Grassland Society of NSW Inc.

YOUR SYSTEM – TAKING IT TO THE NEXT LEVEL

Proceedings of the 30th Conference of the Grassland Society of NSW Inc.

COWRA SERVICES CLUB, COWRA 24–26 JULY 2017





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Edited by Karl Behrendt

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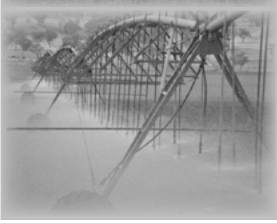

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Grassland Society of NSW Inc.

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

The Grassland Society of NSW Inc. was formed in March 1985. The Society now has about 350 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 issues affecting grasslands husbandry and to encourage the adoption into practice of results of research and practical experience. The Society now holds a biennial 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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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 30th Conference, of our society. Some will note the term 'Annual' has been removed as the Society has moved to a 'Biennial' format for the conferences since 2015. This is the first time Cowra has hosted our conference and we look forward to meeting many locals and enjoying their hospitality. Our society deems the sharing of our conference locations as a very strong attribute of the society, trying to disseminate 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 have proven to be a great success, allowing many more participants to be reached on an annual basis. Over the past three years, the Society has conducted in excess of 15 Pasture Updates, with attendances now approaching 1000 people for the total Pasture Update series. MLA have funded this program for another three year period (2017–2019), and updates in Grafton, Glen Innes, Bega and Tocal have already been conducted in 2017. There will be others later in the year, so please keep and eye on the Society website for up-coming opportunities nearer you.

With NSW having such a diverse range of pasture production systems and regions, it seems inevitable that not everyone is 'getting a season' at the same time. That is particularly true of this year. Conditions are quite good in the north of the state this year, and through parts of the central and southern tablelands and slopes. Unfortunately, many of our friends and family in the north-western and western regions of the state have not been so lucky. Our thoughts are with those who aren't being so fortunate, and we encourage them all to think of the good times ahead. Your turn will come, hopefully, very soon.

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

The conference this year, with its theme 'Your System – Taking it to the next level' will challenge us all. The presentations cover attributes of the plant/animal production systems, and are complemented by the bus tours. I encourage everyone to ask questions and learn from the experiences of others.

Our sponsors are an integral part of our society. They continue to provide great assistance, either financial or in-kind, and it is their involvement that makes many of the society's activities possible. I am fully aware that the commercial world is getting tougher. To those sponsors of our society for the 2017–2018 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 from these. I encourage all conference delegates to visit the commercial displays and take the time to talk with the representatives. Their product knowledge and the resources they have available may be just the key to improvements you can achieve in your own business.

To the conference organising committee, thank you. The enthusiasm and organisational skills that you brought to this year's event are greatly appreciated. I would also like to thank the many employers of the conference committee, as it is 'their time' that is contributing to the conference program. Many hours of voluntary work have come together for all our benefit, and for that we are grateful. We look forward to hearing and seeing the wonderful program that has been put together.

In encouraging '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 people's collective input.

Enjoy your time here,

David Harbison, President

Conference Program

Time	Topic and Speaker
MONDAY 24 JULY – COWRA SERVICES CLUB	
3.30 pm	**Pre Conference Registrations**
5.30 pm	Grassland Society of NSW Inc. Annual General Meeting
6.30 pm	Happy Hour and Canapes
DAY ONE – TUESDAY 25 JULY – COWRA SERVICES CLUB	
8.00 am	**Registrations**
9.00 am	**Welcome and Welcome to Country** *David Harbison, President, Grassland Society of NSW Inc.* *Representative of Wiradjuri Local Aboriginal Land Council*
SESSION 1 9.10 am	**Theme: Big Picture** • *The Australian red meat industry and the path to long term prosperity.* Richard Norton, Managing Director, MLA • *Increasing pasture production and utilisation: Still the best investment there is* Bill Malcolm, Department of Agriculture and Food Systems, University of Melbourne
10.40 am	**Trade Displays and Morning Tea**
SESSION 2 11.10 am	**Theme: Filling the feed gap – A flexible system** • *Forage improvement: The evolution of within species variation in cocksfoot, Mediterranean tall fescue and perennial ryegrass available to producers across temperate Australia* James Sewell, Australian Research Manager, PGG Wrightson Seeds • *Australia's ability to fill the feed gap* Julie Brien, Producer, Greenethorpe • *Filling the Feed Gap: A Case Study and Farmers Perspective* Stuart Tait, Producer, Mandurama
12.30 pm	Collect lunch, warm clothing, boots etc., board buses
SESSION 3 12.45 pm	**Bus Tours Depart Cowra Services Club to visit farms in the following localities:** **Tour A – Mandurama / Woodstock district** Both "Sunny Downs", a beef breeding, trading and finishing family business near Mandurama, and "Greylands", a prime lamb and beef production enterprise, integrate cropping to achieve productive perennial pastures.
	Tour B – Gooloogong /Canowindra district Firstly, Australia's largest intensive barn style dairy. Achieving high animal production on a large scale from quality pastures and crops. Then, Lucerne hay, prime lamb production, long term perennial pastures, irrigation and dual purpose crops.

	Tour C – Cowra / Greenethorpe district A diverse farming and manufacturing business, comprising irrigated lucerne, lamb production and an energy and labour efficient automated lamb feedlot finishing system. The role and benefit of a range of traditional and new pasture species, as well as winter forages, in maintaining year-round livestock production both in 'as-fed' and 'conserved forms'.
5.30 pm	Buses return to Cowra Services Club
6.30 pm	Conference Dinner & Entertainment (Nick Lee – Former 60 Minutes Cameraman)
DAY TWO – WEDNESDAY 26 JULY – COWRA SERVICES CLUB	
8.00 am	**Registrations and Trade Displays**
8.30 am	Welcome / House Keeping
SESSION 4 8.40 am	**Theme: Opportunities** • *Legumes and nitrogen – it's time to stop assuming* Belinda Hackney, Central West LLS, Forbes • *How do you get the most out of native grass pastures without breaking the system* Meredith Mitchell, Agriculture Victoria Research, Rutherglen • *Alternatives and Fundamentals – considerations when using fertilisers and ameliorants.* Neil Griffiths, NSW DPI, Tocal • *Feed gaps and pasture utilisation: challenges of grassfed beef production.* James Bjorksten, Producer, Yeoval
10.30 am	**Trade Displays and Morning Tea**
SESSION 5 11.00 am	**Theme: Technology** • *Pastures from drones: the potential to use UAV's to monitor pasture biomass and quality in temperate grazing systems* Anthony Clark, NSW DPI, Orange • *Making the most of your dry sheep equivalent (DSE) potential* Matthew Monk, General Manager, Sundown Pastoral Company, Kingstown • *The practicalities of technology in commercial sheep production* Hannah Marriott, Greta, Victoria
12.30 pm	**Trade Displays and Lunch**
SESSION 6 1.15 pm	**Cowra Research Station** • *Perennial crop research at NSW Department of Primary Industries, Cowra* – Matthew Newell • *Potential benefits of internal pelvimetry in Merino ewes* – Gordon Refshauge • *The effect of extensive feeding systems on growth rate, carcass traits and meat quality of lambs* – David Hopkins • *Dual-purpose cereal variety evaluation in mixed farming systems of NSW – research update* – Peter Matthews
3.15 pm	**Conference Close and Afternoon Tea**

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Invited Papers

The Australian red meat industry and the path to long term prosperity

R Norton

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The Australian red meat and livestock industry is operating in a complex and dynamic environment, presenting a number of challenges and opportunities.

Fundamentally, demand remains strong for Australian product, underpinned by our integrity systems and our superior reputation for quality in the minds of consumers in our key markets. The global drive for food security is also expected to continue to inject new investment into the Australian red meat and livestock industry.

However, the trade environment is challenging and unpredictable. A changing political landscape and rising nationalism in some major international economies have cast doubt on recent free trade agreements and the prospects for future multilateral trade deals. Market access hurdles remain a frustration and economic conditions in some markets are lukewarm at best. Against this backdrop, international competition from other red meat suppliers is intensifying.

At the same time, Australia's red meat industry continues to contend with supply constraints and escalating costs, while domestic competition from other lower cost proteins is relentless. Together, these factors present an unprecedented challenge to Australia's processing and retail sectors that may only be relieved by a recovery in the Australian herd and flock, changes to business models and the embrace of productivity-enhancing innovation.

Herd numbers and turnoff should continue to slowly recover over the year ahead although export demand will continue to impose price pressures on domestic beef and lamb consumers. Seasonal conditions, as always, will have a critical impact.

Domestically and in our established international markets, community expectations around environmental and welfare practices remain high. Consumer interest in the provenance of the food they consume continues to grow.

The red meat and livestock industry operates on nearly half the Australian land mass, albeit sparsely, so the industry is under continuous scrutiny for its impact on the environment.

However, there is continued opportunity to both protect and enhance the natural resource base while at the same time deliver increased productivity gains. Demonstrating this stewardship of the land is a key opportunity.

The Australian red meat and livestock industry maintains a premium reputation for quality, underpinned by robust integrity systems and on-farm practices that have instilled confidence in our trading partners and consumers alike. Enhancing this position in the face of increasing scrutiny from multiple stakeholders remains both a necessity and an opportunity for our industry to maintain what is also a competitive advantage.

Profitability will remain the central driver of producer and industry advancement. Producers across all three sectors of the industry – beef, sheepmeat and goatmeat – have enjoyed record prices after enduring decades where prices paid increased at a faster rate than prices received. However, the long-term prosperity of the production sector relies on the maintenance of positive returns and a new emphasis on productivity.

For processors, significant input costs such as labour, transport and energy remain higher than our major competitors and, particularly in the case of energy, continue to escalate. The search for cost savings will remain a critical driver, meaning productivity improvements are essential for the industry to remain profitable and sustainable.

The industry's collective productivity imperative requires research, development and innovation that deliver real commercial outcomes along the entire value chain. Objective measurement technology, processing automation and the capture and shared application of data offer huge economic potential through collaboration between value chain partners.

A critical challenge remains the need for adoption, not just of new research and development, but also those latent opportunities for productivity gains that have already been identified. Adoption in large areas of the industry, particularly in northern beef production, remains unsustainably low. The need for new drivers of adoption coincides with the continued reduction in public extension services. MLA is helping to fill these voids by facilitating adoption and building the capability of private providers, levy payers, and other partners across the value chain.

At the same time, the expanded use of new mobile and online communication tools offers potential that is only constrained by network limitations. As new automation and measurement technologies emerge and as the footprint of digital technologies expand, there will be more ways for MLA to help producers and their value chain partners share information and adopt new practices and business models. Together, all these factors will drive the increasing globalisation of Australia's red meat and livestock industry.

Increasing pasture production and utilisation: Still the best investment there is

B Malcolm

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Abstract: *Declining increases in productivity in Australia's grazing industries, when competitors are increasingly competitive and global demand is growing, is a concern to farmers, the public, the private sector and all organizations involved in research, development and extension. Done well, investing to improve pastures and increase dry matter production and consumption per unit of area of the limiting resource land is as good an investment as any investment in the economy.*

Keywords: pasture, productivity, investment, risk.

1. First, the Big Picture

Change is the name of the farming game. There is much change afoot in Australian agriculture. There is plenty of good evidence that in the next 30 years the world population will hit 'Peak People', and in the next century or so 'Peak Heat' is on the way too. The population of the world will grow rapidly from the current 7 billion to 9–10 bn by 2050, and an extra couple of degrees average global temperature is locked in. Both phenomenon pose challenges and create opportunities for farmers.

Farmers will adapt to the hotter, rougher weather, as they always have. The extra 2 bn people by 2050 will nearly all be in what are currently the poorest countries on earth, though many of the world's poor people will also become wealthier as economic growth proceeds in all countries. More people with more income will create opportunities, but only for those farmers who are the best in the world at what they do. In Australia, being best, surviving and succeeding in the farming business, has always meant continually increasing productivity at a faster rate than competitors around the world – all of which depends critically on investing plenty in agricultural research, development and extension (R,D&E), and doing the agricultural R,D&E at the highest standards. Worryingly though, the annual increases in farm productivity that were achieved regularly from the 1950s to 2000, and which underpinned past farm profits has declined markedly. In Figure 1 it can be seen that productivity increases in grazing over time have been low, and getting lower.

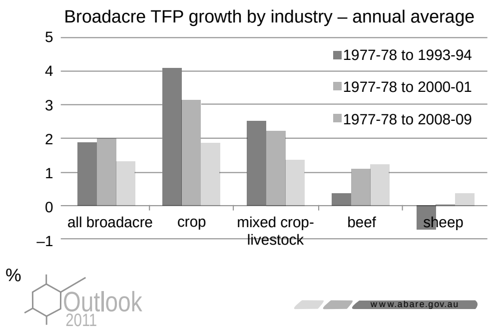

Figure 1. Productivity growth Australia's broadacre industries (from ABARES 2013).

According to the ABARES (2013) between 1948–49 and 2013–14 total factor productivity (TFP) in Australian agriculture grew at 2.0% a year on average. This was responsible for more than 80% of the increase in farm output growth over this time. Annual growth in agricultural TFP slowed since 2000, from an average 2.6% per cent a year between 1948–49 and 1999–2000 to an average of 0.9% a year since the late 1990s. Over the 30 years to 2011 the average annual percentage growth in total factor productivity in beef and mixed cropping-livestock has been around 0.9%, and –0.3% in the sheep sector. The reasons for this decline in productivity growth is related, in part at least, to the quantity and quality of investment in agricultural R,D&E in Australia. Meanwhile, the competitors of Australia's farmers are getting better at what they do.

The other permanent features of farming in Australia, the rising input costs, downward trending farm product prices (continuing cost-price squeeze) and rising protectionism world-wide remain front and centre. Indeed, the threat of increasing protectionism is growing apace world-wide.

Over most of the past century, and in recent times, prices paid for inputs have edged upwards in most years, while prices received fluctuate around a declining trend. The effect of these two factors mean that to maintain farm profit, farm productivity (input to output ratio of farm product) has to increase regularly, to offset the squeeze effect of rising costs and declining prices.

Productivity is king. If productivity increases sufficiently it offsets the declining terms of trade and profit and returns to capital are maintained. This has been achieved in the past; the challenge is to do so in the future. Added to the widespread farm economic illiteracy evident in parts of agricultural service sectors, a growing anti-economics generally, a rising tide of pseudo-science and anti-science evident in parts of agricultural service sectors and in modern society, and the outlook for Australia's agricultural productivity increases is challenging.

The focus in this paper is on that minority of farmers in Australia who make up the best farmers in Australia and who produce the vast majority of gross value of agricultural product. A major feature of this future will be that the quantity and quality of information available to farm decision-makers will be massively greater than could ever have been imagined only a decade ago. Just on and over the horizon is a future with immense and exciting prospects, which, if grasped, would mean the best of Australian agriculture will continue to be one of the best investments in the economy. This future though comes with greater uncertainty than usual because, in the future compared to the past, farmers face the prospect of having less good science and farm economic knowledge support to help develop and apply the new technologies that supply the much-needed increases in productivity and profit, and which enable farm families to achieve their goals.

What are the implications in the here and now for farmers in Australia? As in the past, to succeed the best operators will gather and master as much information as possible and put together the few pieces they control of the jigsaws that make up the big picture which makes up the environment in which they must run their businesses: the whole global economy; the whole national economy; and the whole farm economy. One way or another, to succeed, the best farmers successfully manage the consequences of the operation of these economies, usually with little control over anything except decisions they make about their own domain, on their farms.

Regarding changing climate, much focus is given to whether most farmers will successfully adapt their businesses to hotter, rougher weather. This is the wrong question: farming has always been about coping with change, adapting to change has long been (along with having good equity) the main arts in farming survival and success. The real question about the potential effects of changing climate is whether the technologies the best farmers will need to keep improving productivity and maintain profit will keep on coming. The farm solution to coping with changing climate is ultimately an economic solution, no different to the cost, price, productivity, risk and uncertainty challenges that farm businesses have had to adapt to in the past to succeed. Solutions will continue to be: farm well, master new information, manage new data, have high(er) equity, grow the business over time, and spread risk by setting the portfolio principle to work for you, both on farm and off farm, spatially and across time.

Regarding feeding the growing world population, the main thing that has to happen for world population to plateau at around 9-10 billion by 2050, is the poor countries have to get richer. Economic growth has to proceed apace for population growth to slow. The combined effect of more people and more wealth in the world means more demand for food. Demand for food refers to people with money to buy food, and total demand depends on both the size of the population and size of their wallets. Three phenomena with implications for farming come into play as people become wealthier. First, the demand for food is subject to a phenomenon known as Engel's Law, which holds that as people's income grows the proportion of their *extra* income that is spent on food declines. This phenomenon explains why, as economies grow, the relative share of Gross Domestic Product (GDP) attributable to agriculture declines as a proportion of total GDP, reaching around 1–2% in the wealthiest countries.

The second phenomenon which has occurred as countries have become wealthier is they almost inevitably protect their own farmers from international competition. Australian farmers have long had to battle, for example, the protectionism of Europe, the USA, Japan, South Korea, China, and Indonesia. This phenomenon is not going away. And, don't be fooled by the smokescreens of bilateral free trade agreements where glacial rates of tariff reduction pose as opening 'brave new worlds' of trade opportunity.

Third, we also know that growth of economies and world-wide economic activity will happen not smoothly but inevitably in cycles, with perhaps the only certainty being that booms will bust. Agricultural activity too will proceed in cycles with profit deriving from swings in supply stemming from the normal volatility of seasonal conditions, the big natural phenomena of drought, flood and disease, and the biological nature of farming, such as herd and flock build up and liquidation. Demand too will go up and down with the economic cycles, swings usually exacerbated by policies of protection when prices rise or fall. Given this future of a strong trend in growth in demand for food world-wide, the biggest mistake any farmer or potential investor in Australian agriculture could make when contemplating their short to medium term future is to simply presume that this likely growth in the number of people and world income means that there is some inevitably about them sharing in this expanded market by selling their products. There is no such inevitability about this happening, for any farmer anywhere in the world. The competition for Australian farmers will be fiercer than ever before, as traditional and newly emerging competitors start doing their agricultural R,D&E better, as competitors access to new technologies suited to their local systems grows fasters than in Australia – none more so than in the newly emerging economies intent on increasing their own agricultural production by increasing productivity. The race will only go to the fittest, the best equipped, farmers.

Australian farmers will find that their long held traditional advantages of increasing productivity and producing low cost commodities (representing the all-up value for money farm product for ranges of consumers), and for some, sometimes producing high quality products too, will all be increasingly challenged as competitors to Australia's farmers improve their fitness rapidly. At the same time, the average rate of increase in productivity in broad-acre agriculture in Australia has dropped off. So too the number of scientists and graduates trained in agricultural science and farm economics declined, and people in the farm service sector equipped to analyse farm decisions using post-1940s farm management economics. On the other hand, investment in agricultural R,D&E and increasing agricultural output is proceeding apace in the newly emerging economies (e.g. China, Brazil, Eastern Europe) and 'set to emerge' economies (e.g. India).

The overall theme of this paper is that in the modern farming game in Australia, the match goes to the fittest and the game is getting harder. While Australia's farmers will be challenged in making good on the opportunities that will come from growing global demand and maintaining and increasing profit because of increasing competition, increased protectionism, increased volatility of weather and markets, declining increases in agricultural R,D&E investments, accompanied by less good science, less good farm economic analysis, the best farmers will continue to make a good go of things, and earn returns on capital as good as anything else in the economy.

2. Second, on the farm

2.1 How graziers can lift productivity by investing in pastures

Cropping has a markedly better record than grazing when it comes to increasing productivity. This is partly because opportunities in cropping to achieve economies of size are greater than in the grazing industries. In grazing activities quantities of feed required and costs increase in quite direct proportion to the number of head managed, and scope for labour efficiencies are limited, though increasing a little with technological developments. Still, there are well-established farm innovations in grazing industries that are proven to increase productivity that still have much potential for greater adoption. These include:

- Reducing further environmental constraints of the farm system to increase the livestock carrying capacity and to express genetic potential of superior genetic animals. This can be done by introducing pasture species with improved genetic potential, and improving the nutrition and grazing management of these improved pastures to lift dry matter consumption per hectare and improve activity and whole farm gross margin and operating profit.
- Adopting scientific breeding and selection methods to improve the genetic potential of animals which can now be expressed in the farm system where the environmental limits have been raised.

The term pasture improvement covers a range of actions and degrees of change, for example, from clearing scrub and fully preparing a seed bed for a mix of pasture species to spray-grazing and minimum tillage, direct drilling to simply pasture topping to control seed set, with numerous combinations and permutations of these actions in between. The 'sub and super' revolution of the 1960s made possible increases in stocking rates across grazing lands of Southern Australia; along with increases in soil acidity necessitating latter-day inclusion of liming into investments in pasture improvements. Carrying capacities and activity gross margin/ha were able to be lifted from 4–6 DSE/ha and gross margins of \$10–\$15/DSE, to 12–15 DSE/Ha and \$20–\$25/DSE (albeit aided and abetted by a generous subsidy on superphosphate). In lifting potential pasture production and improving grazing management and thus increasing carrying capacity and net value of liveweight turned off from a farm system and activity and whole farm gross margin, the key question is about the number of extra megajoules of metabolizable energy (MJ ME) consumed over a time period, and the value of the extra MJ ME in the farm system. Note, the investment required is two fold:

- Investment in capital for pasture and animals, and
- Investment in management expertise to manage well the grazing to harvest of the extra pasture produced and convert it to income. The tonnes of dry matter consumed varies widely across livestock systems, suggesting there is a wide range of levels of expertise in grazing management.

Time is involved in investing to improve pasture, and the investment may have a life of 10–20 years, or more sometimes, with risk and uncertainty also an important part of the investment. An investment in pasture can be represented as in Figure 2.

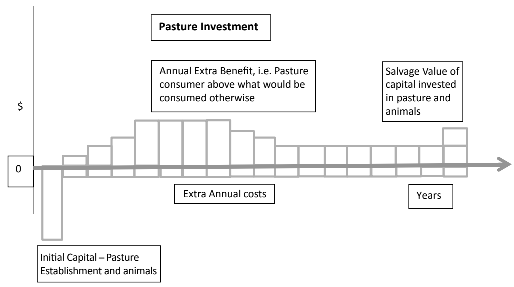

Figure 2. Pattern of costs and returns from investment in improving pasture.

The key components of the decision to invest to improve pastures, and the key determinants of success or failure of the investment, are:

- how much extra dry matter (MJ ME) is produced over the life of the investment and when it is produced during a year
- how long it takes for the pasture to reach peak production, how much production varies over time and how long this level of annual and seasonal production or thereabouts is sustained over time
- the potential of different species to be managed to maintain population density
- how the extra dry matter grown is used, what it is worth in this use and how much this value varies over time

- how much it costs to establish and maintain the new pasture
- how much profit the capital used could produce in an alternative use
- how much capital has to be borrowed, at what interest rate, and the length of time required to recoup the initial capital invested
- the increased future profit potential of the land lifts its value too, if it were sold anytime during the life of the improved, more productive, more profitable pasture. (Note: cannot count *both* the increased annual profits and the increase value of the land as one causes the other, i.e. it'd be double counting).
- How does the intensification – the added investment in pasture and livestock in the system – affect the risk of the farm situation. There is an important rule here: Intensification increases both the average return over time and the volatility of the annual returns around the average annual returns. *Higher returns only comes with higher risk. This is because it is the higher risk that creates the higher return.*

In weighing up the investment in pasture, the comparison is compared with the situation that would apply without this investment. Note, something often overlooked, in the farm economic way of thinking is a future decline in production that is avoided as a result of investing to improve pasture and stock carrying capacity and activity and whole farm gross margin, is a benefit of the investment, i.e. a cost avoided is a benefit. A further confounding factor is that, while the stocking rate achieved is a function of pasture production, the pasture production is a function of the stocking rate and, more important, the grazing management of both the pasture and the stock, i.e. it's all a very dynamic process.

Provided the extra dry matter produced (pasture consumed actually is what matters) in the farm system as a result of the investment *is a sufficiently large addition to the pre-existing level of dry matter and MJ ME production and consumption,* analyses of opportunities for investing in pasture consistently show expected returns to marginal capital of 15–20% (nominal, after tax, real returns more than 10%–15%). So, what is 'a sufficiently large addition to the pre-existing level of dry matter and MJ ME production?' This depends on how much using the extra DM produced adds to annual farm profit and the costs of producing it. The theoretical framework for answering these questions is the farm management economics way of thinking. In particular, the concepts of:

- The whole farm approach
- Principles of diminishing marginal returns, equal-extra returns to extra inputs, and opportunity costs
- Risk and uncertainty in agricultural management

What is the whole farm approach? New Zealand's Wilfred Candler sets this out:

> Let me first define what I mean by the Whole Farm Approach to management advice. This merely 'refers to advice which has been budgeted to ensure that it really does result in an improved farm plan, from the farmer's point of view'.
>
> 'Budgeting allows the best proposal from a number of alternatives to be selected. Unbudgeted advice, on the other hand, is simply bad advice. A soil test alone cannot, repeat cannot, tell you whether it would be profitable for a farmer to put on more or less fertilizer, since profitability depends, inter alia, upon the number of stock run'.
>
> Thus, the Whole Farm Approach is obviously an integral part of a farm management training. Occasionally one hears a rather peculiar phrase 'the whole farm approach to farm management'. I say peculiar because this statement implies there is another approach to farm management.

The principle of diminishing marginal returns tells us that the world is not linear, it does not come to us in straight lines. Instead, as we add more and more inputs to production, such as fertilizer or capital, the extra return from extra inputs diminishes. Thus average figures are not relevant. Marginal thinking is required. The same applies to equi-marginal returns to extra inputs and opportunity costs. Opportunity cost is the benefit you give up by doing one thing instead of an alternative. Equi-marginal returns to extra inputs means if the gains from increasing output from one part of the farm system are big, this should be done. This process continues until the gains from changing one part of the farm system is about the same as would come from changing another part of the system, i.e. all opportunities are looked at and the best opportunities picked off until all opportunities are being utilised, theoretically.

The question about the merit of a pasture investment can be reduced to a small number of the critical, most unsure, characteristics of the pasture that will grow. These are:

- Extra stocking rate
- Value of extra feed produced
- Life of the investment in the pasture

What is the value of extra pasture produced? Extra DM produced can be valued by putting it through extra animals, or the same number of animals producing extra output. Alternatively, the extra pasture itself can be valued in its own right. There are two ways of tackling this question of the value of the extra pasture in its own right: the value of a similar alternative farm input – equivalent pasture dry matter – in the economy; or the value of the dry matter components of metabolizable energy and crude protein in the economy.

Example 1

An investment in improved pasture analysed using a single year, steady state partial budget process.

1. An extra 40 hectares of improved pasture
2. $400/ha to establish the pasture. Assume this capital has 10 year life, no salvage value, i.e. annual depreciation/ha of 'pasture capital' is $40.
3. Carrying an extra 8 DSE/ha in full production,
4. Each DSE is $75 in capital investment, producing in most years an annual Gross Margin/DSE of $25 including annual pasture maintenance costs and an additional allowance for extra supplementary feeding. No extra labour required and no extra overheads involved.
5. Extra GM/ha = 8 x $25=$200/ha
6. Minus extra depreciation = $40/ha
7. Gives Return on Marginal Capital $160/ ($400 pasture capital + $600 livestock capital (i.e. 8 DSE x $75/DSE)), which = $160/$1000 invested/Ha=16% (real return on marginal capital before tax).

Example 2

Another way to think about the question is to estimate the value of the extra DM of pasture based on the values of equivalent MJ ME as set in markets beyond the farm. The approach is that if the extra feed is to be produced and used in the farm system then the value of the MJ ME value in the farm system is what matters. Logically, the value of extra MJ ME grown in a farm system must be between

(i) Minimum $/MJ ME value which is an agistment value

or

(ii) Maximum $/MJ ME value which is a replacement value (cost of obtaining the MJ ME into the farm system in another way) of equivalent MJs of ME

The basis for thinking about the value of extra MJ ME is that if extra pasture is worth using in a grazing system (i.e. feeding to your own animals), its value in the system must be more than what the owner of the pasture could get by using it in the farm system rather than selling it to another user as agistment or 'standing hay'

and

Must be less than the owner could purchase the equivalent pasture dry matter from off the farm (replacement value) and use the purchased DM in their system, i.e. if obtaining extra pasture by growing it was more expensive than buying it in, valued 'as fed', it would be bought in.

Thus pasture used in grazing systems has to have a value in that system that lies between the minimum (agistment/standing hay) and maximum (replacement value) as shown in Figure 3.

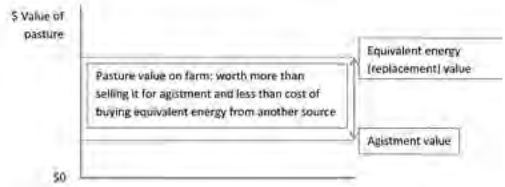

Figure 3. Market values of megajoules of metabolizable energy.

These two values, agistment/standing hay and market price of equivalent MJ ME 'as fed', can be used to analyse the returns from investing to increase the farm supply of pasture DM. If the returns on capital are acceptable using these market values of equivalent DM/MJ ME values, risk, then it is a sound investment.

An example including risk analysis: Agistment where one DSE consumes 3000 MJ ME per year. At $0.40/week agistment that is $0.40 × 52=$20.80/year. One MJ ME is worth $20.80/3000=$0.007/MJ ME.

Replacement ME as grass hay, with 9 MJ ME/kg DM, $220/t with 90% DM (adjusted for DM and counting waste) = $0.018/MJ ME

Value of extra ME is between 0.7c/MJ and 1.8c/MJ. Including risk analysis in the analysis, suppose these possible values are uniformly distributed, as such each value between these two extremes could apply in any year of the pasture investment, as shown in Figure 4.

Suppose it costs $450/ha to establish the improved pasture, with extra annual maintenance costs accounted for, peak production occurs in year 3 and declines by year 10. The extra stock are able to be carried by the improved pasture in the following way; most likely will carry an extra 7–8 DSE/ha in most years at peak production, but some years could be less, as low as 3 extra DSE, and occasional years even be one DSE/ha better than the 'most likely'. The distribution of extra stocking rate is as shown in Figure 5.

Using the discounted cash flow technique, and risk analysis methods, the possible returns to the pasture investment can be estimated, as shown in Figure 6.

In this example, there is an 80% chance the investment will earn more than 8% return on extra capital p.a., and a 50% chance it will earn more than 10% p.a., and no chance of earning more than 15% or less than 5% return on the investment.

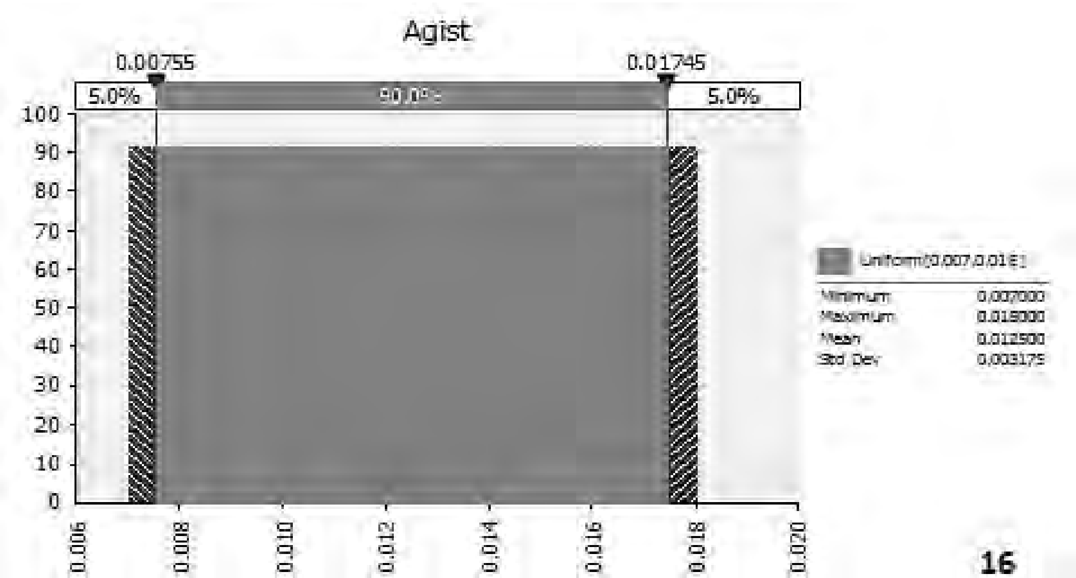

Figure 4. Distribution of possible values of MJ ME.

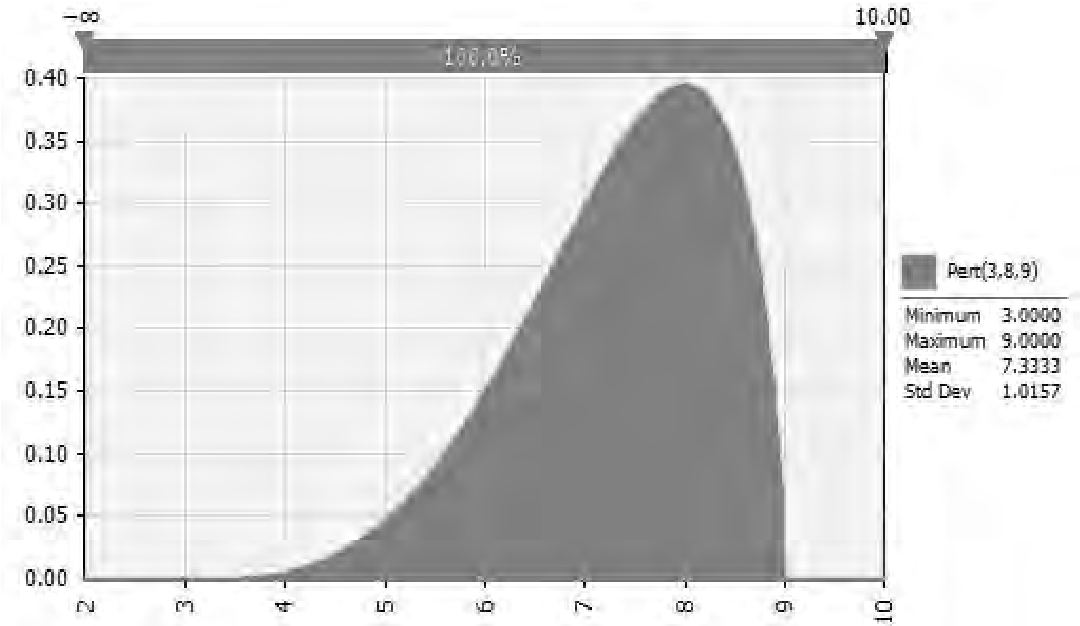

Figure 5. Distribution of possible extra stocking rates from improved pasture.

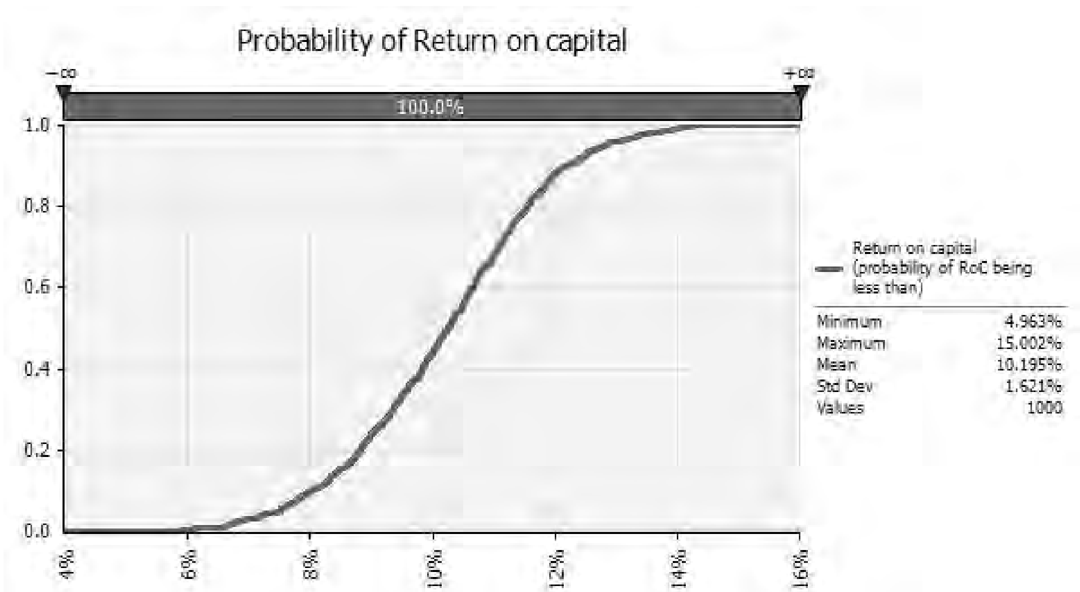

Figure 6. Probability of return on marginal capital from investment in improved pasture.

Example 3

Life of pasture – persistence

The question of persistence of pasture is raised regularly. Indeed, the life of the capital invested in improved pasture is critical in determining the returns to that investment, up to a point. The issue here is whether the initial capital invested in capital fertilizer, seed, sowing, livestock remains productive and profitable for a long time or not. Typically, the initial capital invested in the improved pasture declines in annual productivity over some time ranging from 10–20 years, though 50 year old phalaris pastures can be found. If a pasture reaches peak production and maintains this indefinitely, then the questions of optimum life, when to replace it, or persistence, do not arise – simply, the longer it goes on the better. In the more typical situation where the annual pasture production increases in the early years, maintains a peak level for a number of years, and eventually declines, the question of optimum replacement time becomes important. The way to think about this question is shown in Figure 7.

The pattern of profit from pasture over time shown in Figure 7 means maximum profit over time comes from the maximum average production from each cycle of pasture, not from the maximum production/profit from any one cycle. This means the time to replace a pasture is when the expected annual average return (or more precisely, the annuity) from a ***new*** cycle of pasture investment is greater than what is expected to be produced by one more year of the existing pasture.

This question about when to replace a pasture is analysed for a standard set of production parameters *viz*: unimproved pasture producing 2100 kg/ha consumed pasture, feeding 6 DSE/ha/yr replaced with a pasture producing a peak of 11,500 kg DM/ha/yr by year 4 and maintained until year 7, then declining to 65% of this peak by year 20. This carries an extra 15 DSE/ha, valued at agistment rates of $0.35/DSE/week and annual maintenance cost of $50/ha.

At 8% discount rate for future net benefits for this pasture that maintained peak production from years 4–7, and then declined to 65% of this peak production over the duration of its life to year 20, persistence of the pasture beyond year 8 was not more, or less, profitable than persistence to year 20. Seemingly counter-intuitive, that you'd be equally as well off if you replaced the pasture in year 8 or year 20, the reason for this is that once the annual pasture carrying capacity declined to 65% of the peak annual carrying capacity, the annuity of the investment was the same whether the life of the investment was for any of 8,9,10,…18,19, or 20 years (Figure 8). For more on this see Malcolm *et al.* (2014).

The point is that, if the pasture is expected to decline in productivity from a peak after 7–8 years of life to say around 65% of the peak by the end of its life, then the annual contribution to wealth of the initial pasture investment is the same regardless of whether the pasture has a life

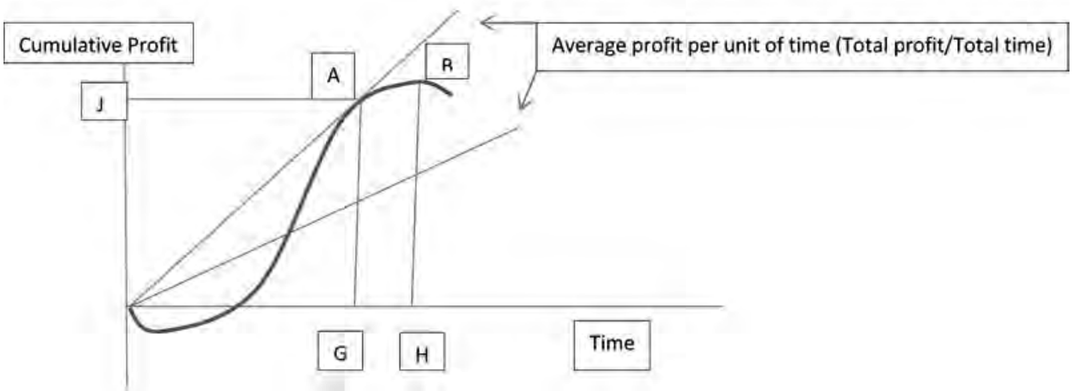

Figure 7. Optimum time to replace a perennial pasture. Total profit B $10,000 over 10 years at H = $1,000/year. Compared with total profit A of $9000, over 7 years at G = $1285/year.

of 8 years or 20 years. This means, if the pasture is to be replaced with another one of the same expected annual profitability, the replacement decision of the existing pasture beyond year 8 can be based on other factors, such as when there are propitious product prices and seasonal conditions, or the arrival of superior new pasture varieties.

2.2 How graziers can lift productivity by investing in animals – after they have lifted the pasture constraint on production

Lifting the environmental constraints to production makes possible fuller expression of the genetic potential of the animals in the farm system. Investing in purchasing and producing animals with superior genetic potential is an exercise in futility unless limits to expression of this potential are lifted. Similarly, the exercise in improving the genetic potential of the animals is futile if the genetics are not a good fit with the system into which they are fitted, or the system does not make economic sense, such as calving or lambing systems that are a poor fit with the natural environment or the market. Regarding selecting genetically superior animals, and doing so using the extremely valuable information about Estimated Breeding Values (EBVs) for different traits of differing importance to particular farm systems, remains remarkably under-done; meanwhile the alternative unscientific methods equally remarkably persists. A similarly odd phenomenon is the persistence of beef calves hitting the ground in the dry, feed-short autumns of Southern Australia.

Effective use of animal EBVs in lifting productivity in the animal industries is hampered by breed societies claiming, wrongly and in defiance of basic farm economic theory in so many ways, that combined trait EBVs expressed as '$Indices' somehow indicate 'net profit' per animal and addition to 'farm profit'. This is simply not true, demonstrating alarming ignorance of the economics of farm systems. Combining all the EBV information into a spurious EBV-amalgam called a linear

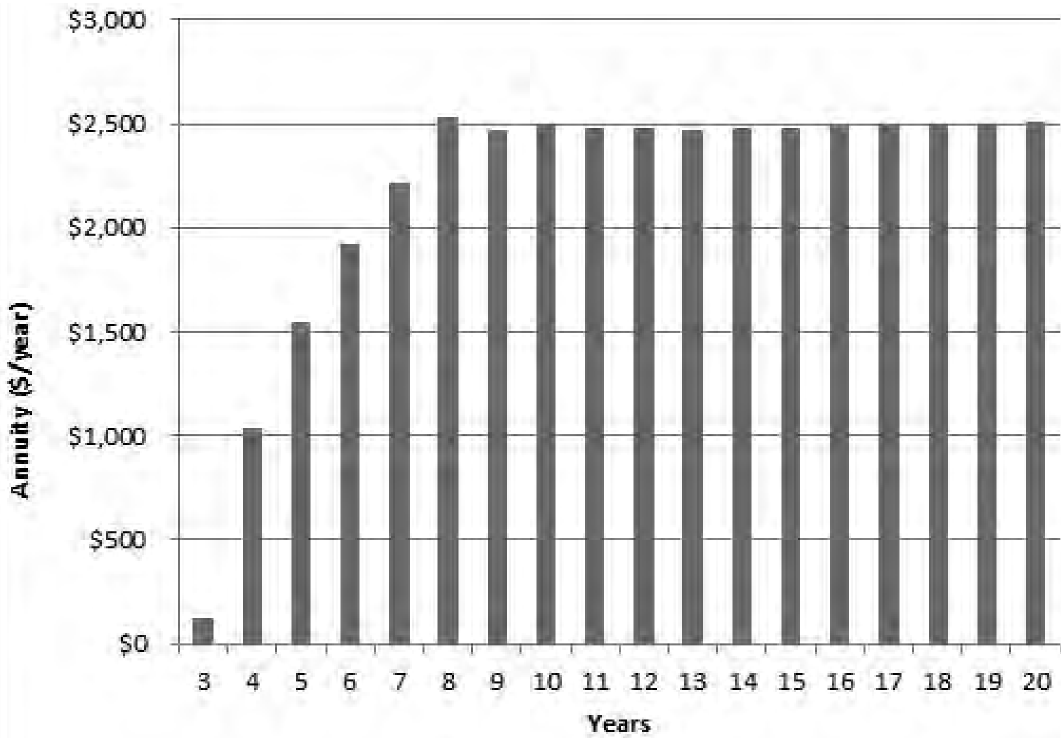

Figure 8. Annuity (equivalent profit from each year for life of pasture) from pastures with different lives. Annuity 20 year life, declines to 65% of year 7 peak by year 11, at 65% until year 20 (8%, 50ha), i.e. doesn't matter 8–20 years.

and arbitrary 'Profit Index' is not helpful. The information value supplied by the EBVs of traits that are key drivers of particular systems is much nearer the mark. As well as the prevalence of non-scientific breeding selection decisions, a gap between the continual advance of the high science of quantitative genetics and the practicalities of farm business management and economic analysis of farm systems also exists. Parts of the modern animal genetic industry is uncomfortably reminiscent of Jack Makeham's comment nearly 40 years ago about the then- and should be now-discredited Show breeding caper: 'Probably no sector of agriculture has been more prone to the wiles of rapscallions than has the breeding game' (Makeham and Malcolm 1981, p.222).

3. Finally

For graziers to make the most of the opportunities that are here and now and just over the horizon they will need to be able to increase their productivity at a much better rate than in the past couple of decades. To do this will require new technologies from their investment in agricultural R,D&E, allied to sound farm economic analysis.

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Forage improvement: The evolution of within species variation in cocksfoot, Mediterranean tall fescue and perennial ryegrass available to producers across temperate Australia

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Abstract: *There are many cultivars of cocksfoot (*Dactylis glomerata*); perennial ryegrass (*Lolium perenne*); and winter active tall fescue (*Festuca arundinacea*) available in Australia, but there are only a few 'types' of each of these species. Differing types can be quite different and, before selecting cultivars within a type, perceptive producers need to understand the diverse types and appreciate the likely relevance for their particular livestock system. This article describes the evolution of the various types, their distinctive attributes and their environment and management needs. This paper also focuses on the consequential within species variation for three important forage grasses utilised across the temperate Australian grazing regions: cocksfoot, perennial ryegrass and winter active tall fescue. The advantages and disadvantages of each species is addressed as well as a brief review of literature around different grazing management practices required to maximise productivity from each individual subspecies. Given the recent achievements in phalaris (Phalaris aquatica) improvement and importance to many dryland regions of New South Wales, this paper intends to only highlight the challenges, opportunities and recent developments of the three other grass species and how they may have a fit within a grazing system.*

Key words: Cocksfoot, Perennial Ryegrass, Mediterranean Tall Fescue, Phalaris

Introduction

Both within species and subspecies variability exists across many current and future cultivars available to livestock producers in temperate southern Australia. Understanding these differences and selection of the right interspecies type is crucial to match feed demands and expected reliability and so deliver a pasture system that will maximise sustainable production and withstand climate variabilities. The genetic background of the different types and an overview of the breeding behind this variation is needed to understand this variation. This discussion lists the drivers of key traits such as cool season growth, summer dormancy, relative maturity and plant survival mechanisms. The importance of endophyte and its influence on perennial ryegrass and tall fescue production system is also addressed.

Cocksfoot

Cocksfoot (*Dactylis glomerata*) is an important dryland forage species both for Australian and international agriculture. It is one of the top four temperature grass species used in Australia (Pearson *et al.* 1997) and is the second most commonly sown pasture grass in New Zealand (Mills *et al.* 2006). Its popularity for widespread cultivation in dryland environments is due to its adaption to shallow, acid soils (common throughout tableland regions of southern Australia); persistence under low soil fertility and response to fertiliser application; absence of any known animal toxicoses (unlike phalaris (*Phalaris aquatica)* and wild-type endophyte-infected perennial ryegrass); a range of adaptive subspecies (continental, Mediterranean and Hispanic) exist that can tolerate varying levels of water stress, tolerance of many major pests and diseases, and finally is highly competitive and persistent once established. The use of cocksfoot is limited in that it is not well adapted to poorly drained or saline soil; is susceptible to leaf rust (cultivar dependant); and is generally slow to establish. Like phalaris, with inappropriate grazing management it can become rank. Bulky tufts form which can become difficult to manage.

The most common commercial species of cocksfoot in Australia derive from northern, western or Eastern Europe from the subspecies *Dactylis glomerata* spp *glomerata* (i.e. France, Portugal, North West Spain and United Kingdom). This has resulted in cultivars developed for the higher rainfall regions (<750 mm average annual rainfall) where permanent, long-term pastures are common (Stewart and Ellison 2014). Traditional breeding efforts for Australia have focussed on the use of this germplasm from these homologous climate zones and has resulted in a series of very well-adapted cultivars. Examples of these higher rainfall continental types are 'Porto' and 'Tekapo', and the more recent cultivar 'Savvy' with improved summer activity, quality and disease tolerance. However, Stewart and Ellison (2014) explain that the full genetic diversity within this species has not been exploited as yet allowing further scope and diversity for on-going forage improvement programs.

The subspecies *Dactylis glomerata* spp. *hispanica,* commonly referred to as 'hispanica' type, include more drought tolerant and summer dormant cultivars which express a range of levels of summer dormancy. This subspecies has been developed for lower rainfall climates (300–450 mm) and those frequented by droughts and originate from material in the western Mediterranean and North African regions (i.e. Spain, Portugal, Morocco and Algeria). An example of this cultivar once common in Australia is 'Kasbah', developed by the Waite Institute in South Australia following germplasm collection in Morocco (Reed 2014). More recently, a densely tillered and fine-leaf cultivar 'Uplands' was developed by the Tasmania Institute of Agriculture from germplasm collected in Spain and released in 2008. Both these cultivars express moderate (i.e. 'Uplands') to very high levels (i.e. 'Kasbah') of summer dormancy (Norton *et al.* 2001).

The intermediate subspecies *Dactylis glomerata* spp. *glomerata* with an introgression of subspecies (spp.) *hispanica* (Lolicato and Rumball 1994) are often referred to as the Mediterranean type cocksfoots. They originate mainly from regions bordering the northern and southern shores of the western Mediterranean Sea (Stewart and Ellison 2014). The summer activity of these intermediate types can be high to moderate with the more drought tolerant cultivars finding use in regions down to 475 mm annual rainfall. A classic example is the cultivar 'Currie', developed jointly by CSIRO and the Western Australia Department of Agriculture from Algerian material and released in the 1950s (Reed 2014).

The main environmental variables of temperature, nitrogen and moisture affect the production of dryland cocksfoot in pasture systems. With greater understanding of this information, best practice agronomic management to maximise production can be discussed in relation to key inputs for Australian grazing systems. Cocksfoot is often recommended for low to moderate soil fertility and summer dry regions because of its ability to produce, survive and persist when subjected to moisture stress and drought. In many cases cocksfoot is often sown as part of pasture mixes (grasses and legumes) because of this ability to persist under dry and poor soil conditions. Maximising dry matter production of more dominant cocksfoot based pastures in Australian grazing systems is often secondary because it could be argued that inputs, such as Nitrogen (N) based fertilisers, are often underutilised in many dryland grazing operations and a considerable cost with no payback. Often the lack of a robust and persistent legume component in many cocksfoot based pastures is also limiting N supply and a contributing factor to low yield potentials. Additionally, it is common that cocksfoots, and some subspecies of cocksfoot (i.e. ssp. *Hispanica*), are sown primarily to maintain ground cover on sandy, north facing hills and slopes etc. and animal production is secondary. This further suggests that there is reluctance to fertilise these pastures as the response is not known or advocated, or it is perceived that moisture is a predominate limitation of production.

It is very likely that N supply is likely to also be a key and substantial constraint to cocksfoot performance in Australian pastures. Mills et al. (2006) investigated the effect that temperature, water and nitrogen has on the pasture production and quality of an established cocksfoot stand in Canterbury (Lincoln University, New Zealand) and the results clearly showed that N, rather than water, was the factor most limiting cocksfoot production. There is considerable opportunity to further expand the use of Australian specific legumes (i.e. annual clovers and lucerne *(Medicago sativa)* to supply N and encourage better dry matter production and quality responses with strategic N use.

Key traits for persistence of cocksfoot species (and subspecies) are defined and examined in regards to drought tolerant traits such as dehydration avoidance and tolerance, summer dormancy and tolerance to other stresses such as grazing management. Cocksfoot can employ one or more survival strategies to ensure it lives through prolonged periods of moisture stress, or drought. These include: dehydration avoidance; dehydration tolerance and summer dormancy. Further, it is most adept at regenerating from self-sown seed.

Drought tolerance – Dehydration avoidance and dehydration tolerance

The extent to which a plant regulates its water status as soil moisture becomes limiting can be characterised by either dehydration avoidance or dehydration tolerance. Both dehydration avoidance and dehydration tolerance have been suggested to be explanations for why there are population differences for superior summer drought survival. Some cultivars have higher fructan concentration and enhanced dehydrin expression (which is associated with dehydration tolerance) in Mediterranean types over the continental types. For example, Volaire (2002) in a glasshouse experiment, found that the accumulation of dehydrin proteins differed greatly between cultivars (hispanica > Mediterranean > continental) as the drought progressed. Dehydrins are a subfamily of proteins that may play a role in the protection of other proteins' membranes to preserve structural integrity, act as regulators of cell osmotic potential and protection of sucrose accumulation (Volaire 2002).

Summer dormancy

Cocksfoot expresses varying levels of summer dormancy in different subspecies and cultivars. Dormancy can occur in either winter or summer. It is a physiological response that ensures the plant survives when exposed to severe stress events such as moisture deficit or cold/frost injury. In cocksfoot, summer dormancy usually involves reduction in leaf growth, complete or partial senescence of herbage and possible dehydration of stems. It is expressed under environmental conditions of Mediterranean summers with long days and high temperatures (Volaire and Norton 2006).

The more summer dormancy a cultivar expresses, the greater the impact this has on seasonal yield. Experiments conducted in the western Mediterranean basin evaluating a diverse range of cocksfoot cultivars, subjected to drought, concluded that 'Kasbah' had the highest survival after three years and was also the one that expressed the highest level of summer dormancy (Annicchiarico et al. 2011).

The summer dormancy trait has shown to clearly enhance plant survival over hot, dry summers. The compromise on yield however may be a disadvantage to grazing systems. Therefore, summer dormant cocksfoot species such as the spp. *hispanica* types should only be used in situations where survival is threatened, such as on exposed north facing hills to prevent soil erosion by providing ground cover. They are not appropriate in medium to higher rainfall environments where yield is the primary driver for production.

Grazing Management

Grazing management of cocksfoot can affect its persistence of the stand. Under intensive and prolonged grazing by sheep, cocksfoot was less persistent than phalaris (Lolicato and Rumball 1994). Grazing management recommendations in Australia have often been derived from those based on phalaris. Given its different morphological and physiological growth characteristics, the adoption of grazing management based on phalaris may be contributing to the poor performance of cocksfoot (Avery *et al.* 2000). High grazing pressure through the summer could be a critical factor contributing to decline in cocksfoot persistence. It has been observed that following a summer rest period, individual plant size increased, greater root development resulted and new plants emerged from seedling recruitment (allowing plants to set and drop seed). However no data was presented to support this. Note that, increased plant size may lead to sizeable plant ‘clumps’ which can become hard to manage in a practical sense.

Cocksfoot has often been known to be susceptible to plant pulling which can affect persistence at certain times of the year. Various authors (Ridley and Simpson (1994); Avery *et al.* (2001) reported that cocksfoot plants have been observed to be pulled out of the ground in late summer and early autumn in various regions (i.e. north-east Victoria). This is a characteristic which is not reported in phalaris. According to Ridley and Simpson (1994) a large proportion of cocksfoot roots are regenerated annually and root development occurs only when secondary tillers have developed. After rain in autumn, both phalaris and cocksfoot developed new tillers but the development of phalaris roots was more rapid. The occurrence of cocksfoots plants being uprooted by stock can be explained by the difference between phalaris and cocksfoot in the proportion of live roots surviving over the summer and the relatively poor early root growth of cocksfoots. This ultimately would result in the plants not having adequate physical anchorage in soil; this could be greatly exacerbated in lighter, sandier soils. Excluding their work, there are limited studies on this concept in cocksfoot pastures in Australia, even though it is generally accepted as a major issue contributing to poor persistence.

Cocksfoot needs spelling to adequately replenish water soluble carbohydrate (WSC) reserves. Rotational grazing management must allow greater tillering and root growth, but prevent the plants turning rank and unpalatable. Rawnsley *et al.* (2002) investigated morphological and physiological changes of cocksfoot during regrowth in an effort to define optimal grazing management. Their results indicated that repeated defoliation before the 4-leaf stage would limit tillering (through depletion of WSC reserves) and long-term survival of plants. WSC concentration significantly increased between the 4- and 5-leaf regrowth stages. The authors concluded that a defoliation interval coinciding with this regrowth stage would allow adequate time for cocksfoot to replenish WSC and root growth, initiate tillering and maximise quality and utilisation.

Perennial Ryegrass

Perennial ryegrass (*Lolium perenne* L.) (PRG) is the most important forage grass for high rainfall and irrigated pasture of south-eastern Australia. It is valued for its ease of establishment, high herbage yield potential, high nutritive value, familiarity in farming systems and ease of management in relation to other pasture species (Reed 1996; Fulkerson and Donaghy 2001). A recent survey by Donald *et al.* (2012) showed perennial ryegrass dominated area of pasture across both Victoria (4 M ha) and Tasmania. Perennial ryegrass sown with subterranean clover (*Trifolium subterraneum*) or white clover (*Trifolium repens*) covered 19.2% and 29.3% of grazing land in Victoria and Tasmania respectively, compared with 1% in South Australia (SA) and New South Wales (NSW).

One of the defining limitations of perennial ryegrass in temperate grassland pasture systems in Australia is its poor persistence in relation to three other commonly sown pasture species. A review by Waller and Sale (2001) provided a thorough description of these constraints and grouped them into four major contributing factors which included: 1) climatic; 2) edaphic (soil physical properties, soil nitrogen and phosphorus status); 3) biotic; and 4) the influence of grazing management. Their review highlighted an important concept often neglected in industry that persistence should not be classified as a single standalone trait, but should be considered as a complex range of characteristics and multiple stress events that all ultimately contribute to the pastures longevity for both agronomic and economic performance. A recent paper by Culvenor and Simpson (2014) further discussed this concept in a wider context of other perennial grass systems, and the importance of understanding multiple stresses and interaction that can occur between these. Highlighting that the influence on plant survival often occurs concurrently with adverse consequences for persistence and the complexity of management.

Evolution of breeding

Perennial ryegrass (PRG) occurs in nature as a diploid (2n = 2x = 14) obligate outbreeder and suffers serious inbreeding depression (Cunningham *et al.* 1994). Being a diploid it contains 2 sets of 7 chromosomes in each cell of every plant. Early in the century, treatment with the chemical colchicine allowed for increasing the ploidy level and creation of tetraploids (2n = 4x = 28), these have recently been further developed for acceptable agronomics in plant breeding programmes and a number of tetraploid cultivars have been released commercially.

A number of reviews have described the genetic improvement and the future breeding objectives for perennial ryegrass improvement in Australia (Cunningham *et al.* 1994; Reed 1996; Reed *et al.* 2001; Reed *et al.* 2014). Cunningham *et al.* (1994) reviewed the history of PRG improvement in Australia, the performance of introduced cultivars, breeding objectives and the effect of endophyte on agronomic performance of PRG and grazing animals. The authors outlined a detailed timeline of the history of perennial ryegrass improvement in Australia in each state, from the first introduction of perennial pasture grasses in 1860, to the Victorian Department of Agriculture commencing selection and evaluation in 1928 of introduced and naturalised populations of pasture species, to the recent improvement programmes within Victoria by both public and private sectors. The cultivar 'Victorian' PRG was based on local ecotypes from the western and central areas of Victoria and was first certified for commercial release in 1936 (Drake 1942). Reed *et al.* (2001) highlighted that 'Victorian' ecotype is the most commonly sown cultivar across the 6 million ha in Australia.

In Victoria, the first of three further breeding efforts in the public sector to improvement the ecotype Victorian reviewed by Cunningham *et al.* (1994) commenced in 1980 from collections of plants at sites in irrigation and medium-high rainfall production areas of Victoria and the Shoalhaven area of southern NSW. Wide genetic variation was observed for the traits measured and subsequently subjected to mass selection for improved productivity. Even though 25% improvement in yield scores in comparison to the mean was reported, none were superior to the New Zealand cultivar 'Grasslands Nui' (Kelly 1985). Following the severe drought of 1982–83 in southern Australia, a second programme commenced to collect drought surviving genotypes and inter-pollinate for further evaluation. A third programme commenced in 1989 and aimed at improving seasonal yield, disease resistance, persistence and adaptability for Australian conditions. This involved evaluation at three breeding sites across south-western Victoria on half-sib progenies, with further progeny testing at other sites and is further described by Cunningham *et al.* (1994).

Direct selections from deliberate introductions of PRG seed by early settlers sown in the Kangaroo Valley districts were made by the NSW Department of Agriculture in 1988 (Cunningham *et al.* 1994). These ecotypes were known as 'Kangaroo Valley' and two distinct types, an 'early' and a 'late' were certified, but recently have merged and only recognised as one. A collaborative effort commenced in 1992 to improve 'Kangaroo Valley' with the objectives to produce cultivars with more winter and late season growth, productivity, and persistence; resistance to fungal diseases such as crown rust (*Puccinia coronata*) and stem rust (*P.graminus*); and ensure high seed production and uniformity.

The Tasmanian Department of Primary Industries and Fisheries had an active PRG improvement programme since 1956 (Cunningham *et al.* 1994). In the 1966 Australasian Plant Breeding newsletter, Martin (1966) outlined a recurrent selection programme using Tasmania agro-ecotypes as base genetic material. Phenotypic selection for productivity, maturity, rust resistance were polycrossed and progenies then selected in grazed swards and multiple locations from marginal PRG zones to high-rainfall irrigation. Improvements in rust resistance were made, but productivity and persistence were no better than 'Grasslands Nui', which was subsequently recommended as the preferred cultivar and terminated in 1976 (Cunningham *et al.* 1994). Further breeding work occurred based on the early derived material, and base population broadened to include desirable traits from more recent cultivars with two varieties subsequently released.

A collection of PRG from the Mediterranean region was characterised at the Waite Agriculture Institute in Adelaide in the late 1950s (Cunningham *et al.* 1994). A cultivar was released originating from three locations near Medea in Algeria and released as 'Medea'. It expressed high summer dormancy for persistence and generally more autumn-winter productive than the common ecotype 'Victorian'.

As highlighted in the review papers, early varieties of ryegrass were generally based on northern European material that was introduced to Australia and New Zealand, which were then either selected from or naturalized in different climatic zones. Ryegrass from northern Europe typically grows from spring through to autumn and then very little during the cold months of winter when it would be normally subjected to freezing temperatures and snowpack. Ryegrasses from this region are not usually well adapted to our mild winters and summer droughts, however, many years of natural selection in Australia has resulted in diversification of this material and some improvement in drought tolerance. Some newer varieties have been bred with improved winter growth and enhanced persistence, however they remain of northern European descent.

A limitation of many northern European or derived naturalised Australian ecotypes (i.e. 'Victorian') has been the lack of winter growth. A valuable source of germplasm from North West Spain (NWS) was recognised during the late 1970s which exhibited the unusual combination of winter activity, late flowering, low vernalisation response and excellent crown and stem rust resistance (Stewart 2006). Although direct introductions of germplasm can seldom be used as cultivars in their own right the introgression of germplasm into cultivars can be valuable as seen in this instance. These regions in NWS experience warmer, dry summers and milder winters and as a result ryegrass grows from autumn through to spring and is better adapted to summer droughts. The NWS cultivars seem to be day length insensitive; that is, they do not recognise the shortening of day length as the winter months approach and will continue to grow whenever moisture is available. Elite varieties incorporating this material have shown themselves to be well suited to Australian conditions with superior winter and total production and persistence if well managed.

Harmer *et al.* (2016) analysed 46 Australian and New Zealand experiments and identified two distinct periods of genetic gain in perennial ryegrass, pre-1990 of between 0.25–0.73% and post-1990 with consistent gains of 0.76%. It was discussed that the introduction of NWS germplasm was a major driving factor behind this change, as well as superior endophyte technology and tetraploidy. The authors showed that total forage yield of cultivars was strongly correlated with their winter, late spring, summer and autumn growth but did not correlate with early spring growth. This reflected the priority breeders have placed on improving growth in the seasons of low forage availability and consequently high forage value (Chapman *et al.* 2016) to reduce farms supplementary feed requirements and/or allow increased stocking rates.

Importance of endophyte

Many cool season grasses form a mutualistic symbiotic relationship with an ascomycete fungus, in particular with the genus Epichloë and derived species. Both the fungus and the host grass benefit from this relationship and this forage grass-endophyte association is the most intensively studied (Easton 2007). The hosts of these fungi include perennial ryegrass (associated with *Neotyphodium lolii*) and tall fescue (associated with *Neotyphodium coenophalium*). Endophyte resides within the intracellular spaces of the leaf sheath and pseudo-stem of the plant and does not invade the cell wall (Schmid and Christensen 1999). The host plant provides the endophyte with protection, nutrition and a unique means of dispersal (Prestidge and Ball 1993). Endophytes are transmitted through seed and complete their entire life cycle within the plant; therefore reproduction is asexual and maternally inherited in the seed embryo and is not observed in pollen (Easton and Fletcher 2007).

Perennial ryegrass, like many other grass species, has coevolved with these symbiotic fungal endophytes. The naturally occurring endophyte present in many current populations of perennial ryegrass in Australia is often referred to as Wild Type (WT) endophyte; other common names of the naturalised WT endophyte include Standard Endophyte (SE) or High Endophyte (HE). The WT endophyte is very widely distributed in both sown and naturalised perennial ryegrass pastures. For example, Reed *et al.* (2000) undertook a survey of 56 populations of 'Victorian' and 45 populations of 'Kangaroo Valley' perennial ryegrass sampled from old pastures within the recognised zone of naturalisation for both ecotypes. These workers subsequently found all populations were infected with WT endophyte, with the mean frequency within populations of 'Victorian' and 'Kangaroo Valley' ecotypes being 88% and 93% respectively.

Natural selection favours endophyte-infected plants and the association with a host plant is beneficial as it imparts unique bioactive properties which increase the plants' tolerance to a range of biotic (e.g. insect predation) and abiotic (e.g. soil water deficit) stresses (Malinowski and Belesky 2000; Popay and Bonos 2005; Easton 2007). Agronomic performance of endophyte-infected grass cultivars has been studied in many different countries, with reports of agronomy experiments and cultivar evaluations predominantly cited in New Zealand (NZ), northern United States of America (USA) and Australia. Biotic tolerance is largely driven by a degree of protection, either directly against, or as a feeding deterrent to a range of invertebrate insects that are known to influence the survival and production of perennial ryegrass in Australia. These major pests observed include Argentine stem weevil (*Listronotus bonariensis*) (Popay and Bonos 2005), African black beetle (*Heteronychus arator*) (Reed 2002), root aphid (*Aploneura lentisci*) (Hume *et al.* 2007) and pasture mealy bug (*Balanococcus poae*) (Pennell *et al.* 2005).

Hume and Sewell (2014) recently reviewed the literature for Australia and presented new data that examined the agronomic effects of endophyte both in the establishment phase, and in the mature pasture sward. All regions studied reported significant ($P < 0.05$) positive responses to endophyte-infection, while a further 10 out of the 18 experiments reported either higher yields and greater plant or tiller densities than endophyte-free (nil endophyte) plants of the same cultivar. The magnitude of the advantages ranged from +7% to +212%. For example, yield advantages for cultivars infected with WT endophyte in south-east QLD were +6%, +31% and +44% for the first, second and third year respectively (Lowe *et al.* 2008). In experiments which reported full seasonal data, the endophyte effects were greatest in the summer and autumn period (Launders et al. 1996; Wheatley 2005; Lowe et al. 2008). No experiments reported statistically significant ($P < 0.05$) negative yield responses to endophyte-infection.

Different endophyte strains produce different concentrations of the alkaloid profiles in conjunction with their host plant. The naturally occurring WT endophyte of perennial ryegrass evolved to produce two major toxic alkaloids – lolitrem B and ergovaline, both of which are implicated in a range of animal disorders commonly referred to as perennial ryegrass toxicosis (PRGT). This strain also evolved to produce the invertebrate toxin, peramine, but no adverse effects on animal health have been reported with this particular chemical group. The effects of endophyte in pastoral livestock systems are less well studied in Australia as opposed to the USA (predominantly focussed on tall fescue) and NZ (predominantly focussed on perennial ryegrass). Despite the small number of studies in Australia, significant effects have been identified (Hume and Sewell 2014). Considerable progress has been made in the identification and commercial release of new strains of 'novel' endophytes (i.e. AR1® and AR37®) that continue to produce beneficial alkaloids to confer agronomic advantage, but do not express those associated with animal toxicosis (Bluett *et al.* 2005).

Tall Fescue – Mediterranean

Mediterranean tall fescue is suited to areas with dry summers and 450–550 mm rainfall and are therefore better adapted to summer drought than the temperate varieties (Easton *et al.* 1994). The level of summer dormancy varies between cultivars, and can range between totally dormant to some summer production. These varieties are more suited to western areas of NSW tablelands and slopes, southern NSW, south-east SA, central and east coast of TAS and lower rainfall regions of south-west WA and Victoria.

Mediterranean tall fescue (*Festuca arundinacea L.*) is a deep-rooted, out-crossing species well adapted to low rainfall/high drought stress environments. It is not only the species persistence that is valued in these circumstances, but its high autumn and winter yield Reed (1996). Some existing cultivars exhibit a high degree of environmental stability and perform exceptionally well within low rainfall areas of Australia and the Mediterranean. Stability of production minimises risk for producers but seedling growth in this species is slow and can lead to establishment failure.

Mediterranean tall fescue is a morphotype of Tall Fescue (the others being Continental and Rhizomatous) whose centre of diversity in northern Africa and the Middle East (Reed *et al.* 2004). Several plant collection expeditions to the Middle East have been completed and many accessions of this species are available to researchers and plant breeders (Cunningham *et al.* 1997).

Diversity within available accessions of Mediterranean tall fescue has been investigated by state researchers and with few exceptions (Reed 1996; Jahufer and Reed 2001) data on the performance of accessions is generally not published, and released cultivars are few. One exception is a variety cv. Epic of North African origins. Testing for this cultivar release was conducted at Hynam, South Australia, with most dramatic results (Hill 1982). A probable reason provided for its commercial failure was the experiments were tested at the species level, rather than appreciating the environmental niche for different subspecies. Another exception is cv. Fraydo, which was bred from cv. Melik, an accession of Israeli origin (Reed *et al.* 2004b). More recently cv. Resolute was developed through phenotypic selection from within cv. Melik for improved seedling vigour, finer leaves, tiller density, yield, improved seed production and increased homogeneity (Wrightson Seeds 1999).

The most persistent and likely most commercially successful cultivar in Australia is 'Flecha'. This cultivar was bred in South America (Gentos) from material of Tunisian origin. Work across trial sites in SE Southern Australia and the Mediterranean region (Pecetti *et al.* 2011) demonstrates 'Flecha' to be very persistent in locations with severe drought stress and in all but the highest rainfall environment, it was the highest yielding cultivar trialled.

A recently developed cultivar 'Temora' is soon to be released from Grasslands Innovation Ltd (GIL) which is a cross between cv. Flecha and cv. Resolute II. Selection was focussed on capturing the key traits and attributes of both cultivars that gave them key advantages in the Australian market including increased tiller density and higher summer dormancy over Resolute, improved dry matter yields for autumn and winter and improved disease tolerance.

Winter active tall fescues are best suited to regions with particularly short-growing seasons with low to medium winter/spring dominant rainfall pattern. It is generally accepted that the species may not be as productive as phalaris (total yield), but they do provide very fast, high quality and high autumn/winter DM production without any associated toxicity issues. It can be compatible with a number of lucerne mixes, however is complicated by rotation length and palatability of these. It is recommended to avoid spring sowing (unless irrigation is available) due to slow establishment and summer dormancy effects. The late season grazing management is critical to reduce the rapid onset of stem elongation. Heavy stocking densities or mechanical slashing may be required and necessary during this period.

Grazing management

It is generally accepted that rotationally grazing during vegetative growth periods, commencing grazing at the 2.5 leaf to 3 leaf stage or canopy closure with an aim for a post grazing residual of 50 mm is suitable for tall fescue. Unpublished data from PGG Wrightson Seed's grazing studies have shown that Mediterranean tall fescues respond better to rotational grazing south of the dividing range (Tasmania in particular, but certainly SW Victoria) – without rotational grazing after 3–5 years often results in thin, narrow rows with only one or two tillers and poor yield potential. Mediterranean tall fescue will tolerate set-stocking with more intensive sunlight. For example, trials in early 2000s at Gundagai (Southern NSW) showed that Mediterranean fescues were more tolerant of set stocking, particularly with cattle, because of greater sunlight intensity (likely leading to greater photosynthesis) and warmer temperatures.

Once established, Mediterranean tall fescue requires careful grazing management (i.e. strategic high stocking density) to prevent it becoming rank and losing quality in early spring when many farm systems may be reluctant to push animals too hard at this time of year. The EverGraze program concluded that, early spring pasture swards of winter active tall fescue should be set stocked during its reproductive phase, to prevent the production of reproductive stems and maintain a more nutritional (vegetative) sward. During this period a target dry matter coverage of 1200 kg DM/ha should be maintained. The trial work also indicated that continuous grazing during spring will stimulate tillering, improving the density and persistence of the pasture sward, however, the period for continuous grazing should not exceed 12 weeks. After this time, the plants carbohydrate reserve in the root system is severely depleted reducing long term persistence (Raeside and Sanford 2010).

The environmental drivers for the increased agronomic performance of endophyte-infected tall fescue are not well studied in Australia as opposed to the USA and New Zealand. There is a need for further field research under the contrasting Australian conditions to characterize what these abiotic and biotic drivers and influences are and to quantify their influences. It is essential that the endophyte status of all cutlivars in experimental field studies should be verified in trials where agronomic comparisons between cultivars are being made, and in any plant or animal experiment using endophyte-infected tall fescue (Hume and Sewell 2014). This can be achieved using an easy sampling procedure and a relatively inexpensive laboratory analysis. This is needed to ensure the lines entered in trials have a high frequency of endophyte-infection prior to sowing, that newly sown plots have an effective high frequency of endophyte, and can be used to monitor endophyte infection throughout the life of the trial.

As some endophyte-driven differences become apparent within the first year of production, while others do not develop until the third or fourth years, experiments need to be conducted preferably for 5 or more years if agronomic performance in relation to endophyte is to be properly evaluated. Regular monitoring of endophyte frequencies can help explain variability and different results.

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Australia's ability to fill the feed gap

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Abstract: *The aim of this paper is to present information on the decision making process that illustrates how we got to where we are in our farming system. It discusses the influences and progression to show how the current farming method came to be. Specifically, the different genetics, pastures and crops used to make up the current farming system are discussed. I have been fortunate to travel to other countries as part of a Nuffield scholarship and seeing the challenges farmers face in those countries and strategies they use to overcome these challenges have greatly assisted in implementing new technology in our farming system. Although Australian farming systems may be constrained by climatic factors, we do have many advantages compared to other countries and if we are smart in manipulating these advantages, we can take our systems to the next level.*

Introduction

Ardnai Pastoral is a mixed farming operation at Greenethorpe NSW. It is run over 400 ha and is made up of sheep, crops and contract hay. Half the farm is dedicated to a mixed cropping enterprise based on wheat, canola and legume crops, being either lupins or clover. The other half of the farm is dedicated to pasture production which runs the self-replacing meat composite sheep and the hay production. Hay contracting is also an outside aim of this business.

History

My grandparents moved from Cowra/Morongla to "Glenholm", Greenethorpe in 1926 which is still part of the operation today. My father Neville continued to farm here after my grandfather, Oliver's, death in 1960. As is the way of much of Australian agriculture, my grandfather had accumulated several of the neighbouring properties in his time and my father Neville did too, aquiring the properties "Lonepine" and "Ardnai". My brother David and I returned to farming after university/college and experience abroad and in Australia. After taking over most of the manual tasks we began to specialise in different areas in the business with David taking on most of the cropping operation and myself most of the livestock enterprise. We started to take on more management as we headed into 10 years of drought in the 2000's, which was a very challenging learning curve.

At this time I was doing a university degree externally through the University of New England and became very interested in genetics which coincided with buying some composite ewes on Auctions Plus from a retired CSIRO researcher who had worked with the Booroola gene (a gene relating to increased reproductive potential) and had about 30% incidence in his flock.

As many of our crops were failing or frosted in this period David and I realised that starting from our small base of 800 ha (now two 400 ha properties with David owning one and I the other) that leasing in those conditions were risky and unlikely to go ahead with other more established farmers taking on most leases in the area. So we started Brien Ag Enterprises which was mostly a hay contracting business.

Progression – expanding the business, reducing the risk

Part of the experience we gained in this period was managing to be diverse and endeavouring to maximise profits in trying conditions such as failed crops due to drought and frost. This built up the hay reserves on our own farm business, but also that of many of the locals with our baling business. We did Top Fodder training and other courses and joined the Australia Fodder Industry Association; all in attempt to build our knowledge so we could build the business for ourselves and our clients.

We changed the direction of our farm after we spoke to Ashley White of the NSW DPI and did a 'GrazClock' during this drought to manage our stock numbers and feed distribution and that allowed us to draw a new program from our business, target our reproduction and maximise feed utilisation. With the hay business taking more of our time, spring lambing was becoming increasingly difficult so we moved from two lambings a year to one in winter where we could grow feed to meet the feed gaps.

The Nuffield experience

In 2009 I applied for, and was granted, a Nuffield scholarship supported by Meat & Livestock Australia. My initial travel part of the global focus program took me to the Philippines, China, USA, Canada, France and Ireland. That was the first six weeks, and as my research topic was making more from the same ewe base, and we didn't see a single sheep in that time, I was off to a great start! But seriously, I went on to visit Wales, New Zealand, South Africa and South America. It was no holiday meeting researchers, producers and groups several times a day with lots of transport hours in between, but it was an invaluable experience. Farmers face many of the same issues the world over, regardless of language and environmental challenges.

I gained a great respect for our ability to grow fodder to meet the feed gap and also the quality of that fodder we produce. We have grazing crops, numerous pasture species which have been adapted to fit best in different areas for the improved timing of feed growth, quality of feed and success under different climatic stresses and soil types. Then we farmers take those species and put them into the best management system we have to meet the outcomes we hope for, and to give the best production and flexibility in our system.

Our climate might be tough but we are well situated

Countries at similar latitudes to ours, such as South Africa, have systems where instead of alpacas they use donkeys to guard the flock due to large predators being an issue (Figure 1). The feed quality can be good in some zones where some cropping is incorporated in the farming system, but there is much competition for feed from other wild grazing animals, such as the antelope family.

South America has regions, such as Patagonia, where there are many sheep, but snow fall events mean the majority of the flock and indeed sometimes the whole flock, can be engulfed in snow and lost. The more productive regions north of Patagonia has forced out of cattle and sheep in favour of crop production. Meanwhile, the pastoral industry has been pushed south where losses of sheep and cattle to large predators, such as the puma, are more likely.

Areas in the northern hemisphere such as the UK and France could indeed increase their production. They are not limited by predation of feed supply or their grazing livestock but largely by government policy and competing land use including housing. Other areas such as USA, could be a real competitor in terms of sheep production. A lot of research on improving fertility and survival of sheep has been undertaken including intensive feeding systems, but luckily sheep have not been a large part of their culture, but they certainly have the capacity to compete. These countries have stable governments and good pasture growth systems however the USA pasture areas are often for hay (e.g. timothy grass) which is often sold for horses or maintaining cattle through winter (Brien, 2009).

Figure 1. Donkeys used for protection of sheep in South Africa.

Taking it to the next level

We have been working on our farm to improve our system. We have been working with Belinda Hackney with pasture trials for nine years to find the percentage of different pasture types we want to have in our system to ensure a good mix for grazing and fodder opportunities. We have also been looking at nitrogen fixation levels and hard seededness to minimise resowing and reduce costs. We have tried many new species such as serradella, (yellow and pink), bladder clover, biserrula, gland clover, arrowleaf and balansa clovers.

We also grow grazing crops in the winter, such as Wedgetail wheat and 970 canola, so that we can meet our maximium feed requirements (when ewes are lactating and lambs are starting to graze). An example of the success of canola is the grazing of a 20 ha paddock of canola with 1000 heavily pregnant ewes for 3 weeks, allowed a short recovery and then lambed 600 ewes for another month. This must also be high quality feed to ensure maximum growth rates, and mineral supplementation is used to reduce risk of animal health issues. The types of crops we grow are primarily for grazing but also provide an option for hay, especially in lower country where frost is a high risk. Grain prices and the finish to the season can also determine the end use of these crops. Weed burdens are sometimes managed by ensiling crops, those with a heavy or resistant weed burden, as an alternative to reliance solely on chemical options.

We have taken the option to always ensure fodder conservation is part of our program. It allows flexibility in our system particularly in season where climatic conditions are poor. The fodder conservation option also means pressure can be removed from pasture paddocks in winter when plants have low growth rates and are rapidly susceptible to overgrazing or selective grazing under such conditions. Having conserved fodder on hand allows us to maintain a more constant and higher level of nutrition for a breeding herd. Much research and effort has gone into monitoring animal performance and increasing weaning rates over the drought period and this will continue. Genetics have been a key focus with specialised genes such as the Booroola gene added into the flock as opposed to chemical or hormonal options. We aim to maintain our adult ewe weaning percentage at 150%. With land prices continuing to increase, we must produce as much as possible from each unit of land and dual purpose cropping allows us more resilience in our system to do that. We do try to monitor our soil health quite closely to optimise pasture and crop production.

Different pastures in the system allow for different purposes and longevity of pastures. Poorer granite/sandy soils tend to have longer pasture phases and are more suited to grazing. A range of pasture types are used here as opposed to a paddock of high fertility where hay production would be an option. These longer term pastures tend to be a mix of serradella and sometimes biserrula, but in our system serradella has been a standout due to its high feed quality and the presence of tannins along with less risk of photosensitivity. Additionally, there are no infertility issues associated with serradella (Craig 2005). An added bonus, due to the high hard seed levels, is its ability to regenerate well after short cropping phases which removes the need for resowing. These pastures do well in these soils and do very well in drier years due to their deep root systems. I feel in our system, hardseeded legumes are a great fit but in really high fertility paddocks, a dedicated pasture phase works best, particularly in a wet year. In these higher fertility paddocks, species such as balansa clover, lucerne and bladder clover grown as a mix has been found to perform well and also has the added option of fodder production. The mix of these species and their different growth patterns allows for feed production throughout the year to fill the feed requirement (Figure 2).

Figure 2. An adult ewe with quads in a clover-grass pasture.

Lucerne is great for hay production but also for maximising growth on summer rain and finishing lambs when most other pasture is dormant or at low production levels (Figure 3). Crop stubbles fill a gap in the summer and allow us to join stock on a rising plane of nutrition due to stock capturing lost grain and weed seeds. Lucerne pastures are grazed in the autumn as stubbles are returned to early sown grazing wheat, canola or pastures. Once these crops are locked up for grain production then the differing pastures are great for being able to finish lambs, hopefully over quite a long period of pasture production due to a few varying mixes and through use of conserved fodder. Chicory and clover is also sometimes used in short pasture phases to allow for good summer grazing. Another advantage of using several pastures fit for purpose is that there is also many different root structures involved, which also helps is soil structure.

Figure 3. A 12 month old ewe with triplets on a lucerne-clover pasture.

Conclusion

We are in a great place to be able to farm as we do especially when compared to many other countries of similar latitudes, such as South Africa and South America or similar farming systems such as the UK. We can improve our stock fertility and management systems along with managing our crop and pasture production to be able to meet the feed gaps and even conserve fodder for our own reserves and for sale. Our family has seen much change over the last 90 years of farming here and continuing to improve our knowledge skills and farming practices is something we will endeavour to continue, meeting the many challenges, environmental and otherwise. Part of this has been done through research in sheep fertility and genetics, many through ongoing pasture trials, modifications to our cropping program and crop types and risk management. Hopefully with some help and good advice we will find the most productive system we can which will continue into the future.

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Filling the feed gap: A case study and farmers perspective

S Tait

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Introduction

Tait Pastoral Company is a family farming business based at Mandurama on the NSW central tablelands, farming 1670 hectares across three farms. The business runs three main enterprises; beef breeding and finishing, beef trading and finishing, at Mandurama, and dryland cropping at Canowindra. This paper focuses on the 1400 ha property at Mandurama, which is approximately 700 metres above sea level, and receives an annual average rainfall of 800 mm, with August and January being the wettest months, and March and April being the driest. Soil types range from red basalt to chocolate silty loams, and are naturally acidic. Autumn is the most unreliable season and can become the most severe seasonal feed gap, whilst a feed gap is also experienced through the winter months as perennial pasture growth rates slow significantly. Whilst dry feed is usually available over summer, quality finishing feed is commonly in short supply.

The past

In the year 2000, the property was running approximately 1,200 Angus cows across 1600 ha (200 ha has since been sold), and aiming to turn off the progeny to feedlots at +450 kg liveweight (lwt).

Moving forward to November 2006, the key problem which emerged during the drought was that the business was inflexible and had a limited ability to adapt to sudden changes in seasonal conditions and feed availability. Running a sole enterprise of beef breeding meant that at certain times of the year, liquidity was low with store stock being difficult to sell, especially in a drought market. It also meant that in good seasons, the business was running fat cows on good finishing pastures and was unable to fully capitalise on the season.

For the business, three main options emerged to endure the drought; to continue purchasing and feeding out thousands of dollars' worth of fodder; to seek agistment elsewhere; or, to reduce the cow herd to a more manageable figure until seasonal conditions improved. Rightly or wrongly, the latter option was chosen, and the cow herd was reduced from 1,200 head to 600 head in a matter of weeks. This decision forced the business to rethink its enterprise mix and management strategies. One important consideration was the suitability of the property for finishing beef cattle, as against being simply a breeding property. The 'solution' to the problem came in two parts.

1. To better match stocking rate to the pasture growth curve.
2. To find cost effective ways to bend the pasture growth curve. In other words, to fill the seasonal feed gap.

The present

The sale of breeding stock in 2006 freed up a significant amount of capital in the business, reducing debt and facilitating the purchase of trade stock. The business now runs a 600 cow herd, alongside a beef trading and finishing enterprise, turning off between 400 and 800 steers and heifers annually. Ultimately, all animals will reach slaughter weights of +520 kgs lwt, and will enter into a certified grassfed program, attracting a price premium. Currently, the lead of the fat animals are sent to grassfed programs, whilst the remaining cattle are sold to feedlots in the 450–520 kg lwt range.

Matching stocking rate to pasture growth

The beef trading enterprise has dramatically changed the business for the better and created a high level of flexibility and liquidity, as well as increased profitability, better labour efficiency, and better land use. A basic set of guidelines have been established to help maintain the success of the trading enterprise. Keep in mind that the overall goal of the enterprise is NOT to speculate on the cattle market, but to value-add cattle and to put on as many kilograms of beef per hectare as possible at a low cost of production. The three guidelines are:

- *Genetics;* purchase quality, well-bred, *Bos Taurus* cattle which are from a similar climate and fit for purpose, and which are sought after by buyers. Good animal temperament is also critical here to aid in weight gains. Cattle are bought in between 240–320 kgs lwt.
- *Animal Health;* an animal that is not in good health will not be performing at its best.
- *Pastures;* productive, quality pastures are vital for a finishing enterprise to achieve maximum kilograms of beef per hectare.

The trading enterprise has become the seasonal management tool for the business, as stock numbers can be significantly adjusted in a matter of days without risking capital breeding stock or profitability. Trade cattle won't be purchased in the first place until there is an acceptable quantity of feed available and a promising seasonal forecast. If trade cattle are already on hand, and the season deteriorates, trade cattle can be sold easily into any number of markets. Even considering a fall in price, a financial loss is unlikely due to the fact that cattle have gained weight since purchase.

A further aim of the trading enterprise is to maximise profit margins by finishing cattle out of season, when slaughter prices are at their peak. This is not attainable without low cost, productive finishing pastures throughout key periods of the year.

Filling the feed gap

Pasture and Crop Species: Ryegrass

Short term, high production ryegrass pastures has been a game changer for the business. In 2016, 66 ha of Winterstar II annual ryegrass was grazed through late winter and spring by 500 yearling steers, after a split application of 290 kg/ha urea in September. This application of nitrogen increased dry matter levels substantially, and estimates are that the cost of the urea was recouped within 4 days of grazing, based on current beef prices and achievable daily weight gains of 2 kg/hd. Daily pasture growth rates in winter can be around 15–20 kg DM/ha/day, and in spring can be upwards of 80 kg DM/ha/day. The high stocking capacity of the ryegrass allowed vast areas of perennial pastures to recover and set seed during spring, and build a significant feed wedge heading into autumn. This in turn also allowed land to be set aside for summer forage to be planted and established which then assisted in maintaining stock over summer.

Perennials

Phalaris, cocksfoot and tall fescue are all utilised to provide quality feed at different times of the year. Mediterranean tall fescue varieties provide good levels of winter feed, with growth rates around 10–15 kg DM/ha/day. Phalaris provides feed throughout the shoulder seasons with spring growth rates at approximately 50 kg DM/ha/day, however winter growth rates drop to approximately 5 kg DM/ha/day. Cocksfoot features similar growth to Phalaris, yet it is more summer active. Having a large stand of dry perennial pasture available heading into autumn allowed the business to commence buying in trade stock in early autumn prior to the breaking rains. The standard mix sown included Holdfast Phalaris @ 2 kg/ha, Resolute Fescue @ 2 kg/ha, Banquet Perennial ryegrass @ 1 kg/ha, Goulburn subterranean clover @ 3 kg/ha and Tahora White Clover @ 0.5 kg/ha. More recently, the mix has altered to include Greenly or Lazuly Cocksfoot @ 2.5 kg/ha, Flecha Fescue @ 2.5 kg/ha, Campeda subterranean clover @ 3 kg/ha, Zulu Arrowleaf Clover @ 1 kg/ha and Persian clover @ 1 kg/ha. Phalaris is no longer included with the release of soft leaved, highly palatable cocksfoot varieties to improve daily liveweight gains.

Pasture management

Emphasis is placed on ensuring that pastures are as weed free as possible, with a major winter spraying program occurring annually across two-thirds of the property. This spray pass also provides an opportunity to apply gibberellic acid on certain paddocks to build a feed wedge. Heifer calving commences on July 1st for six weeks, so designated calving paddocks are locked up in the last week of May, with 100 kg/ha urea and 10 gm/ha Gibberellic acid applied. The application results in an increase in available dry matter for calving heifers of over 10%, and has led to a significant increase in pregnancy rates for cows joining for their second calf.

Soil tests have previously been done at irregular intervals and on paddocks to be improved, however in 2016 an extensive soil testing program started across the scope of the property to get a complete understanding of our soils health. The importance of correct soil health and chemistry cannot be underestimated, and as a result of the recent soil tests, a custom fertiliser and lime program has been developed to rectify some serious deficiencies across key nutrients. Target levels of key nutrients have been identified and capital applications of fertiliser have been carried out.

A greater emphasis has also been placed on grazing management, whilst still employing a flexible, rotational grazing system, and this is continuously being refined. The continued focus will be on maintaining pasture covers above 1200 kg DM/ha, and managing different species to ensure that key species are rested at critical periods for that species. For example running a high stocking rate on ryegrass in spring allows phalaris pastures to be rested and set seed, whilst also building a dry feed wedge for autumn.

Timing of operations is also critical for ensuring that pastures and crops are utilised to their potential. A great deal of time is continuously spent on planning and organising tasks, in particular, the planting of crops and finishing pastures is crucial.

Zero supplementary feed

A point is made to avoid any supplementary feeding to any stock on the property, and currently no fodder is conserved on farm, and the only hay used is for yard weaning purposes, which is quality, feed-tested oaten hay sourced from local suppliers. Any form of conserved fodder can be between two and four times the cost per kilogram of dry matter as standing feed, plus labour and machinery costs need to be considered when feeding out. Money that may otherwise be spent on conserving fodder is instead invested in fertiliser and pasture improvement.

Challenges

Some challenges to filling the feed gap include:

- *Establishing crops and pastures on time in adverse conditions;* good planning and preparation, and professional advice from external consultants is important. Dry sowing is an option.
- *Issues with pugging in grazing crops in wet winters;* aim to operate a minimum till system, select paddocks carefully for drainage, and have a backup plan e.g. perennial pasture paddock.
- *Persistence of ryegrass;* the search for the perfect ryegrass continues. A 2–3 year Italian is preferred; however dry, hot summers affect persistence.

The future

Filling the feed gap is a key focus to increase profitability and productivity of the business. Plans are in place to establish a four-year intensive finishing rotation involving dual purpose canola and wheat, two year tetraploid ryegrass, as well as summer forage options including cover crops and hybrid sorghum. This rotation is designed to work in conjunction with perennial pastures, to provide large volumes of quality finishing feed throughout the year, as shown in Table 1 below.

Table 1. Estimated seasonal growth rates of pastures and crops (from Saul and Sargent 2013).

Crop/Pasture	Approximate Growth Seasonal Growth Rates (kg dry matter/day ha)			
	Autumn	Winter	Spring	Summer
Grazing cereals + canola	40–60	25	N/A	N/A
Short term Ryegrass	0–50	15–20	70–100	0–40
Forage Sorghum	20–60	N/A	N/A	70–100
Phalaris	40	5	70	0–25
Tall Fescue	30	10	75	0
Cocksfoot	30	10	60	0–30
Chicory	20	10	70	75

Chicory is also being trialled as a specialist pasture to provide quality summer feed to finish stock, and more intensive grazing systems are also an option to increase pasture utilisation.

The increasing intensity of the system creates greater pressure on management to fine tune stocking rates and areas designated to specialist pastures, and fine tuning the system will be aided by benchmarking against ourselves. Key indicators and targets are currently being established in relation to soils, kilograms of dry matter produced per hectare, kilograms of beef produced per hectare, and ultimately, profit per hectare.

Conclusion

A two part approach is critical to the success of the business; matching stocking rate to pasture growth, and using pastures and crops to fill the seasonal feed gap. The system is constantly being refined and involves a significant amount of trial and error. Specialist pastures such as Italian ryegrass, chicory, and tall fescue together with dual purpose grazing crops are used in combination to create a resilient, low cost and profitable beef finishing system.

Legumes and nitrogen – it's time to stop assuming

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Abstract: *The role of legumes in providing nitrogen to non-legume pasture components or for following crops in mixed farming systems has long been recognised. As an industry we generally assume this happens. The process of nitrogen fixation though, is dependent on a symbiosis (mutually beneficial partnership) between the legume plant and its associated rhizobia resulting in the formation of nodules on the root system. A recent survey across the Central Tablelands, Central West, Monaro and Riverina regions of NSW has found nodulation is inadequate in ninety percent or more of paddocks surveyed (n=225). Soil chemical issues, specifically soil pH and availability of key macro and micronutrients along with other management issues, specifically herbicide use are likely to be impacting negatively on legume nodulation and thus limiting pasture productivity. It is proposed that renewed focus on, and correction of, these fundamental issues affecting legume growth, nodulation and nitrogen fixation should result in improved overall pasture production.*

Keywords: legume, nodulation, soil pH, phosphorus, sulphur, trace elements, herbicide

Introduction

Assumptions are a necessary in life. Some are pretty sure bets such as '*The sun will come up in the morning*' or '*The world will keep spinning*'. What is it that makes us believe these assumptions are true? It's confidence and that confidence comes from experience and exposure. We have all experienced the sun coming up and the world continuing to spin as have our forebears and therefore we can be fairly confident that these assumptions will hold true. Specific to agriculture, we can generally assume that if we have good seasonal conditions, reasonable soil fertility and favourable plant species that pasture growth will be pretty good. How do we know? Again our personal experience and the backing of scientific studies that have proven this is so.

So what does all this pontificating have to do with legumes and nitrogen fixation? Well, most of us grow or recommend the use of legumes in pastures to fix nitrogen (N), make that nitrogen available to non-legume components of the pasture thereby boosting overall pasture growth and the quality of that pasture for livestock consumption. The general assumption is that a well nodulated legume will provide 20–30 kg N/t of above-ground dry matter (herbage) that it produces. Nothing *generally* wrong with that assumption as it is backed by many scientific studies (e.g. Peoples and Baldock, 2001). However, implicit in this assumption being true is that the legume is indeed *well nodulated*. Effective nodulation can only be achieved if a number of prerequisites are in place and these include:

i) A sufficient population of the appropriate rhizobia in the soil for nodulation to be initiated,

ii) Adequate nutrient availability to support the nitrogen fixation process and plant growth, and

iii) Growth of the host legume plant (root and shoot) and survival of the associated rhizobia is not inhibited by soil chemical or physical constraints, pathogens or herbicide residues (Drew *et al.* 2016).

In reviewing the above criteria, how *confident* are you in assuming that the legumes you grow are effectively nodulating and reaching their nitrogen fixation capacity as reported in scientific literature? Without adequate nodulation and nitrogen fixation, pasture production, pasture quality and therefore livestock production will be compromised. In our advisory capacity, we frequently receive reports of poor legume and overall pasture performance. It is relatively easy to check legume nodulation status by digging up some plants and washing off the root system. In the remainder of this paper we will report on results of recent pasture paddock surveys to quantify legume nodulation status and factors (soil and management) that may be impacting nodulation and we will discuss what you might be able to do to improve legume performance.

The survey region and methodology

Two hundred and twenty five paddocks were sampled across four regions (Central West, Central Tablelands, Monaro and Riverina) as part of this survey. Surveys of the Central West (60 paddocks) and Riverina (81 paddocks) were completed in spring 2015 while those in the Central Tablelands (30 paddocks) and Monaro (54 paddocks) were completed in spring 2016. Participants in the survey were selected through a general call for expression of interest, through industry advisors and/or via consultation with producer groups. Participants then volunteered paddocks for sampling. Within the paddock, a representative area of 20 m × 20 m was selected. A minimum of 15 legume plants were carefully excavated from this area and the root systems washed in water to remove soil. The plants were then scored for nodulation using the 0–8 scale of Yates *et al.* (2016) where a score of 4 is considered adequate.

A composite soil sample (0–10 cm) was collected from the sampling area for chemical analysis. Botanical composition was also assessed using the rod-point method with 80 sampling points within the sampling area. The participating producers were also asked to provide information on paddock history including species sown, year of sowing, fertiliser application history and herbicides used where this information was known.

Survey results

The botanical composition of the pastures sampled varied considerably both between and within regions (Table 1) however average legume content in the Central West and Riverina was approximately double that of the other two regions. The most commonly encountered legume was subterranean clover (*Trifolium subterraneum*) while annual medics (*Medicago* spp.) were common in the western parts of the Central West. Lucerne (*M. sativa*) was also encountered, however it was only sampled if it had been sown in the year of the survey due to difficultly in excavating mature lucerne plants.

Of the paddocks sampled, at least 90% had a nodulation score of less than four, which is considered inadequate (Table 1). In the Central West, no nodulation (score of 0) was recorded in more than 20% of paddocks.

Average soil pH was similar across all regions with considerable variation within region. In terms of rhizobia function, more than 70% and 94% of paddocks had a soil pH below the level considered optimal for function of Group C and Groups AL/AM rhizobia respectively (Table 1) (Drew *et al.* 2014, Yates *et al.* 2016). These acidic soil conditions are likely to be contributing to poor nodulation of the subterranean clover and annual medic paddocks sampled. Based on surface soil tests, exchangeable aluminium levels were likely to limit lucerne growth (> 5% exchangeable aluminium) in 10% of paddocks in the Central West and 20% of paddocks in other regions (Table 1) (Lattimore 2008). Obviously with deep-rooted, aluminium sensitive plants such as lucerne, testing soil from deeper in the profile would be necessary before making a decision on use of such species.

Low levels of available phosphorus (P) were encountered more frequently in the Central

Tablelands than in other regions with more than 60% of paddocks having a Colwell phosphorus of less than 30 mg/kg (Table 1). More than 30% of paddocks had a Colwell phosphorus of 1.5 times greater than critical, while more than 15% of paddocks contained more than twice critical soil P. Sulphur (S) deficiency was prevalent across all regions (more than 60% paddocks deficient across all regions) but was particularly severe in the Central West where all but three of the paddocks sampled had inadequate sulphur (Table 1). Very low sulphur levels (<4 mg/kg) were found in more than 60 of the paddocks sampled.

What do the results mean and how can nodulation be improved?

With 90% or more of all paddocks sampled having inadequate nodulation and up to 20% of paddocks in some regions having no nodules present on legume plants, it is highly likely that the assumed 20–30 kg N/t DM produced is not being achieved in the majority paddocks surveyed. This means it is probable that pasture production and pasture quality is limited by nitrogen availability and hence livestock performance may also be affected.

Now that the extent of the problem has been identified across the regions sampled, the next question is what can be done to improve nodulation in pastures? Perhaps more relevant though is examining the factors that may potentially have led to the problem arising in the first place and considering what management actions may be taken to address the issue of poor nodulation. The survey presented in this paper has highlighted potential fundamental issues that may be contributing to poor nodulation.

Soil pH

Many publications have been produced that report on the effects of soil pH on plant growth (e.g. Howieson *et al.* 2000). However, what is often forgotten in dealing with legumes is the effect soil pH has on rhizobia function, survival and root infection. In many cases, rhizobia are more sensitive to declining soil pH than the host legume plant (Figure 1). If we consider subterranean clover (Figure 1), it can be seen that plant growth and function is generally not limited from a pH_{Ca} of 4.8–8.0. However, its associated rhizobia (Group C), operates optimally from pH_{Ca} of 5.5–7.0. In our survey, the average pH_{Ca} was around 5.0. If we refer to Figure 1, it can be seen that whilst still

Table 1. Legume nodulation, legume content (%) and key soil chemical parameters from a legume nodulation survey of 225 Paddocks across the Central Tableland, Central West, Monaro and Riverina regions of NSW. Range of results in parentheses.

	Number paddocks	Legume (%)	Average nodulation score (0–8)	pH_{Ca} (0–10 cm)	Al (% CEC)	P (Colwell) (mg/kg)	S (KCl–40) (mg/kg)
Central Tablelands	30	27 (7.5–53)	2.3 (0.8–4.3)	5.0 (4.4–5.7)	3.1 (0.1 –12)	30 (6–133)	7.1 (2.7–14.6)
Paddocks less than critical (%)[1]			93	87 (100)	80	63	70
Central West	60	50 (7.5–95)	1.8 (0–6.7)	5.2(4.3–7.6)	1.9 (0–10)	29 (8–150)	5.0 (0–18)
Paddocks less than critical (%)			90	73 (96)	90	41	95
Monaro	54	24 (4–68)	2.6 (1.1–5.1)	5.1 (4.2–8.2)	4.1 (0 –29)	44 (11–120)	7.9 (2.0–31)
Paddocks less than critical (%)			96	80 (94)	81	43	63
Riverina	81	[redacted]	2.2 (0.5–4.9)	5.2 (4.3–6.7)	3.5 (0.5–24)	42 (6–170)	6.5 (1.0–24)
Paddocks less than critical (%)			96	75 (100)	80	37	72

[1] For nodulation shows percentage of paddocks with nodulation score <4. pH first number is percentage of sampled paddocks with $pH_{Ca} < 5.5$ and in parentheses $pH_{Ca} < 7.0$. For exchangeable aluminium <5% of CEC, the level above which lucerne likely to be sensitive. Colwell P less than critical value based on phosphorus buffering index and sulphur paddocks less than 8 mg/kg.

surviving, the function of Group C rhizobia is compromised at this pH. Importantly, there were many paddocks that had a pH of less than 5.0 and rhizobia function and therefore ability to fix nitrogen would be very poor (Figure 1).

As shown in Figure 1, plant species and their associated rhizobia differ in their ability to tolerate soil acidity (and alkalinity). If we consider serradella (*Ornithopus* spp.), it can be seen that the serradella plant is more tolerant of low pH than subterranean clover. Additionally, the rhizobia used for inoculation of serradella (Group S) is more tolerant of low pH than Group C used for subterranean clover. Lucerne can grow relatively unimpinged where soil pH_{Ca} is as low as 5. However, survival and function of its associated rhizobia at this pH is very poor. So as these examples show, the legume plant is generally more tolerant of declining soil pH than its associated rhizobia. It is worth remembering that a legume plant that is not fixing nitrogen from the atmosphere will be using it from the soil nitrogen pool. This means that the legume may still appear healthy at low pH if there is access to sufficient nitrogen in the soil but it will actually be using soil nitrogen and not building it.

So what's the key message on pH? Soil pH is critical to health and function of the plant AND its associated rhizobia. It's always worth remembering that pH is measured on a log scale. This means that a pH of 5 is ten times more acidic than a pH of 6 and a pH of 4 is 100 times more acidic than a pH of 6 so all of a sudden those relatively small changes in soil pH actually are very important. Generally aim to keep you soil pH_{Ca} in the top 10 cm (where most of the rhizobia live) at around 5.5 where possible to optimise both plant and rhizobia potential.

Exchangeable aluminium in the soil

Aluminium is a common component of clay minerals and becomes available in the soil solution as soils acidify. Generally, aluminium will increase rapidly when pH_{Ca} falls below 4.8 (Bromfield *et al.* 1983). Aluminium can affect plant growth particularly through stunting of the root system and removing root hairs. The root system of a legume plant sends out signals to rhizobia that results in nodulation. If the root system is damaged by aluminium, then this signalling is interrupted and it is likely that nodulation will be reduced. Further, high quantities of aluminium in the soil solution can be harmful to rhizobia (Drew *et al.* 2016). So if both the size of the root system and the population of rhizobia is being reduced by high levels of aluminium, then nodulation can be significantly reduced. Correcting this issue can be achieved by liming where this is feasible.

Soil macronutrients

There is an abundance of scientific research showing adequate supply of soil nutrients can increase pasture production (e.g. Watson *et al.*

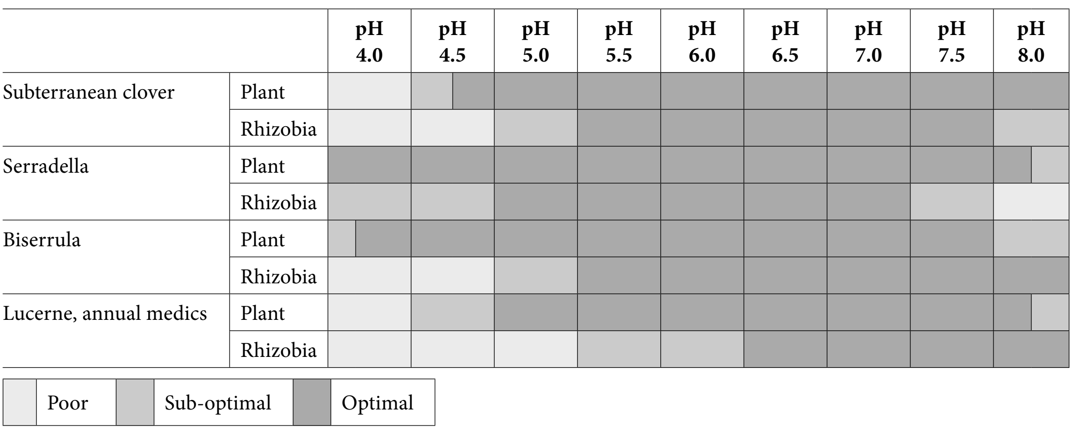

Figure 1. The tolerance of various species of pasture legume and their associated rhizobia to a range of soil pH_{Ca} and indicative productivity (poor, sub-optimal or optimal) at specific soil pH (from Yates *et al.* 2016; various departmental publications DAFWA and NSW DPI).

1969; Hochman *et al.* 1990). In reference to pasture legumes, phosphorus and sulphur are critically important. Phosphorus is essential in supporting early root growth and for photosynthesis and thus plant growth. From the perspective of rhizobia (a bacteria), phosphorus is essential for bacterial growth and for the conversion of atmospheric nitrogen to ammonia – the key role of rhizobia in agricultural systems.

Sulphur is frequently the 'forgotten' nutrient in pasture nutrition. From the plant perspective it is necessary for the formation of chlorophyll, amino acids (the building blocks of proteins), proteins and enzymes. In terms of rhizobia, adequate sulphur ensures greater supply of sugar enabling the population of rhizobia to increase and it is also a key component of the enzyme nitrogenase which rhizobia use to convert atmospheric nitrogen to ammonia in the nodule.

The key message here is adequate attention to soil macronutrient supply is critical for both the plant and rhizobia. Remember, while phosphorus attracts a lot of attention in pasture nutrition, sulphur should not be forgotten. Our survey showed that many producers are using mono-ammonium phosphate (MAP) or di-ammonium phosphate (DAP) fertiliser when sowing new pastures. Both of these fertilisers contain P, but no S. For an establishing annual legume, there needs to be an adequate supply of S close to the seed to enable early nodulation, therefore it is critical to ensure a sulphur-containing fertiliser is used at sowing where sulphur less than the recommended 8 mg/kg (based on KCl_{40} test). Additionally, where pastures are being topdressed, it is critical to consider soil S levels in choosing appropriate fertiliser.

Soil micronutrients

Molybdenum (Mo) is a critical micronutrient for both plants and rhizobia. In plants (including legumes), adequate Mo is required to enable breakdown of nitrates taken up from the soil. For rhizobia it is a component of the nitrogenase enzyme and therefore critical for nitrogen fixation (Weir 1984). Molybdenum availability decreases with declining soil pH and therefore Mo applied to acidic soils may not be available to the plant. Liming to increase soil pH can increase availability of Mo. It is critical not to apply too much Mo as excesses can cause animal health disorders. Molybdenum deficient areas are generally well defined in NSW and our survey covered some of these known locations. Despite this, there was almost negligible management of Mo nutrition amongst producers. It should be remembered that it is not practical to assess Mo via soil analysis. Testing plant tissue is a more reliable method of determining whether Mo is adequate.

Other management factors

Research undertaken in Western Australia recently has shown significant negative impact of some commonly used herbicides on legume root growth and nodulation (Loi, 2016). Some of these chemical groups include sulfonyl ureas and clopyralid. Residues of these chemicals can cause significant root pruning resulting in poor communication between the plant and rhizobia resulting in poor nodulation. Significant root pruning also affects the ability of the plant to harvest moisture and nutrients further affecting growth. In our survey, we encountered evidence of root pruning arising from use of these herbicides (Figure 2). It is absolutely critical to observe plant back periods on herbicide labels to reduce the incidence of these issues.

Figure 2. Subterranean clover plants from control (non-sprayed) area (left) and area where sulfonyl-urea had been applied showing root pruning and reduced nodulation on upper root system (right). Photo: Jo Powells.

Anecdotally, we have received many reports of use of sulfonyl urea herbicides in broad spectrum herbicide mixtures either just prior to sowing of legume-based pastures or for the control of broadleaf weeds such as Paterson's curse (*Echium plantagenium*) within the growing season. It is strongly advisable not to undertake this practice if the intent is to promote legume growth and nitrogen fixation.

Conclusions

Inadequate nodulation in 90% or more of the 225 paddocks sampled in this survey is cause for significant concern. Given these results, it is unlikely that the assumption of 20–30 kg N fixed/t DM produced is being achieved in most paddocks. This may mean that legumes are essentially acting like grasses in the pasture and accessing nitrogen from the soil nitrogen pool and not building soil nitrogen. This is likely to be compromising pasture production, pasture quality and mining soil nitrogen. Certainly it would appear that while soil pH while may not necessarily be limiting plant performance, it is likely to be reducing survival and performance of the associated rhizobia in the majority of paddocks sampled. Poor soil nutrition is also a possible contributor to the situation and particularly deficiencies in sulphur (and probably molybdenum in some cases). Some commonly used herbicides may also be contributing to poor nodulation in some paddocks.

So what's the overall message from this? As an industry, we appear to have lost sight of the importance of agronomic fundamentals in managing pastures and particularly with respect to factors affecting legume establishment, growth and nodulation. None of the information on factors that may be affecting nodulation presented in this paper are new, but they do, as ever, remain critical. It is critical to:

- Measure your soil pH and monitor it over time, correct it where you can or choose plant species and associated rhizobia that may be better suited to acidic soils.
- Measure soil nutrients and aim to achieve critical targets, particularly for phosphorus and sulphur if optimising pasture production is your goal.
- Be careful when choosing herbicides to use pre-sowing and within the growing season and read labels carefully.

Changing the current situation relies on addressing the probable causes of poor nodulation and not applying band aids to the symptoms. We cannot expect optimal performance from plants growing in sub-optimal conditions.

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How do you get the most out of native grass pastures without breaking the system?

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Abstract: *Native grass is a general term for over 1,000 grasses that occurred naturally in Australia before European settlement. Whether it is a native grass or introduced species is less important, having the appropriate species for sustainable landscape function is more important. Increasing perenniality in the landscape is key. Native grass pastures tend to persist in areas where introduced species either do not persist well or it is uneconomic to establish them.*

The main ways to improve native grass pastures are to grow more pasture, utilise a higher proportion of the pasture and/or graze with higher value livestock. Recognition of species is the key to managing native grass pastures. Many native grass species are responsive to increased phosphorus levels. Within native grass pastures, destocking benchmarks of ground cover (i.e. 70% flat country and 80–90% on hill country) and herbage mass (i.e. 800 kg DM/ha) are critical for the stability of the pasture and the maintenance of the perennial species.

Key words: fertiliser, seedling recruitment, lamb production

Introduction

By definition, a native grass pasture is 'any pasture where the main perennial species is a native grass' (Crosthwaite, Malcolm 2001). About 3.1 million hectares (22%) of the agricultural area of south-eastern Australia can be classified as native grass pasture (Hill *et al.* 1999). This area is generally located in the high rainfall zone (> 600 mm annual average rainfall) of the southern agricultural zone in soils that are shallow, low in phosphorus (P), acidic (pH_{Ca} < 5.5). These soils are considered non-arable (Simpson, Langford 1996) and therefore not suitable for the sowing of introduced species. After decades of widespread grazing in southern Australia, there have been considerable changes in the composition of native grass pastures. Many native species have declined and in some cases disappeared altogether, while some introduced species (particularly annual species) have successfully adapted to these new conditions.

This paper explores how livestock grazing enterprises can optimise productivity and sustainability of native grass pastures whilst maximising profitability. There are three ways in which profit can be improved on native grass pastures: grow more, utilise a higher proportion of the pasture and/or graze with higher value livestock. Traditionally native grass pastures have been grazed by wethers, for wool production, but integrating the management of improved and native grass pastures by grazing with a single flock of ewes is more profitable than grazing ewes and wethers separately (Sargeant, Virgona 2014). Fertilising native grass pastures may improve productivity (Garden *et al.* 2003; Graham 2006) but it is important to note that much of the response to fertiliser comes from the naturalised introduced species rather than the native grasses. This presents a difficulty when competition from fertilised annuals threatens the perennial native grass pasture. The benefits of using fertiliser must be captured by utilising the extra growth, which means increasing stocking rate.

1. Grow more

Know what you have

A wide range of native perennial grasses occur in our pastures. There are over 1,000 different species that can be classified as native grasses. Some species have traits that are beneficial to grazing and others do not. Therefore, it is important to understand what species are present in your pasture.

Native grass pastures usually have a range of species present, so learning to identify both the desirable and undesirable plants is essential. As well as identifying what species are present, it is important to understand their condition and productivity level. Different species have different management requirements and purposes in the farming system. In addition, an understanding of the key characteristics of species – i.e. the time of year for pasture growth, seeding pattern, recruitment time – are essential to develop appropriate grazing management strategies for livestock.

In many native grass pastures, the productivity of the system is driven by the annual components. These annual species are, in many cases, more responsive to fertiliser applications than are the native perennial grasses. For example, a native grass pasture that has a high component of annual ryegrass *(Lolium rigidum)* will be more responsive to fertiliser than one that is dominated by sweet vernal grass *(Anothoxanthum odoratum)*.

Why fertilise native grass pastures?

Several studies, at a number of sites and over a number of years, have reported the doubling of pasture production by addressing phosphorus (P) and sulphur (S) deficiencies in native grass pastures (Friend *et al.* 2001; Garden *et al.* 2003; Dowling *et al.* 2006). The livestock component in all these trials has been sheep. In many cases, a positive economic response can be achieved without the need for sowing introduced species (Garden *et al.* 2003; Nie *et al.* 2009; Clark *et al.* 2014; Waddell *et al.* 2016).

Applications of P stimulate the annual legume component of native grass pastures, increasing the nutritive value of the feed leading to increased animal performance (i.e. growth rates, g/head/day). Nitrogen (N) fixed by the legume stimulates the native perennial grass, but also the volunteer annual grasses and weeds. When fertiliser is applied to native grass pastures often an explosion in production of both annual grasses and legumes is seen, particularly in the spring. For species such as wallaby grass (*Rytidosperma* spp.) and red grass *(Bothriochloa macra)* this can be quite detrimental if there is insufficient grazing pressure, especially in the spring, because this allows annuals to shade and smother the native perennials.

Some areas of native grass pasture should not be fertilised, such as pastures on rocky soils, steep hills, and westerly aspects. On these areas, responses to increased fertility are poor. In these areas it is more important to preserve the native perennial grass cover to control erosion.

2. Utilise more

Grazing management systems seek to optimise the relationship among animals (i.e. stocking density), plants and soils by regulating the number of animals and the duration and location of animals (Cox *et al.* 2017).

To maximise productivity from increased native grass pasture growth as a result of fertiliser application, producers must manage stocking density effectively. The volunteer annual grasses and weeds tend to be more competitive as P and N fertility increases, leading to a decline in the native perennial grass component. This leads to an uneven feed supply, with an excess in the spring and then poor growth over summer leading to bare ground and erosion risks. To avoid this risk, it is recommended that legumes should be at most 20% of pasture on offer in spring. Grazing and lower fertiliser application rates (i.e. < 10 kg P/ha/year) can be used to maintain the legume content of native grass pastures at this level.

Within native grass pastures, destocking benchmarks for ground cover are 70% on flat country and 80–90% on hill country and a minimum herbage mass of 800 kg DM/ha is critical for the stability of the native grass pasture and the maintenance of the existing perennial species. It is also important that producers defer grazing over the summer period to ensure native grass pastures are able to produce seed and build up root reserves. These paddocks can then be grazed in late summer or early autumn.

The EverGraze site at Orange, NSW found that grazing intensity influenced productivity and profitability from native grass pastures (Badgery *et al.* 2015). Within a rotational grazing system, individual animal performance was greater for low intensity grazing systems (1-Paddock) when compared to higher intensity grazing systems (4-Paddock and 20-Paddock). However, under situations where greater feed on offer (FOO) is available, higher stocking rates can be run with increased intensity leading to greater productivity per hectare. Economic modelling identified that when lambs are retained on farm for longer periods after weaning (i.e. 6 out of 10 years), gross margins were higher in a 20-Paddock system (Badgery *et al.* 2015).

Regardless of grazing treatment and the physiological stages of growth for the native pasture, ewes consistently selected green, vegetative components from the pasture to graze (Cox *et al.* 2017).

3. Grazing with higher value livestock

Often native grass pastures run low levels of stock and return low levels of profit per hectare (Dorrough *et al.* 2007). In many instances, the economic viability of these systems relies on managing large areas of land, or being complementary to high-input pastures based on introduced species (Crosthwaite *et al.* 1996).

Traditionally native grass pastures have been grazed by wethers, for wool production. However, the EverGraze site at Holbrook, NSW, demonstrated that native grasses could be grazed by ewes, if an integrated approach across the farm was used (Sargeant, Virgona 2014). In an 'Integrated' system, where a single mob of ewes were grazed across native (63%) and phalaris-based (37%) pastures, they produced 136–225 kg/lamb/ha and 11–18 kg wool/ha. In the 'Separate' system, where ewes and lambs were rotated on phalaris-based pastures and wethers were set stocked on native pastures, 75–156 kg lamb/ha and 18–21 kg wool/ha was produced. Gross margins of the Integrated system were significantly higher than the Separate system for wool and lamb. The Integrated system also achieved significant increases in stocking rates over the Separate system, 17 DSE/ha compared with 4 DSE/ha respectively. The 'Integrated' system had the advantage that it allowed stock to be completely removed from the native grass pasture over the summer months, allowing the native grasses to set seed.

Native grass pastures can form the basis of a successful store lamb production system with good weaning weights and acceptable reproductive performance. At the EverGraze site at Chiltern, Victoria, native grass pastures comprising *Microlaena stipoides*, low quality annual grasses and very low clover content obtained average lamb growth rates to weaning (November) ranging from 206 g/head/day – 320 g/head/day (depending on season), equating to average weaning weights of 29–32 kg respectively (Linden *et al.* 2013). The higher stocking rate system had greater lamb production per hectare (78 kg/ha–165 kg/ha) than the lower stocked treatment (49 kg/ha–101 kg/ha). This was despite the fact that per head production at higher stocking rates tended towards lower weaning weights (average weaning weight 32 kg vs 36 kg). In lower production systems, increased stocking rates needs producer awareness of the overall potential of the production system. Higher fertiliser inputs need to be balanced against potential gains in productivity and additional production costs and grazing management. Where native grass pastures contain a minimal legume content or annual grasses that are not responsive to fertiliser application, returns from capital investments in fertiliser are marginal and therefore not advisable.

Maintaining the system

Pasture re-sowing occurs in Australia on average once in every 20 years in the most favourable areas for pasture renovation (Malcolm *et al.* 2014). When productive pastures are established they need to be maintained. One potential reason for low pasture re-sowing rates is that the profitability of sowing new pastures is marginal when prices for livestock products are low (Vere *et al.* 2001).

To ensure species persistence of new and established pastures, controlled grazing is essential. In many instances the performance of perennial grasses within pastures is based entirely on the performance of existing plants, as recruitment of perennial grasses is a rare event (Briske 1996; Kemp *et al.* 2000). Seedling recruitment within established pastures is frequently low, only occurring sporadically during years with favourable moisture and temperature conditions, or when disturbances create spaces (Lodge and Whalley 1981; Briske 1996; Virgona, Mitchell 2011; Mitchell *et al.* 2014). The seedbanks of pastures in temperate areas tend to be dominated by annual species, with very few perennial grasses present (Mitchell *et al.* 2014). There is limited published information on the survival of new recruits to form adult plants. This highlights the importance of maintaining existing perennial plants in a vigorous state.

Conclusion

If recognised and properly managed, native grass pastures can be very productive. These grasses have persisted well on most farms due to their tolerance of acidic and low fertility soils, a wide range of soil texture types, and drought and frost tolerance. In a native grass pasture there is also considerable genetic diversity as they have adapted to the harsh and varying climate over many generations.

No two native grass pastures are the same in species composition, soils, fertiliser history or aspect; therefore there is no one simple 'recipe' that can apply to all native grass pastures. Each 'recipe' will be different and needs to be based on species present, the growth pattern of these species, your enterprise goals and how these pastures fit into your farm system.

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Alternatives and fundamentals – considerations when using fertilisers and ameliorants

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Abstract: *A fundamental knowledge of soils and soil testing, combined with understanding plant nutrient requirements, will help producers make decisions about which fertiliser or ameliorant or alternative will be best or most profitable in any situation. Examples are given where alternative fertilisers have been compared with commonly used products for nitrogen topdressing and phosphorus application, also examples of manure and compost use show that in some cases alternatives are very cost effective and in other situations they have not produced a response and proved very expensive.*

Key words: nitrogen topdressing, poultry litter, pasture, alternative fertiliser, compost

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.

Ameliorants are defined as products that improve the condition of something. In soils that usually means improves the growing conditions for plant roots and often refers to products such as lime, gypsum, dolomite, compost or biosolids which are applied in large amounts per hectare. These ameliorants may improve growing conditions by improving soil pH, improving soil structure, water infiltration or moisture holding capacity. In some cases, such as manures, they may also supply nutrients.

When deciding what fertiliser or ameliorant products to apply it is logical to start by understanding the soil and what deficiencies it may have for plant growth. This first requires a field assessment of soil for features such as paddock history, topsoil depth, compaction, drainage etc and a soil test to determine nutrient levels. Sometimes testing may also be needed to measure soil biological activity or physical features such as bulk density. Step two is to identify what products could be used to overcome any deficiencies and step three is to decide which product will be most cost effective or profitable.

Today conventional fertilisers refers to chemical, synthetic or manufactured fertilisers while alternative fertiliser or ameliorant 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.

The following examples illustrate comparisons of various fertiliser and ameliorant products in a range of farming situations.

Nitrogen topdressing using traditional and alternative fertilisers

In 2009 trials were established at Tocal, Taree and Berry in response to questions from dairy farmers interested in 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). Farmers were hearing about a range of products which were being promoted as cheap, more productive, better for the environment and feed quality, soils, soil biology and clover and wanted confirmation of the claims. Suppliers active in the area at the time were invited to nominate suitable products and the rate they should be used in a comparative trial. The range of products included in trials represented traditional fertilisers (urea), liquid organics, biologicals, plant hormone and poultry litter. Some treatments varied with site. At Tocal, forage yield and feed quality were measured with limited observations on clover content and soil biology in two trials over a two year period. Trial 1 results are summarized in Table 1. Treatments were applied after each harvest.

Table 1 shows that a number of the 'alternate' fertilisers contained very low N 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. The various coated ureas were all more expensive than straight urea but did not produce a consistent yield advantage to cover the extra cost. Some of the 'alternative' products were very expensive when considered in terms of cost of extra dry matter produced compared to the nil control.

Phosphorus and sulphur drive growth in native pasture trials

Leech (2012) observed that there was 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 native perennial pastures on low fertility soils.

Products used in these trials varied widely in phosphorus (P) and sulphur (S) availability (Table 2). Results in the six years the trials were monitored showed that products which delivered the highest amounts of available phosphorus and sulphur produced the most pasture herbage (Figure 1).

Relative cost effectiveness of fertiliser products

An economic comparison of each product tested at Binalong is presented in Figure 2, based on the spring herbage mass measured in 2012 and winter plus spring herbage mass measured in 2014. Only products which grew significantly more pasture than the control treatment in each of those years have been presented. Any product which did not yield more than the control was regarded as not cost effective.

The cost used in 2012 was an average of the annualised cost in each of the first 4 years (2009–2012) while the cost used in 2014 was an average of the annualised cost in each of the 6 years (2009–2014) of the trial. Note that the values presented for the cost of additional pasture grown over the control (nil) treatment are only a relative measure of the cost effectiveness of each product as it is based on pasture grown for

Table1. Tocal topdress repeat treatment trial. Total production and cost for two years.

Treatments	Kg N/ ha/application	Total kg DM/ha	Difference to control	Difference %	$ Cost per application	Total Cost$/ha	Cost extra DM $t/DM
Nil	0	15637					
Twin N	0	15751	114	1	30.00	270.00	1574.05
Liquid Blood & Bone 20 L/ha	2	16098	461	3	111.20	1000.80	1447.60
TNN 15:5:5 10 L/ha	1.5	16118	481	3	69.45	625.05	866.50
TNN Organic NK 20 L/ha	3.54	16224	587	4	73.00	657.00	746.29
Liquid Blood & Bone 10 L/ha	1	16350	713	5	55.60	500.40	467.95
Urea 50 kg/ha	23	18170	2533	16	37.25	335.25	88.25
Twin N + 50 kg/ha Urea	23	18658	3021	19	67.25	605.32	133.58
Entec Urea 50 kg/ha	23	19458	3821	24	47.30	425.70	74.28
Green Urea 50 kg/ha	23	19791	4154	27	42.45	382.05	61.32
Entec Urea 100 kg/ha	46	20024	4387	28	94.60	851.40	129.38
Green Urea 100 kg/ha	46	20244	4607	29	84.90	764.10	110.58
Urea 100 kg/ha	46	21570	5933	38	74.50	670.50	75.34

Table 2. Total quantities (kg/ha) of Phosphorus and Sulphur applied to treatments at Glenroy and Kia-Ora trial sites after 6 years.

Treatment	Water Soluble Phosphorus	Citrate Soluble Phosphorus	Insoluble Phosphorus	Total Phosphorus	Total Sulphur
Control	Nil	Nil	Nil	Nil	Nil
Single Super	51	13	2	66	83
Agri-ash	Nil	28	137	165	21
Trio-min/Eco-min Balance	1	6	10	17	13
SEP Pig Manure	6	83	88	177	34
Groundswell Compost	1	9	11	20	15
YLAD Compost Mineral Blend					
– Glenroy	No laboratory analysis undertaken on fertilizer applied				
– Kia-Ora	< 1	3	46	49	71
YLAD Compost Tea	< 1		< 1	< 1	< 1
BioAg Blend	< 1	2	70	72	29
Ecology FF/Dical 64	< 1	8	64	72	22
Urea	Nil	Nil	Nil	Nil	Nil

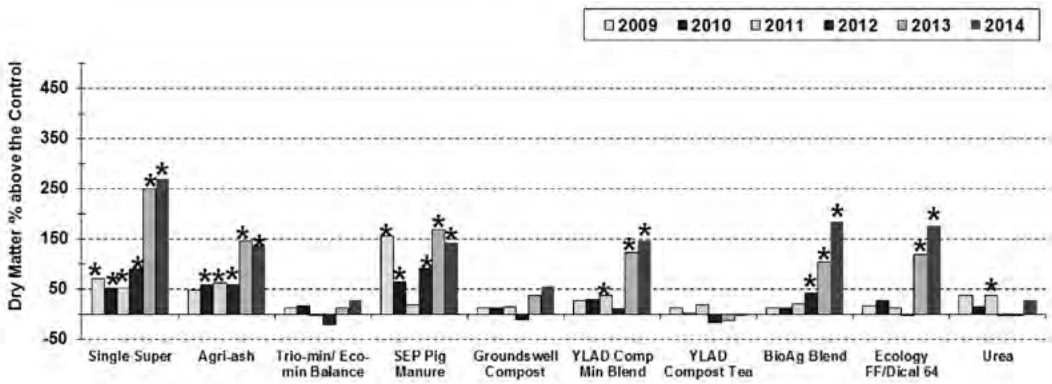

Figure 1. Mean Spring/Winter+Spring Herbage Mass relative to unfertilised control treatment 2009–2014 at Binalong. Treatments with an * were statistically greater than the nil control (from Leech, 2015).

only a short period, i.e. spring only in 2012 and winter plus spring period in 2014. The relative cost was calculated by dividing the average annualised cost per ha (consisting of a product cost, freight charge to Yass and spreading cost all GST exclusive) by the herbage mass (kg DM/ha). Note, that if the total amount of pasture grown throughout the year had been measured, the cost of additional pasture grown would have been much less.

- One of the key drivers of pasture growth from the fertiliser products trialled is P. This response is in line with other pasture field research. The level of solubility of the P in the products and pattern of application has determined the relative cost effectiveness compared to single super.
- Products containing water soluble or citrate soluble P release plant available P into the soil allowing plants to access the P very quickly. In contrast products containing primarily citrate insoluble P release P for plant growth at a much slower rate. The rate of release is also dependent on soil pH and soil moisture content. Citrate insoluble P will be solubilised more quickly in wetter and more acid soils. Some 'slow release products' were more cost competitive in 2014 than 2012 illustrating the extra time needed for these products to work.

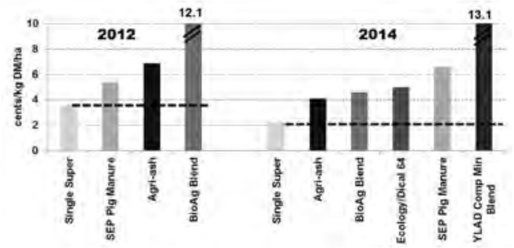

Figure 2. Glenroy site, Binalong – Economic comparison of fertiliser products in 2012 and 2014 showing the cost of additional pasture grown above the control within the measurement period in each of the years (from Leech, 2015).

- The study has shown that some of the products tested are not economically competitive at the sites in question.

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 (Griffiths unpublished) 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. 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 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 pH_{CaC} 5.6 and P tests 195 ppm (Colwell) and 53 ppm (Bray).

A comparison of pasture produced and cost of fertiliser inputs in Table 3 shows that in this situation the poultry litter cost approximately half of what fertilisers Urea, di-ammonium phosphate (DAP) and Muriate of Potash cost when considered in terms of $/t dry matter produced. The cost advantage of poultry litter would be even greater on a more responsive site which needed phosphorus as well as nitrogen and potassium.

Poultry litter is quite variable which is an issue when buying and applying this type of product. Table 4 illustrates the variability between farms while Table 5 illustrates the variability on a single farm between years.

Compost use is increasing

Composts are gaining popularity in some areas as an option to reduce volume and manage organic waste disposal and also to recycle nutrients and carbon back to the broader landscape. Composts are being used to help manage farm wastes or by-products such as

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

Treatment	Total pasture produced in 7 years–tonnes of dry matter/ha	Total cost of fertiliser $/ha	Cost of pasture $/tonne dry matter
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

Table 4. Poultry litter nutrient survey 2010 (Griffiths, unpublished data).

Source of litter	Broiler litter Tunnel		Broiler litter Conventional		Turkey Litter		Layer manure	
Number of samples	16		6		8		8	
	Range	Ave	Range	Ave	Range	Ave	Range	Ave
Nitrogen %	2.5–5.6	3.9	2.9–3.6	3.3	2.4–5.4	3.8	3.1–7.6	5.8
Phosphorus %	0.46–1.9	1.05	0.81–1.7	1.33	1.3–2.3	1.7	1.1–4.0	2.2
Carbon %	33–44	41	40–43	42	36–42	39	25–37	33
Potassium %	0.85–2.3	1.47	0.95–1.7	1.33	1.5–3.0	1.9	0.91–2.7	1.68
Magnesium %	0.31–0.64	0.43	0.31–0.5	0.44	0.32–0.94	0.46	0.32–1.0	0.49
Calcium %	1.2–2.7	1.7	1.1–2.4	1.9	1.8–3.5	2.7	3.2–14.0	9.2
Sodium %	0.2–0.49	0.35	0.34–0.44	0.40	0.25–0.53	0.33	0.24–0.51	0.36
Sulphur %	0.29–0.73	0.49	0.34–0.54	0.43	0.38–0.55	0.49	0.29–0.66	0.45

Table 5. Litter nutrient values from the same Victorian chicken farm, reported on dry weight (from Warne, 2014).

Analysis (%)	Percent (%)/dry weight			
	Aug 2009 (shavings)	Mar 2010 (shavings)	Mar 2011 (shavings)	Apr 2012 (rice hulls)
Total Nitrogen	4.12	2.51	4.28	4.57
Phosphorus	0.74	0.58	1.03	1.20
Potassium	2.29	1.21	1.71	2.10
Sulphur	0.64	0.4	0.52	0.52
Calcium	1.22	1.25	2.22	2.25
Magnesium	0.60	0.44	0.51	0.64
Sodium	0.51	0.28	0.31	0.35

manure or high carbon trash, husk or straw. This composting may help reduce waste volume and recycle valuable nutrients and carbon but it does not create new nutrients.

There has been a large increase in the use of compost in urban areas as landfill becomes more limited and expensive. This urban compost is variable depending on source, separation and management as shown in Table 6.

Guidelines on use vary depending on the type of compost, with application of mixed source compost restricted compared to green waste compost. The volume of urban compost produced now exceeds what can be used close to source in landscaping and nurseries and so it is now transported longer distances for agricultural use. The value of compost in broadacre farming will depend on its ability to improve soils and improve production. The farmers' ability and incentive to pay for these products depends on the benefit or profit which can be derived from it.

Application rates of compost vary widely depending on cost, soil type and industry, with horticulture tending to use higher rates followed by cropping and pasture based grazing enterprises. Application rates have exceeded 100 t/ha in some horticulture (Chan 2008) and reclamation uses. Application of mixed source compost is limited to 10 t/ha by the NSW EPA and in pastures application is often much less than 10 t/ha. The changes to soil which are

Table 6. Example ingredients in urban compost taken from product MSDS (from Anon 2009).

This product is comprised of refuse-derived material. Moisture content is approximately 35% to 55% of material weight. General (dry) proportions are:

Organic Material	25–60%	typically	35–50%
Calcium	2.0–3.5%		
Nitrogen	0.5–2.5%	typically	1.5–2.0%
Phosphorus (as P2O5)	0.2–2.0%	typically	0.5–1.5%
Potassium (as K2O)	0.3–1.5%	typically	0.7–1.2%
Inert Material	30–50%		

Physical contaminants:
Total glass metal (> 2 mm) & hard plastic (> 5 mm) target < 2.8%, current typically 1.0–5.0%.
Light and film plastic (> 5 mm): target < 0.3%, current typically 0.1–0.5%.
Stones and other consolidated mineral contaminants > 2 mm: < 5%, typically <1%.

achieved by applying one-hundred tonnes per hectare or more of compost cannot be expected when applying much lower rates.

Compost can supply nutrients and trace elements and can be compared with other fertilisers or manures for nutrient content and cost of nutrients. It will also supply carbon in various labile and stable forms. This carbon can improve soil structure and associated bulk density, water infiltration rates and water holding capacity. Compost can also be a source of microorganisms and the labile carbon on which they depend.

The expected benefits of compost in a pasture system will depend on soil characteristics. Typically permanent pastures will have higher soil carbon levels than soils which are cultivated for cropping or lucerne. Where soil carbon levels are already adequate in a permanent pasture then benefits from adding more carbon in the form of compost will be limited. In this case any increase in production is more likely to be due to nutrients applied in the compost.

The benefits of composted dairy waste to soils, forage crops and permanent pastures were investigated at Wagga Wagga by Hayes *et al.* (2016) in both field and pot experiments. Application rates ranged from a nil control up to 5 t/ha in the field and up to 20 t/ha in pot experiments. Few significant increases in forage biomass were observed with the application of low rates of compost in either the field or pot experiment. In the pot experiments, a highly significant soil type effect was found with a sandy, acidic soil from Binnaway showing yield increase and benefits to soil, where more fertile soils from Euberta and Wagga Wagga did not. In the field experiment, compost had little impact on crop herbage mineral composition, soil chemical attributes or soil fungal and bacterial biomass.

They suggest that farmers might increase the response to compost by:

i) Increasing compost application rates;
ii) Applying it prior to sowing a crop;
iii) Incorporating the compost into the soil;
iv) Applying only to responsive soil types;
v) Growing only responsive crops;
vi) Reducing weed burdens in crops following application.

Discussion

As the old saying goes 'there is a place for everything and everything in its place'. When considering fertilisers and ameliorants this requires that fundamental features of the product are known, its cost is known and can be compared with other alternatives, and its ability to correct a deficiency or induce a profitable response is also known so that it can be used in the right place. 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, a 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 mis-information 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 in the correct situations.

The studies of nitrogen and phosphorus 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.

Compost products may be cost effective in the right situation however a permanent pasture may not maximise the benefits from compost if for example soil carbon levels are already high. With compost being a 'low analysis' input, large quantities are often needed to change soil fertility so price is a major consideration.

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. With or without adequate research and evidence of efficacy, fundamentals such as understanding nutrient content and cost comparisons between products, soil testing and nutrient requirements will help to make informed decisions about which fertiliser or ameliorant to purchase.

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Feed gaps and utilisation: challenges of grass fed beef production

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Introduction

Producing high quality grass fed beef in a dryland grazing environment can be challenging, especially when supplying certified grass fed markets. Filling feed gaps, correcting poor feed utilisation and feed efficiency, and managing bloat risks have to be achieved without the use of feed additives and grain. Close management of lifetime growth path to lift weight for age, ensuring adequate weight gain for the last 30 days pre-slaughter, and achieving adequate rib fat depth at slaughter are vitally important to maximising grading compliance and eating quality of beef carcasses. Best practice grazing management is required to maintain high individual animal performance, whilst maintaining a healthy pasture stand that is responsive to rainfall and fertiliser. Pasture selection for species that grow at different times of the season, whether in a mixed 'shotgun' pasture or sown separately in different paddocks, can effectively spread out the growing season of pastures and available dry matter for grazing livestock. Winter cropping is an important strategy to fill winter feed gaps in the Central West of NSW when pasture growth is at its lowest, and allows perennial pastures to be rested to rejuvenate for spring grazing.

This paper will focus on pasture availability and quality on our properties at Yeoval, Central West NSW during 2016–17 and the effect this had on animal performance and rib fat depth of carcasses graded for the Hereford Red brand. The paper will also discuss strategies that are being implemented to minimise identified feed gaps and improve feed utilisation throughout the season.

Feed demand vs pasture growth and quality

Identifying the mix of native and improved annual and perennial pasture species growing on your property, understanding their annual growth cycles and dormancy periods, along with historical average rainfall, soil moisture and temperature data for your area will help establish your properties pasture growth curves and total annual growth potential. When this is matched up with current and future stocking rates, times of surplus and deficiency can be calculated.

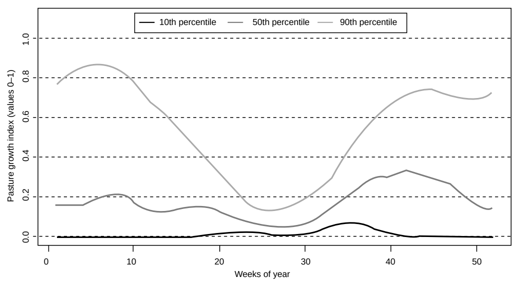

Figure 1. Pasture Growth Index of Yeoval, NSW (from www.rainfall.mla.com.au).

As can be seen in Figure 1, the Yeoval district pasture growth index dips during the autumn, is lowest during the winter, and peaks in mid spring.

Half of our breeders calve down from February-April, so feed demand also peaks during this time. As a consequence, autumn is a particularly challenging time to fatten our steers and excess heifers, due to low feed availability and a drop in digestibility of our finishing pastures (see Figure 2). A drop in feed availability and digestibility leads to reduced daily dry matter (DM) intakes and an overall decline in energy intake and average daily gains. In addition to this cattle have to deal with a significant ruminal transition from dry, low protein and high fibre to high moisture, high protein and low digestible fibre after a 'break'. New pasture growth is low in dry matter and high in water, leading to low retention times in the rumen and low overall DM intake. Coupled with low 'functional' or long fibre, cattle may struggle to ruminate adequately to maintain a stable rumen environment. The resulting acidic rumen is not favourable for fibre digesting bacteria, so the little fibre that remains in the rumen is not well digested. High levels of available nitrogen in the form of nitrates and nitrites, both of which can be toxic to the rumen microbial population (especially fibre digesting bacteria), is another factor that can result in poor animal performance during this time of year.

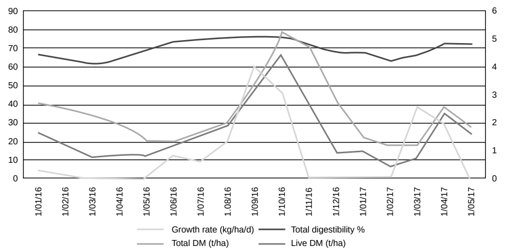

Figure 2. Modelled growth rate and digestibility of chicory, cocksfoot, phalaris and sub clover pastures at "Wandoo Wandong" Yeoval NSW during 2016–17, based on a stocking rate of 1.3 steers/ha (from W Badgery pers. comm.)

Historically spring delivers the most pasture growth in our area, at a high level of digestibility – around 75% dry matter digestibility (DMD) for our finishing pastures. This was certainly the case in 2016 after record winter rains. This quantity and quality of feed equates to high DM intakes, weight gain and finishing potential during this period. This is certainly of benefit to our autumn calves that are weaned in the spring, and for the balance of our cows that calve in later winter/spring. It is also of great benefit to our autumn calving cows that are able to put on valuable body condition over spring and summer to help buffer a decline in feed availability for their following calving.

So does this seasonal pattern of feed availability and quality impact the quality of the beef that we grow in a grass fed system? The answer is 'yes'. How and why this is the case will be discussed in the following sections.

Effects of feed availability and quality on animal performance and grading

Autumn 2016 presented a significant feed gap challenge, with low feed availability and quality from March to May due to very low rainfall. It is worth taking note of the 'Live DM t/ha' curve in Figure 2 as this is most representative of the green pasture growth the cattle are selecting, and this was below our minimum residual level of 1.2 tonnes of dry matter/ha during these months. This feed gap reduced the condition score of our finishing steers (see rib fat depth in Figure 4) which carried on throughout the winter and into early spring of 2016, primarily due to the delayed planting and grazing of forage oats. This was compounded by poor grazing conditions when the cattle were grazing oats in July and August, leading to sub-optimal weight gains. Consequently the finishing steers struggled to regain condition until late spring. This phenomenon was experienced across our region, with an increase in the percentage of cattle being non-compliant for minimum MSA rib fat during winter and spring 2016 (Figure 3).

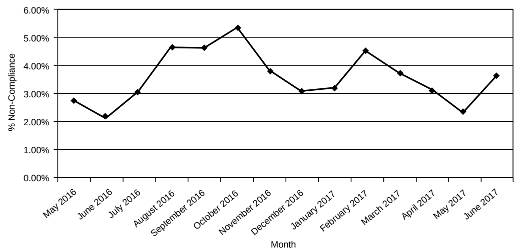

Figure 3. The percentage of animals in the Central West, NSW that were non-compliant for rib fat (< 3 mm) in 2016–17 (from www.mymla.com.au).

Rib fat is an accurate measure of cattle condition and has a significant weighting on MSA grading performance. As can be seen in Figure 4 the MSA Index of steers killed for Hereford Red over 2016–17 mirrored that of the trend in rib fat depth. It is worth noting that while marbling has the largest correlation with our MSA index (r = 0.6), marble scores are also strongly correlated with rib fat (r = 0.22). From the grading data collected, it appears that declining feed availability and intake over autumn/winter, is the main driver of reduced rib fat depth and marbling in our Hereford steers. Conversely a high level of intake over an extended period of time (i.e. 60–90 days) will improve rib fat and marbling deposition, as seen in the December 2016 kill. This is an area that warrants further investigation in a grass fed environment.

Another noteworthy point is that high performance during spring often results in high grading results a little later in the season, presumably as increase in fat depth on the rib takes time. In a grazing situation where cattle are gaining 1.3 kg/day it will take approximately

50–60 days to build one body condition score, which is the equivalent to 2–3 mm of rib fat. An adequate level of fat cover can then be maintained over summer, whilst still achieving adequate weight gains, and consistent grading results will often be achieved during this period.

Addressing seasonal feed gaps

Addressing seasonal feed gaps will increase the overall supply of feed for your herd, which will enable more stock to be carried and or higher quality beef to be produced. Faster growth post-weaning has been shown to increase intramuscular fat percentage (marbling) leading to improvements in predicted and actual eating quality of beef (Wilkens *et al.* 2007). High weight-for-age will result in heavier carcass weight at a lower physiological age (low ossification), which is important in achieving high grading results. An adequate plane of nutrition for the last 60-90 days pre-slaughter to maintain or increase fat condition score, and provide enough muscle glycogen for satisfactory post-slaughter glycolysis to prevent dark cutting beef, will improve the number of compliant animals in a consignment and overall grading scores.

As can be seen in Figures 1 and 2, autumn and winter are feed gaps in our grazing system, with autumn being a particularly hard time for finishing stock, as the feed on offer is lower in quality and more suited to breeding stock. Early sowing of long-season grazing oats using zero tillage is a strategy that we have implemented for over 15 years. Zero tillage allows us to get crop in the ground quickly. As a forage crop, grazing oats can provide high levels of DM/ha (up to 8t/ha) of high quality growing and finishing feed, and can fill the autumn feed gap during April and May and through the winter months if rotationally grazed. We plan to have enough paddocks sown so that they once our finishing or growing cattle go onto crop they can stay on crop until the second week of August. While not only filling a feed gap, grazing oats also allows us to rest our perennial finishing pastures over winter, to bulk up for spring grazing.

Fertilising cereal crops with nitrogen after the first grazing can be a cost-effective way to produce extra feed during winter, and may be the difference between getting a second graze or not, which is significant when you are aiming to rest the perennial pastures until spring. At a cost of 2–2.2 cents per mega joule (MJ) for an extra 180 kg DM/ha it is cheaper (on an energy basis) than supplementing with grain, and without the extra infrastructure and labour requirement.

Locking up paddocks and fertilising with 150–200 kg/ha superphosphate in late summer to stimulate autumn growth is another strategy that we have recently put more emphasis on, to help fill the autumn feed gap. For this strategy we are especially targeting paddocks with good levels of clover and native grasses such as *Paspalidium jubiflorum* (Warrego summer grass), to take advantage of its excellent early autumn growth pattern. As has been previously reported by Garden *et al.* (2003) we were able to achieve a positive economic response from fertilising, with steers gaining 1.8/kg/day during April at a stocking rate of 3 steer/ha, to maintain a +100 day weight gain of over 1 kg/day (which is our annual target).

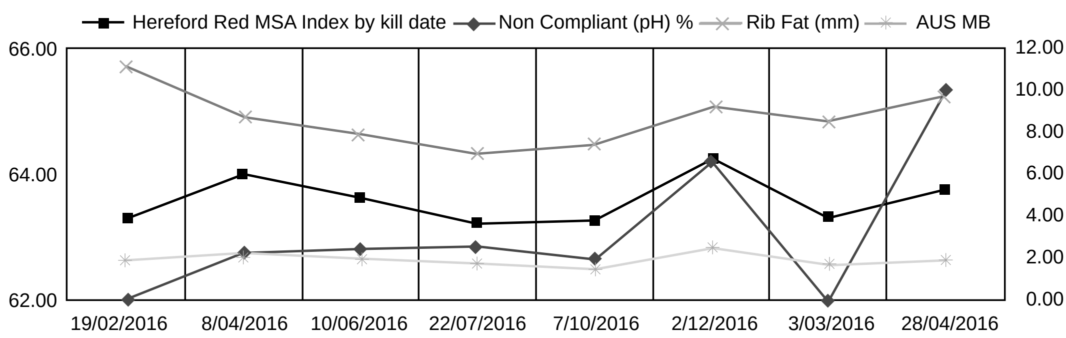

Figure 4. MSA Index values, non-compliance (pH) percentage, rib fat and AUS-MEAT marbling score of Hereford steers selected for the Hereford Red beef brand between 2016 and 2017 (from).

Finally, planning stock turnoffs of our trade cattle and excess females from August to December is an important strategy for our grazing operation. The aim is to reduce the impact of the autumn feed gap and to avoid being caught with heavy cattle which we are not able to finish and sell during this period. Reducing our stocking rate and hence grazing pressure and demand during this time also benefits the longevity and ground cover of our perennial pastures, especially those that contain phalaris which likes to establish new tillers in late summer.

Grazing management for improved animal and pasture performance

The extent to which a pasture is utilised, or converted into beef, is determined by its availability or height, the digestibility of the herbage and how much pasture is trampled and wasted. All grazing strategies should be focussed on one thing – to maximise intake of energy and protein. This is achieved by optimising both pasture height and pasture digestibility through good grazing practices. The energy density of a pasture is derived or calculated from its digestibility, and intake is determined by the height of a pasture and the level of digestible and indigestible fibre it contains. So it makes sense to graze pastures at their highest digestibility, and at a height at which it is most available. In a mixed pasture stand this can be achieved by grazing at the optimal height and density of 10–20 cm or 1.2–3 t DM/ha with full ground cover. In our operation we like to graze plants a little higher and later in maturity (i.e. with lower digestibility) during times of high bloat risk (in lucerne and clover dominant pastures) and during autumn to improve rumen retention and rumen health. In situations where animals are grazing highly digestible, short pasture or crop, strategic supplementation with straw or mature cut hay is a useful method we implement to slow the rate of passage in the rumen and improve nutrient uptake.

Vigorous pastures that are responsive to rainfall and provide year-round growth go a long way to achieving consistent growth rates in beef cattle. Rotational grazing is one of the best ways to improve the vigour of pastures, and can improve stocking rates and gain per hectare without any negative effects on growth rates of beef cattle (Bertelson *et al.* 1993). The number of paddocks in a rotation and the number of grazing days needs to be practical and suit the number of cattle run on your property. If you are running mobs of 100–200 head of cattle, then 25 ha paddocks are suitable and will provide 7–21 grazing days depending on the available dry matter and desired residual cover. Moving cattle more frequently than this has been shown to increase per hectare gain, but will compromise individual animal gain and condition scores. In a grass finishing system this will result in a lower eating quality carcass, and more animals falling outside market specifications for potential premiums.

Conversely under-grazing pastures, i.e. letting them enter a reproductive and post reproductive phase will limit intake as the plants become lignified digestibility falls. It is important to prevent perennial grasses from entering this growth phase for as long as possible by increasing stocking density, which will in turn encourage new leaf growth, prevent sugars being diverted to the seed head, and keep pasture digestibility high (>70% ideal). If your grass pasture enters a dormancy phase then supplementing with protein is an effective strategy to improve intake and weight gain per animal and per hectare. Also consider grazing this type of feed with another stock class such as dry or pregnant cows or growing replacement heifers that have a lower growth target.

Implementing sound grazing rotations must be aligned with matching stock type to feed quality. Weaner and yearling cattle have a higher demand for protein than trade weight and mature cattle as they are growing more lean muscle and less fat. Understanding this will help formulate and modify grazing plans throughout the year. Although some glycolytic proteins can be turned into energy, it is most efficient to graze young animals on high protein, legume-dominant pastures and older finishing cattle on more mature or grass-dominant stands that have higher energy to protein ratio.

Conclusion

It is clear from analysing our pasture growth rates, and carcass grading data that the autumn feed gap presents the largest feed challenge for our dryland grass fed beef operation. Declining DM intakes and variable digestibility during these months contributes to reduced condition scores of our finishing cattle, as reflected in rib fat depth. This has a direct and residual effect on eating quality of beef carcasses, especially if grazing of winter forages is delayed. Strategies to address this feed gap include fertilising native grass paddocks in late summer, improved timing of early sowing of grazing oats and more accurate cattle turnoff in summer. These strategies are constantly evolving and require further work to reduce the effect of feed supply on the quality of beef grown in our grazing system.

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Pastures from drones: the potential to use UAV's to monitor pasture biomass and quality in temperate grazing systems

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Keywords: pasture, Grass Surface Model, UAV, agriculture

Introduction

The value of regular non-destructive pasture monitoring to livestock businesses is well understood, but existing field assessment techniques used by farmers are labour intensive, qualitative and do not effectively capture the spatial heterogeneity of grazed swards. Existing cost effective remote sensing platforms provide guidance, but at a resolution of 250 m^2 or 30 m^2 at fortnightly or monthly frequency, this platform does not capture the interaction between livestock and the pasture sward, particularly to support accurate assessment of forage quality and abundance ('Food on Offer') required by producers. UAVs have considerable potential to address these shortfalls and provide farmers with a relatively cheap, non-destructive and high resolution pasture assessment, where they govern the frequency of measurement to suit their management needs.

Methods

As part of the FarmDecisionTECH® program, trials from Germany (Bareth *et al.* 2015) and Sweden (Granholm *et al.* 2015) were successfully repeated at a research plot (alpha site) and commercial scale (beta site) near Orange in NSW in the Spring of 2016 and Autumn 2017. Commercially available low cost UAV systems (DJI Phantom 4 and Inspire) were flown collecting overlapping RGB imagery (Figure 1).

Results and discussion

Modelling to produce 3D Grass Surface Models (Biomass) and vegetation indices (quality) was undertaken, with moderate to high correlation (0.7–0.9) with field measured pasture height, biomass cuts, BOTANAL quality assessment and laboratory forage analysis. Similar to other trials the techniques had difficulty tracking small (1 cm) changes in grazed pastures under extreme resource limitation (below grass residuals of 2 cm in height). These results reinforce the potential identified in other trials, but also point to a number of barriers for farmer adoption. This includes flight autonomy and safety, the ongoing need for ground control and calibration, the processing of large payloads in broadband limited environments, trade-offs between UAV system cost and alternatives to RGB cameras, workflow automation and interoperability with other farm planning tools.

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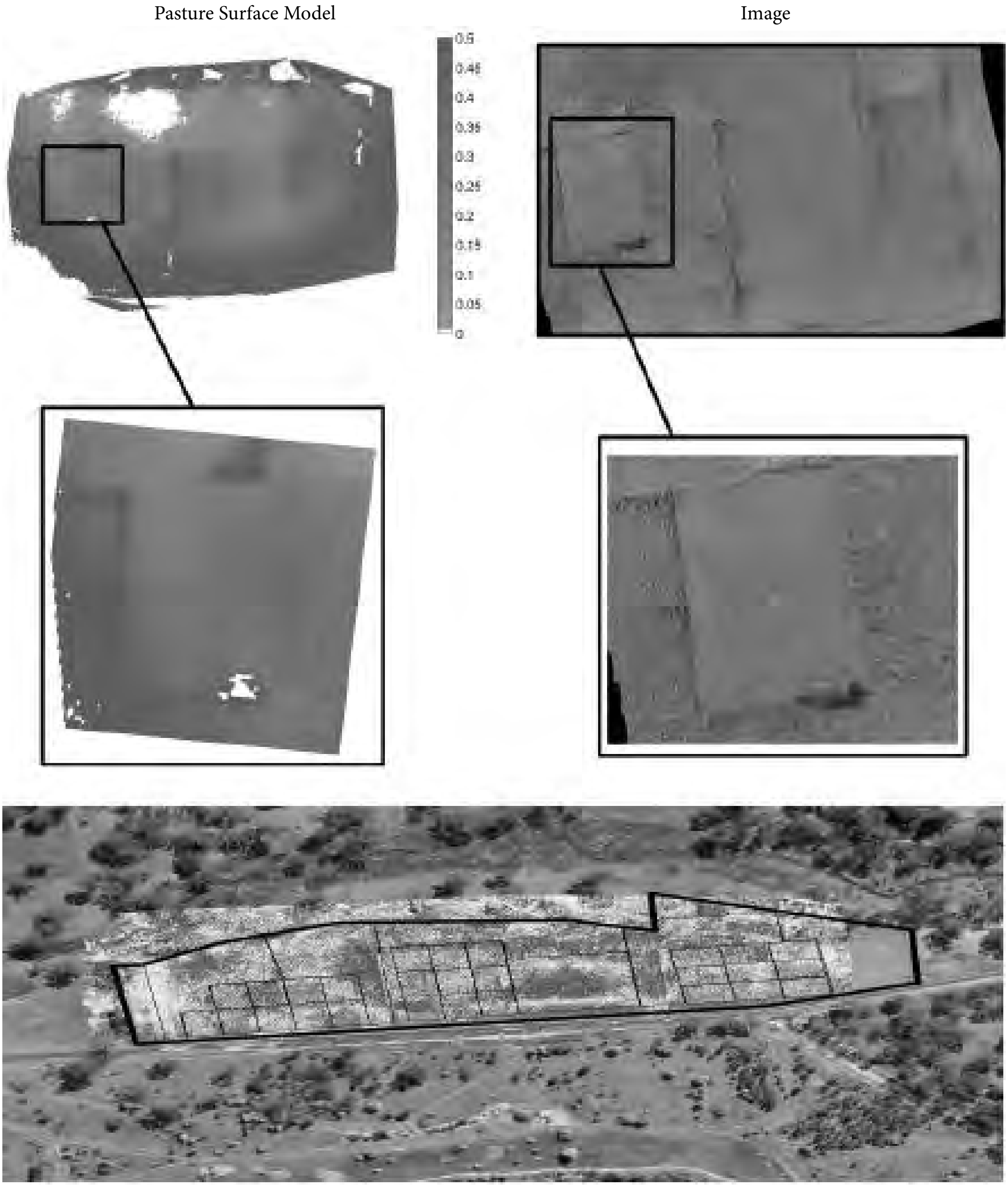

Figure 1. Grass Surface Models at the alpha site (Orange Agricultural Institute) and pasture quality estimate at the beta site. More 'greenness' indicates higher pasture quality.

Making the most of your dry sheep equivalent (DSE) potential

M Monk

Sundown Pastoral Company, Kingstown NSW 2358

The acquisition of agricultural land began in the mid 1960's.The owners of Sundown Pastoral Company (Sundown) have always been market focused and profitability driven with a passion for agriculture. This market focus, profitability and passion unfortunately do not always line up. However, it is the businesses basic principles, and how they have been implemented, that have made this agricultural aggregation the success it is today.

The basic principles that have helped Sundown achieve what they have can be classified into four areas:

1. The **markets** in which they operate – understand them, be customer focused, and ensure quality and quantity of products being produced are never compromised
2. **Efficiencies and economies** of scale – and the investigation and implementation of technologies that enhance the above
3. **Your system** – understand it, monitor it, challenge it, challenge yourself, and then implement the KISS principle (keep it simple stupid)
4. **Risk management** – vertically integrate, diversity and specialisation, aggregate not separate

There are many properties in the Sundown aggregation, and various levels of integration within those properties. Table 1 provides a snap shot of some of the key information and production capacity within the company.

Pasture dry matter (DM) drives production capacity. The pasture base varies across the properties as a result of variation in soil and climatic conditions (Table 1). The pastures support both a steer back-grounding operation for the feedlot and are also used directly for finishing of grass-fed beef. Additional to pasture species selection, preparation of potential

Table 1: Property summary and key data for Sundown Pastoral Company

	Keytah Cattle Operation	New England Cattle Aggregation	Keytah Cropping
Properties Involved /Land area (ha)	One property 6070 ha	18 properties (30,750 ha), now integrated into three management properties (two of which were sold to Paraway in Oct 2016, and remain under Sundown Management, and a Feedlot at Gunnee Station	One property Irrigation – 10,250 ha (63,780 megs) Dryland cropping – 7400 ha
Production Potential	Finishing Cattle – 10 000 head	Finishing Cattle – 54,000 head Feedlot Cattle – 35,000 head	Cotton – 150,000 bales Wheat – 140,000 t
Improved Pasture	Grazing crops – 4050 ha, 1620 ha fallow	18,430 ha, species include lucerne, fescue (summer and winter active), phalaris, cocksfoot, subterranean, gland and white clovers	
Natural Pasture	400 ha Mitchell Grass	12,160 ha, the dominant species are red grass, danthonia, microlena, couch, kikuyu	
Soil types	Basalt (100%)	Sundown Valley – Granites (60%) and Traprock (40%) Paradise Stn – Basalt (100%) Newstead – Basalt (100%) Gunnee Station – Basalt (100%)	Basalt (100%)
Elevation (m)	180	580–1300, pending property	180
Rainfall (annual mm)	550 (Spring/ Summer)	700–1125, pending property (Spring/Summer)	550 (Spring/Summer)

pasture paddocks, plant nutrition assessments and corrections and grazing management are just some of the very important requirements of this successful pasture based business.

Across all the properties, there are now some 12,000 ha that have pastures greater than 10 years old and pasture development still continues. In the last 10 years, another 19,000 ha has been developed. In line with the paper title, driving DSE's is about realising property potential, and capitalising on the opportunities in front of you.

Grazing crops are used in many situations, none more so than at Keytah. At times, up to 2000 ha of lab lab is sown annually, which can also be complemented by oat plantings. Oats is also used on other properties as part of the pasture preparation period. Outside of grazing crops, the pasture compositions vary. There are approximately 3500 ha of lucerne, the majority of which is dormancy 7, 3400 ha of summer active fescue and 6400 ha of winter active fescue, both with gland, white and sub clover, 1000 ha of tropical grasses, and upwards of 12,000 ha of older introduced perennial pasture containing phalaris, cocksfoot, fescue, sub clover and white clover.

The Cattle enterprise revolves around pasture 'backgrounding' for entry to the feedlot. There are clearly defined parameters that enable the weight requirements, at both purchase and feedlot entry, which must be met. Entry weights to the pasture base range between 250–350 kg, and over the typical backgrounding time of 100–150 days, sees these animals enter the feedlot at weights of 400–450 kg. The business has an average daily weight gain (ADG) target of 1–1.2 kg/day averaged across the year.

The issues impacting animal performance that the business can easily influence via management, are stress, animal health, pasture quality, the environment and understanding the breed and type of cattle purchased. Considering all these issues, and taking into account matters like weaning, purchasing, transport, induction/receival, and handling all make for better performance. The Belvior cattle performance technology is used exclusively through the business, and every animal is tracked through its time at Sundown.

Changing the system to achieve the DSE potential

Sundown has a very methodical process; it challenges itself with when looking to develop country and increase DSE's. It starts with **assessing and analysin**g, specifically, understanding the existing system or base you are working with. To capture the full benefit of change you need flexibility and understanding of enterprises and market specifications as well as appreciation of the capacity of a given property to support such production goals. Capital expenditure requires accurate budgeting and planning. To achieve such development, a property plan, a gross margin assessment of existing enterprises and alternative enterprises, a fully costed budget on development and a cash flow budget are all essential. Risk is generally the reason why people are averse to development and DSE change. You must understand the risks and strategies required to undertake change.

Lifestyle is also a major decision in increasing DSE. Your lifestyle will change when increasing DSE's as the enterprise becomes more intense. The usual reaction to this is to increase labour resources, which, in the vast majority of cases, is the incorrect decision. Labour needs to be deployed in a smarter and more efficient manner.

Water is the key requirement when increasing DSE. A very simple analysis says your enterprise requires 50–80 litres/10 DSE/day. The water volume required invariably increases three fold when changing the system, due to the 'new' stock demand that will be managed on the improved pasture. There is a requirement of at least seven days storage as a breakdown is rarely fixed in one day. Extreme weather variations such as heat waves can double water requirements. Good quality water can contribute up to 25% of weight gain. Clean quality water is paramount when increasing DSE. Dam water generally degrades as DSE's are increased. Trough water is the preferred source as this can be strategically placed to aid in pasture utilisation. Additives such as bloat oil can be easily administered in a good trough system if they are required. A backup water system (e.g. a dam) can and will give better security to the system. Water is generally one of the highest development costs to increase DSE.

Soil and Pasture nutrition is a 'not negotiable'. Sundown has had a long history of fertiliser use, which expanded to manure use (chicken litter) in the 1990's. Sundown Valley was the first property to use the manure, with the program expanding, using feedlot manure, to Paradise in the early 2000's and Newstead from 2006. The acquisition of the Gunnee feedlot has also enabled the business to value add their own feedlot manure for the last eight years.

Soil nutrition is simple. Monitoring of paddock fertility is done using an annual soil testing program and nutrient removal budget (based on DSE/ha). A comprehensive soil test will indicate soil requirements and amelioration required. All arable areas are fertilised annually according to those results, 'married' with an understanding of stocking rates and paddock performance. Nitrogen is used annually, with indicative rates varying from 100–120 kg/ha of urea. In general, over the whole operation, there is approximately 18,200 ha that receives annual fertiliser (pending soil test results), with nitrogen additional to that on approximately 12,000 ha. The manure program continues, with up to 4000 ha receiving treatment each year.

Unfortunately, in Australian grazing systems, we have lost direction and advice on the basics of soil chemistry. Graziers are being bombarded with alternatives and silver bullets to solve the soil fertility story. This is one of the most difficult parts of development, if soil chemistry is not understood or advice is being given with a commercial or emotional sway. There are basic guidelines for soil nutrient requirements for all major and trace elements for Australian soils. These guidelines have been developed over the past 100 years. It is an ongoing science and there is no simple recipe and 'cost per kg of nutrient applied' should be the deciding factor. Organic and inorganic sources of nutrients can be successfully used in combination, provided the nutrient value of such sources are known and accuracy of application can be achieved.

All agricultural systems require input of nutrients to function and produce. Nutrients cycle within all plant and animal systems, and contribute to the plants' nutrition needs. However these nutrient levels need to be monitored, and replaced if necessary. With continuous nutrient removal in our produce, there are no "free lunches" in these systems.

Sowing a pasture is the easy bit, keeping it is the challenge. With such a large area of improved pasture to manage, attention to detail pre, at and post planting is paramount. The planning, preparation and development of pastures involves some key stages. These include;

- Fallow-minimum 5 months, ensuring complete weed/insect control
- Manure pre planting with rates typically 2500 kg/ha pending history. This manure is topdressed during the fallow period, with additional fertiliser required at sowing determined from soil test results and applied with the pasture seed the following autumn.
- Planting February – May
- Disc Planter, at 75 mm spacing (3"), enabling planting capacity of 70–100 ha/day
- Planting rates – depending on species or mix being sown, indicative seeding rates are; fescue mix (25 kg/ha), lucerne (12 kg/ha), tropical grasses (10 kg/ha), oats (50 to 100 kg/ha) and lab lab (20 kg/ha)
- Seed treatments – fungicide, insecticide, lime pellet and inoculate (LPI)
- Post planting treatments – broadleaf control six weeks after planting, insect control (boomspray) and spring nitrogen applied, if required, to meet feed demand budgets.

Pasture composition and feed gap management is the secret to increasing DSE. Once the enterprise (type of and size) is determined and market specifications are set, the desired species can be selected. Species selection needs to be carefully thought out, and needs to meet the quality and quantity of feed required. The location of the different pasture mixes listed above is principally driven by soil type and depth, rainfall and temperature. A complex range of species can be very difficult to manage and not achieve consistent weight gain. If required, supplementing pasture systems is useful, however, the cost of supplementation, if not managed, can quickly lead to a decline in profitability.

Grazing management of pastures is simplified if the infrastructure and enterprise is developed to maximise utilisation. Laneways are critical in labour efficiencies and stock movement/management. Utilisation is the easiest and biggest gain that can be made from increasing DSE. Growing DM and turning it into kilograms of meat or fibre is the main focus of the grazing management systems Sundown have developed. There are a wide range of methods, opinions and advice given to graziers on such management, however, in the Sundown system, simplicity is important to ensure utilisation can be achieved.

Managing over 40,000 ha of pasture presents a challenge to achieve utilisation and ensuring weight gain targets can be achieved. Increasing and managing increased intensity is not as simple as just adding livestock. A fully integrated approach is required to ensure that both DSE and kilograms per hectare production targets are achieved. The pasture systems at Sundown have been setup to ensure there is a feed supply all year round and systems are in place to ensure that livestock can be increased or decreased according to the feed quantity and quality that is available.

The management of these pastures is critical to their performance, persistence, and also to the business. As such, there are some basic principles used to ensure this process is simple, effective, and follows the 'keep it simple stupid' (KISS) methodology.

- Flexible rotation
- Majority four paddock rotation (100 ha)
- Mob size usually 250 head (vary depending on weight)
- Movements of stock are determined by physical observations and DM estimates (minimum 1200 kg DM/ha is a trigger point); pasture growth rates (PGR); rainfall; average daily gain (ADG) and the behaviour of the cattle themselves

Some other tools used to help monitor pastures, and the quality of the feed base being produced are forage tests, satellite imagery and drones. Weed control is implemented on an 'as needs' basis, with the main issues being annual grasses and thistles. There are also a few woody weeds. Should it be required, the decision to replant or depreciate pastures should be based on measured performance rather than visual inspections.

Fencing type and paddock size will be determined by enterprise. General principles of rotation and stock type need to be understood fully to ensure success. Experience in systems managed by Sundown Pastoral Company has revealed the following:

- Conventional fencing has longer term labour efficiency benefits,
- Electric fencing is beneficial to temporary subdivision or small operations,
- Paddock design is determined by topography, soil type, water availability and rotation time and,
- Movement of livestock in under seven days has a negative effect on weight gain.

Pitfalls and hidden costs occur in any system change. Budgeting, planning and responding are key aspects to a successful profitable business. Costs can easily blowout with incorrect or ill-informed advice or knee jerk reaction. You need to have systems in place to ensure that the decisions being made are not at the expense of the business.

Understand your end market and ensure you have exit strategies for extreme conditions. Always analyse your decision before you make it. Beware of witchcraft, silver bullets and snake oil. Remember, there are no free lunches, and you get nothing for nothing.

There is a growing industry in Australian agriculture of unproven products that are being claimed to be more efficient because of new technologies. Most of the time these products are more expensive up front, and less efficient, thus result in a higher cost due to loss of production.

The practicalities of technology in commercial sheep production

H Marriott

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Introduction

I am currently working on a commercial sheep and cattle property at Greta in North East Victoria and have been managing farms for the past 10 years. I grew up on a property near Benalla, where Merinos dominated initially before this changed to prime lamb production from a composite ewe base. I completed a Bachelor of Rural Science (Hons) at the University of New England.

Background

My interest in better understanding the variation in individual productivity of animals within a flock started when I was feed-lotting lambs in 2008. When average liveweight gain per day was 250 g but individual growth rates varied from 90–520 g/hd/day, I knew there was more to measuring productivity than purely by using averages.

While I have continued to look at systems to more accurately identify and manage individual animal performance in lamb finishing operations since that time, my recent focus has been on individual variations in ewe efficiency; specifically, how such variation can be manipulated in order to select the best replacement ewes.

In 2014, I completed a Nuffield Scholarship on 'Individual Animal Management in Commercial Sheep Production'. My research focussed on using objective measurement, through electronic identification (eID), to optimise and align animal productivity with end-product specifications.

This paper will highlight some of the key messages I learnt from my study, as well as what I am doing on-farm to optimise the potential of eID technology in commercial sheep production.

Maternal efficiency

By calculating how many kilograms of lamb liveweight each ewe weans (weaned litter weight), and comparing this to her liveweight (at weaning time), a maternal efficiency index can be calculated, thereby allowing comparisons between the most and least efficient ewes. Breeding selection decisions can then be made according to if (and by how much) an individual's production falls above or below the mob average. The weaned litter weight figure also supports selection of favourable component traits, such as fertility (including early conception), number of lambs born, lamb survival, lactation and growth rate of individual lambs or across whole litter.

In current commercial conditions, linking ewes to their lamb/s is done through Pedigree Match Maker (PMM). This technology analyses the sequence and repetition of eID tag reads to determine which lamb/s are being raised by which ewe. Although there are some inaccuracies using this method, these can be minimised by training the flock to behave normally around PMM systems (Figure 1), and by ensuring that monitoring times allow for repeated collection of tag read data. Once established in the annual management calendar, PMM systems provide good levels of accuracy and circumvent the errors associated with ewe selection that is solely based on visual assessment.

Figure 1. Pedigree Match Maker (PMM) is usually set up around a feed or water attractant to get the ewes and lambs to walk past the scanner, which is set up on the side of the wooden pallet. Photo: Hannah Marriot.

Using PMM technology, I am currently linking 2-year-old ewes (on their second lamb) and lambs with an objective to remove the bottom performers from the main breeding flock and to either sell them as 2.5 year old ewes or join them to terminals. The aim is to only keep and breed replacements from my top reproductive performers, based on maternal efficiency.

Some results from matching ewes and lambs are highlighted in Figure 2. In this example, a total of 670 lambs were matched to 400 ewes using PMM. The weaned litter weight (total kilograms of lamb/s weaned) per ewe was 47 kg. However, the range in weaned litter weights varied by 88 kg across the flock – from a low point of 21 kg to a high of 109 kg. On an economic basis, when these lambs were sold as stores ($2.80/kg liveweight):

- There was a $246 variation in the value of lambs sold between the top performing ewe to the bottom performing ewe; and,
- The bottom 25% of ewes weaned 47% of their liveweight ($81 in lamb value) while the top 25% weaned 114% of their liveweight ($182 in lamb value).

As staggering as these differences are, they are further magnified when you consider that ewes are usually allocated the same price per head across any mob, and they are treated the same way in terms of management, nutrition and health inputs. This highlights the significance of the opportunity that exists for individual animal efficiency selection, and subsequent flock productivity, in the sheep industry. These gains would not be possible and/or as quick to achieve in the absence of individual objective measurement.

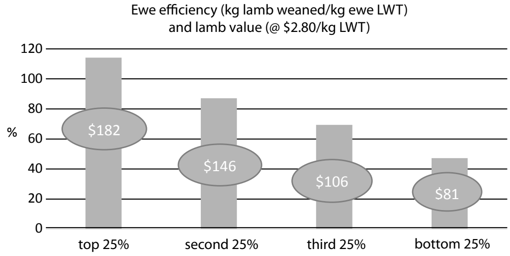

Figure 2. Variation in ewe efficiency (kg lamb weaned/kg ewe lwt) and value of lamb sold (@ $2,80/kg lwt) for the top to bottom 25% of lambs.

Total productivity

Most sheep produce two saleable products, a carcase and wool. Carcases can be in the form of meat or in the form of surplus ewes/stock. Looking at one without the other (as is often the case in Merino enterprises) would be like looking solely at the home team score at a football match. It may not be the highest score but you wouldn't know because you didn't look at the other score. In other words, looking at meat production without wool (or vice versa), could give you biased information that could lead to incorrect – and economically costly – decisions being made. A twin-bearing Merino ewe will most likely have a lower wool cut. If only wool is being measured to keep replacement stock, the twin bearing ewe may be classed-out even though her 'total productivity value' ([fleece value + total litter value]/ewe value) was one of the highest in the flock. Commercially, if we have data that are given commercial value based on wool and meat prices, a ewe can then be classed visually and objectively to identify the best replacements based on economics. In addition, the higher the lambing percentage, the more surplus stock available to select from, thereby increasing selection pressure for multiple trait selection.

Working from the ground up

The fundamental questions to address in running a commercial farming enterprise are:

- What is my breeding objective?
- What is my business objective?

Here is an example I've made up! Let's target 130% lambs marked, selling 70% of lambs as suckers to the export market and increasing wool cut by 0.5 kg a head over the next three years.

Then I think to myself – Where has that come from? What's it based on? Did I just pluck these figures out of the sky?

I have recognised that my key drivers for decision making are economics and labour efficiency. Others could be: environment, what you like doing, where your expertise lie, proximity to market, short- and long-term financial needs, what your children are interested in, etc.

It's important that these issues are considered before setting a breeding or business objective; once established, they can be considered against current production levels and used to establish a sound objective. This all needs to be done before any technology enters the property and before any measuring begins. Understanding a clear (and accurate and achievable) objective is pivotal to ensuring that technology will positively impact your business. Otherwise, it may do the opposite as it is not free to collect data.

Conclusion

Practical use of technology on-farm can help enable increased productivity if the data collected are used to their full potential and aligned with the objectives of the business. Ewe efficiency, monitoring growth rates in feedlots and obtaining product feedback are the areas of work in which I have had experience. In a flock where wool is a major part of the breeding objective, measuring wool value per head will help achieve an accurate 'total productivity' value. When accurate objective measurement is combined with visual assessment, opportunity exists to increase the profitability of the business.

Perennial crop research at NSW Department of Primary Industries, Cowra

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Abstract: *Designing agricultural production systems based on perennial grain crops has the potential to sustainably integrate cropping and livestock systems, particularly in higher rainfall environments. Over the last 10 years, perennial crop research in Australia has demonstrated the potential whole-farm economic benefits, evaluated a range of breeding material over several years, and examined aspects of perennial cropping systems. This paper summarises that effort and highlights the potential value of a dual purpose perennial cropping system from both an economic and ecological stand point. There are several technical challenges to the commercial deployment of perennial crops, concerning persistence, stability of grain yield, and complementarity between grain crops and legumes grown in mixtures. However, with continued global research, these challenges can be overcome allowing new perennial grain crops to successfully integrated into the market.*

Key words: Perennial wheat, persistence, polyculture,

Introduction

World food security depends on annual based cropping systems that produce grains. Cereals, oilseeds and legumes occupy 70% of our agricultural land and comprise the vast majority of calorie intake across a growing population (Glover and Reganold 2010). Modern Agriculture's ability to meet the increasing demand for agricultural products has hinged on simplifying traditional agroecosystems and increased yields through the use of external inputs of energy and chemicals (Bommarco *et al.* 2013). The intensification of agricultural production has been successful in meeting global food demand by increasing productivity per unit area. However, this has come at a substantial environmental cost such as soil degradation caused by the run-down of organic matter in cropping soils and disruption of the hydrological balance within landscapes by the replacement of endemic perennial based vegetation with annual based crop and pasture systems (Lefroy and Stirzaker 1999). Much has been written about the ability to restore function to the landscape and reverse degradation through the use of perennial plants (Crews *et al.* 2016). This has led some to suggest that our agricultural systems need to be 'redesigned' to reduce the negative impacts of current agricultural practice on the environment while increasing agricultural output and landscape resilience (Fedoroff 2015). Developing perennial cereal crops has the potential to offer a more environmentally sustainable grain production system into the future. Reductions in soil erosion, salinity and acidification as well as reduced cost and increased diversity in agricultural production are some of the proposed benefits of incorporating this novel technology (Culman *et al.* 2010).

There is a global effort to perennialise some of our major crops, with around 19 perennial species under development (Kantar *et al.* 2016). Perennial crops can be derived either through direct domestication of a perennial species with selection for improved grain attributes, or through hybridizing annual crop species with a perennial relative to install the perennial habit. Perennial sorghum (*Sorghum bicolor x S. halepense*) and perennial rice *(Oryza sativa x O. longistaminata)* are nearing commercial deployment in Sub-Saharan Africa and Asia respectively. In North America, domestication of a perennial relative of wheat, intermediate wheatgrass (*Thinopyrum intermedium*) or Kernza (Jungers *et al.* 2017), has made its way into the commercial supply chain in small niche markets as beverages, baked goods and side dishes, with further interest from larger milling companies to increase its use across a range of cereal products. With a high demand for sustainably produced food the successful integration of perennial grain into commercial cropping and food processing systems appears promising. The challenge for researchers will be in the continual development of well adapted material and agronomy packages to support commercial production.

Perennial cereal research in Australia

Initial evaluation

The majority of the research conducted on perennial crops in Australia has occurred at the Cowra Agricultural Research and Advisory Station. The focus for Australian research has concentrated on perennial wheat, derived from tall wheatgrass (*Th. ponticum*) or intermediate wheatgrass crossed with various annual wheats. These hybrids have the greatest potential to fit into our current production systems. Initial modelling by Bell *et al.* (2008) suggested perennial wheat producing 40% of the grain yield of annual wheat and an additional 800 kg/ha of grazable biomass over autumn and winter would provide an economically viable addition to current production systems. Since then a range of international breeding material has been evaluated (Hayes *et al.* 2012), with a number of lines showing ability to persist and produce grain for up to four years (Larkin *et al.* 2014). This work demonstrated the proof of concept that it was biologically feasible to grow perennial cereals under Australian conditions.

Grain and graze potential

The economic analysis undertaken in Australia identified that profitability of perennial cereals was enhanced if they could be used for both grazing and grain production. This is supported by the initial field evaluation which concluded that early generation perennial wheat was likely to be best adapted to higher rainfall environments in SE Australia (Hayes *et al.* 2012), where grazing is the dominant enterprise. An initial field study was undertaken to assess the tolerance of four experimental lines of perennial wheat to defoliation, compared to one line of Kernza and a commercial annual winter wheat, cv. EGA Wedgetail which was re-sown annually (Newell and Hayes 2017). The study also examined the forage quality and mineral composition of the breeding lines in order to establish their suitability for animal production. In the first year of the experiment, several of the perennial wheat lines were able to exceed the benchmark of 40% of the grain yield of annual wheat (Table 1). A significant finding of the study was that there was no significant difference in grain yield between Wedgetail wheat and three of the four hybrid lines in the second year of the study, with one line yielding 60% more than the annual wheat control. This result highlights the importance of being able to monitor perennial crop performance over a longer timeframe, because in contrast to annual plants, the relative performance of perennials is not usually favourable in the establishment year. Harvest index (HI) for the annual wheat was significantly higher than all perennial species in both years, indicating a greater proportion of assimilate being allocated into grain yield. The lower HI of the hybrid wheats could suggest that some plant resources are being used to drive post-harvest regrowth. Lines were grown as spaced plants and therefore changes in plant density could be closely monitored. Much of the decline in perennial wheat yield over time previously reported is likely to be attributed to plant mortality rather than reduced yield potential.

Digestibility, metabolisable energy and fibre content of the perennial lines averaged over winter and spring were similar to that of annual wheat,

Table 1. Yearly grain yield (grams/plant) and harvest index (HI) of Kernza, perennial wheat lines (PW) and annual wheat (Wedgetail) (from Newell and Hayes 2017).

Entries	Year 1		Year 2	
	Yield	HI	Yield	HI
Kernza	3.4	5.6	2.8	2.9
PW1	14.7	22.6	17.7	22.5
PW2	11.2	14.2	21.4	15.7
PW3	6.9	15.3	8.1	10.2
PW4	13.1	21.1	30.0	24.7
Wedgetail	30.7	44.7	18.6	41.8
l.s.d Yield (P = 0.05)	5.89			
l.s.d HI (P = 0.05)	2.75			

with crude protein observed to be 62% and 25% greater in the Kernza and the perennial wheats, respectively, compared to Wedgetail (Table 2). In some cases, cumulative biomass of the perennial lines over a 12 month period was more than 3 times greater than that of annual wheat. This is largely attributed to post harvest regrowth observed during summer and autumn. The winter herbage of the perennial lines generally had a higher proportion of Ca, Mg, K and P but lower proportion of Na compared to annual wheat. The study concluded that perennial wheat would provide valuable feed for livestock over a longer grazing window compared to annual wheat. However, due to the imbalance in forage mineral content, livestock grazing perennial wheat during winter are likely to still require Ca/Mg mineral supplementation to mitigate the risk of nutritional disorders in late pregnant or lactating ewes, as recommended in annual grazing wheats. Future research should consider the implications for the grazing enterprise of growing perennial crops in mixtures with a legume, rather than in pure swards.

Polycultures

The vision for perennial grain agriculture is to move away from the simplified monoculture agroecosystem of modern annual cropping to one that mimics natural ecosystems, containing a diverse range of complimentary species (polyculture). A pilot study was undertaken to investigate the impact on crop yield, total biomass and nitrogen fixation in swards sown to experimental perennial wheat lines grown in mixtures with subterranean clover (*Trifolium subterraneum*) in various spatial arrangements (Hayes *et al.* 2016). It was found that clover biomass and regeneration was substantially reduced when grown amongst a vigorous crop canopy (Mix treatment) (Table 3), leading to a reduction in nitrogen fixation of 30–90%. Spatially separating the perennial crop from the legume in alternate drill rows (1_{crop}:1_{clover}) more than doubled legume biomass and reduced weed incursion by 37% compared to where the two species were sown in the same drill row. However, excluding the crop from alternate drill rows inhibits the ability of the crop to achieve complete canopy cover and has a tendency to lower grain yield. The inability of the perennial crop to compensate for wider row spacing facilitates greater legume survival within the crop canopy and increases overall productivity (crop + legume biomass) of the system. With better integration of livestock and cropping components, the shortfall in grain yield could potentially be alleviated by the extra grazable dry matter produced by the spatial separation of species. The combination of crop and legume in

Table 2. Crude protein, dry matter digestibility (DMD), metabolisable energy (ME), neutral detergent fiber (NDF), acid detergent fiber (ADF) and ash content of forage averaged over winter and spring from Kernza, perennial wheat lines (PW) and annual wheat (Wedgetail) (from Newell and Hayes 2017)

Entries	Crude protein (%)	DMD (%)	ME (MJ/kg DM)	NDF (%)	ADF (%)	Ash Content (%)
Kernza	32.8	91.2	14.1	31.9	12.4	12.8
PW1	24.4	84.0	12.8	39.5	20.2	11.7
PW2	25.1	89.0	13.7	39.7	18.5	9.9
PW3	26.5	87.0	13.7	38.0	18.2	11.2
PW4	25.0	83.7	13.3	40.0	21.0	12.3
Wedgetail	20.3	85.0	12.8	39.0	19.5	9.0
l.s.d (*P* = 0.05)	1.29	1.97	0.34	1.92	2.31	2.04

Table 3 The effect of row arrangement on perennial crop grain yield (kg/ha), clover dry matter (t/ha), clover germination (plants m^{-2}) and weed incursion (%) (from Hayes *et al.* 2016)

Drill row configuration	Grain Yield (kg/ha)	Legume herbage (t/ha)	Clover germination year 2 (plants m^{-2})	Weed (%)
1_{crop}:1_{clover}	939	2.23	230	14
Mix	1030	0.97	78	37.3
Nil Legume	1240	0.05	0	55
l.s.d (*P*=0.05)	ns	0.29	46	8.7

grazable biomass may also improve the overall quality of the forage and limit the need for mineral supplementation of grazing animals.

The profitability of perennial cropping systems based on crop-legume mixtures is enhanced by reduced nitrogen fertiliser costs. When estimates of the total inputs of fixed N from the clover were compared with the amounts of N removed in grain by the different perennial wheat treatments, it appears feasible that a companion legume could fix sufficient N to maintain the N balance of a perennial cropping system producing 1.5–2.0 t grain/ha each year.

More research is required to refine management strategies and define yield potential of perennial crops grown as polycultures. A range of management strategies should be tested in future research to manipulate competition dynamics between crop and legume species to optimise production, including choice of companion species, seeding density and spatial configurations.

Conclusion

The future for perennial crops appears promising as current research has demonstrated that a genuinely perennial cereal crop is biologically feasible in Australian environments and that perennial cereals can contribute significantly to a dual purpose grain and graze production system. Global demand for sustainably produced grain is growing and initial deployment of current perennial grains into this market has shown success with the release of products such as Long Root Ale and significant investment by General Mills in other perennial cereal product development in the United States.

However, there are several technical aspects requiring further research to progress perennial cereals towards large-scale commercialization. Future perennial crop research needs to focus on several key areas to improve persistence through adaptation to local environments, stabilising grain yield over time and improve end use grain quality. Development of a novel cropping system will also be an important component of research to move away from crop monocultures and produce profitable perennial mixtures of cereals and legumes. This will require global collaboration between organisations and development of multidisciplinary teams across the development pipeline to successfully integrate perennial crops into commercial cropping and food processing systems.

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Potential benefits of internal pelvimetry in Merino ewes

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Abstract: *The sheep industry loses $540M revenue per annum due to perinatal lamb mortality. Industry extension and adoption strategies aim to reduce perinatal lambing losses to environmental factors such as starvation/mismothering, difficult birth exposure and predation through programs to improve ewe body condition and feed availability. However, in well managed flocks, lamb mortality remains around 20% with 48% of these losses explained by difficult or prolonged birth. To combat this, a method to identify breeders most at risk of dystocia needs to be developed. One proposed method to achieve this is through internal measurement of the pelvic inlet area. Ewes will undergo pelvic measurement with callipers at the Cowra Agricultural Research Station during 2017 with this being the first time such evaluation has occurred in Australia. Over 450 ewe hoggets will be measured for frame size, weight, condition, pelvic dimensions and lambing ease, while their lambs will be measured for birth weight and physical dimensions of the face and shoulders. The long-term view we hold is that if the pelvis can be successfully measured, then tools for sheep and seedstock producers can be developed in the form of genetic selection and ewe management to reduce perinatal mortality in Australian breeding flocks.*

Key words: dystocia, lamb survival

Introduction

In NSW studies involving Merino and crossbred ewes, average lamb losses are 16.5% for singles and 31.5% for twins (Fowler 2007). Dystocia explains 17.7% (Luff 1980) to 48% (Refshauge *et al.* 2016) of pre-weaning lamb losses. When the cost of ewe mortality due to dystocia is included in the net cost of perinatal mortality, the loss to industry is $540M (Lane *et al.* 2015).

Currently, the available tools to minimise the risk of dystocia include strategic management of ewe nutrition and sire Australian Sheep Breeding Values (ASBVs) for the genetic traits of lambing ease and birth weight. Producers manage ewe nutrition to avoid overfat single-bearing ewes and/or skinny twin-bearing ewes, but only those that adopt real-time ultrasound pregnancy scanning and who direct their contractor to scan for twins are in a position to utilise such a strategy. About 30% of producers are using ultrasound pregnancy scanning, and perhaps some 60% of these identify twin lambs (Refshauge and Shands 2013).

There is a common belief within the industry that a larger frame size in ewes reduces the likelihood of difficult parturition. However, to collect the data necessary for calculation of lambing ease and birth weight ASBVs, ram breeders must be in the lambing paddocks making observations and collecting newborn lambs and not all studs collect such information.

In cattle it has been found that there is a significant relationship between pelvic inlet area and calving ease (Holm *et al.* 2014) and genetic relationships between frame size, birth weight and pelvic area. These relationships are positive in association; therefore an increase in one leads to an increase in the others (Benyshek and Little 1982; Morrison *et al.* 1986; Glaze *et al.* 1994; Koots *et al.* 1994; Upton and Bunter 1995). However, increasing frame size leads to larger birth weights, negating the potential benefits of a larger pelvis. Clearly more needs to be understood for sheep, a species that has larger litters and considerably higher neonatal mortality than cattle.

Dystocia

Dystocia is defined as a "difficult birth" by George (1975). The frequency of dystocia in Australian flocks is between 3 and 53.6% dependent upon breed of sheep and environmental factors (Hinch and Brien 2014). All causes of dystocia are identified in Table 1, which identifies feto-pelvic disproportion as the leading cause that also has the potential to be selected against. Feto-pelvic disproportion is the mismatch between foetal size and the size of the pelvic inlet.

Meat & Livestock Australia (2015) found that dystocia was the third most costly health condition influencing sheep performance, costing the sheep industry $142M per annum (Lane *et al.* 2015). Dystocia has been linked to 40% of perinatal lamb losses, mostly arising from difficult and delayed birth (Holst 2004). The most recent neonatal lamb autopsy study shows that the inclusion of brain injury assessment during the autopsy increased the number of lambs categorised in the broad class of dystocia, to 48% (Refshauge *et al.* 2016). This broad class of dystocia includes those lambs physically stuck in the birth canal, as well as lambs that die very soon after birth or up to 5 days after birth. The commonality between these lambs is lesions of the brain and blood vessels of the central nervous system (brain, spinal cord and spinal column). While dystocia causes significant financial challenges to the sheep industry it is important to remember that there are also significant ethical and welfare issues associated with the management, prevention and treatment of dystocia. These welfare and ethical concerns include prolonged postpartum periods resulting in higher stress levels associated with pain and loss, uterine infections and/or cervical stenosis and reduced reproductive performance (van Rooyen *et al.* 2012).

Table 1. Causes of dystocia and their relative occurrence (%) in ewes (from Thorne and Jackson 2000).

Cause	Relative Occurrence
Fetal maldisposition	50%
Obstruction of the birth canal	35%
Fetal-pelvic disproportion	5%
Fetal monsters/ abnormalities	3%
Others	7%

Table 2. Effects of the use of internal pelvimetry for selection in heifers on calving fate, after adjusting for lean body weight (from Holm *et al.* 2014).

Fate	Dystocia	Unassisted Birth	Calf birth weight
Culled	58 %	19%	29.0 kg
Retained	28%	41%	29.5 kg

Pelvimetry

Pelvimetry is the measure of the dimensions of the pelvic inlet. The area of the pelvic inlet can be calculated through a radiographic technique (Haughey and Gray 1982 and Cloete *et al.* 1998) or via a pelvic meter (Rice and Wiltbank 1970). The pelvic meter has been widely used in cattle and has successfully resulted in a higher proportion of unassisted births as shown in Table 2 (Holm *et al.* 2014). A South African study using Dorper ewe lambs examined the use of internal pelvic callipers to measure pelvic dimensions and to determine the correlation between body parameters and pelvic inlet area (van Rooyen *et al.* 2012). It was found that pelvic area can be successfully measured using internal callipers, however, there were only weak correlations between those measures and external body parameters (Table 3), leading to the imperative to measure internal pelvic dimensions in Australian sheep.

Methodology

Modified sheep callipers will be used to internally measure the pelvic dimensions (height and width) of ewes, as shown in Figure 1. To achieve accurate measurements on live animals the assessor will calibrate

Table 3. Correlation of pelvic measurements with the body parameters; body weight, shoulder height, chest depth, shoulder width, hindquarter width, rump length, chest projection and rump slope from a South African study (van Rooyen *et al.* 2012).

	Body Weight	Shoulder Height	Chest Depth	Shoulder Width	Hind-quarter Width	Rump Length	Rump Slope
Pelvic Width	0.26***	0.12*	0.24***	0.11NS	0.30***	0.04NS	0.20***
Pelvic Height	0.24***	0.09NS	0.24***	0.10NS	0.24***	0.03NS	0.27***
Pelvic Area	0.24***	0.10NS	0.26***	0.12NS	0.25***	0.05NS	0.26***

Level of significance: * = P < 0.05, ** = P < 0.01, *** = P < 0.001 and NS = not significant the modified sheep callipers based on their technique. The calibration occurs through the comparison of live measurements to the same measurements collected post-slaughter. In van Rooyen, Fourie, & Schwalbach (2012), a correlation of 80% between live and slaughtered animals is considered adequate. Following initial training calibration tests in abattoirs, the pelvic dimensions of maiden Merino hogget ewes will be undertaken at the Cowra Agricultural Research Station. These ewes will be assessed for pelvic height and width along with other body height and weight parameters. The hoggets will progress normally through their pregnancy. During lambing, ewes will be measured for parturition performance, such as lambing ease, while lambs will have birth weight, litter size, sex, meconium score, thorax and cephaly recorded. This data will then be analysed to determine the association between pelvic dimensions, body parameters and dystocia. The collection of data for all these traits will allow for the analysis of pelvic dimensions and its association with dystocia and lamb mortality.

Discussion

Dystocia results in significant lost revenue for producers and lower welfare for affected ewes and lambs. Since there is no method available to completely prevent the occurrence, producers devote their time to the treatment of ewes experiencing dystocia or to restricting nutrition to minimise prevalence. Strategies used in cattle present opportunities to develop methods for the measurement of pelvic dimensions in sheep. This research aims to develop a technique that is suitable for industry adoption, and thereby substantially reduce the financial and welfare impacts of dystocia on the Australian sheep industry.

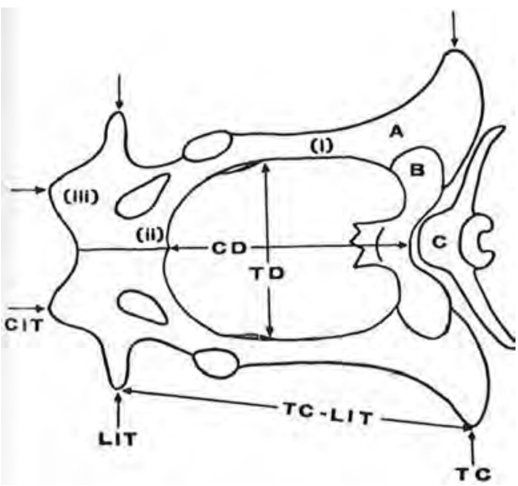

Figure 1. Sheep pelvis, ventral view. A, Ossa coxarum, (i) Ilium, (ii) Pubis, (iii) Ischium; B, Sacrum; C, Last lumbar vertebra; CIT, Caudal tuber of the tuber ischia; LIT, Lateral tuber of the tuber ischia; TC, Tuber coxae; CD, Conjugate diameter; TD, Transverse diameter (from Fogarty and Thompson 1974).

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The effect of extensive feeding systems on growth rate, carcass traits and meat quality of lambs

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Abstract: *This short paper will cover a few examples of published work that has reported the effects of feeding lambs various forages and also provide a table summarising the results from a review of the literature. Literature already shows that finishing lambs on high-quality pasture/forages can produce satisfactory growth rates without compromising carcass and meat quality traits. Lately, consumer demand has focussed on products perceived as 'healthy', and that are produced where animal welfare is optimal and under systems which do not impact negatively on the environment. This has heightened interest in lamb production under extensive systems, as lambs raised on pasture/forages can meet many of these specifications. For example, lambs fed higher-quality green pasture can produce meat with greater amounts of health-claimable omega-3 fatty acids such as EPA + DHA than feeding systems based on feedlot pellets, grain, or dry pasture/straw. It is apparent that in some previous published research, the number of animals allocated for each treatment and the lack of replicates, makes it difficult to formulate a correct understanding of the effect of forages on lamb carcass and meat quality. But overall, there are minimal differences for meat and eating quality traits between forages, although some do exhibit higher levels of vitamin E, a natural antioxidant which can be important in lessening lipid oxidation and extending shelf-life of meat.*

Key words: forages, fat levels, tenderness, fatty acids, sensory traits

Introduction

The quest for 'healthy' food and the desire for better nutritional value and sensory properties of meat is the new market demand. A number of strategies have been used to supply sheep meat according to this new consumer demand, including the use of genetics which has seen the development of breeding systems that can now account for meat quality traits (Hopkins and Mortimer 2014). The other major approach has been to develop feeding systems as a part of production systems and to use the diet offered to sheep, specifically lambs, as a means to improve meat characteristics (Ponnampalam *et al.* 2016).

When developing feeding systems, the peculiarities of production systems must be considered (Zervas and Tsiplakou 2011). Lamb meat production in some countries is based on extensive feeding systems that can include irrigated, dryland, green and senesced pastures (Ponnampalam *et al.* 2014), but animals raised in these systems can have slower growth rates, thus affecting the efficiency of production (Carrasco *et al.* 2009) and the ability to reach target liveweights within a particular period. Often in such systems it is necessary to provide additional feed as supplement to improve energy and protein balance and thereby satisfy the nutritional requirements for optimal growth and carcass production (Turner *et al.* 2014). There have been a number of studies conducted to determine the effect of feeding systems (intensive or extensive) on lamb growth rates, carcass characteristics, and meat quality. This paper will concentrate on a selection of studies that illustrate some important findings within the context of extensive feeding systems and provide a summary table to outline the outcomes on meat quality.

Lamb production systems

Extensive production systems are diverse and are determined, for the most part, by environmental conditions and survival capacity of the pasture species, which all have an impact on the pasture growth cycle and feed availability. Depending on the types of pasture and the nutrient availability, the performance of lambs finished on pasture can be comparable to those finished in a feedlot system. Recently, it was shown that lambs finished on lucerne pasture had similar growth rates and carcass traits compared with those finished on a commercial feedlot diet (Ponnampalam *et al.* 2017). Furthermore, lambs finished on perennial pasture, mainly lucerne, showed a higher growth rate and greater carcass weight than lambs fed annual ryegrass and grain supplements (Burnett *et al.* 2012).

Lambs maintained under grazing have a different feeding behaviour and have more physical activity than lambs maintained under indoor systems, and this behaviour may influence their patterns of feeding, due to a difference in social familiarisation by lambs that graze in flocks compared to those housed indoors (Zervas *et al.* 1999). Their activities affect metabolism, causing a higher mobilisation of lipid reserves than mobilising energy reserves of muscle tissue. This, in turn, reduces the level of carcass fatness and consequently, lambs grazing in general have less fat compared to lambs fed in indoor systems (Díaz *et al.* 2002).

Another important factor for lambs under extensive grazing systems is the selectivity of preferred plant species in the diet. The composition of the sward, either young or matured, and the nutrient availability of the sward provide options for the lambs and this can change the selection pattern (Penning *et al.* 1993). Grazing on mixtures of plants allows lambs to select, and this selection will not be necessarily based on the nutritional value of the plants, making it difficult to predict the actual nutritional quality of what is eaten (Ramos and Tennessen 1992). Sheep preference for grass over legumes was found by Norton *et al.* (1990); and in other studies sheep showed a preference to select clover in mixed swards (Ridout and Robson 1991; Parsons *et al.* 1994). Ponnampalam *et al.* (2014) found the growth rate was higher for lambs grazing on annual ryegrass pasture, compared with lambs fed lucerne pasture or a feedlot ration, but carcass weights were similar, indicative of variation in gut content or non-carcass components between groups. Penning *et al.* (1997) reported greater selectivity of white clover over perennial ryegrass by sheep offered a mixed pasture, and this preference for the kinds of plants or even parts of plant can influence performance, carcass characteristics, and meat quality.

The pastures available for sheep to graze are often a mix of natives and introduced species and the latter can increase the quantity of biomass and nutritional value, and thus the growth of animals grazed on such pastures (Arvizu *et al.* 2011) and such an approach is a useful strategy. Previous studies showed the prospects of forage production and its nutritional value across the different seasons of the year. Hume *et al.* (1995) evaluated six mixed pastures and found that a mixed pasture of perennial ryegrass (*Lolium perenne L.*) plus chicory (*Cichorium intybus L.*) and red clover (*Trifolium pratense L.*) can produce more dry matter per hectare in winter than a mixed pasture of tall fescue (*Festuca arundinacea Schreb.*) plus chicory, prairie grass (*Bromus willdenowii Kunth*) plus chicory, or chicory alone, which are more productive in the summer period. Annual ryegrass (*Lolium rigidum* Gaud.), which shows high productivity in winter and in the early spring, senesces fast and has reduced soluble carbohydrates and essential fatty acids in the late spring (van Ranst *et al.* 2009) and autumn periods (Burnett *et al.* 2012). Pastures of chicory plus arrowleaf clover and lucerne had higher digestible organic dry matter (DOMD) and crude protein than brassica, bladder clover, serradella, and lucerne plus phalaris in the middle-spring period (McGrath *et al.* 2015), and those forage-types also produced lambs with higher dressing percentages and fatter carcasses (De Brito *et al.* 2016).

Monoculture pastures of chicory and white or red clovers have been reported to increase lamb growth rates during the summer and autumn period compared to perennial ryegrass (Fraser and Rowarth 1996; Moorhead *et al.* 2002; Fraser *et al.* 2004). An increase in performance of lambs fed mixed pastures of chicory, plantain, white clover, red clover, and ryegrass was observed from birth to weaning in spring (Kenyon *et al.* 2010). Either monocultures or mixed pastures have the potential to improve growth rate and carcass weight of lambs grazing for short periods whilst high levels of good-quality biomass are produced. When high-quality forages are available for consumption, lambs fed pastures do not appear to have any disadvantage in terms of growth rate, carcass, and meat quality compared to those run under more intensive feeding systems.

When comparing the production differences between lambs grazing under extensive feeding systems, it was apparent that many studies included insufficient replication and/or studied only small numbers of lambs. These factors make it difficult to compare outcomes between finishing studies as they hinder the interpretation of the results.

Lamb growth

It is known that the feeding regime has an influence on lamb growth rate and weight gain. When lambs are raised on pasture the available forage mass can influence intake, performance, and body weight (Turner *et al.* 2014). Lambs fed legumes have more efficient dietary protein utilisation and grow faster than lambs fed grass, in part due to a more rapid rate of digestion (Fraser and Rowarth 1996; Fraser *et al.* 2004; Speijers *et al.* 2004; Merry *et al.* 2006; Howes *et al.* 2015). The similar growth rate observed for lambs fed either chicory or lucerne (Young *et al.* 1994; Hopkins *et al.* 1995c) may have been due to the similar quality of these forage types.

Lambs grazing on red clover (cv. Merviot) had higher live weight gains and needed fewer days to reach slaughter-weight than lambs fed lucerne (cv. Luzelle) and perennial ryegrass (cv. Abersilo) (Fraser *et al.* 2004); and the authors attributed this partly to a higher herbage intake from lambs fed red clover and also to improved nitrogen utilisation. Higher live weight gain also was observed for lambs on mixed pastures (chicory – *Cichorium intybus* cv. Choice; plantain – *Plantago lanceolate* cv. Ceres Tonic; red clover – *Trifolium pratense* cv. Sensation, and white clover – *Trifolium repens* cv. Tribute) than for lambs on ryegrass-dominant pasture (*Lolium perenne* cv. Stirling AR1) (Hutton *et al.* 2011). Higher crude protein and metabolisable energy, as well as lower fibre, were found for the mixed-pasture treatment, providing better forage quality for the conversion of feed into animal products. Campbell *et al.* (2011) evaluated Brassica goliath (*Brassica napus, cv* Goliath); Brassica winfred *(Brassica napus, cv* Winfred); turnip *(Brassica rapa, cv* Hunter); radish (*Raphanus sativa, cv* Graza), pasture commando (*Lolium perenne, cv* Commando); plantain (*Plantago lanceolate, cv* Tonic), and red clover (*Trifolium pratense, cv* Colenso), and they found higher live weight gain for lambs fed on Brassicas goliath and winfred independent of sex, and lambs fed on radish had lower carcass weights and just maintained their live weight. However, it is difficult to evaluate the effect of the forages on nutrient intake and animal characteristics based on this work, since the authors did not specify the feed value of the forages, there was an absence of replication and there was a large variation in the number of animals for each treatment (10 to 31) which can introduce bias in the interpretation of results and confound the real effects of forage types.

Feeding systems based on pasture are cheaper and have attracted interest by producers because the meat is viewed by consumers as more natural, 'healthier', and the production systems are considered more animal welfare friendly (Hersleth *et al.* 2012; Vasta *et al.* 2012). This has led to the development of 'pasture assured' programs to meet consumer demand. Furthermore, the increasing price of cereals (maybe not in 2017!) ensures interest in pasture-based diets (Ripoll *et al.* 2008). Nevertheless, when forage-based feeding systems are evaluated, the forage value and the efficiency of utilisation are very important for animal production. Forage utilisation efficiency can be determined by the feeding value of the forage, the voluntary feed intake (influenced by palatability), apparent digestibility, and efficiency of utilisation of digested nutrients (Barry 2013). Besides this, some forages such as plantain and chicory contain condensed tannins which have an anthelminthic effect that reduces worm burdens on the animal (Woodfield and Easton 2004), and the condensed tannins also help to reduce protein degradation in the rumen, which may increase the availability and absorption of non-degradable protein in the gut and nitrogen utilisation in the body (Ripoll *et al.* 2008).

Carcass characteristics and meat quality

Lambs under grazing systems produce carcasses with less fat and, consequently, leaner meat, and they are produced at a lower cost than lambs grown indoors on a feedlot diet or with supplementation (Zervas *et al.* 1999). The market preference is changing and the demand for more 'healthy' food is increasing (Zervas and Tsiplakou 2011), meaning that animals raised on extensive feeding systems can be a good strategy to meet the consumer demand for lean meat. De Brito *et al.* (2016) found fatter carcasses for lambs fed chicory plus arrowleaf clover, lucerne or brassica than lambs fed lucerne plus phalaris, or bladder clover, and they attributed this to the higher content of metabolisable energy and crude protein for chicory plus arrowleaf clover and lucerne pastures. However this did not follow for brassica which had a lower metabolisable energy (ME) and crude protein (CP) than several of the other forage-types evaluated. Thus the rumens ability to process feeds will vary and this will be reflected in carcass fat levels.

In the work of De Brito *et al.* (2016) there were minimal differences in meat quality between lambs. Related to this some authors have not reported a difference in shear force values (measure of toughness) for meat from lambs grown under different grazing systems (Young *et al.* 1994; Hopkins *et al.* 1995a,c; Ekiz *et al.* 2012; De Brito *et al.* 2016; Table 1). However, Hopkins *et al.* (1995b) evaluated the meat of lambs fed lucerne, lucerne silage, lucerne plus oats, or oat-lupin grain and they found a

Table 1. Summary of number of animals, replicates and predicted means for meat quality characteristics of *longissimus* muscle of lambs fed pasture.

Diet	No animals	No replicates	pH at 24 hrs	Shear force (N)	L*	a*	b*	Reference
Pasture								
Forage rape	60	0	5.5	26.5	37.1	15.2	8.9	Hopkins *et al.* 1995a
Irrigate pasture	65	0	5.6	30.5	35.1	15.0	8.1	Hopkins *et al.* 1995a
Chicory	20	0	5.6	43.2	36.2	14.2	7.0	Hopkins *et al.* 1995c
Lucerne	20	0	5.6	41.2	36.8	14.1	6.9	Hopkins *et al.* 1995c
Dryland pasture	54	0	5.8	22.6	39.2	14.1	7.3	Hopkins *et al.* 1997
Irrigated pasture	54	0	5.7	21.5	40.8	13.9	7.3	Hopkins *et al.* 1997
Lucerne	40	2	5.6	–	36.7	17.8	6.8	Hopkins and Nicholson 1999
Oak-wooded pastureland	23	0	5.6	–	38.6	16.4	5.2	Díaz *et al.* 2002
Natural pasture	16	2	5.6	–	41.6	7.60	9.8	Priolo *et al.* 2002
Alfalfa pasture	24	2	5.6	–	48.0	8.9	9.5	Ripoll *et al.* 2008
Pasture + Wheat stubble (Weaned)	12	0	5.7	69.7	35.4	12.3	0.8	Ekiz *et al.* 2012
Pasture (Unweaned)	12	0	5.6	54.9	37.3	12.0	0.9	Ekiz *et al.* 2012
Naturalized pasture	13	0	5.5	14.8	41.1	19.9	9.2	Ramírez-Retamal *et al.* 2014
Rangeland pasture	11	0	5.5	17.7	41.0	19.6	9.3	Ramírez-Retamal *et al.* 2014
Brachiaria spp and *Cynodon* spp	40	2	–	57.9	39.3	15.9	10.1	Ricardo *et al.* 2015
Bladder clover	12	3	5.6	34.6	38.0	15.5	1.2	De Brito *et al.* 2016
Brassica	12	3	5.6	36.2	37.2	16.0	1.1	De Brito *et al.* 2016
Chicory + Arrowleaf clover	15	3	5.6	34.3	38.9	15.8	1.5	De Brito *et al.* 2016
Lucerne + Phalaris	11	3	5.6	36.3	38.0	15.9	1.6	De Brito *et al.* 2016
Lucerne	12	3	5.6	37.4	38.5	15.2	1.2	De Brito *et al.* 2016

Where L* = lightness of the meat colour; a* = redness of the meat; b* = yellowness of the meat difference in shear force just between lucerne plus oats and oat-lupin grain treatments, without differences in pH and fat content. From this, it could be speculated that the higher shear force value for lambs fed oat-lupin grain could be attributed to a higher content or insolubility of connective tissue in the muscle. However, since there was **no replication** in this study (Hopkins *et al.* 1995b), it is difficult to confirm whether there was a direct dietary effect on shear force.

In terms of eating quality De Brito *et al.* (2016) found no effect on this trait from feeding the five different forages. Interestingly the work of Hopkins *et al.* (1995a) showed that if lambs were fed for an extended period (3 months) on brassicas, trained panellists could detect off flavours compared to meat from lambs grazed on a perennial pasture. For both the M. *longissimus thoracis et lumborum* (LL) and M. *biceps femoris* (BF) from rape-fed lambs, flavour was considered significantly ($P < 0.05$) stronger than for the same muscles from pasture-fed lambs, as was the aroma of the LL. Overall, the BF from pasture-fed lambs was significantly ($P < 0.05$) more acceptable to panellists than BF from rape-fed lambs, with no difference for the LL. However there was again no replication of treatments unlike the study of De Brito *et al.* (2016), so it is not possible to extract any general conclusions from the work. **Lack of replication** is also often seen in 'industry based' experiments.

Flavour is one of the attributes of meat palatability and is also the most important sensory characteristic of sheep meat affecting consumer preference when tenderness is constant (Thompson *et al.* 2005; Díaz *et al.* 2011). It is therefore an important attribute to be considered when comparing lambs fed on different forage types. According to Mahgoub (2000), another important characteristic is the fat content of the meat, since it improves the palatability, texture, juiciness, and flavour. Some authors (Masters *et al.* 2006) found no difference in meat flavour of lamb meat from lambs fed different species when they evaluated Prima gland clover (*Trifolium glanduliferum* Boiss) and Dalkeith subterranean clover (*Trifolium subterranean* ssp. *subterranean* L.). Norman *et al.* (2013) studied the effect of high-quality forage subterranean clover (*Trifolium subterranean* L.) and bladder clover (*Trifolium spumosum* L.) and they found that for lambs grazing on both species there was no significant impact on sensory attributes (juiciness, flavour, odour, overall acceptability, and residual fat in the mouth), with high acceptability by consumers for meat from lambs grazed on both species of clover.

Grazing systems also increase the concentration of conjugated linoleic acid (CLA) in meat (Webb and O'Neill 2008; Scerra *et al.* 2011; Ramírez-Retamal *et al.* 2014) and the concentration of health-claimable omega-3 EPA + DHA (eicosapentaenoic acid + docosahexaenoic acid). Diets rich in forage promote the growth of fibrolytic microorganisms that are responsible for the hydrogenating process in the rumen and, consequently, this increases the production of C18:1 trans 11 (precursor of CLA in tissue) and CLA (Bauman *et al.* 1999). The total fatty acid composition can differ between the forage types; the proportion of C18:1, C18:2, and C18:3 was highest in the meat of lambs grazed on red clover (legume) compared to meat from lambs grazed on lucerne or perennial ryegrass (Fraser *et al.* 2004), and this finding was attributed to a higher polyunsaturated:saturated (P:S) ratio for the legume compared to perennial ryegrass and also to the higher dry matter intake observed for lambs grazing on the legume. However in the work of De Brito *et al.* (2017) there was little difference in the fatty acid profile across two muscles from lambs fed five different forage types. A diet based on green pasture will increase the omega-3 polyunsaturated fatty acid (PUFA) concentration in meat (Turner *et al.* 2014; Ricardo *et al.* 2015), provide antioxidants (such as vitamin E) and anti-inflammatory properties that are transferred to meat and other animal products (Zervas and Tsiplakou 2011), thus improving the oxidative stability (Faustman *et al.* 2010; Ponnampalam *et al.* 2012) compared to a diet of senesced pasture. Unfortunately, with a diet based only on forage due to changing environmental conditions (onset of summer), it is often necessary to provide supplementation for finishing lambs, and the kind of supplementation can alter the meat fatty acid concentration and, consequently, this can have an effect on meat quality and the sensory attributes.

Based on a comparison of published work, it is evident that there is inconsistency about the effect of extensive feeding systems on the eating quality of lamb meat. In general, the effect of extensive feeding systems on sensory attributes of lamb meat are complex, and more controlled studies are necessary in this area to develop a more complete understanding since many pre- and post-mortem factors can influence eating quality (Resconi *et al.* 2009).

Conclusions

Lamb production under extensive feeding systems is an important strategy to decrease spending on inputs and to produce meat in a way that respects the environment, animal welfare, and which also produces 'healthier' meat for human consumption. A forage-based diet can produce lean lambs with a low fat content; however, the use of forages with high feeding value can provide lambs with good growth rates, heavy carcass weights, and 'healthier' meat. The meat of animals fed forage-based diets has a high proportion of PUFA's, a low omega-6:omega-3 ratio, and sometimes higher levels of natural antioxidants which is beneficial to avoid oxidation of meat with high PUFA content. However, there are some factors that can change the meat quality characteristics (forage species and cultivar, feeding length, climate, forage management, supplementation, physical exercise, diet selection, animal breed, animal individual genetic aspects, and others factors), and sometimes the interaction of these factors can induce incorrect interpretation of results. Thus, careful evaluation of different forage-types should be conducted so as to establish the nutritional value and the content of fatty acids and antioxidants of forages available to finish lambs. Related to this, in most of the published research, the number of animals allocated for each treatment and the lack of replicates makes it difficult to formulate a correct understanding of the effect of forages on lamb carcasses and meat quality. Future research should concentrate on conducting well-designed experiments with an adequate number of lambs and appropriate paddock replicates per treatments when investigating the potential of finishing lambs using legumes, improved pastures, and specialised forages on growth rate, carcass traits, and the nutritional value of meat.

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Dual-purpose cereal variety evaluation in mixed farming systems of NSW – research update

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Key words: Grazing cereals, forage, dry matter, wheat, oats, triticale, barley.

Background

Dual-purpose crops give growers an opportunity in mixed farming system to produce additional forage in key periods of the year when pasture systems might not be able to meet livestock requirements. They can be substituted for grain-only crops or in more intensive livestock operations for forage-only crop types, allowing the grain produced to be used on farm or sold. Selecting the right crop type, variety and then managing them properly can boost returns across both the livestock and grain production units in the farm business. A jointly funded project between NSW DPI and the Grains Research and Development Corporation (GRDC) has been evaluating new cereal varieties for suitability as dual-purpose types across NSW for the past four years.

Methods

The project has evaluated new long-season barley, oat, triticale and wheat varieties from breeding programs across Australia for their suitability for use as dual-purpose varieties for both grazing and grain production. Figure 1 shows the experimental sites in NSW for the project from 2013 to 2016, including Bathurst, Cowra, Cudal, Culcairn, Holbrook, Purlewaugh, Somerton, Spicers Creek and Wagga Wagga, representing the main environments where dual-purpose cereals are grown (not every site was sown every year).

Key measurements recorded at the sites included dry matter (DM) production through the season at key periods: mid tillering and then before stem elongation i.e. growth stage (GS) 31 (Zadoks *et al.* 1974). The experiments are then grazed by livestock following DM measurement and allowed to recover for either further DM assessment or carried through to grain production. Growth stages are also recorded for all varieties when DM measurements are taken. Grain yield and the grain quality parameters such as grain protein, screenings, grain size and test weight are also measured.

At the core research site at Wagga Wagga in addition to measuring variety performance, further experimental treatments, including the influence of variety and sowing time on DM production and the time of flowering response of wheat and triticale, are being studied. Additional plant measurements such as flowering time, number of tillers and leaf area on a core group of varieties are being recorded at the Wagga Wagga site to provide a greater understanding of how the different varieties accumulate DM and then recover for grain production.

Results and discussion

The results and discussion in this paper are limited to the currently available commercial varieties and do not include the names of unreleased lines from the various breeding programs. Given the amount of information generated by the project, only key summaries

Figure 1. Location of dual-purpose grazing experiments in NSW for 2013–2016.

are provided here. More detailed results can be found in Matthews and Barary (2017).

Part of determining the suitability of new varieties for use as dual-purpose types for grazing and grain recovery is quantifying the flowering time response by varieties to sowing time. The variety's maturity is largely controlled by responses to vernalisation and photoperiod. These are controlled by a number of key genes, some of which have been identified and are used to characterise varieties. Vernalisation is a varieties response to a period of cold temperatures that triggers the transition from vegetative to reproductive development, while photoperiod is a variety response to day length. However, these genes do not act independently, the level of influence on flowering time differs for each variety. Therefore, while a variety might carry a vernalisation or photoperiod gene, its specific response to sowing time still needs to be determined once the vernalisation or photoperiod requirement has been met. At the Wagga Wagga site, flowering time experiments have been conducted looking at the response of new wheat and triticale varieties to various sowing times. Figure 2 shows the variety response in flowering time for a subset of wheat varieties sown in 2016, highlighting the importance of the vernalisation and photoperiod genes to control the development and flowering time for those wheat varieties.

EGA_Gregory (shown by A in Figure 2) does not have a strong response to vernalisation or photoperiod. Its response to time of sowing in 2016 was consistent for all four sowing times, flowering within 128–136 days (Figure 2). For a true winter wheat such as EGA_Wedgetail (B), which does have a strong vernalisation requirement, the flowering period was delayed the earlier it was sown, from 172 days at time of sowing 1 (TOS1), down to 130 days at time of sowing 4 (TOS4) in 2016.

In addition to the vernalisation genes, varieties react differently once vernalisation is met. EGA_Wedgetail, EXP1 and Manning (D) all carry vernalisation genes, but once this requirement is met, they take different periods to flower. Therefore, they are adapted to different growing regions in NSW. EXP1 has a quicker time to flowering, meaning it would be suited

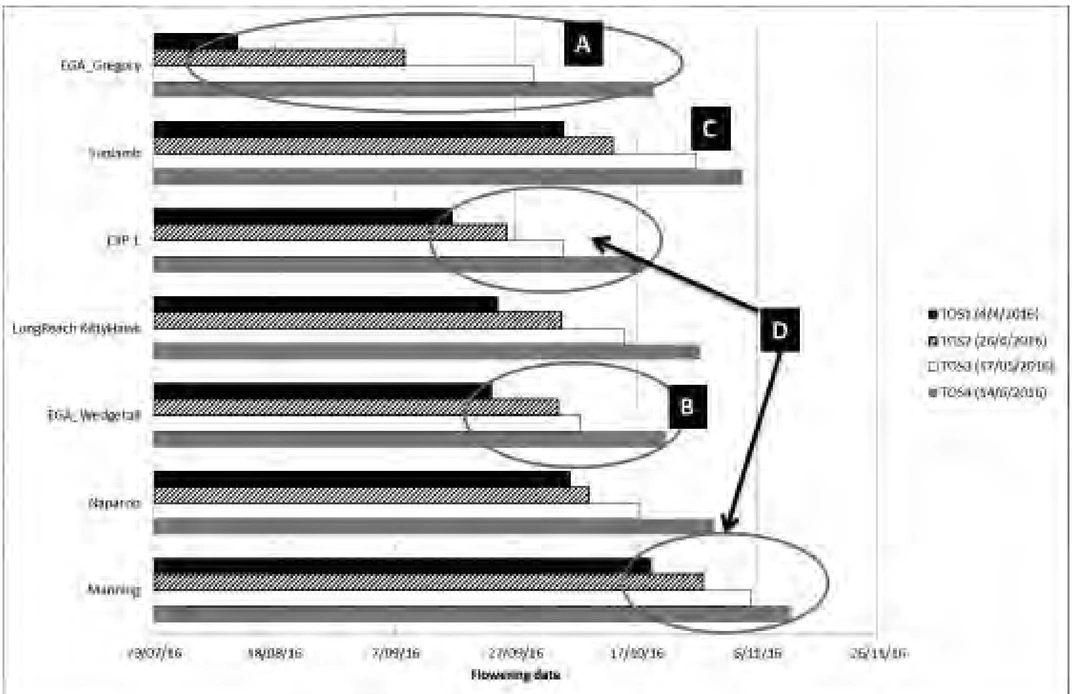

Figure 2: Flowering time response of wheat varieties to time of sowing (TOS) at Wagga Wagga 2016. (P < 0.001, LSD 5% – 3 days).

to the low–medium rainfall growing regions, flowering early enough to avoid the heat stress through late spring. By comparison, Manning takes longer to flower and is better suited to the higher rainfall zones of NSW.

Development of Sunlamb (shown by C) is controlled largely by photoperiod and so responds to daylight hours. A higher proportion of overcast days in 2016 delayed Sunlamb's maturity compared with EGA_Wedgetail. In previous sowing time experiments, Sunlamb has shown to be similar in flowering time to EGA_Wedgetail. These differences are important when considering which variety will fit your farming system, matching DM production for livestock utilisation and maximising grain recovery, as well as matching the grain filling period to local climatic conditions in spring.

Table 1: Average DM production of oat varieties across seven dual-purpose grazing experiments in NSW in 2016.

Variety	Dry matter 1 (kg/ha)	Dry matter 2 (kg/ha)
Bimbil	2361	1839
Eurabbie	2387	1828
Mannus	2155	1691
Nile	2673	1888
Yarran	2259	1598
Yiddah	2447	1855
Aladdin	1760	1284
Bond	2226	1535
Boss	2149	1076
Empire	1888	1054
Genie	2201	1256
Mammoth	2155	1491
Savannah	2008	1102
SF_Colossus	2317	1437
SF_Tucana	2413	1585

Whilst the focus of this project has been on identifying cereal varieties for grazing and then grain recovery, a number of forage-only varieties have been included in the experiments to allow growers to see the benefits or disadvantages of growing a dual-purpose versus a forage-type in their farming system. In 2016 we compared 36 oat varieties across seven sites. All the experiments were crash grazed to a common height to avoid any selective grazing by the livestock.

Table 1 shows the average DM production of a subset of the tested varieties. We compared the average DM production of dual-purpose types (23) with forage types (9). On average, the dual-

Table 2: Average DM production and grain yield of barley, triticale and wheat varieties across seven dual-purpose grazing experiments in NSW in 2016.

Variety	Crop type	Average DM1 (kg/ha)	% of EGA_ Wedgetail	Average DM2 (kg/ha)	% of EGA_ Wedgetail	Average grain yield (kg/ha)	% of EGA_ Wedgetail
Urambie	Barley	2351	98	2267	107	5089	90
Cartwheel	Triticale	2235	93	2384	112	6268	111
Crackerjack2	Triticale	2415	100	2017	95	4282	76
Endeavour	Triticale	2533	105	2410	114	5838	103
Tobruk	Triticale	2227	93	2549	120	6405	113
Tuckerbox	Triticale	2826	118	1570	74	4717	83
EGA_Gregory	Wheat	2586	108	1440	68	4826	85
EGA_Wedgetail	Wheat	2405	100	2123	100	5650	100
LRPB Kittyhawk	Wheat	2307	96	2133	100	5339	94
Mackellar	Wheat	1696	71	1848	87	5437	96
Manning	Wheat	2294	95	1962	92	5708	101
Naparoo	Wheat	2372	99	2282	107	5331	94
RGT_Accroc	Wheat	2163	90	2131	100	6509	115
SF_Adagio	Wheat	1985	83	1902	90	5971	106
SF_Scenario	Wheat	2359	98	1987	94	5401	96
Sunlamb	Wheat	2273	95	1723	81	5361	95

purpose types produced 9.8% more at the first DM cut, showing there was no disadvantage in growing a dual-purpose type for DM production through autumn and winter compared with a forage-only oat type.

Although the difference between dual-purpose and forage-type in the second DM is larger, it should be noted that dual-purpose types tend to be more prostrate in their growth and less susceptible to shoot damage compared with the more erect forage types. To avoid a potential drop in DM recovery in forage types after the first grazing, growers need to adjust their grazing management to suit the type of oat being grown. When growers are considering whether to grow a dual-purpose variety versus a true forage variety, the need for forage in spring has to be compared with the value of grain for sale or use as stock feed on farm.

One of the key outcomes of the project has been the evaluation of the latest cereal varieties across NSW production zones to provide information to industry on their performance and fit in NSW farming systems. Since the start of the current project, six new wheat varieties have been released that have application as dual-purpose varieties including Manning, Sunlamb, LRPB Kittyhawk, RGT Accroc, SF Adagio, SF Scenario. Cartwheel has also recently been released as a dual-purpose triticale. Table 2 shows the average DM production and grain yield of the latest releases across seven sites in NSW in 2016 compared with commonly grown industry standards. Further information on these varieties, such as recommended sowing times for NSW, disease resistances and grain quality can be found in the NSW DPI *Winter crop variety sowing guide 2017* (Matthews *et al.* 2017).

Table 3: An example of an economic comparison of oat, triticale and wheat varieties from Spicers Creek oat dual-purpose grazing experiment in 2016.

Variety	Crop type	Total DM (DM1 +DM2) (kg/ha)	DM minus field losses and residual (kg/ha)	Conversion rate (kg DM to kg meat)	Meat pro–duction (kg)	Meat ($/kg)	Meat ($/ha)	Grain yield (kg/ha)	Price ($/ tonne)	Grain ($/ha)	Gross return ($/ha)
Bimbil	Oat	3741	1393	10	139	4	557	3297	130	429	986
EGA_Wedgetail	Wheat	4755	2204	10	220	4	882	5002	160	800	1682
Endeavour	Triticale	4335	1868	10	187	4	747	3912	150	587	1334
Eurabbie	Oat	3776	1421	10	142	4	568	3105	130	404	972
Mannus	Oat	3791	1433	10	143	4	573	4039	130	525	1098
Nile	Oat	5453	2762	10	276	4	1105	2968	130	386	1491
Yarran	Oat	3439	1151	10	115	4	460	3743	130	487	947
Yiddah	Oat	3919	1535	10	154	4	614	3328	130	433	1047

Note: Economic comparison assumptions – grain (oats feed, triticale feed and wheat ASW) and lamb meat prices, March 2017, Dubbo region; dry matter stock wastage estimated at 20%; 1600 kg/ha residual dry matter after grazing; conversion ratio of DM to liveweight gain estimated at 10 kg DM to 1 kg meat.

Deciding which crop type or variety is best suited to your farm depends not only on agronomic suitability or grain yield for your region, but best dollar return in your business enterprise. Table 3 shows an example of an economic analysis for a subset of varieties at Spicers Creek in 2016. The highest DM producing variety was Nile oats at 5432 kg DM/ha, compared with the highest grain yielding variety EGA_Wedgetail wheat of 5002 kg DM/ha. When the value of the livestock weight gain and grain were added together, EGA_Wedgetail was estimated to have gross return of $1682/ha versus $1491/ha for Nile. Undertaking this type of analysis within your farm business is critical in making the right decision on whether a dual-purpose cereal has a fit on your farm.

Acknowledgments

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Contributed Papers

Stratified pH in soil surface signals need to revisit acidic soil management

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Abstract: *Soil pH_{Ca} measured from standard sampling depths of 0–10 cm and 10–20 cm is commonly used to guide liming programs and species selection. However, these bulked samples do not detect pH stratification. Finer sampling at 5 cm intervals detected severely acidic layers at depths of 5–15cm and showed that in most situations lime is not moving below 5 cm. Topdressed lime that is only incorporated by the sowing operation under minimum tillage systems results in lime being concentrated in the shallow surface soil and an elevated pH_{Ca} at 0–5 cm. Irrespective of liming history, severely acidic layers were detected at 5–10 cm and 10–15 cm across a range of soil types in a recently conducted survey. Severe acidity at 10–15 cm indicates that commonly applied lime rates are likely to be insufficient to prevent subsurface acidification. Incorporation of adequate rates of lime to a depth of 10 cm is recommended to facilitate amelioration of acidity at 5–15 cm. Where incorporation is not possible lime rates and/or application frequency may need to be increased. Individual producers are not collecting sufficient soil data over time to assess the effectiveness of their acidic soil management programs. We recommend, finer soil sampling at 5 cm intervals to identify the location of acidic layers, followed by testing at 3 to 5 year intervals to monitor pH trends and to provide confidence in adjusting lime rates.*

Key words: acidification, incorporation, stratification, acidity

Introduction

The medium and high rainfall zones of central and southern NSW are dominated by soils with acidic surface layers of $pH_{Ca} < 5.5$. Investment by NSW Government in the Acid Soil Action program of the 1990s and early 2000s promoted the role of liming in increasing soil pH, improving the productivity of acidic soils and preventing environmental degradation. The research from this initiative highlighted the economic cost and insidious nature of soil acidification, and provided guidelines aimed at increasing pH in the surface soil layers and preventing subsurface acidification (Upjohn *et al*. 2005). Industry responded and the most obvious legacy of the investment is the expansion of acid-sensitive crops and pastures, including wheat, canola and lucerne, onto soils that were once considered unsuitable.

Although farming systems have been modified in the last 20 years, particularly with the widespread adoption of no-till systems and minimum disturbance sowing equipment, most producers and advisors still use pH of the 0–10 cm surface soil sample to guide liming decisions. The critical pH_{Ca} used by producers and advisors to trigger re-liming ranges from about 4.8 to 5.2. In general, there is an assumption that 'acceptable yields' from acid-sensitive crops such as faba bean, chickpea, canola and barley, and persistence of lucerne and clover is an indication that soil acidity is being managed effectively.

This paper presents the results from a survey of commercial paddocks, which examined soil pH to a depth of 20 cm, at 5 cm intervals. Although these paddocks had received two or three lime applications since the early 1990s, fine sampling at 5 cm intervals detected moderate (pH_{Ca} 4.5–5.0) to severe ($pH_{Ca} < 4.5$) acidic layers in the top 5–15 cm of the soil profiles.

While previous studies have reported pH stratification and the presence of acidic layers at 5–20 cm in agricultural soils (e.g. Paul *et al*. 2003; Scott *et al*. 2017), and an 'acid throttle' at 10–20 cm (Conyers *et al*. 2012), the severely acidic layers reported in this paper, at 5–15 cm across a range of soil types, indicate an urgent need to revisit current approaches to acidic soil management. Furthermore, we found that insufficient soil information is being collected by producers and advisors to monitor and assess the effectiveness of liming programs in ameliorating soil acidity (Mackenzie and Dixon 2006).

Method

A survey was undertaken from 2015 to 2017 in which soils were sampled from 16 commercial sites in the medium to high rainfall, mixed farming zone of south-eastern NSW (500–700 mm annual average rainfall). Sites were between Albury and Woodstock in a zone within 50 km of the Olympic Highway.

The sites are a biased sample from the region, selected as paddocks believed to be well managed for control of soil acidity. Most had been sown to either acid-sensitive pulses (faba bean, lentil and chickpea) or lucerne, with two sown to narrow-leaf lupin. The site locations were chosen to ensure the soil types sampled were representative of the most productive regions of the mixed farming zone of southern NSW. These ranged from Sodosols and Yellow Chromosols (solodics and podzolics) with a cation exchange capacity (CEC) of 4, to Red Chromosols (red earths) and Dermosols (alluvial soils and red-brown earths) with a CEC of 13 (Isbell 1996).

Using at least 20 cores per composite sample, soil was collected from depths of 0–2.5 cm, 2.5–5.0 cm, 5.0–7.5 cm, 7.5–10 cm, 10–15 cm and 15–20 cm at 12 sites in 2015 and 2016, and from depths of 0–5 cm, 5–10 cm, 10–15 cm and 15–20 cm at an additional 4 sites in 2017. Bulked samples were also collected at all sites from the industry standard depths of 0–10 cm and 10–20 cm. Soil pH_{Ca} was measured at the NSW DPI laboratory at Wagga Wagga. The pH_{Ca} values for depths of 0–5 cm and 5–10 cm for the 2015 and 2016 samples were estimated by averaging test results from the 0–2.5 cm and 2.5–5.0 cm samples and the 5.0–7.5 cm and 7.5–10 cm samples, to better reflect the sampling depths that may be practical for industry.

The sites were grouped on the basis of recent liming history: Group 1 – those that had received surface-applied lime within the last 5 years; and Group 2 – those that had received no lime in the last five years.

Results

The average soil pH_{Ca} profiles for the 12 sites sampled in 2015 and 2016 are presented in Figure 1. Irrespective of lime history, the lime effect was concentrated in the shallow surface layer (0–2.5 cm) and decreased with depth.

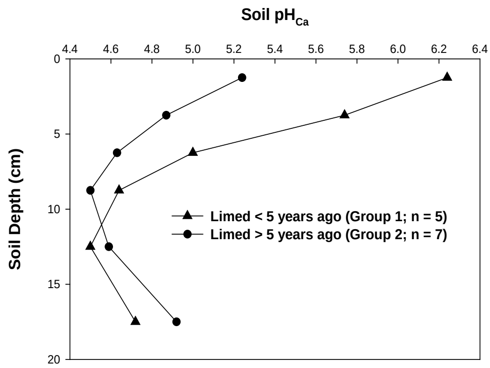

Figure 1. The stratification of soil pH_{Ca} with depth on mixed farming properties of southern NSW in 5 paddocks (Group 1) which had received surface-applied lime within the last 5 years (—▲—) and another 7 paddocks (Group 2) which had not received any lime for at least 5 years (—●—). Samples were collected at 2.5 cm intervals to a depth of 10 cm and then at 10–15 cm and 15–20 cm depths.

Lime incorporation for most sites relied on mixing by the sowing operation alone, using minimum disturbance systems with knife point tynes or disc seeders. At one of the Group 1 sites lime was effectively incorporated prior to sowing, by drilling prilled lime into sowing rows to a depth of approximately 10 cm. A Speedtiller® was used at another site specifically to incorporate lime, but fine sampling indicated this was ineffective in mixing lime below 5 cm.

Table 1 presents the estimated mean pH_{Ca} of the top 20 cm of soil profiles at sample intervals of 5 cm as well as 10 cm bulked samples from Group 1 and 2 sites. The impact of recent lime applications on pH of the surface 0–5 cm layer was apparent for Group 1 sites, which had a mean pH_{Ca} of 6.12 at the 0–5 cm layer, compared with 5.15 for Group 2 sites. Recent lime application resulted in greater stratification within the 0–10 cm surface layer in the Group 1 sites, with an estimated drop in pH_{Ca} of 1.4 from the 0–5 cm to the 5–10 cm layer, compared with an average drop of 0.64 over this depth range in Group 2 sites.

These results highlight the need for finer sampling to detect acidic layers at depths of 5–15 cm. For example, the estimated mean pH_{Ca} of 5.53 for the 0–10 cm bulked samples from Group 1 sites suggests that lime was incorporated effectively to a depth of 10 cm. However, this is misleading as it fails to detect the sharp drop in pH_{Ca} within the 0–10 cm layer, from 6.12 at 0–5 cm to 4.72 at 5–10 cm.

Similarly the mean pH_{Ca} of the 10–20 cm bulked samples from Group 1 (4.72) and Group 2 sites (4.67) overestimate do not detect the severely acidic layers at the 10–15 cm depth, with pH_{Ca} levels of 4.49 and 4.50, respectively. The 10–15 cm layer was the most acidic layer for both the Group 1 and Group 2 sites. Most soils showed an increase in pH below the 15 cm layer.

Discussion

The widespread adoption of zero or no-till systems in the last 20 years means that most applied lime is not incorporated. The exaggerated stratification of soil pH_{Ca} detected by fine sampling of the recently limed Group 1 sites demonstrates the poor incorporation of lime achieved under these tillage systems. The lime was concentrated in the surface 0–2.5 cm and had limited effect in neutralising acidity below 5 cm.

Thorough incorporation will hasten the lime reaction and increase the depth of the lime effect. Lime moves slowly into layers below the depth of incorporation. Recent studies by Conyers (2017) indicate that well planned strategic cultivation will cause minimal harm to soil structure. Delaying sowing of acid-sensitive species for at least 12 months after lime incorporation allows time for the lime to react and increase pH to the depth of incorporation.

The pH stratification within the 0–10 cm layers was not detected using samples collected at standard depths of 0–10 cm. This sampling approach is a relic of dated farming systems where regular cultivation normally mixed the surface 10 cm of the soil. We advise occasional use of finer sampling at 5 cm intervals to detect the location and severity of acidic layers in the surface 20 cm. Sampling at these intervals every 3 to 5 years at locations recorded using GPS coordinates will provide a mechanism to monitor the effectiveness of lime applications on (i) ameliorating acidic layers at 5–15 cm; and (ii) preventing subsurface acidification.

Irrespective of liming history, the severe acidity in the 5–15 cm layers at both the Group 1 and 2 sites was unexpected, considering the biased sample we surveyed. Thirteen of the 16 sites had a pH_{Ca} <4.7 in the 5–15 cm layers. Although collaborating producers reported

Table 1: The mean pH_{Ca} of the surface 20 cm of soil profiles at intervals of 5 cm (fine sample) and 10 cm (bulked sample) for Group 1 sites (n = 7) that had received lime in the last 5 years and Group 2 sites (n = 9) that had not received any lime for at least 5 years. The ranges of pH levels for the groups are in parentheses.

Depth (cm)	Group 1: Limed in < 5 years		Group 2: Limed in > 5 years	
	Fine sample	Bulked sample	Fine sample	Bulked sample
0–5	6.12 (5.6–6.35)	5.53 (5.13–5.8)	5.15 (4.65–5.62)	4.84 (4.4–5.3)
5–10	4.72 (4.3–5.32)		4.51 (4.15–4.89)	
10–15	4.49 (4.2–4.75)	4.72 (4.5–4.94)	4.50 (4.1–5.0)	4.67 (4.1–5.2)
15–20	4.84 (4.57–4.94)		4.87 (4.2–5.7)	

yields in excess of 2 t/ha from canola and 6 t/ha of wheat from the most acidic sites, the potential of many crop and pastures species, including many wheat varieties, canola, lucerne, phalaris and subterranean clover is likely to be compromised in soils when pH_{Ca} falls below 4.7. The effect of pH_{Ca} <5.0 is amplified when plants are compromised by additional stresses such as cold and/or wet conditions, compaction layers, herbicide residues and poor nodulation of legumes (Burns *et al.* 2017). Only highly acid-tolerant species, such as oats and serradella are unaffected at pH_{Ca} below 4.4 (Upjohn *et al.* 2005).

Previous surveys conducted in southern NSW in 1995 and 2006 detected pH stratification with an increase in pH_{Ca} at 10–15 cm (Scott *et al.* 2017). However, in the current study the estimated pH_{Ca} of the 10–15 cm layers for Group 1 and 2 sites are marginally more acidic than the layers above (Table 1). When we also consider the drop in pH_{Ca} of 1.4 and 0.64, from the 0–5 cm to the 5–10 cm layers at the Group 1 and Group 2 sites, respectively, this suggests that the lime rates being used by the majority of growers in this study are insufficient to prevent acidification of the 5–15 cm layers. None of the collaborating producers had detailed soil pH records that enable them to monitor pH trends and therefore adequately assess whether their acidic soil management programs were effective in preventing subsurface acidification.

The severity of the acidic layers reported here indicates a need for industry to review and update current lime management strategies and resources. Amelioration of the 'acid throttle' at 5–15 cm and prevention of subsurface acidification requires regular liming to maintain the 0–10 cm surface layer at pH_{Ca} > 5.5 (Conyers *et al.* 2003). Liming to achieve a surface soil (0–10 cm) pH_{Ca} of 5.2 will remove most of the issues associated with acidic soils, such as aluminium and manganese toxicity. However, if the pH_{Ca} of the 10–20 cm layer is also <5.0, liming to pH_{Ca} > 5.5 will ensure a net movement of alkali down the profile and prevent subsurface acidification (Upjohn *et al.* 2005).

Conclusion

Lime applied in minimum tillage systems remains concentrated in the shallow surface layers. Sampling soil at standard depths of 0–10cm and 10–20 cm is not detecting the intense pH stratification within the 0–20 cm depth. Finer sampling at 5 cm intervals is recommended to locate acidic layers and guide liming programs and species selection. Incorporation of adequate lime rates to a depth of 10 cm will hasten amelioration of acidic layers at 5–15 cm. Monitoring of pH at 5 cm intervals will provide producers and advisors with a measure of the effectiveness of acidic soil management programs and the confidence to adjust lime rates and liming frequency.

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My life amongst grasslands – Observations and thoughts

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Introduction

To many people in Australia, the term 'pasture improvement' is an oxymoron, camouflaging what they regard as needless interference with Australian native vegetation, which was adapted to and in balance with the local environment. The environment included nutrient-poor soils, low grazing intensities, low rainfall, drought, heat, bushfires and, over the past 60,000 years, the activities of indigenous Australians. A reluctance to depart from British and European mindsets, management practices and machinery is blamed for the approach of generations of graziers and farmers who, some say, have degraded rural landscapes in a little over two centuries.

The historical record details the exploitation of Australian native grasses by livestock managers during the 19th and 20th Centuries (Wolfe and Dear 2001), along with the concurrent clearing of large areas of 'the bush' (Watson 2014) to provide timber for a developing nation, to encourage the grassland component of the woodland ecosystems and to prepare land for cropping. These grazing and cropping activities changed the botanical composition (Moore 1970), hydrology (Wasson and Sidorchuk 2000) and ecology (e.g. Morton *et al.* 1995) of Australian landscapes. However, not all of the impacts of the new settlers and their descendants were irredeemably negative, as implied by many environmental scientists and advocates. There have indeed been many worthy stories of 'agricultural improvement', especially if one takes into account the widespread use of superphosphate and exotic pasture legumes to enhance soil fertility and boost the productivity of pastures and crops, along with the introduction from around the world of tropical and temperate grasses and their matching to parts of the Australian landscape that favour their culture. According to Smith (2000), who outlined the focus of Australian agronomists and landholders on achieving 'natural gain' in the agricultural lands of southern Australia, good science was a feature of systematic efforts to ameliorate with pasture legumes the predominantly poor local soils for the reliable production of pastures, crops and grazing livestock. Smith was also careful to mention the important complementary role of innovative farmers, who made discoveries, developed equipment and managed these modified agricultural systems for productivity and sustainability. Together, scientists and farmers have collaborated in the development of sustainable agricultural approaches, practices and systems in the notoriously variable Australian environment (Tow *et al.* 2011).

This paper is an account of the successful activities of a grazier and businessman, Des Green and his family, in the high-rainfall grazing zone of central NSW. Des has lived for 70+ years on properties near Mandurama, a small hamlet between Blayney (Central Tablelands) and Cowra (Central-Western Slopes). His story is an inspiring account of his inquiry, discovery and application of simple but hard-won principles for pasture improvement, soil management, business management and family leadership in order to achieve profit, satisfaction and sustainability from his grasslands. Here is his story, which should be of interest to grassland managers and grassland scientists.

Agricultural beginnings

My grandfather, John Green, acquired "Rhondda Villa" in 1922 and this property was where I first became interested in agriculture. In 1956 my father George, a former council worker who later undertook share-farming and contracting, came to an arrangement whereby he would progressively take over the farm from John. I began fulltime farm work in late 1958, after gaining my Intermediate Certificate at Cowra High School. The headmaster at Cowra HS, who had his eye on me as a future scholar, was disappointed that I did not continue my studies towards a professional career, and he forthrightly told me so. However, I heeded my father's advice to aim for a 'free-enterprise future' and to back myself. I worked for no pay as a farm hand but, at 16, I had a driver's licence (initially for up to 10 miles from Mandurama), access to some pasture at "Rhondda Villa" for my four Hereford cows (purchased with a £1000 loan from my bank), and free board.

From this early business beginning, I set about achieving three objectives over the next 10 years, encouraged by positive people like a well-travelled Presbyterian minister and my parents, who urged me to do everything that was possible. These objectives were:

- To accumulate wealth and assets by any legal means available. My early sources of income included a small cattle herd, share-farming, contract work, wheeling and dealing, delivering fuel, servicing equipment, wool buying, and taking on agencies for chain saws and welders and sundry rural equipment.
- To undertake a range of practical courses that were available for young farmers, delivered by TAFE and the NSW Department of Agriculture at places such as Cowra, Bathurst, Orange and Yanco, on topics that included crop and livestock production, pasture management, motor maintenance and farm business management.
- To travel the world. By the time that I was 21, I had visited 27 countries including Europe, the Soviet Union, the Mediterranean, North America (LA) and Central America (Panama).

Formulating and implementing plans

In 1968, as a young entrepreneur, I took stock of my situation. First, I became engaged to Sally Crofts, a member of a prominent Blayney family that included Uncle Frank, at the time a Senior Lecturer in Agronomy at the University of Sydney; I married Sally in June that year and she has been a true supporter and partner ever since. Second, the Green family were on the cusp of implementing the next stage of their carefully considered succession plan, whereby my father and mother would retire to a small farm (80 ha) that they owned at Mandurama, enabling Sally and I to acquire and run "Rhondda Villa", sharing the property and livestock. Prior to the deal, my assets had progressed to an established Hereford stud, 50% of the livestock on "Rhondda Villa", one acre of land in Mandurama and my new wife. Sadly, George (Dad) died at this time, an event that threatened the deal but, with the support from my mother (Jessie) and Dad's brother Eric, I was able to proceed with Sally in terms of the original plan. We set about establishing ourselves, dealing with a loan taken out to acquire "Rhondda Villa" and to pay off another debt – the probate on George's estate. I made an appointment with the Deputy-Commissioner of Taxation in Sydney, a Mr Farmer, and explained my situation. After hearing me out, Mr Farmer gave his decision – "Get to work, pay what you can off the probate debt (interest free) and phone me at the end of the first year to let me know how you are going". The probate and property was cleared in five years.

Aside from small areas of cropped land, "Rhondda Villa" was unimproved. I now turned to the best farmers in the district and a network of advisors, mentors and contacts to determine a plan for pasture improvement and animal production. The main ingredients of the plan were:

- *Fertilising* the property to an initial target of 0.5 tons/ac (1250 kg/ha) of superphosphate on all paddocks. This plan was soon fast-tracked, financed by the sale of stud heifers from my growing Hereford herd;
- *Sowing improved pastures* based on phalaris and subterranean clover in paddocks that were first cultivated and seeded with a pioneer crop of wheat, a crop that was sometimes grazed out and sometimes harvested depending on the feed supply/demand situation. In retrospect, the decision to sow a persistent perennial grass early in the pasture improvement phase rather than

later was the correct one. This approach was based on my discussions with friends and successful farmers, who advocated phalaris establishment before the occurrence of two potential threats to pasture stability. These threats were (1) the inevitable build-up of nitrogen-loving weeds that compete with sown grasses and/or (2) a documented decline in soil pH after years of 'sub and super' (Donald and Williams 1954) to levels that (it was later discovered) threatened the establishment of species that were sensitive to the lower pH of soils.

- The development, refinement and implementation of a *specific timetable for farming operations*. This schedule was detailed almost down to the day level, for operations involving pastures (fertilising, sowing, baling), livestock (joining, lambing, calving, weaning, shearing etc.) and my share farming/contract work. The farm schedule was supported by a full set of records and charts on the management of each paddock.

By 1974, when the first stud bull sale occurred, "Rhondda Villa" was paid off. We 'celebrated' by buying an additional 160 ha from a neighbour nearby. We also visited Western Australia to look at the potential there, as well as visit Hereford Studs and some district Shows. We decided to stick with what we knew and stay in our home country.

Soil acidity

During the 1970s and 1980s, I became fascinated with a problem that occurred at an increasing frequency in well-fertilised paddocks, and I sought answers. The problem appeared to be soil-related and the apparent cause, soil acidity, was under research by the Department of Agriculture at Rydalmere, Wagga and elsewhere. I became part of a soil monitoring program conducted by NSW Agriculture on more than 100 sites in the Central Tablelands of NSW. Over a few years on my monitored site, the soil pH declined from pH 6 to pH 5.

However, the messages from the Department at the time were confused and there was no active promotion of the absolute need to spread lime to counter the increase in soil acidity that was known to occur with 'sub and super' (Donald and Williams 1954). By the early 1980s, I had nutted out a solution (liming) from the confusion of information available from a range of sources, including discussions (not necessarily advice) from my district agronomist (DA) (Warren McDonald), a soil chemist (Ian Vimpany), a NZ agronomist (John Stanley) who was working and advising farmers in the border region of NE Victoria and southern NSW, and my contacts in NZ where liming was a routine practice.

The recipe that I used to overhaul the fertiliser program has always embraced the need for regular applications of fertiliser (P, S, Mo) for the legume and grass components of pastures. I dealt with the acidity issue by first substituting dicalcic phosphate (an idea from NZ) for single superphosphate, followed at a later stage with the liberal use of lime (and sometimes dolomite) and more recently, through my belief, the addition of gypsum (see below). The overhaul, begun during the 1980s, was much needed because we were again under pressure from clover ill-thrift (there was not a viable clover plant on the entire property in 1981), droughts in 1981 (autumn, spring) and most of 1982–83, our purchase in 1981 of "Errowanbang" (400 ac, now "Chesney"), and the lease of additional country (also 1981).

By late 1983 when the drought broke, our appreciation of the soil acidity problem was falling into place. We had many useful discussions on a range of topics with a student from Hawkesbury College, Rob Eccles, who spent a 6-month work placement on "Rhondda Villa" and used the farm as a case study for his degree in Applied Science (Agriculture). This post-drought period ushered in a time of reorganisation (1982–85). The stud Herefords were dispersed in favour of the production of bullocks, and a program of 'by the book' soil testing was implemented to assess the levels of soil P, pH and available cations prior to making decisions on the application of superphosphate and lime. Our friendship with Rob has continued and he recently visited the family properties and enterprises again to check on progress.

Also, I continued my discussions with agronomists and scientists about plant nutrition. For example, Ian Vimpany and I agreed on some points and disputed others. I rejected his suggestion to apply to paddocks a double-rate of molybdenum – we apply a single rate every 4–5 years – because I was aware of the risk of inducing copper deficiency due to the copper-sulfur-molybdenum interaction. However, I pricked up my ears when he mentioned that North Coast banana growers used gypsum to get calcium deep into the soil profile – bananas have a high calcium requirement. This mention was a 'light bulb' moment for me and it set in train a new line of thinking on the potential value of gypsum.

I acknowledge that a pool of knowledge was eventually built up and extended from the Rydalmere, Wagga, Rutherglen and local teams assigned to investigate the problem of soil acidity, along with the implementation by NSW Agriculture of a State-wide 'Acid Soil Action' advisory program. Those programs, which began with research in the 1970s and continued in the extension phase through to the 1990s (Scott *et al.* 2000) explained the phenomenon of pH decline due to the influence of 'sub and super' on the natural carbon and nitrogen cycles. These programs also identified the effects of low pH on the legume-rhizobium symbiosis; pinpointed the release of toxic ions (particularly aluminium, Al^{3+}), normally insoluble in neutral or slightly acid soils, on the root development of susceptible species, which included lucerne, phalaris, barley and canola; and confirmed the need for regular applications of lime to sustain the healthy growth of pastures and crops.

Gypsum

During the 1980s and 1990s, farmers in central and southern NSW, in common with farmers throughout southern Australia, became interested in canola. Canola in the crop rotation was a great break crop for wheat, much reducing the incidence of fungal pathogens in wheat or barley crops and boosting their yields. Canola is sensitive to soil acidity and to sulfur deficiency, and I could see business opportunities in seeking out relatively cheap sources of lime and gypsum. I noticed an advertisement about an old brick pit in Sydney that was used as a dump for lime slurry, a by-product of a nearby ammonia plant. Lime slurry, which was given away free to anyone with a wish to utilise it, could be delivered to Mandurama for $10 a tonne. I also located a source of cheap gypsum (as Anhydrite) in Sydney. Lime and gypsum in a 2:1 ratio formed a mixture that was dry enough to be applied to the soil with conventional bulk equipment. So, I developed a sideline business supplying the lime + gypsum product to farmers. When this cheap source of gypsum ran out, I found in Sydney a supply of factory-reject plaster board, which was manufactured from high-quality gypsum and sourced directly off the production line, to go with the cheap lime. The transport and stockpiling operations reduced the plaster board to small chunks and it was easily spread using existing equipment.

I have a theory about the use of gypsum with lime, a theory that goes beyond the benefits of bulk lime (raising soil pH) and gypsum (supplying sulfur, raising soil calcium) – I hypothesize that gypsum with lime plays a role in taking calcium deeper into the soil profile, a feat that is difficult to achieve with lime alone. My benchmark is to get calcium to the level of 80% of the cation exchange capacity of the 0–30 cm soil zone. I have clients who willingly invest in the lime + gypsum theory but agronomists, whether they are government or private, have not yet come fully on board. Livestock do well on soils with adequate calcium. People do not believe the do-ability and need to raise calcium levels deeper into the soil, nor the potential synergy between gypsum and lime in combating subsoil acidity. This issue, I believe, is one instance of conventional agronomy failing the farmer. I would like to see experiments undertaken to evaluate my lime + gypsum theory and substantiate the benefits of lime + gypsum for plant and livestock growth. I discussed the possibility of lime + gypsum upsetting the Ca/Mg ratio with the DA at Cowra, Brett Butler, and the consensus then and since has been that there is adequate Mg at depth in local soils, accessible to plants once the 'acid throttle' to plant roots is removed. One observation I have made of gypsum use is the elimination of pin rush from paddocks, presumably by enhancing deep drainage, raising soil Ca and removing sodium. I hope my theory on the use of lime with gypsum can be validated one day, and becomes part of textbook agronomy.

Also, I was interested in the use of sewage sludge as a source of nutrients. I was the only farmer present at the Bio Solids Summit in Sydney in the early 1990s and I made my presence count in debates on the rates of spreading the product and the need for monitoring its use to prevent the build-up of potentially toxic elements. I unsuccessfully tendered for the rights to use this product.

Trace elements

I have already mentioned the need for a moderate level of molybdenum and the care needed to avoid copper deficiency. I watched for signs of other trace element issues including the following:

- *Selenium* – We started using selenium in the 1970's and have continued to monitor the farm and district situation.
- *Cobalt deficiency* – Sudden death disease in sheep grazing phalaris, a disorder that does occur on the Central Tablelands is caused by a deficiency of cobalt. This disorder is most prevalent on basalt soils, and the administration of cobalt bullets into the rumen alleviates the problem. I kept an eye out for this problem but it didn't occur on my pastures at "Rhondda Villa" where the soil parent material varies but is principally basalt.
- *Boron deficiency* – NSW Agriculture at Orange had not sighted this deficiency in clover in the district but my friends in State Forests said that they could not grow pine trees without it. Rob Eccles took a photo of a "Rhondda Villa" white clover plant with what appeared to be classic boron deficiency leaf symptoms when matched with a boron AgFact produced by NSW Agriculture. We sent the photo to the district agronomist at Orange for his comment – he undertook strip tests on suspect country but visually there was no response. In the end, we didn't apply boron because no further plant symptoms appeared with a resumption of normal seasons on our limed soils.

Weed management

Some parts of our landscape are threatened by many weeds, especially serrated tussock (distributed from nearby properties by wind) and blackberry (distributed by birds), which are two of the worst. True Scotch Thistle and Chilean Needle Grass are now added to the list. It is a shame that many landholders clearly do not know the approaches, nor understand the vigilance needed to get on top of these problems. One source of ideas was Barney Milne of the Weeds section in NSW Department of Primary Industries (NSW DPI), who taught me the usefulness of chemicals such as simazine (for silver grass control), paraquat (a useful knock-down herbicide) and MCPA (broadleaf weeds). He helped me appreciate what is now a theme for our family business – "Look further forward than tomorrow".

I have learnt or worked out some innovations that help me and I am happy to share these ideas with other landholders (so long as these practices are permissible). First, in approaching country with a cover of serrated tussock, it is essential that paddocks be sown first to a persistent perennial grass (phalaris) as soon as it is practical to do so. The first stage of redevelopment may involve liming and fertilising according to soil tests, followed by a pioneer crop of oats/wheat and then seeding with phalaris or, if the soil pH is high enough, the use of glyphosate and sod-seeding (direct drilling) to establish phalaris. During the next year, the newly-sown perennial grass and the serrated tussock seedlings are essentially annuals – they will be killed by weedicides such as flupropanate (targeting the tussock) or even paraquat (which I use as a marker to indicate where the spray has been applied). After the initial year, once the new perennials have put up a seed head and entered a phase of summer dormancy, they can tolerate paddock or spot spraying with flupropanate, or paraquat that better defines the areas that have been sprayed. The use of a recommended wetter (surfactant) is essential. 'White' tussock plants are eaten by cattle.

I regularly tour my paddocks by motor bike to spot-spray serrated tussock or blackberry. For blackberry, I adhere to the recommendations for the use of metsulfuron ('Brush-off'). However, I have another theory that (like the gypsum theory above) needs to be tested by science before it can be generally recommended. This theory is a discovery I have made on herbicide synergy, involving the use of a two-step approach to spraying blackberry. I am convinced that this approach is more effective than the use of metsulfuron alone. I would be happy to talk with NSW DPI or another not-for-profit agency to help me in potential discussions with a commercial herbicide company who may be interested, with a view to testing my theories on herbicide synergy and registering the approaches with APVMA.

Horizontal business integration

In 1992, we bought the Mandurama Auto Port, which has an excellent location on the Olympic Way to southern and central NSW. At the time that we bought the business, it had a dangerous goods licence for handling fuel and we added chemicals, thus utilising the facilities to the full. This purchase was a way of lessening our dependence on the production side of agriculture, and it also provided a means by which we could capture and sell the expertise that we had built up as a successful farming family. This expertise is available to a loyal group of clients, not only for fertiliser sales and spreading but also when farmers purchase seeds of pasture grasses and legumes. We also supply rural merchandise such as agricultural chemicals, wire, steel, silos, sheds, fuel, lubricants, equipment and contract services – in short, all the stuff that is supplied through the Ruralco group, of which we are a member. In 2003, we purchased the Blayney Tyre Service and joined the Tyrepower buying group, thereby owning almost all of the products required to conduct our farming enterprise. We sold the Tyre business in 2007 but retained the building.

I acknowledge the importance of my valued business partner, Richard Bloomfield, from Lyndhurst NSW, who made it happen in the field. Richard, a fellow farmer and member of the grass seed variety selection committee for the Grassland Society of NSW Inc., developed a conversion method for old Shearer disc drills, fitting them with boot/caldow points. He converted four drills, each with a fold-up hitch, and adapted a trailer to transport them from place to place, hiring the machine out to farmers who needed to sow pasture. The seed and fertiliser was provided from our business in Mandurama. One machine, which we have retained, had the box divided so trial sowings could be done in various configurations, enabling the testing of many pasture plants long before they were released to the public, sometimes with as little as a matchbox full of seed from the plant breeder. I am sure this level of innovation led to the business being selected as one of only three in Australia for a study tour of the industry in NZ. Naturally both Richard and I went, adding to the learning process.

Richard has now retired and his place has been taken by the involvement of the next generation in our family business – this involvement of family was never really a foundation plan but the idea naturally evolved, attracting our son and youngest daughter, with their spouses, into the partnership. These developments are a source of considerable satisfaction to Sally and I. Our son Stuart has professional qualifications in law and commerce. He, his wife Gemma (a midwife, Lifeline professional) and their three children prefer the farm life to city life; they lease from us 1000 ha and they now own 1300 ha. They undertook a major project to convert a large woolshed into their family dwelling. This project, which was completed in 2015, won the Marsden Rural History Award in 2016. Stuart has maintained the emphasis on productive pastures and, in addition to cattle and sheep rearing, he engages in livestock trading activities.

Our daughter Joanne (a graduate of Sydney University's Orange Campus) married Mark Richardson, also an Orange graduate, a son of a cattle grazing family at Omeo. Together they have taken over and boosted the rural supplies store and fuel station in Mandurama. Our eldest daughter Alison (an Orange graduate), does not have any direct links to the farm businesses, but conducts her own business Advice Service from an office in Orange. Then, to provide each family with security and some independence, the various businesses were divided up equitably in 2011.

Grassland societies and congresses

For years, I have actively followed the Grassland Society of NSW Inc., and have hosted many field days and attended several seminars. The Society has an appealing model of giving equal weight to the voices of scientists and farmers about the management of grasslands. I have attended the annual conferences when I can, contributing a paper on farm management in 1993, and the Green family maintains its membership through two farm businesses, Chesney Pastoral and Greens Rural. Chesney (Stuart and Gemma) hosted one of the Grassland Society's 'Pasture Updates' in 2015.

We received notification about the 2008 International Grassland Congress (20th IGC in Hohhot, Inner Mongolia) and Sally happened to talk with a NSW DPI manager who had made an earlier visit to Inner Mongolia, the site of much grassland work that has been undertaken by Orange-based (NSW) scientists (Kemp and Michalk 2011). One thing led to another and we attended this event, which was very well organised by the Chinese hosts. We seriously considered attending the 2013 IGC in Sydney in 2013 but I was receiving medical treatment at the time and we were unable to be present. We were determined to visit India for the 2015 (22nd) IGC in New Delhi, and we enjoyed this Congress and our visit to India. I believe it is important that the IGC organisers involve practicing farmers in these events, as was done in IGC 2015 at a Farmers' Forum, unfortunately without a broader involvement from international grassland managers. Still, I had some wonderful conversations with the many scientists and the small contingent of farmers from around the world. A strong *esprit de corps* developed between these farmer participants and perhaps the NSW Grassland Society model may be advocated for the next IGC (in Kenya) and subsequently. One consequence of these international links was a visit in March 2017 to central and southern NSW, including properties at Orange, Mandurama and Cowra, by a group of 37 farmers, advisers and industry people from Argentina. Ted Wolfe and I collaborated closely with Dr Guadalupe Klich from Argentina to set up and conduct the itinerary.

Soil carbon

When an Australia-wide soil carbon testing program tested our long-lived phalaris pastures (sown 1930's), they recorded the highest readings of stored carbon in the program, and we dealt with a revisit to explain why this was so. It makes me wonder about the promotion of many government-funded programs for carbon sequestration when a highly productive, deep rooted permanent pasture can do more for carbon storage and farm profit.

Our holdings are now over 10 times the size of the original farm, an area that is still growing under the new management of our son Stuart and his family. Meanwhile, Sally and I have taken on a property in another Mandurama location, in soil new to me. We have reduced from an initial value of 50–60% Al saturation of the cation exchange complex to less than 2%, and I am eliminating weeds and establishing phalaris. My aim is to get the Ca value to 80% of the CEC and we do this all by spreading on top with our lime-gypsum-fertiliser mix. We are finding that the other good elements increase naturally, including P and Mg, and believe that an aim of achieving a perfect chemical balance produces further benefits in organic matter accumulation and soil biology.

Summary

There have been many learning experiences along the course of Des Green's successful life, and a few regrets. This account is an inspiring example of how a determined grazier/business/ family man, has matched ideas with scientists and dealt with the limitations within his family's production systems. Along the way, he has never doubted his ability to achieve a command of topics such as grassland management, soil science and herbicide chemistry, and his observations and ideas have often challenged the 'comfort zone' of scientists, professionals and bureaucrats. The Grassland Society of NSW Inc. has always made a special effort to encourage, discuss and record the ideas and observations of successful farmers. Scientists advocate the importance of evidence-based decision-making on farms (Virgona and Daniel 2010) and they rigorously protect the integrity of the knowledge base. However, scientists sometimes forget that a farm is as much a socio-economic system as it is a way of converting sunlight into animal products. Farmers must unselfishly listen to successful farmers and welcome their contributions towards innovation in grassland science and practice.

Des Green acknowledges the important role of science in agricultural R&D but he also questions the inability on occasions of conventional agronomy to produce more benefits for farmers. Farmers must ask questions on how well served they are by their industry bodies (i.e. public and private agencies, bureaus and companies) that are involved in the delivery of services for research, extension services and policy. The whole process of research needs to be targeted towards the needs and well-being of the Australian grazing industries. Has sufficient work been done on a whole-of-industry approach, one that captures and presents easily accessed and up-to-date packages not only for production, productivity and economic efficiency in the grazing industries but also fostering the social and environmental well-being of rural families, communities and agricultural landscapes?

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