a very large bulk of grass of moderate to low quality. Pastures dominated by Coolatai grass can be productive, although the management requirements are higher than that commonly employed." Coolatai grass continues to expand its range across southern Australia, which will be enhanced by the predicted increases in summer rainfall and milder winters due to global warming.*

Introduction

In agriculture we spend much of our time trying to kill what wants to live and keep alive things which would rather perish. Improved pastures have a definite place in areas of good fertility and rainfall, coupled with slope and aspect as do our more productive native species. Much of the area, however, contains soils of low fertility, little organic matter, and pasture species of low quality. These areas often cannot make the necessary return to capital to justify expensive and labour intensive improvements. They can only be effectively managed with low inputs and geared to farming practices which are not linked to high output or high performance i.e. breeding as opposed to fattening operations or wool production not fat lamb production. "Coolatai grass (*Hyparrhenia hirta*) is a long lived summer active perennial grass that forms dense tussocks. It is cold tolerant and found from sea level to 1500m. It thrives in both subtropical and temperate conditions however seedlings are sensitive to heavy frost." In 2004 it was estimated that Coolatai grass already infested 1 million hectares in NSW" (NSW DPI 2010).

Nutritional Value of Coolatai Grass and Growth Habit

Coolatai grass provides a large bulk of moderately digestible feed for the larger part of the year. It is observed that during the cooler months of the year growth slows, however, it rapidly resumes once temperature and moisture levels are adequate.

It is often maligned as being of poor nutritional value and of little use, however, in many paddocks on the lighter trap type soils it outcompetes species such as three awned speargrass (*Aristrida* spp.) and slender rats tail grass (*Sporobolus elongatus*) which has been reported to loosen horses teeth whilst attempting to graze it (Robinson 1983). Also due to the soft seedheads it does not cause carcase and eye damage and downgrading of sheep at sale, along with wool damage caused by rubbing.

Digestibility is a term for the amount ingested to the amount ejected expressed as a percentage. For high animal production animals require 70–80%, down to 55–60% for maintenance and below that stock will lose weight. Crude protein levels are also very important and are positively linked to digestibility levels. "Failure to appropriately manage Coolatai grass pastures will see a monoculture of tall rank growth of low digestibility (less than 40%) and protein (7%)" (NSW DPI 2010).

Grazing Strategies

Like most grasses if Coolatai grass is allowed to become mature and rank, quality will decline and digestibility will become low. By heavy grazing pressure and strategic rest periods it is possible to manipulate the Coolatai pasture and maintain it in a more palatable state. Once rested the Coolatai grass will rapidly produce fresh new growth including seedheads which are readily consumed by both sheep and cattle. Cattle actively seek out the seedheads and routinely graze these parts as a favoured forage. "Only 4–10% of florets produce viable seed and it is assumed that around 12% of consumed seed based on studies of annual ryegrass will remain viable" (nsw.dpi.gov).

Climate Variability and Drought

Over the past three years we have seen below annual average rainfall with a more noted peak and trough to the rainfall pattern. Maryland and Severn Vale (my farms) have sadly been in something of a rainshadow with the bulk of good falls sliding south. Forecasts of future rainfall events are for a pattern much like the last three years. If this is the case then we need pasture species which have a robust nature to cope with times of intense grazing pressure and limited moisture availability whilst maintaining groundcover to trap, utilise and grow bulk following intense but infrequent rainfall events. It is also very significant to note that from an economic point of view it is far cheaper to cart supplements such as dry licks, wet mixes (molasses based) and cottonseed to assist with the utilisation of the lesser quality bulk of Coolatai grass than to transport hay and provide gut fill. From a biosecurity point of view it also greatly reduces the risk of bringing new weed species onto the farm especially when much hay has been carted great distances.

Roadside Grazing

During the past 12 months, beginning August 2013, we suffered a prolonged period of minimal rainfall and essentially no effective rain fell between August and late March at which point I received 175 mm over four days with 100 mm on the first day. This abysmal period of low rainfall coupled with a strategic move to incorporate cattle into the farm mix forced me to adopt some new strategies. As a result I have taken to the long paddock and included it into a paddock rotation as time has allowed me to watch cattle and turn them in and out when needed. Initially they were trampling large quantities of moribund vegetation (mostly Cootatai with a lesser proportion of African Lovegrass and native species). Over a series of grazing events I have watched it change into a more productive and useful grass with the aid of dry lick supplementation consisting of urea, bypass protein and a mineral/vitamin mix. Coupled with this I have used fire to remove many years of built up lovegrass litter which in places was up to 50 cm thick and impenetrable to sheep and unusable by cattle. Once the initial shock treatment had been received and the area had been returned to actively growing shoots it suddenly had nutritional value. There is a distinct increase in the number of roadside kangaroos who now find this to be the most desirable feed which can be attested to by the righting off of my ute.

Supplementation Strategies

My main strategy has been the use of dry licks with eight percent urea, however, in the worst of this drought I pushed that to 12 percent. These are proprietary licks which also contain bypass protein and a vitamin/mineral additive. I try to give access to a lick year round and find it is a good indicator of general pasture conditions as consumption levels vary. Presently with the unusually mild winter conditions and green pick the cows are barely sniffing dry lick. Licks can be easily regulated in covered troughs with the use of additional salt which also prevents the risk of gourging. Salt is also used as a starter when introducing any stock onto licks. My feeders are made from covered 44 gallon drums and are easily moveable for both sheep and cattle. Generally I refill these troughs every two days when conditions are tight and use their placement to maximise herd impact in specific areas. They are generally placed at the far end of a paddock from water to encourage better and more even foraging.

During the period from January through to March I fed cottonseed at a rate of 1 kg per cow per day to maintain condition as the cows were being pulled down by their calves. Once the cows started onto cottonseed there was a dramatic decline in the intake of dry lick. I would not have been able to feed cottonseed without a source of roughage (i.e. Coolatai grass).

Shelter for Livestock

A less well known benefit of Coolatai grass is the provision of shelter during inclement weather. While this is of limited benefit to cattle, there is a wealth of data showing the importance of shelter to newborn lambs and sheep off the board, along with anecdotal evidence from those of us who have experienced it first hand. Most lambing in this area occurs in late winter/early spring and the risk of cold snaps decimating lamb numbers is very real. Whilst sheep do not generally utilise Coolatai grass as well as cattle they can gain great benefit from the reduction in wind-chill it offers. Treelines even well designed do not cut winds to the extent of a good dense grass sward and lamb survival can be greatly enhanced.

Conclusion

Whilst not an advocate of a Coolatai grass monoculture I believe it can play a valuable role in resilient, diverse grazing systems and it is of particular value in times of erratic rainfall. It can be severely punished allowing other areas of the farm to recover. With appropriate supplementation and attention to and observation of stock it can play an important role in farm profitability. It is here to stay so we need to learn to live with it and utilise it or move on.

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Practical application of integrating pasture and cropping systems

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Abstract: *This paper discusses strategies that have been implemented to best integrate pasture and cropping systems on a mixed cropping and beef cattle farm in the Delungra area, on the North West Slopes of NSW.*

Introduction

Most farms with cropping enterprises in our district also have areas that are unsuitable for cropping for they might be too steep, stony, timbered belts or waterways. These areas are mostly utilised with livestock enterprises. Inevitably, there will be seasonal variations; winter feed gaps or requirements for high productive pasture that require cropping areas to be used to benefit livestock enterprises. The challenge on any mixed farm is to best integrate the cropping and pasture enterprises to maximize overall farm profitability, resilience and sustainability. Mixed farming enterprises provide diversified income sources, which help to buffer against trade, price and climate fluctuations. I will discuss benefits and compromises of integrating cropping and livestock enterprises and general principles relevant to the integration of pasture and cropping on our farm.

Property overview

Our farm Pearsby Hall consists of 2,700ha of undulating black vertisol, chocolate basalt and red laterite soils, stony ridge tops, timber belts and waterways. From the lowest creek bed to the highest hilltop, elevation ranges from 580–730m. Our average annual rainfall is 660mm. All arable areas are contoured. We grow various annual summer and winter cereal, pulse and forage crops including wheat, sorghum, chickpea, lab lab and grazing and hay oats. We use lucerne in our cropping rotation. We have planted areas of tropical pasture with varied success. Our beef enterprise consists of a breeding herd of Angus and Angus cross cows. We grow out our calves to enter into the feedlot market. Recently we reduced our core-breeding herd with the idea of trading cattle when seasons are more favorable. Over the last few years, the day-to-day management of the farm has been passed on to myself and brother Shaun.

Integrating cropping and livestock systems

In general, I believe it is best to fence off cropping from grazing areas and manage them as separate systems to enable the most suitable management to be applied to each. However, when operating a mixed farm there are times when cropping systems can benefit livestock enterprises. On our farm, cropping areas allow for hay production, grazing of oats and lab lab, grain gradings are used in cattle rations, and crop stubble can be grazed.

Pasture systems and livestock enterprises can have benefits to cropping enterprises as well. Failed grain crops can be grazed with livestock to assist in recovering some of the cropping input costs. At times grain can be value added by feeding it to livestock when grain prices are low and there is a premium paid for fat cattle. Manure from livestock can be spread on cropping paddocks. Grazing and hay oat, and lucerne phases assist in integrated weed management strategies.

I feel that the benefits provided to livestock enterprises from cropping country are generally at a cost to the cropping enterprise. There is an added risk of soil compaction when grazing cropping areas, and stored soil moisture is used for fodder crops compromising the following grain crop. Higher labour inputs are another consideration on a farm with mixed enterprises.

Feeding cattle grain

We early yard wean our calves with a focus on minimising stress and provide them with a ration of high protein hay, grain, chickpea gradings and a feedlot additive for trace minerals. This has the following benefits; cattle are sold earlier at heavier weights; heifers are heavier when first joined; empty cows can be sold and pregnant cows do not require as high quality feed compared to when they are lactating; and the better quality pastures can more efficiently be provided to weaners after 4–6 weeks on a grain ration.

We have had success supplementing our cows with up to 2 kg/hd day of a ration mostly made of grain and chickpea gradings at the start of joining to stimulate fertility. We have taken the opportunity to do this when cattle have been fed hay reserves in a nearby sacrifice paddock. We ran the mix out of the feed mixer each day along a fence line allowing all the cows equal access to the feed supplement, which reduces gorging. We have had a pregnancy success rate in excess of 95% and many early calves, which we partly attribute to this practice.

Finishing cattle on grain rations has been a practice on our farm more commonly in the past. In recent years, (after factoring in grain prices, fat cattle prices and inputs) we have considered it more economical to sell the grain, and sell the cattle out of the paddock, rather than feeding grain to cattle in our on farm opportunity feedlot. We believe large feedlots are able to fatten cattle more efficiently than we can.

Lucerne

Straight lucerne stands in rotation in our cropping areas provide benefits to the livestock enterprise and increase our farm carrying capacity. Lucerne phases also provide breaks in weed and crop disease cycles. The soil nitrogen (N) levels in paddocks where we plant lucerne are increased due to the plants ability to fix atmospheric nitrogen into plant available nitrogen. Although I have not tested soils before and after a lucerne phase, we have experienced high protein levels in wheat and barley crops that have followed lucerne and attribute this to more plant available nitrogen in the soil. I have read that lucerne and pasture in cropping rotations have the ability to increase soil organic matter, and deep rooted plants such as lucerne have the ability to bring nutrients from deep in the soil profile and deposit them towards the surface making them available to following crops which otherwise would not be able to access these nutrients. Typically, we will get 6–10 years out of a lucerne stand. As the plant densities reduce over the years these areas are returned to a crop rotation and lucerne stands are established in other paddocks.

Growing hay

We grow hay oat varieties and cut lucerne for hay for feed reserves, and for mixing with grain rations when yard weaning our calves. Hay oats and lucerne are used as part of an integrated weed control strategy reducing the reliance on herbicides. For example, if there is a cropping paddock with a black oat problem, this paddock can be planted to hay oat where all black oat seed will be cut and removed before it matures. Alternatively, the paddock can be planted to lucerne where the black oats are preferably grazed by stock or out competed by the established perennial lucerne plant.

We have the ability to wrap up cut fodder into silage bales if it may be spoiled by a rainfall event during the haymaking process. Making silage has not been our preferred option over making hay due to the increased labour requirements when baling, carting fodder off the paddock, wrapping bales and feeding out the silage.

Dual purpose cropping

We have participated in grain and graze trials where selected areas of a wheat and a canola crop were mown to simulate grazing. Measurements of the amount of feed removed, and variations in yield at the end of the season between each treatment were recorded. In the year of the trial, as a result of grazing, profits/ha were comparable in the canola and grain yield was not reduced in the wheat. It must be noted that the wheat was grazed at early tillering and the crop experienced favourable spring rainfall. I think in practice for a graze and grain system to work in our area it is important for the crop to be planted earlier, extra nutrition provided and favourable spring rain received.

Soil compaction

A risk to mixed farming can be an increase in soil compaction when grazing cropping country. To minimise this we avoid grazing cropping areas during wet conditions or while the soil surface is drying after a rain event. However, our black cracking clay soils, through wetting and drying cycles can repair themselves over time from compaction.

Weed management in fallow

If grazing stubble in fallow where there has been a germination of weeds (in minimum till practices), I believe it is important to spray and kill the weeds before grazing. If the weeds are grazed prior to being sprayed, the effectiveness of fallow herbicide sprays are reduced because the stock have eaten or trampled leaves into ground, which inhibits the ability of the plant to take in chemical.

Flexibility in cropping options

On Pearsby Hall, we do not stick to a set rotation in the cropping program. We have a more opportunistic approach to be able to take advantage of favorable markets and seasonal outlooks. If seasonal conditions allow, we will follow sorghum with a chickpea crop. We avoid residual chemicals when growing wheat to allow pulse crops to be grown in the following summer such as mung beans or lab lab.

We currently have a flexicoil tyned planter that allows us to plant directly into stubble and plant over farm-over banks.

An opportunistic approach can come at a cost. For example, following a 3 t/ha wheat crop in 2012 we grew a big bulky lab lab crop that was grazed multiple times during the wet 2012/13 summer. During the following fallow period, there was insufficient rainfall to replenish soil moisture that the lab lab had used. We still planted a sorghum crop in 2013 that was reasonably established following 30 mm of rain after planting. Unfortunately we did not strip a grain of this crop as it ran out of moisture during the dry 2013/14 summer. Instead, it was grazed and provided useful stock feed. Neighboring sorghum crops in similar soil types that had been planted into a long fallow from 2012 wheat and chickpea stubble, yielded very well at a time of high grain prices. In the future, we still would consider summer pulses following wheat crops as we generally receive a summer dominant rainfall.

Measure inputs and production

I find it helpful to keep records to assist in making management decisions and to determine if these decisions were a success. We measure and record inputs and production to determine the profitability of varying land uses on individual paddocks. For example, we measure the cost of inputs of growing oats for weight gains on steers versus growing a wheat or barley crop for grain sales, versus returning the paddock to pasture.

Soil tests are taken periodically to monitor soil nutrient levels, to assist management decisions regarding what crop to plant, fertiliser requirements and to ensure the sustainability of our farming system.

Appropriate land use and fencing to land capability

On Pearsby Hall, we have fenced off different land uses such as native grass from cultivation. Fencing off areas with varying productivity allows the most appropriate management to be applied to different land types with regard to grazing, fertilising and all cropping processes. We grow crops in arable areas with the best soil and grow a mix of native and planted pastures on the poorer soils.

An example of a recent change in land use on Pearsby Hall is with regard to our red laterite soils. For years they had been used to grow mostly winter crops of oats and barley in rotation with lucerne. When trying to grow grains in these areas, minimal yields and profits/ha were achieved compared to the heavy black basalt soils. In 2011 and 2012, we decided to plant these areas to tropical pastures consisting of a mix of Premier digit, Gatton panic, Katambora Rhodes and lucerne. We believe this will be a less expensive, more sustainable use of land that will hopefully provide greater profits/ha. This will be determined with time when we are able to calculate how much feed can be grown, weight gains achieved and the fertiliser inputs that are required.

In 2011 and 2012, we also tried to take some steeper, stonier areas of heavy black clay soils out of a cropping rotation by planting them to a tropical pasture mix of Bambatsi panic, Floren bluegrass, Katambora Rhodes and lucerne. This was a failure as we achieved a very poor seed germination and pasture establishment on the heavy black soil. Meanwhile, at the same time we had good establishment on the red laterite soils. We do not believe seed depth or available moisture to be the reason why our plant populations were so low. Let's just say we have found it easier to establish tropical grasses on our lighter red soils and we're still exploring options for our black soils. A temperate pasture mix using new varieties of phalaris, tall fescue and lucerne may be easier to establish in the heavy black soils. The use of chicory may be another option for its anti-bloat qualities.

Create and implement a property plan

A mixed farm can be very complex and I consider a property plan to be a very useful tool to understand the direction we are going in our farm business. Having a property plan helps to priorities tasks such as fencing and provides confidence that we are not spending money on things that are not supporting the long-term goals of the farm.

When you start to create a property plan you disregard existing infrastructure and first look at the natural resources; soil type, vegetation, waterways, slope, etc and create areas of different land use. You then plan your ideal farm if money was not a barrier. Commonly you would find that the majority of fences and infrastructure are already where you would like them to be, but a property plan will help identify which fences not to replace, or where to create new fences. It may help to identify new and better stock watering points, or areas that might be best returned to pasture from cropping.

I have found aerial imagery and computer mapping software very useful to create a property plan and identify areas of land that could be better utilised. Our property plan is constantly a work in progress as over time views change and ideas are modified. When investing money in farm projects we give priority to what will provide the greatest economic and environmental benefit. This exercise has highlighted to us the need to achieve greater production from the large areas of native grasses. In the future, we hope to promote the legumes in our native grass paddocks.

When creating our property plan we considered the most suitable paddock size for the land type and preferred mob size. This needed to suit our lifestyle and other considerations within the business with regard to how often we want to be shifting stock from one paddock to the next.

I think another important element of a property plan is planning for future business succession. This is often not given adequate consideration.

Paddock size, mob size and grazing pressure

We try to adopt grazing practices where we have a high stocking rate on an area for a shorter period. This results in less selective grazing of pasture species, more targeted grazing to suit the growth stage of pasture, and greater recovery time of pastures between grazing periods. This can be achieved by fencing into smaller paddocks if watering points can be provided, or a cheaper alternative is to box mobs to run a larger mob size. For example, we changed from having an autumn calving and a spring calving herd to just having one larger spring calving herd. This doubled the grazing pressure on the paddocks and meant we required shorter grazing periods for this mob.

Added benefits to running a single joining herd include only having once a year processes such as, calving, weaning, pregnancy testing and marketing. The added efficiencies have enabled us to put a greater focus on animal nutrition and supplement for production and fertility when required.

If we graze a cropping paddock when dry, we have found it beneficial to have smaller cropping paddocks (or larger mob size). During dry conditions, stock can strategically graze the paddock for a shorter period, which reduces the risk of soil compaction.

Running a larger mob size, can cause a lot of damage to pastures in a short period if they are overgrazed when stock are left in a paddock too long. It is important to look at the ground and state of the pasture when making decisions on stock management. If you think there is an increased risk of feed shortage ahead I consider it important to destock early before pastures are compromised, stock lose condition and generally markets slip. If stock are to be fed hay, silage or another ration, they should be fed in a suitable sacrifice paddock so not to damage pasture over a large area. We will use manure from our sacrifice paddocks to spread over our grazing and cropping paddocks.

Conclusion

Every farm business is different and the practices we currently adopt on Pearsby Hall may not be suited to your mixed farming business. There are many factors to consider including soil types, topography, climate, farm infrastructure, labour, machinery, and level of risk you are comfortable taking in order to best utilise the natural resources on your mixed farm.

The management strategies I have mentioned all assist in integrating the cropping and livestock enterprises on our farm. The success of many of the recent changes cannot easily be determined with quantitative data from just the past few years. However, there has been a noticeable change in areas such as:

- Increased groundcover across native pastures,
- More resilience in dry seasons,
- Quicker pasture response to rainfall events,
- Fewer weeds,
- Reduced erosion in arable areas, and
- Higher pregnancy testing percentages.

I hope from sharing some of my experiences that you may take something that will help you with your own farming endeavours. Like all farmers, we are constantly changing and refining our management practices. I would appreciate any feedback or input you may have.

Finlay Hay "Emu Plains" Texas - Switching from pasture to cropping under irrigation

G Finlay

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Introduction

At Finlay Hay we have built a large business based on fulfilling shortfalls in pasture. We supplement both quantity and quality of feed to a multitude of production systems in beef, cattle and goat dairies, horses, sheep and wool. This we do by working with our environment when managing our lucerne hay production.

My Grandfather bought "Emu Plains" in the Dumaresq Valley in 1937 and installed the first irrigation system when electricity came to the Valley in 1952. My father operated "Emu Plains" from 1962 with a Hereford Stud and Commercial herds and developed irrigated grain crops and lucerne hay. After aphids devastated lucerne in the valley in the 1970s he changed to irrigated and dryland pastures. Along with open undulating country and timbered hills back off the floodplain, he had built the "Emu Plains" aggregation and was running up to 3000 head of Bos Indicus cattle on native and improved Queensland bluegrass (*Dichanthium sericeum*) and Pitted Bluegrass (*Bothriochloa decipiens)* pastures with the assistance of the irrigated pastures and crop.

I came back to the family farm in 1989 with an accounting and finance background. I was shortly joined by my two brothers, one with the same accounting studies and the other with a rural technology background in animal nutrition. With everyone back home we recognised that our way of operating would need to change. My golden opportunity came when I attended the first Grazing for Profit Course run by Resource Consulting Services in April 1990 at Yeppoon, Qld. I came home a convert to "Cell Grazing", however, it was a number of other things that I learnt in that school run by Stan Parsons and Terry McCosker and the subsequent RCS Executive Link programme which altered the course of my agricultural career and the way the family business was to operate.

The Switch

Our soils are silty clay loams and sandy clay loams and hold 40 percent of the moisture that black soil farming country does. Grazing oats and forage crops are really the only dryland crop in our valley. Our soils, however, are ideally suited to crops that like a well drained soil for long term success, such as lucerne and peanuts. After trialling a number of crops in the 1990s including irrigated wheat, barley, mung beans, soybeans, faba beans, gritting corn and cotton we have settled on a rotation of lucerne hay, peanuts and annual ryegrass for haylage in the winter. Although cotton often has a higher year to year profitability it doesn't suit our system to produce Cotton. We grow forage sorghum at times on our heavier soil in the rotation. Our lucerne and peanuts typically have Gross Margins of $2500 to $3000/ha which along with the ryegrass haylage is the most profitable rotation for us for reasons I will explain.

With this rotation we continued to finance the expansion of our irrigation. The cell grazing areas were pulled out to make way for the centre pivot irrigators which significantly increased our land values.

As our soils were depleted from years of oats monoculture they were typically hard setting. Since 1996 we have not stocked the irrigation country to reduce compaction and to allow more winter growth in our lucerne. We have gone from deep ripping billiard table size chunks of hard setting soil to a relatively healthy soil with higher organic matter, fertile and friable from years of soil conditioning with the above established rotation and minimal use of artificial fertilisers. There are also an increasing number of earthworms on the peanut digger at harvest time. This has also helped our water use efficiency considerably which has been critical in a variable climate often with water supply issues, not to mention huge water and pumping price increases.

Lucerne, the king of fodder

My second brother, Dougal, was instrumental in switching back to lucerne production in 1991 on returning to the farm from University. After presenting the facts and figures he convinced our family to get back into lucerne hay production. Commencing with the original 40 acres of sideroll irrigation for lucerne hay we continued to develop our lucerne with gritting corn grown under our only centre pivot at the time. Lucerne has been invaluable for its higher profitability and cashflow all year round as our cattle breeding and finishing operation was often at the mercy of drought conditions in the 1990s. We continued to develop more area to lucerne with sideroll irrigators and in 1996 installed three more centre pivots and developed more underground bores.

Since 1991 we have progressively built our customer base by a focusing on quality control and service. We are now supplying over 4000 t of hay annually. Lucerne is the backbone of our business and our cash cow. We market through our brand Finlay Hay which has become widely known. Using technology such as our website finlayhay.com.au has been important in gaining sales and new customers. Potential customers can see what we are about and that we are professional and the website also allows a detailed explanation of products like haylage which many customers may need to be educated about. Our website has over time become more valuable to us as a brand than the original brand, it helps close sales.

Lucerne: Versatile Production in a Variable Climate

We have built our whole business system on the versatility of lucerne in our variable climate. Lucerne has a deep taproot which it uses to access water and nutrients and for carbohydrate storage. It also, if managed, has a long life. It is my understanding that the roots can go down more than six metres. We have tried many lucerne varieties including Pioneer 581,545, Sequel, Heritage Seeds Sardi 7 & Sardi 10, Seed Distributors L55 and L56. We have ultimately settled on L56. This cultivar for our farm has a good leaf disease rating. It also has a good balance of winter dormancy and activity with a rating of 5 which importantly allows us to grow and make hay in the cooler months to take advantage of irrigation limitations. Foremost is the ability for L56 to yield well in summer - up to 5 t/ha in a single cut while still growing all the way to June.

Lucerne is a great conditioner of soils and puts a lot of nitrogen (N) back. On our lucerne paddocks we apply some potash and very minimal herbicide. I would argue that lucerne brings a lot of nutrients up to the surface with its deep root system. I consider all of us farmers, no matter how good your intent, are mining the soils and that possibly we are more sustainable for longer if we are mining 6 m instead of one metre.

We are very particular at planting time where we aim for a fine, level seed bed. The lucerne is sown at 13 kg/ha preferably in May and June. The seeds drop onto an angled sheet metal tray to bounce and provide broad coverage instead of defined rows, this is followed by light prickle harrows to give a good covering. Centre pivots allow us to water the newly planted lucerne with 5 mm regularly until germination. We go to a lot of effort at planting because a dense stand of lucerne is instrumental for the on-going productivity and profitability of the lucerne enterprise. With the high cost of irrigation you must have an adequate plant population to optimise production. By following this process we can make the first cut by October or November and the total yield produced in the first year is not too far behind established stands. The high plant population also helps keep grass from invading. Lucerne invaded by grass weeds severely undermines profitability. Over time lucerne stands will progressively thin out and populations are not high enough to maintain production, so we rarely keep a lucerne stand more than three years.

With our relatively fertile soils and favourable climate our lucerne does very well. It has a thicker stem than lucerne from other areas, it is hollow and strong, it can support a tall plant (up to 1.5 m). Unlike fine stemmed hay from other regions that can be hard and brittle our stems are fully digestible. We have had yields of up to 4.84 t/ha in a single cut. We work on getting 11 to 15 t/ ha per year depending on opportunity and conditions. By growing and making hay and haylage in winter we get an additional cut in comparison to other producers. We seek to cut every 4 weeks and aim to have no more than 15 percent of plants in flower at mowing. This is the balance between optimising production and quality. By not allowing plants to over mature it also helps maintain high plant populations. Our lucerne is very nutritious as in a typical feed test analysis in Table 1. Our best bulk product which we market as Dairy One ranges between 20 to 23 percent protein. All of our production system from planting to haymaking is directed at quality. It is by having hay that is of consistent high nutrition and quality assured all year round that we have been able to continue to grow the business to what it is today. Most of our hay goes to people with production systems using our lucerne hay all year round. Typically they are cattle and goat dairies, lamb feedlots, beef feedlots and cattle operations with a turnoff system. Many beef breeders get hay throughout the year to be ready for winter supplementing where a little lucerne can fill an animal at the same time as giving top feed value.

Lucerne is all important to us in our variable climate. We aim to optimise whole of farm profit. We rarely have the top yields in the valley as we don't go for maximum yields, but optimum whole farm profit.

Peanuts

We have been producing peanuts for 14 years and at just under 1400 tonnes were the largest suppliers of peanuts in Australia in 2013. Australia produces an average of approximately 44 000 tonnes per year of peanuts and cannot supply all of its own needs. Peanuts therefore have a good stable price through the Peanut Company of Australia. Peanuts need a specific soil that is friable and will break away from the peanut at harvest time. The soil must come away from the peanut without breaking the peanut off its peg which hold it onto the bush. The peanuts go into the thresher attached to the whole bush. If the peg is broken then there will be no peanut attached to the bush to harvest. We have had success with our improving friable soils at harvest.

Peanuts are a legume and are exceptional at putting N back into the soil. I have seen no greater conditioner of our soils. In our rotations we see peanuts doing very well after lucerne and vice versa. The peanuts have been very hardy and have helped us be more versatile in a variable climate. They can take extreme conditions and can tolerate a hot dry period. In comparison cotton and corn would take major profitability reductions in the same situation. The peanuts also quickly fill in the rows for 100 percent ground cover in the summer which makes a micro environment and conserves moisture. As for our lucerne, peanuts need very little artificial fertiliser or spraying which is great for soil health.

The by-product of peanuts is the peanut hay. After harvest

Table 1. Typical feed analysis of the lucerne and peanut hay produced at Finlay Hay

	Lucerne Hay	Peanut Hay
Protein	23.8	10.9
ME	9.9	9.1
RFV	174	151

the threshed peanut bush is left in a windrow and baled up. It usually has a lot of peanuts that broke off at harvest or broken shelled peanuts that were blown out. Typical yields are 2 to 3.2 t /ha of peanut hay. Although not much to look at, this hay can test up to 14% protein, but will certainly be over 10% protein see Table 1. Peanut hay typically sells for $180 to $280/t depending on season. It is relatively cheaper than other hay and is believed to be a great modifier of the rumen particularly on dry mature pastures. This is often one of the only cost effective options left to feed on pastures in the winter and it sells strongly.

Importance of water

Irrigation water and rainfall is our limiting factor. We have 15 centre pivot irrigators on over 1500 acres and this allows us to rotate the lucerne and peanuts (which require 2 years rest for disease purposes). If there are drought or heat conditions we can shut down lucerne paddocks and come back to them later. If there are continued heatwaves instead of expending all of your water allocation in the heat and dry we will stop watering or just water a minimum to help the plant survive. When conditions are more favourable we will get back to full irrigation again. Over and above our normal water allocations we often get free flow water events in our river. This is where a rainfall event has put additional flow in the river. When certain minimum river flows are met we are allowed to pump off-allocation, that is, free water. Often the free flow water is not available when needed by many traditional crops. With lucerne, any time there is a free flow event we fill the soil profile and this becomes our storage. With deep taproots the lucerne plant can use this water to our benefit. Most other crops have root zones of 30 to 100 cm and the use of this free water is limited or non-existent. In addition, by mowing centre pivots as half circles we can be watering the one half while we are completing haymaking on the other half. If you had a few hundred acres of lucerne in stand-by mode in summer and a free flow event comes along, within a week you have a full profile of moisture for another 2 to 2.5 normal cuts. The lucerne plant can also help with its own large reserves. Even when you shut off water normally the plant can give a third to two thirds of what is considered a normal cut. When your mowers can do 55 ha an hour and balers 18 km an hour, lower opportunity yields are not really a big issue. Lucerne saved the day in the 2011 floods. Within two weeks the lucerne had stood up, rain washed the dust off and we were back haymaking. We also picked up 2.5 to 5 cm of fertile silt from our neighbours with no erosion.

At Finlay Hay we call early spring and late autumn the “Shoulders” of the Lucerne growing season. This is our time to shine. Instead of fighting against nature we work with nature and make lucerne hay all year round including winter. As our L56 cultivar is partly winter active (5) we can water and get growth most of the year. With the use of our large haymaking equipment we can mow areas of lower yield still quite efficiently and sell the haylage at higher winter prices to make it more profitable. Large modern balers let us bale silage and haylage at high pressure, to exclude air, in large square bales. These are then wrapped with 80 micron UV stabilised plastic wrap using a specialised wrapper for large square bales. We only market haylage not silage. We have developed the process over 10 years to the point that in tight bales with no air, baled with Grevillia Ag inoculant we can successfully make haylage down to 28% moisture. Typically we make haylage at 30 to 40% moisture. As this is considerably less moisture than silage and as it is in a readily transportable square bale there is a ready market in the winter and early spring for this slightly more expensive product.

Finlay Hay and our Customers with Pastures

To finalise my discussion on being versatile in a variable climate I must give our customers a wrap. In my business I have seen a lot of pasture fed operations. We arrive at the customer to fill a quantity or quality gap. I enjoy working with the quality gap people. They run pasture factories and typically have year round production systems and by and large are doing well. As explained to me by dairy nutritionist, these operations typically run more stock on their given pastures and use our hay to top up profitability where more quality is needed in the feed or short term feed gaps or downturns. I get little enjoyment out of supplying quantity shortfalls. Something has gone wrong, the customer’s dreams and finances are being tested. This is where I try to get them out of trouble at minimum cost. At Finlay hay we are passionate about hay and about our customers. We have had to be dynamic, we have had to be versatile, but I think it is being passionate about what we do that has seen us become the large business we are today.

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Contributed papers

Lucerne–grass mixtures outperform single species pastures on the North-West Slopes of NSW

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Abstract: *Pastures with a mixture of lucerne and tropical perennial grass have shown potential to increase total dry matter production and water use efficiency, while helping to conserve natural resources on farm. A lucerne–tropical grass mixture was persistent, increased dry matter production by 25% compared with pure grass swards, maintained ground cover >70% throughout the year, and produced 65% less soil erosion compared with pure lucerne.*

Key words: legume, forage system, water use efficiency, erosion.

Introduction

Tropical perennial grasses and lucerne (*Medicago sativa*) are the two most persistent and productive pasture options for the North-West Slopes of NSW (Boschma *et al.* 2010*b*). Lucerne, however, does have challenges of poor performance in years with below average rainfall (Lodge and McCormick 2010), low growth in winter, risk of bloat in cattle and when grazed potential low ground cover. The recommended benchmark for minimum ground cover is 70% to reduce surface runoff and erosion under most rainstorms on the North-West Slopes (Lang and McDonald 2005).

Sowing lucerne in a mixture with a grass has the potential to increase total pasture production and spread its distribution more evenly through the year, thereby reducing feed gaps and providing greater resilience in variable seasons (Boschma *et al.* 2010*a*). There is a dynamic equilibrium among species in a mixture, which is influenced by the species growing in different seasons, having different water use patterns, rooting depths, growth habits, and/or nutrient requirements. A lucerne-grass mix also has potential to maintain ground cover and reduce risk of bloat in cattle. With lucerne's competitive ability to use soil water, however, it is not known whether a temperate or tropical grass in a mix will best persist and be productive under field conditions on the North-West Slopes of NSW.

An earlier study (Boschma *et al*. 2010*b*) investigated the competitive ability of lucerne in seedling mixtures with temperate and tropical grass species, which indicated the potential for these mixes. A subsequent experiment was conducted to field test two likely pasture mixes—lucerne with a tropical perennial grass or with a temperate perennial grass, grazed by sheep. This paper summarises the results of the study and recommends options for producers.

Methods

A field experiment was conducted on a Brown Vertosol soil at the NSW Department of Primary Industries (DPI) Tamworth Agricultural Institute (31°09′S, 150°59′E; elevation 434 m a.s.l.) from spring 2008 to spring 2012 in replicated plots arranged in a randomised complete block design.

Lucerne (*cv*. Venus, winter activity rating 5), digit grass (*Digitaria eriantha* cv. Premier, summer active) and cocksfoot (*Dactylis glomerata* cv. Kasbah, winter active) were sown using a six-row cone seeder as single species swards and in mixtures of alternate rows of lucerne and grass (1:1). Single species swards of lucerne or digit grass were sown in spring 2008 at a seeding rate of 2 kg/ha, while in mixtures the rate was 1 kg/ha for each species. Cocksfoot was sown in autumn 2009 at 3 and 1.5 kg/ha for pure swards and mixtures, respectively. The mixes were chosen in an attempt to extend the growing season by generating growth from rainfall in both the cool and warm seasons.

Plant persistence, dry matter production, and ground cover

Plant persistence was determined using plant frequency (%) estimated in spring and autumn by the presence of live material in 0.1 x 0.1 m squares within a 1 x 1 m grid and herbage mass was estimated using calibrated visual assessment every six weeks. After each herbage mass assessment, the experiments were grazed by sheep whenever possible or defoliated with rotary mowers to a height of 50 mm. Plant dry matter (t DM/ha) values were accumulated for growing season to show overall contributions and proportions of grass and legume. Ground cover (%) of pastures was visually estimated in five quadrats (0.4 x 0.4 m) at six-week intervals between spring 2008 and spring 2012.

Water use efficiency

Soil water content was estimated at three week intervals by using a neutron probe, calibrated for local conditions, in access tubes installed to 1.9 m depth in each plot. Soil water use, rainfall and herbage mass data were used to calculate water use efficiency (WUE, kg DM/ha.mm; production per unit of rainfall and stored soil water used) for dry matter grown in each six week period that pastures were assessed and mean values over three growing seasons were determined.

Surface runoff and soil erosion

A portable rainfall simulator was used to quantify surface runoff and erosion from pure lucerne swards and mixtures with grasses in spring 2010 and autumn 2011 shortly after plots were grazed by sheep. A simulated rainstorm of 105 mm/h was applied to plots for 30–min and surface runoff was collected and measured at 1–min intervals. Collected runoff water was analysed for sediment content.

Results

Plant persistence

In pure swards, digit grass and cocksfoot persisted and the size of plant crowns increased, but cocksfoot tended to cycle through higher values in spring and lower values in autumn, reflecting dormancy though summer. Lucerne was persistent as a pure sward over the three years. In mixtures, plant frequency of lucerne either maintained (with digit grass) or improved (with cocksfoot) over the three years. Lucerne had higher plant frequency (mean ~40%) when grown with cocksfoot than with digit grass (mean ~20%). Plant frequency of digit grass when grown with lucerne steadily increased (from 40 to ~80%), while cocksfoot strongly cycled through high values in spring and low values in autumn.

Plant dry matter production

Mean annual production over three years showed pure swards of lucerne grew significantly more plant dry matter (17.6 t DM/ha) than did pure swards of digit grass (12.2 t DM/ha) or cocksfoot (10.1 t DM/ha). Annual production of lucerne-grass mixes was marginally less than pure lucerne, but not significant (15.2 and 16.2 t DM/ ha for mixes with digit grass or cocksfoot, respectively). Lucerne-grass mixtures outperformed pure grass swards with a 25 and 60% increase in overall production for the tropical or temperate grasses, respectively.

Lucerne dominated plant dry matter production in mixtures with cocksfoot (average 75% of dry matter) compared with mixtures with digit grass (average 57%) and lucerne provided an increasing proportion of production as the swards aged (e.g. from 69 to 81% for cocksfoot mixture and from 54 to 61% for digit grass mixture). This was accentuated during summer when cocksfoot was dormant. Seasonal conditions in spring 2010, and early summer in both 2010–11 and 2011–12 were cool and wet and this favoured the dominance of lucerne within mixtures at those times.

Water use efficiency

Stored soil water showed an annual pattern of the soil profile drying between spring and autumn with some replenishment during winter. Digit grass recorded the driest profile in May 2010 and soil under cocksfoot tended to have higher water content compared with that under digit. Through time, lucerne and or its mixtures tended to have lower soil water content, compared with pure grasses. Closer examination of the data here showed that lucerne began using soil water 6 weeks earlier in spring compared with digit grass, thereby leading to lucerne dominating growth.

WUE was generally higher in the first full year of production as plant available water and soil nutrients were likely less limiting compared with latter years. Mean annual WUE showed pure swards of lucerne had higher values (18.7 kg DM/ha.mm) than pure swards of digit grass

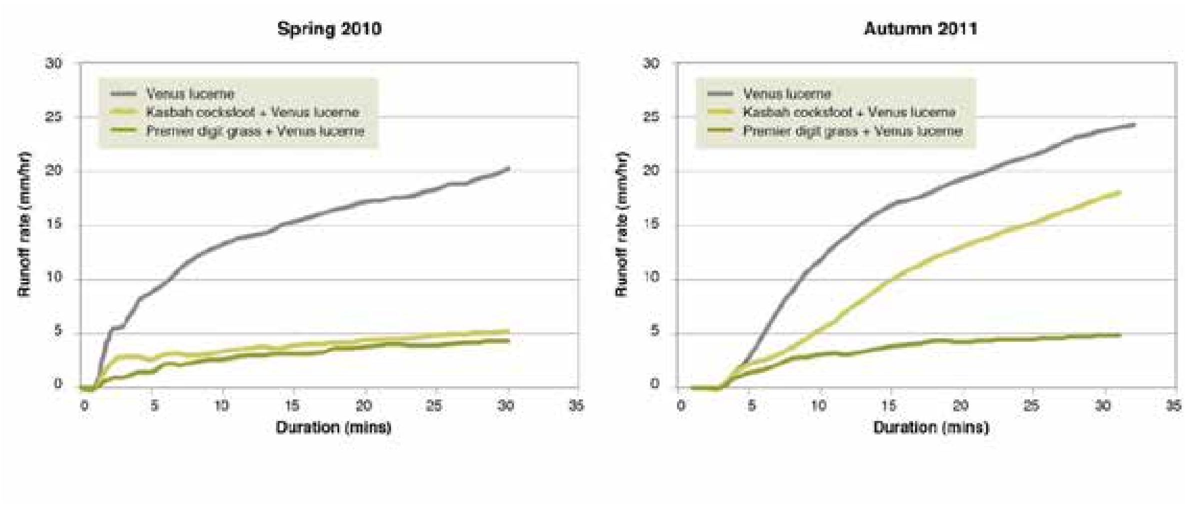

Figure 1. Runoff hydrographs for lucerne and its mixtures with cocksfoot or digit grass under a simulated rainfall event of 105 mm/h for 30–min in spring 2010 and autumn 2011.

(14.8 kg DM/ha.mm) or cocksfoot (12.3 kg DM/ha.mm). Similarly, each of the mixtures had higher mean values (16.3 and 20.2 kg DM/ha.mm for mixtures with digit grass and cocksfoot, respectively), compared with pure grasses. Lucerne-grass mixtures outperformed pure grass swards representing an increase in efficiency of 10 and 63% for the tropical and temperate grasses, respectively.

Ground cover

Ground cover in lucerne was slow to achieve the benchmark of 70%, was variable over seasons and only exceeded the benchmark occasionally. In contrast, pure digit grass quickly achieved close to full ground cover and, excepting the first autumn/winter, maintained it for the remainder of the three years. Ground cover in pure cocksfoot increased over time and generally exceeded the 70% benchmark in the latter half of the experiment.

By the end of the establishment season, ground cover in both digit grass (98%) and the lucerne-digit grass mixture (82%) was above the 70% benchmark, while cover for lucerne was below (59%). The mixture of lucerne and digit grass maintained higher ground cover compared with pure lucerne and was above the 70% benchmark from June 2010 onwards. Cocksfoot attained high ground cover (>70%) through winter and spring, but values sharply declined through summer to be as low as 25% by late autumn. The mixture of cocksfoot and lucerne achieved ground cover levels that were higher than pure lucerne, but values in each autumn declined below the 70% benchmark.

Surface runoff and erosion

Lucerne generated higher rates of runoff (up to 25 mm/h) and more quickly compared with the lucerne-grass mixtures in either season (Figure 1). Analyses of runoff water showed that eroded soil from pure lucerne (135–253 kg/ha) was 2 to 3 times that from lucerne-grass mixtures (53–87 kg/ha).

Discussion

Data collected indicated that lucerne and both perennial grasses were persistent over the experimental period, but (1) cocksfoot cv. Kasbah (winter active) was less productive compared with digit grass cv. Premier (summer active), and (2) both cocksfoot and its mixture with lucerne, had ground cover values in autumn that were below the threshold of 70% required for erosion control. These indicate that the lucerne-tropical grass mixture is more preferable on the North-West Slopes of NSW, while the cocksfoot mixture may be suited to regions with winter dominant rainfall.

Total dry matter production of each lucerne-grass mixture highlights the potential to increase forage supply compared with a pure tropical grass or pure temperate grass. Each mixture demonstrated an ability to take advantage of rainfall in contrasting seasons, and being a combination of grass and legume, would help alleviate risk of bloat in cattle for most of the year. Further, reliance on pure lucerne alone in northern NSW is likely to result in animal intake requirements not being met due to a high frequency of very dry years when lucerne underperforms (~30% of years with rainfall 100 mm below the average, Lodge and McCormick 2010).

Total stored soil water data collected in this study demonstrated the same annual pattern of being driest in late autumn and wettest in early spring, as was observed in an earlier experiment south of Tamworth, where it was documented that tropical grasses capture winter rainfall (Murphy *et al.* 2010). In latter seasons, the pattern of change in values of soil water for each of the mixtures (lucerne-digit grass or lucerne-cocksfoot) tended to mimic that of pure lucerne demonstrating that lucerne was likely driving water use in the mixtures, regardless of the grass. Therefore, while lucerne-grass mixtures are productive for a greater proportion of the year, they are likely to capture less winter rainfall, compared with tropical grass alone.

Runoff data indicate that growing lucerne with digit grass achieved runoff control in both spring and autumn, but when lucerne was grown with cocksfoot, unacceptable rates of runoff were observed in autumn (Figure 1), which was when cocksfoot was still dormant and ground cover was low. Therefore, in a summer dominant rainfall environment like the North-West Slopes, the lucerne-tropical grass mixture is more preferable because of year round protection from runoff and erosion.

While the current research did not measure the contribution made by lucerne to nitrogen fixation, it was assumed the lucerne did make some contribution to the nitrogen balance of the pasture, and this is the subject of new research. Maintaining a legume in the pasture system for nitrogen production is an ongoing challenge. At commercial scale there have been a range of successes when lucerne and tropical grasses have been sown together. Such mixtures are commonly sown in spring, which increases the risk of failure, as seedling lucerne dies when seasonal conditions become too hot, resulting in low lucerne plant density. Annual temperate legumes have been used with variable success. This is problematic as soil under tropical grasses is driest in autumn and variable autumn rainfall prevents reliable annual regeneration of the legume and early dry springs also reduce adequate seed set. Ongoing NSW DPI research is trialing a range of hard seeded legumes to buffer against dry autumns and springs and investigating the role of tropical legumes in mixes with tropical grasses.

A lucerne-grass pasture mix may be a suitable option where a producer wishes to benefit from the feed profile of lucerne, but with reduced natural resource management and livestock risks. Rotational grazing is essential for productivity and longevity of lucerne and so management of a lucerne-grass mix should reflect this. Interactions between stocking rate, seasonal conditions, and stored soil water reserves will determine best grazing management. However, it is also acknowledged that growing mixtures on-farm may have additional challenges such as reducing options for broad-leaf weed control, and the need to reestablish lucerne at some future point.

Conclusions

Lucerne is the most widely sown and adapted perennial legume in northern NSW, and when grown in pasture mixes with a perennial grass, the resulting pasture can be as productive as a pure lucerne stand, but also have the added benefits of maintaining ground cover to prevent runoff and erosion. Under rotational grazing, lucerne is likely to persist well in the mixture and contribute to higher quality forage, reducing potential for bloat in cattle because of the mixed intake, and achieve high water use efficiency.

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