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Morelamb Quality Pastures

Management Solutions Key Program

Abstract

The '*Morelamb'* project used bio-economic modelling to highlight that matching ewe genotype and lamb turn-off system and improving the amount of pasture grown and consumed are critical to further productivity gains in the sheep meat industry. Five on-farm sites which were initiated and managed by specialist lamb producers demonstrated a 50% improvement in production per hectare from subdivision, improved grazing management and sowing commercially available high performance pasture mixtures. Plot-scale grazing experiments showed arrowleaf clover (cv *Arrotas*) extended the growing season by 4 to 6 weeks compared to subterranean clover (cv. *Leura*) and total production from arrowleaf clover in late spring/early summer approached 400 kg lamb liveweight/ha. A simple and practical approach to improving the efficiency of production from existing legume pastures based on offering grass and clover monocultures side-by-side and allowing animals to choose their preferred diet was also developed. Overall, this work has highlighted the opportunity to reconstruct forage systems with plants that complement and enhance each other agronomically, functionally and biochemically. We need to better understand what plants we mix with what and how these are arranged spatially to match nutritional profiles for the animal, together with other attributes such as adaptation to the environment and water use efficiency, to develop more profitable and sustainable sheep meat production systems.

Executive Summary

The volume of lamb exported from Australia has doubled during the last decade and southwest Victoria is a key lamb producing region. Most forage systems in this region are based on perennial grasses, even though they often comprise less than 50% of the total pasture available. An overwhelming advantage of these production systems is their low cost structure, but seasonal and geographical variations in both edaphic and climatic drivers of systems performance are significant impediments to production efficiency and quality control. The propositions underlying this work were:

(a) The profitable production of sheep meat is dependent on high levels of pasture production being efficiently utilised by grazing sheep of high genetic merit.
(b) Most grazing lands are highly heterogeneous in soil resources, climate and landscape and yet a limited range of forage options are widely used.
(c) Productivity gains and the ability to supply high quality lamb all year round will be limited if the industry continues to rely on a limited range of forage options
(d) Alternative annual and perennial pastures have potential to overcome some of the limitations of current systems, such as winter feed gaps and poor summer growth.
(e) The feeding value of legumes is greater than that of grasses but the legume component of most pastures in southwest Victoria is often less than 20%.
(f) To realise this potential in lamb production systems we must identify appropriate plants and their management requirements for different situations and integrate them spatially and temporally into whole farm systems in ways that lead to increased profit and reduced risk.

The '*Morelamb'* project comprised of four modules. We first used bio-economic modelling to identify the components of finishing and store lamb production systems that could be manipulated and their likely impact on whole farm profitability. Based on the assumptions used and factors examined in this analysis the critical control points were: (a) matching ewe genotype and lamb turn-off system (finished or store); (b) pasture utilisation; and (c) pasture production. When producers have optimised these factors the second order control points were: (a) meeting market specifications; (b) ewe nutrition and condition score profile; (c) reproductive rate; and (d) ewe wool value. For individual producers the management and production factors that will provide the greatest return on effort will depend on their current management and production levels, plus the ease and cost with which they can alter their management.

The modelling indicated that if pasture production in winter or late spring and summer can be increased significantly then impacts on whole farm profit are very large, especially for later lambing flocks. Five on-farm sites, which were initiated, established and managed by producers, demonstrated improvements in lamb production per hectare of more than 50% when compared to the remainder of their farm or the top 20% of producers in the South West Monitor Farm Project. These productivity gains presumably resulted from the combined effects of increased subdivision, improved grazing management and sowing commercially available high performance pasture mixtures. There was however minimal variation in lamb output between the three pasture systems compared at each site, which suggests short term ryegrass and longer term fescue based pastures could not be justified from an economical standpoint. This could be due to poor establishment and management of 'new' pastures at several sites, the manner in which the trial was managed (i.e. single pasture type with each system and stocked all year round) and the high performance of the perennial ryegrass/subclover 'control'. Further work is needed to identify the strengths and weaknesses of the 'new' pastures in different seasons and years, and to determine if a matrix of

different plant mixes and monocultures at farm scale can improve output above that achieved from a simple perennial ryegrass/subclover system without increasing risk. All producers involved adopted the pasture systems to varying degrees and made other changes to their production systems such as increasing subdivision in response to 10 to 20% higher weaning percentages on the demonstration sites compared to the remainder of their farms.

Evaluation of late season annual legumes for lamb production showed that arrowleaf clover (cv. Arrotas) was able to extend the growing season by 4 to 6 weeks and maintain a digestibility of at least 5% higher than subterranean clover (cv. Leura) during December and January. Lambs grazing arrowleaf clover at stocking rates up to 24 lambs/ha grew at or above 100 g/day without any supplementation until the end of January, whereas lambs grazing subclover and perennial ryegrass mixed pastures were removed into a feedlot situation by mid to late December. Total lamb production from arrowleaf monoculture pastures in late spring/early summer exceeded 400 kg liveweight/ha. A companion project (ER220) found that arrowleaf monocultures can be used for up to 2 years followed by a crop or pasture to utilize the build up of nitrogen and minimize the risk of nitrate leaching and acidification. Another option is to direct drill arrowleaf clover which has poor winter production into existing perennial ryegrass pastures, since perennial ryegrass/arrowleaf mixed pastures produced a similar quantity of lamb per hectare as arrowleaf monoculture pastures but had greater pasture production and grazing value during winter and early spring. Guidelines for establishment and management of arrowleaf clover have been published as part of this project.

Spatial separation of subclover and perennial ryegrass increased ewe and lamb performance by 20 to 30% compared to traditional subclover/ryegrass mixtures, due largely to increased clover in the diet. Ewes and lambs offered a free choice of grass and clover *ad libitum* consistently included up to 30% grass in their diet but performed as well or better than those grazing pure clover. Ewes on the choice pastures gained liveweight and condition during late pregnancy and early lactation whereas those grazing pure clover maintained or lost weight and condition during this period. There was no difference in feed intake between these treatments suggesting the benefits from offering grass and clover side-by-side could be greatest at the time of highest nutritional demand and result from improved feed conversion efficiency. *In vivo* studies showed that mixed grass /clover diets resulted in a more stable rumen fermentation pattern and *in vitro* work suggested optimal rumen function occurred with a mixed diet consisting of between 67 and 84% subclover. The concept of spatial separation of different vegetation types also allows us to entertain the possibility of applying species-specific management to the individual components to increase overall forage production and use novel plants that do not persist in mixed pastures.

We conclude that we need to change the scale at which we consider the role of plant diversity and expand our thinking from diversity at patch scale to across paddocks, farms and even landscapes, and reconstruct agro-ecosystems with plants that complement and enhance each other agronomically, functionally and biochemically. We need to better understand what plants we mix with what and how these are arranged spatially to match nutritional profiles for the animal together with other attributes such as adaptation to the environment and water use efficiency to develop profitable and sustainable animal production systems. The ‘Evergraze’ project has started this process. The ‘Morelamb’ project successfully achieved its objectives and outcomes from the project can assist producers to increase profitability. The project has already contributed to major extension activities such as Prime Time and Sheep Updates, field days and site visits (7) and external presentations (13). Publications from the project have included one review paper and a Churchill fellowship report, short communications at conferences (8) and media articles (20+). Several papers are in preparation for submission to refereed journals within the next six months and work is ongoing with MLA to package these outcomes with other projects within the Management Solutions portfolio.

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1 Key performance drivers of lamb production systems in south west Victoria

1.1 Background

On-farm benchmarking analysis from across southern Australia indicates the most important profit driver in lamb production systems is the amount of lamb produced per hectare. However, there is no universal optimum production system due to changes from one year to another and unpredictable fluctuations within a production cycle. Flexible management practices are the best and perhaps the only way of coping with seasonal variability in pasture growth rates. A key is to identify the ‘critical control points’ or decision hierarchy for lamb producers to allow them to focus their management attention on the ‘critical’ areas that have the greatest return and to define the criteria (or ‘set of rules’) for pasture and animal management tactics that could be used in response to observed events or conditions as the season progresses.

This component of ‘Morelamb’ aimed to define ‘critical control points’ for different lamb production systems from an analysis carried out using the MIDAS model calibrated for the Hamilton region of western Victoria. MIDAS is a computer model used to assess the impact of changes in a farming system. It describes the biological relationships of a representative farm and this information is used to estimate the profitability of particular enterprises or management strategies. MIDAS was selected as the appropriate modelling tool because it includes a powerful feed budgeting module that optimises animal and pasture management across the whole farm. This makes MIDAS an efficient tool to examine altering the management of a lamb producing flock as it accounts for the changes in the energy requirement of the flock when production potential is altered.

Modelling complex systems can also enhance understanding of the components of the system and highlight areas where further research is required. This approach was adopted for this project. Initially, information was gathered from lamb producers involved the project (see section 2.3.1.) and researchers in the region about the farming systems they currently operate and the constraints to profitability. Subsequently, MIDAS was used to quantify the impact of a range of management variables on profitability. This information can be combined with knowledge of the ease with which farmers can alter management to decide which should be the highest priority.

1.2 Objectives

Objective #1: By 30 June 2005 – Identify critical control points in lamb production systems and develop a systematic approach to enable lamb producers within ‘Morelamb’ to achieve a 50% increase in lamb liveweight per hectare.

1.3 Methodology

1.3.1 The model farm

The model represents a ‘typical’ farm in the Hamilton region in south west Victoria. The total area of the farm is 1000 ha and comprised of three land management units (Table 1).

Table 1. Description and area of each land management unit on the model farm.

Land Management Unit	Area (ha)	Description
Ridges	200	Well drained gravely soils at tops of hills
Mid slopes	600	Moderately drained loams in the mid slopes
Flats	200	Clay soils in lower slopes that are often waterlogged

Four production systems were examined in the analysis and a brief description of each system is given in Table 2. Variation between the systems is related to the genotype of the ewes and the time of sale of the lambs. The details of the two genotypes are outlined in Appendix 1 (Table A1). Each animal production system was evaluated for two different times of lambing. The systems turning off finished lambs were evaluated for lambing in May and July and the systems turning off feeder lambs were evaluated for lambing in July and August.

Table 2. A description of the flock types included in this analysis.

Flock	Description
Second cross lambs - Finished *(2nd X - Fin)*	A prime lamb system in which Border Leicester x Merino ewes are purchased as lambs. The ewes are mated at 19 mths of age to a terminal sire and the 2nd cross lambs are sold as finished lambs at 45 kg.
Second cross lambs - Store *(2nd X - store)*	A prime lamb system in which Border Leicester x Merino ewes are purchased as lambs. The ewes are mated at 19 mths of age to a terminal sire and the 2nd cross lambs are sold as stores at weaning at 30 kg.
Composite ewes - Finished *(Comp - Fin)*	A lamb system with a self replacing composite breed (Romney x Coopworth base). The ewes are mated at 19 mths of age and the lambs are sold as finished lambs at 45 kg.
Composite ewes - Store *(Comp - Store)*	A lamb system with a self replacing composite breed (Romney x Coopworth base). The ewes are mated at 19 mths of age and the lambs are sold as stores at weaning at 30 kg.

The standard pasture grown on all land management units is a highly productive perennial ryegrass pasture with high fertiliser rates and best grazing management practices. The costs associated with reseeding the pastures have been included assuming the improved pastures need to be reseeded once every 10 years. The growth rate of the pastures has been based on simulations using the GrassGro model with climate data from the Hamilton weather station (Steve Clark pers comm.). More details on the pasture productivity assumptions are presented in Appendix 2.

1.3.2 The analysis

This section outlines the sensitivity analysis undertaken using the model. Parameter values were changed systematically (and individually) while the others were held constant. In each case the most profitable system – the current "best bet" - was taken as the finishing point and the increase in profit from adopting optimal management was examined. Most results are presented as the change in profit for a 10% change in the target parameter. For example when changing the feed base through a change in winter growth rate the result is expressed as the change in profit that could be achieved if the growth rate of pasture during winter is increased by 10%. In the case of ewe nutrition and time of lambing the results are presented as the change in profit resulting from a unit of management change.

The sensitivity analysis can be used to improve our understanding of the farming system by estimating the change in whole farm profit resulting from changes to different components of the system (or parameter values). This identifies parameters that are economically more important and thereby which components of the farming systems might be altered for the greatest economic gain. While sensitivity analysis is a powerful tool, results must be interpreted with care. Model results indicate where management change has the greatest potential benefit, however the model results provide no indication of the ease with which the management change or increase in production potential can be achieved in the farming system (say an increase in winter pasture growth). For example a 10% change in winter growth may be more valuable than a 10% change in spring growth but it may be much more difficult (and costly) to achieve. A further consideration is the ease with which farmers may adopt prospective management changes. Improved management that increases the demand for labour for example is less likely to be adopted than an alternative option with less requirements for labour.

In this sensitivity analysis MIDAS was used to determine the profitability of each of the animal systems (described in Table 2) when each of the factors shown in Table 3 was varied independently. It was assumed that the management changes or production changes could be achieved with no additional cost other than costs associated with running extra stock or feeding extra grain (if either of these was required). For example, increasing pasture production in winter could be achieved at no cost but the change in stocking rate that results from the increase in production is costed.

Table 3. Range of management and production variables examined in this analysis.

Description	Detail
The feedbase	Increase pasture growth rate by 10% For Entire Growing Season During Winter only During Early spring only During Late spring only During Summer only
Pasture utilization	Increase annual utilisation by 10% Reduce dry pasture carried into break of next season Reduce losses associated with grazing Better allocation of feed to grazing livestock
Ewe nutrition	Alter target LW of ewes 7 to 10 kg difference in LW throughout the year 3 kg difference at joining or lambing
Reproductive rate	Increase lambs marked by 10% By increasing fecundity By increasing survival

	Combination of above
Time of Lambing	Early and Late
Meeting market specifications	10% increase in average price received
Wool value	10% increase in wool price

1.4 Results and Discussion

1.4.1 The systems analysed

The optimum management and the production profile identified by MIDAS for each of the four animal systems are shown in Table 4.

Table 4. Production and management parameters for the optimum management for each animal production system.

	Animal System			
	2nd X - Fin May	2nd X - Store July	Comp – Fin July	Comp - Store July
Farm profit ($/ha)	200	40	205	298
Wool income ($/ha)	190	195	191	208
Sale sheep income ($/ha)	644	511	557	508
Sheep purchases ($/ha)	254	300	-	-
Stocking rate (DSE/WG ha)[1]	13.9	17.1	17.4	19.7
Supplementary feeding (kg/DSE)	19.8	3.6	47.6	10.4
Flock structure (% ewes)	88	88	87	87
Lambing (%)	142	142	149	149
Pasture growth (t/ha)	8.4	7.6	9.0	9.6
Pasture utilization (t/ha)	4.9	4.7	5.1	5.4
(%)	59	62	57	56

Producing store lambs or finished lambs is a trade-off between the extra income received from finished lambs compared with the lower stocking rate and extra grain feeding required to finish the lambs. The best turn-off system varies depending on the genotype of the ewes. For the composite breed the optimum system is selling stores at weaning. This is $93/ha more profitable than selling finished lamb. To be equally profitable finished lambs would have to sell for $63/hd average when store lambs are selling for $43/hd. For the 2nd cross lamb system the more profitable system is selling finished lambs and this is $155/ha more profitable than selling stores. To be equally profitable stores would have to sell for $56/hd average when finished lambs are selling for $67/hd (including skin).

The difference between the genotypes is related to the differences in the value of the store lamb compared with the value of the finished lamb and this is affected by the value of the skin (see Fig. 1). For the second cross lamb system there is assumed to be a standard skin value of $15/lamb if the lamb is finished whereas this value is not realised if the lamb is sold as a store. For the

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[1] Stocking rate calculated using DSE ratings as outlined in the Farm Monitor Project, Dec 2001.

composite breed the standard value of the skin of the finished lamb is only $1/hd. If the skin value of the finished Composite lamb was $10 rather than $1 then selling finished lambs would be more profitable than stores. However, for the 2nd cross lamb system the profitability of the store system is not as high as the finishing system even if the skin value of the finished lambs was zero rather than $15.

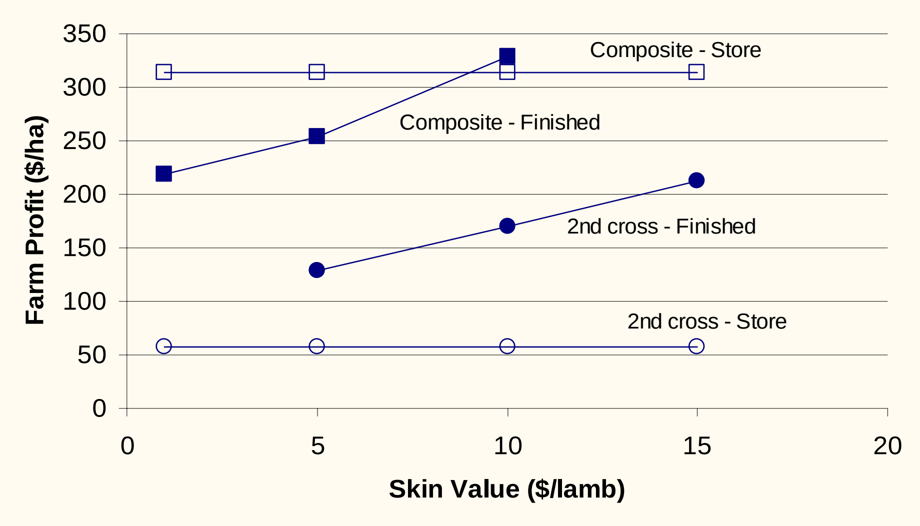

Figure 1. Impact of skin value on profitability of finishing lambs for each genotype.

A flock based on the composite breed was more profitable than a flock based on producing 2nd cross lambs, but the difference in profitability depended on the lamb turnoff system. At standard prices changing from the best 2nd cross system (producing finished lamb) to the best Composite system (producing store lamb) increases profit by $100/ha. However, for a system producing finished lamb both genotypes are equally profitable (if replacement ewes are purchased at $100/hd). The 2nd cross system has a low profitability when used to produce stores. The profitability of the second cross system is penalised by the very high cost of buying in replacement ewes. The cost of $150/ewe lamb is not recouped from the more valuable wool produced from the ewe and the more valuable skin produced by the finished lamb. Ewe lambs would need to be about $100/hd before the profitability of the 2nd cross system was equal to the composite system selling stores (Fig. 2).

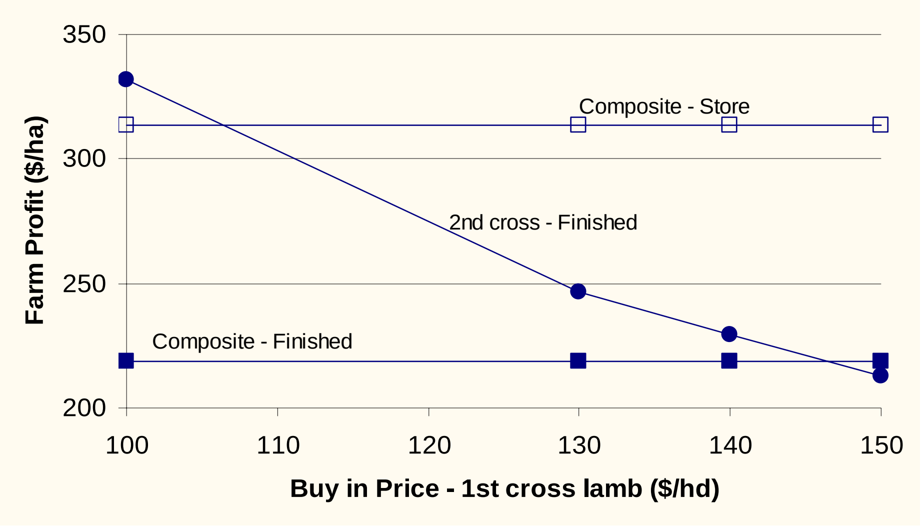

Figure 2. Impact of buy in price for 1st cross ewe lambs on the profitability of the 2nd cross finished lamb system.

1.4.2 Profitability of increasing management and production potential

1.4.2.1 Feedbase

The most valuable time of year to increase pasture growth is in winter irrespective of animal production system (Table 5); a 10% increase in pasture growth in winter corresponds to an extra 2 kg DM/ha/day. This is the time of year that impacts on the cost of carrying more stock and winter also coincides with lactation and peak energy demand for early lambing ewes. The value of extra pasture growth in spring and summer is relatively low for early lambing systems because the main nutritional demand is in winter and unless this gap can be filled there is little benefit of extra pasture at other times of the year. The value of late spring and summer growth is moderate albeit greater for later lambing flocks, however opportunities exist to substantially increase pasture growth at this time using long season annuals and summer active perennials respectively.

Table 5. Increase in farm profit ($/ha) resulting from increasing pasture growth during different periods by 10%. The scenarios presented are for the optimum system using the composite breed (Comp Store – July lambing) and for the optimum system producing 2nd cross lambs (2nd Fin – May lambing).

Change	Profit Increase ($/ha)	
	Comp Store – July	2nd X Fin – May
Whole year	32	38
Winter	28	29
Early Spring	15	5
Late Spring	21	5
Summer	5	1

1.4.2.2 Pasture utilisation

Previous analysis has shown that utilising a high proportion of pasture is a critical control point for Merino wool producing flocks. Increasing pasture utilisation has a high value if it can be achieved by reducing the loss of pasture from trampling (Table 6), which can be achieved by sub-dividing paddocks to reduce the amount of walking done by animals. Increasing utilisation by grazing harder and reducing the summer residual is of lower value as the extra pasture grazed is of low quality being the last pasture consumed. Pasture saved from trampling is of average quality and therefore more valuable. Achieving better utilisation of pasture through improved allocation of the pasture resource to the grazing animals has a value intermediate between the other two options. Better decisions on allocation of pasture requires the manager to be more aware of the pasture and the grazing animals and have strategies and tactics to handle varying seasonal conditions.

Table 6. Change in farm profit ($/ha) resulting from altering parameters associated with pasture utilisation by 10% for the optimum turnoff systems for each genotype.

Change	Composite – Store	2nd Cross - Finished
Summer residual	0	3
Trampling losses	99	46
Better allocation	38	17

1.4.2.3 Ewe nutrition

The impact on profit of altering the target liveweight or condition score of ewes is a tradeoff between the cost of providing the extra feed that is required (either in the form of supplement or lower stocking rate) and the extra value of production from the ewes. This extra value of production comes from extra wool growth and from extra lambs weaned. The higher weaning is a result of extra lambs conceived or extra lambs surviving. The value of extra wool production is related to the amount of extra energy consumed as wool growth is closely related to energy intake and there is little impact of changing fibre diameter on the value of the wool. The number of extra lambs conceived is related to the extra weight of the ewes at joining, and the extra survival of lambs is closely related to the extra weight of the ewes at lambing. An extra kilogram of liveweight at joining and an extra kilogram at lambing have a similar effect on the number of lambs weaned, so the decision about the optimum nutrition strategy for the ewes is related to the availability of feed rather than the existence of a priority time of year. The extra lambs conceived or the extra lambs surviving are not sufficiently valuable to pay for the amount of supplement that would be required to gain the weight. However, feeding supplement to reduce weight loss and ensuring maximum weight is gained on green feed would be profitable.

Increasing the target liveweight for ewes by 7 to 10 kg through reducing stocking rate and increasing grain feeding increases the profitability of each of the flocks by an average of $50/ha. The corresponding condition score profiles depend on the time of lambing, but the minimum condition score for the ‘low’ nutrition was 2.0 to 2.5 versus 3.0 to 3.5 for the ‘high’ nutrition. The decrease in stocking rate necessary to achieve the 7 to 10 kg increase in liveweight was between 0.5 and 1.5 DSE/ha with a concurrent increase in supplementary feed of approximately 10 kg/DSE. Based on the Lifetime Wool project analysis there would be a further advantage from maintaining the composite ewes in higher condition through their progeny cutting more wool during their lifetime however, this benefit hasn’t been quantified.

1.4.2.4 Reproductive rate

Reproductive rate is a combination of fecundity (the number of lambs born per ewe mated) and lamb survival (the number of lambs alive at weaning per lamb born). Reproductive rate can be increased by improving the nutrition of the ewes, improving the genetic potential of the ewes or reducing the reproductive wastage caused by environmental factors. The extra profit from increasing reproductive rate is a trade-off between the extra income achieved by having a flock with more surplus animals for sale and the extra costs associated with meeting the energy demands associated with more ewes pregnant or more ewes lactating. For the flocks examined the increase in profit averaged $47/ha for a 10% increase in number of lambs weaned, implying a break-even point of about $4.70 per ewe to increase overall weaning percentage by 10%. Increasing survival is slightly more valuable than increasing fecundity (Table 7). For the composite flock, the value of having an extra lamb at weaning by increasing survival is $13/lamb greater than having an extra lamb at weaning from getting more ewes pregnant. The best position to focus on in the reproductive process depends on where the greatest wastage is occurring.

Table 7. Change in farm profit ($/ha) resulting from increasing the number of lambs weaned by 10%.

Change	Composite – Store	2nd Cross - Finished
Fecundity	56	34
Survival	68	34
Combination	60	34

1.4.2.5 Time of Lambing

The profitability of lambing later is a trade-off between the lower energy demands of the ewes at the break of season and the higher energy demand of the younger and smaller progeny after weaning. Later lambing makes it possible to carry higher stocking rates through the feed shortage at the break of season and have more animals available to graze the spring flush (see Table 4). Earlier lambing reduces the cost associated with achieving target weights for the lambs. The 2nd cross lamb system was most profitable turning off finished lambs and lambing in May was slightly more profitable ($15/ha) than lambing in July. The Composite system was most profitable turning off stores and lambing in July was $35/ha more profitable than lambing in August. If store lambs could be sold at lower weights then the optimum time of lambing would be later. For each of the systems examined the impact of altering the time of lambing by 4 to 6 weeks was less than $15/ha.

1.4.2.6 Meeting market specifications

The ability to meet market specifications is reflected in a higher average price received for lambs and a reduction in the number of lambs having to be carried over. For this analysis only the first one of these factors has been quantified. The increase in profit resulting from a 10% increase in the value of the lambs is dependent on the initial value of the progeny and the number of progeny sold. For systems selling finished lambs the initial value is higher but the number being sold is lower compared with a store system and the overall value is similar. The 2nd cross system is more sensitive to meeting market specifications because all the animals are being sold so there are more animals that benefit from the higher price (Table 8).

Table 8. Change in farm profit ($/ha) resulting from meeting market specifications and increasing the value of lamb by 10%.

Composite – Store	2nd Cross - Finished
65	80

1.4.2.7 Wool value

Each flock produces between 20 and 30% of the total income from wool sales, so although wool income is not the focus of the enterprise it does contribute to the overall profitability. Increasing the value of the wool produced in the flocks by 10% increases profit by an average of $30/ha. However, altering the fibre diameter of the flock only has a very small impact on profit (less than $15/ha) because wool price is not sensitive to fibre diameter at these levels.

1.4.3 Achieving a high profit system

Based on the factors examined and assumptions used in this analysis the critical control points for lamb producers are:

1. Matching genotype and the turn-off system for the lamb (finished or store)
2. Feed utilisation
3. Pasture production

When farmers have optimized these factors the second order control points are:
1. Meeting market specifications
2. Ewe nutrition
3. Reproductive rate
4. Ewe wool value

Table 9. Summary of critical control points for lambs production systems in south west Victoria.

Control Point	Maximum Value ($/ha)
Genotype: Composite v 2nd cross	100
Lamb System: Store v Finished	155
Feedbase: 10% increase in annual growth	38
Utilisation: 10% increase	99
Ewe nutrition: 7-10kg heavier	50
Reproductive Rate: 10% higher	60
Time of Lambing: 4-6 week change	35
Market Specifications: 10% price change	77
Wool Value: 10% price change	41

For individual producers the management and production factors that will provide the greatest return on effort will depend on their current management and production levels. The analysis shows that there is likely to be scope within the industry to specialise between breeders and finishers. With the prices used in this analysis a breeding unit producing stores will be more profitable with a composite genotype rather than a 1st cross ewe. If producing finished lambs is the system, then the choice of genotype is less important and the focus should be on selecting the individual animals carefully.

Optimising feed utilisation is a critical control point for all farmers. For lamb producers the optimum level of utilisation is lower than for a Merino wool enterprise. Improving feed utilization requires producers being more informed about levels of pasture in different paddocks on the farm and making good decisions about allocating the pasture resource to the grazing animals. The cash costs associated with most of these decisions are low, however they require a high level of technical knowledge. Only when a high level of the pasture grown is consumed is it worth examining ways to increase pasture production. Opportunities to increase pasture growth include increasing fertilizer which increases the growth of the pasture throughout the growing season or changing pasture species. Changing the species may alter the feed profile and better match the feed demand profile. The results show that a 10% increase in summer growth only has a moderate return, however, the possible increase in summer growth rate identified in the 'EverGraze' project is in the range of 200 to 400% so the potential payoff is very large.

2 On-farm evaluation of high performance pastures

2.1 Background

Forage systems for lamb production in southwest Victoria are dominated by perennial ryegrass (Ward and Quigley 1992). Ryegrass based pastures have many strengths, including low seed costs, ease of establishment, tolerance of grazing management practices and high nutritive value, but there are also drawbacks associated with their use. These include dominance of spring growth, low summer productivity, year-to-year variability in growth and poor persistence (Waller and Sale 2001; Nie *et al*. 2004). The large seasonal fluctuations in the growth and quality of ryegrass-based pastures, especially declining pasture quality in late spring/summer, are a major constraint to increasing stocking rate and production efficiency and producing lambs in these environments to meet market specifications. Perennial ryegrass staggers resulting from moisture stress coupled with high ambient temperatures during summer months (Heeswijck and McDonald 1992) also cause major stock losses in some years.

High performance pastures (HPP) comprising of mixtures of new and improved grass, legume and herb species are designed to overcome short-term deficits in pasture supply and quality of grazing enterprises. HPP evolved in the New England and southwest slopes areas of NSW primarily as short-term backgrounding and finishing pastures to fill winter feed gaps (Eccles 2002). Short-term hybrid and Italian ryegrass cultivars are used to increase winter dry matter production, with tetraploid cultivars popular due to their increased nutritive value. HPP can also include medium to long term species of perennial ryegrass and summer and winter active tall fescues to extend the growing season and provide an endophyte free sward eliminating the risk of perennial ryegrass staggers. Mixtures commonly include red clover and chicory to increase summer growth and quality. Eccles (2002) reported weight gains from HPP of 1.0-1.5 kilograms per day during summer for beef and an average of 300 g/day for lamb. Pure stands of chicory in New Zealand have grown in excess of 150 kilograms per day during summer and animal performance is better than ryegrass/white clover pastures (Hare *et al.* 1987; Fraser *et al.* 1988).

There is however limited knowledge of HPP in southwest Victoria and there has been no rigorous evaluation of their production potential across a range of environments and years at commercial scale. This component of "Morelamb" tested the hypothesis that HPP will increase pasture growth and quality during feed limited periods and increase lamb production per hectare compared to current practice.

2.1.1 Objectives

Objective #2: By 30 June 2005 - Demonstrate 20% improvements in productivity per hectare while achieving target liveweights for ewes and lambs, on five commercial properties involved in the project through adoption of 'Management Solutions' that increase pasture production and/or utilisation.

2.2 Methodology

2.2.1 Site location and details

The treatments were implemented on five lamb production enterprises located in southwest Victoria (Fig. 3). Annual rainfall, fertility levels and the area of each site and system are given in Table 10. Two of the sites had a Border Leicester x Merino first cross ewe flock mated to a terminal sire (typically Poll Dorset or composite breed based on Poll Dorset) to produce lambs in the range of 18 to 24 kg carcass weight. The other sites had composite ewes and produced feeder lambs in the range of 28 to 35 kg liveweight that would either be passed onto specialised finishing systems.

Figure 3. Location of 'Morelamb' on farm demonstration sites across south west Victoria.

Table 10. Annual rainfall (2002 to 2004 and long term average in brackets) and soil fertility for on farm demonstration sites across south west Victoria and area of pasture systems compared at each site.

Site	Location	Annual rainfall (mm)	P level (Olsen P)	pH (water)	Area (ha)		
					Pasture A	Pasture B	Pasture C
1	Digby	651 (700)	15.0	5.5	12.3	12.3	12.3
2	Hamilton	687 (700)	15.0	5.2	15.0	15.0	15.0
3	Camperdown	677 (750)	19.3	5.2	22.2	22.2	22.2
4	Condah	646 (800)	11.3	5.5	14.7	14.0	7.5
5	Heywood	687 (800)	13.7	5.6	20.4	20.4	20.4

2.2.2 Treatments

There were three treatments (paddocks) at each site and each paddock was subdivided to allow a four-paddock rotation. The three treatments were formulated by Wrightson Seeds Australia using recently released cultivars to increase forage quality or yield during the normal growing season or during the summer autumn period (Table 11). Pastures were established by collaborating producers in May-June 2002 using sowing rates recommended at that time. The recommended sowing rates have since doubled to 20 kg/ha for the tall fescue and short-term ryegrass species due largely to the larger seed size of tetraploid ryegrasses and the low seedling vigour of tall fescue.

Table 11. Pasture species and sowing rate per hectare.

System A	Rate (kg/ha)	System B	Rate (kg/ha)	System C	Rate (kg/ha)
Perennial ryegrass cv. Lincoln	5	Tall fescue cv. Resolute	6	Perennial Ryegrass cv. Aries HD	6
Perennial ryegrass cv. Fitzroy	5	Tall fescue cv. Quantam	4	Tetraploid Italian Ryegrass cv. Feast II	6
Subterranean clover cv. Leura	8	Subterranean clover cv. Leura	5	Subterranean Clover cv. Leura	4
White clover cv. Haifa	1	White clover cv. Challenge	1	White Clover cv. Challenge	1
		Red clover cv. Astred	2	Red Clover cv. Astred	2
				Balansa Clover cv. Bolta	1
				Chicory cv. Puna	1

2.2.3 Grazing and stock management

Pasture systems were stocked with animals from September 2002 to December 2004. They were initially stocked with a core group of crossbred ewes at a rate 10-20% above the average stocking rate of each participating farm. All subsequent stocking rate adjustments were the responsibility of the producers, the idea being to move additional livestock in and out of each system as required to manage feed on offer (FOO) levels. The target FOO levels throughout the year were as follows: autumn/winter (1500 kg DM/ha), lambing (1500 kg DM/ha), end of spring (2500-3500 kg DM/ha) and autumn break (1000 kg DM/ha). Fifty tagged ewes per paddock at each site were weighed direct off pasture on the five occasions each year: (i) pre-joining; (ii) mid-pregnancy (Day 90 to 110); pre-lambing (Day 135 to 140); (iv) lamb weaning; and (v) prior to sale of lambs. Fifty lambs per paddock at each site were selected at random and weighed at weaning and/or prior to sale.

The number, age, estimated weight or condition, and class of livestock were recorded and carrying capacity was generated by the prediction of metabolisable energy (ME) requirements using a spreadsheet based on a MIDAS manager template (John Young, Farming systems analysis, Kojonup, WA). Dry sheep equivalents were calculated by dividing the monthly total by the ME requirement of a 45 kilogram wether (7.8 MJ ME) (Australian Feeding Standards 1990). Predicted intake was estimated and used to estimate total annual dry matter production for each system.

2.2.4 Pasture measurements

Feed on offer for each pasture system at each site was estimated by visual assessment or weighted disk plate meter at monthly intervals from September 2002 to December 2004 by project staff or participating producers. A minimum of 40 observations per pasture system was undertaken and these were calibrated against 15 to 20 quadrats (0.1 m^2) that covered the range in FOO and botanical composition at that time. Quadrats were harvested by cutting to ground level using a 12-volt electric shearing handpiece. The harvested pasture samples were rinsed in water to remove soil and sheep manure, dried at 100°C for 24 hours and weighed to determine dry matter content. Feed on offer was determined using regression analysis.

Botanical composition was determined from samples harvested using the 'toe-cut' method described by Cayley and Bird (1996). At least 30 samples were cut to ground level from small areas randomly positioned throughout the pasture system. Pasture samples were sub-sampled and sorted into the following components; ryegrass, tall fescue, legume, chicory, annual grasses, onion grass, broadleaf weeds and dead material. Samples of individual species from each system were dried at 100°C for 24 hours and weighed to determine their dry matter weight and proportion of the sward. Botanical composition measurements were undertaken in September 2002 and in August and November 2003 and 2004. Pasture samples collected using the toe-cut' method were also used to determine nutritive value. Immediately post harvest pasture samples were placed in a plastic bag, sealed and kept in an esky containing ice packs and delivered to FEEDTEST®. Samples were analysed for digestibility (OMD), neutral detergent fibre (NDF), crude protein (CP) and metabolisable energy (ME) on an organic matter basis. Nutritive value measurements were undertaken in September, October and November in 2002, fortnightly from September to late December in 2003, and monthly from August to December in 2004.

2.2.5 Statistical analysis

The following statistical analysis was undertaken using Genstat: (a) FOO - Linear mixed model with cubic smoothing splines to test for treatment effects allowing for random site and time effects; (b) Botanical composition - General analysis of variance to test for treatment and time effects and with site as blocking and (c) Nutritive value - Linear mixed model with cubic smoothing splines to test for treatment effects allowing for random site and time effects. Other data is presented as raw means.

2.3 Results and Discussion

2.3.1 Pasture establishment and composition

Pasture establishment was variable across sites and pasture systems and management during the pre and post establishment phases was a major factor contributing to the overall success of HPP. Six months after pasture sowing the proportion of sown grass, legume and herb species ranged from 5 to 55 % of the sward. This variation was due to differences in site preparation and sowing methods between sites and differences in the growth rates of individual species and their ability to compete against weeds. Pasture systems A and C that contained perennial or Italian ryegrass had 50 to 60% of the sward made up of these species and 20 to 30% annual grasses, whereas only 5 to 30% of the total sward was tall fescue in System B (Fig. 4). Low seedling vigour of the tall fescue contributed to poor establishment of system B as it allowed annual grass weeds to dominate.

Paddock preparation and the level of seed set of annual grasses in the year prior to sowing explained the variation in the proportion of annual grasses between sites. This work highlighted the need to plan at least 12 months ahead so winter cleaning and spray topping can be incorporated into the overall process of paddock preparation to ensure successful establishment of HPP. In our opinion, a 'hands-on' extension program focusing on pasture establishment strategies and targeted at farmers, consultants and pasture specialists is required. The most successful method of establishing HPP in the 'Morelamb' project was to sow a Brassica crop in the previous spring. Strategic herbicide applications during the previous winter and spring would be even more effective against annual grass species that set seed earlier and would not expose hard seed through extra cultivation associated with Brassica crops. Winter cleaning of winter grass (*poa annua),* which has the potential to dominate tall fescue pastures, is a critical application because often spray topping regimes in the spring miss the early seed set of the winter grass.

The short term ryegrass based HPP (System C) did not persist beyond 2 years due to poor grazing management at some sites and needed to be over sown with its primary grass component in 2004. The lower than recommended sowing rates and manner in which the trial was managed in that pastures were generally stocked continuously from a few months after establishment undoubtedly contributed to this decline. In contrast, the proportion of tall fescue increased and annual grasses decreased in System B over the 2 years following establishment. It is clear that the establishment phase was more critical for the tall fescue-based HPP but it would be more productive over the longer term. This result influences the decision making and planning process to determine the type of HPP to be sown for different circumstances. It also emphasises the need for production systems evaluations to continue for a number of years.

The clover content in all of the pasture systems was about 20% of total sward mass which is similar to that reported by Ward and Quigley (1992). Maintaining a high proportion of clover in HPP systems is a challenge, as high pasture growth rates can lead to an accumulation of lower quality grasses in late spring and subsequent increased selection for the clover. White clover, red clover and balansa clover were minor components in the first year and largely disappeared from the swards within 2 years. Other work has also shown a strong pattern for complex pasture mixtures to simplify to a few dominant species over a couple of years (Sanderson *et al.* 2005), and indeed that sowing 'shot-gun' mixtures may not only be a waste of money but actually compromise the more persistent species (Jim Virgona; MLA Final Report – Past.311).

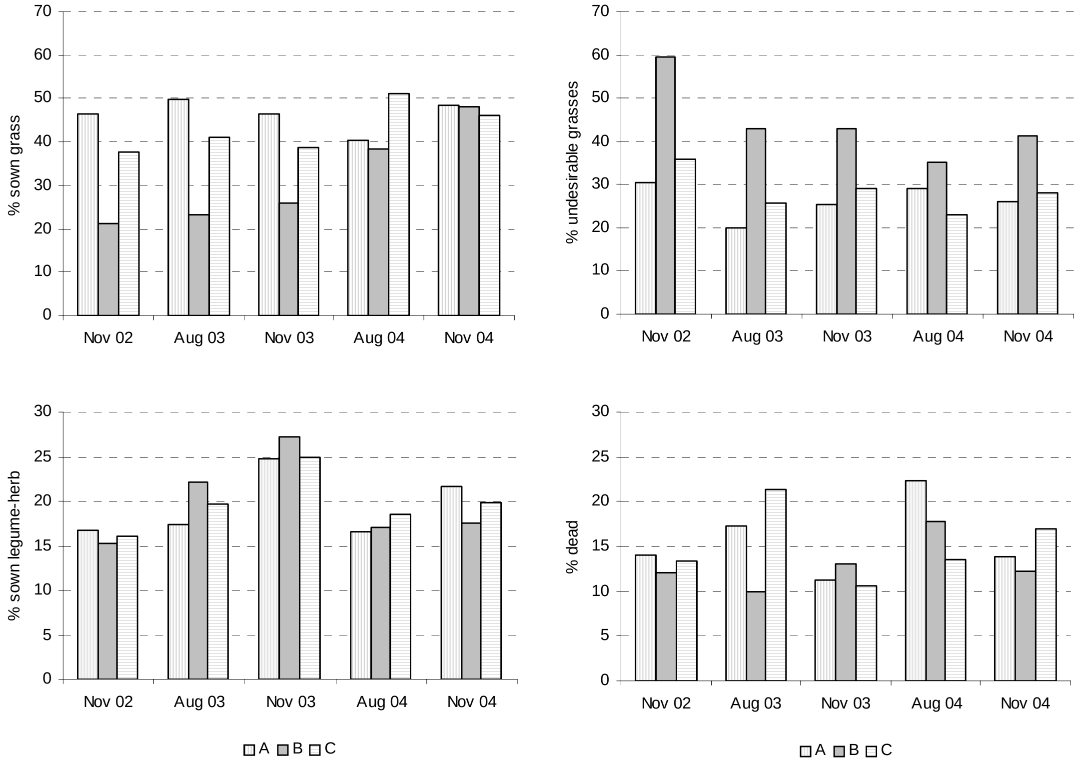

Figure 4. Average botanical composition of three pasture systems based on perennial ryegrass (▥), tall fescue (■) and short term ryegrasses (▤) over 2 years following sowing in autumn/winter 2002 at five paddock scale sites across south west Victoria.

Successful establishment and management of tall fescue represented the greatest challenge for the producers. A farmer case study is given in Appendix 3 to highlight how subtle differences in paddock preparation for pasture establishment and grazing management between two sites led to large differences in the composition of the fescue-based HPP (Table A3.1). The rapid establishment and ease of management of the ryegrass based pastures fitted the current skill set and level of input that the producers currently implemented on other parts of their enterprises. System A was seen as the most robust pasture because it did not require an increase in the intensity of management. The challenges to farm management skill associated with successfully using more complex feed base options should not be under estimated, nor the implications for adoption by industry.

2.3.2 Pasture quality and production

System C had a higher feed quality than the other two systems (Fig. 5). The higher quality of system C is a result of the short-term ryegrass. Chicory was a component of System C but its contribution to increasing feed quality only occurred at one site. At the other sites poor grazing management or the need to remove undesirable weeds from the sward led to its removal by unavoidable chemical application. The digestibility of system B was lower than system A and is a likely result of the quality decline associated with its vigorous growth during spring and level of undesirable species in the sward.

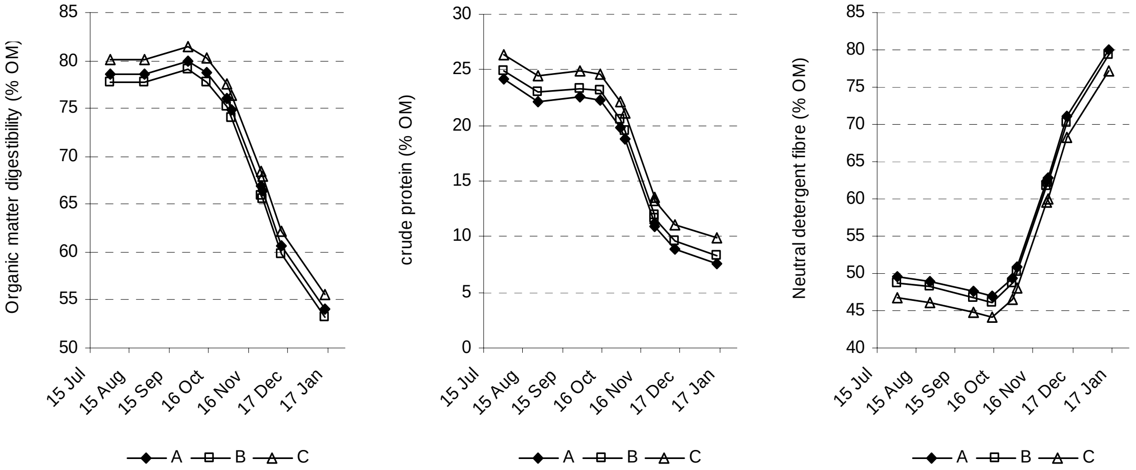

Figure 5. Digestibility, crude protein and neutral detergent fibre of three pasture systems based on perennial ryegrass (◆), tall fescue (□) and short term ryegrasses (△) during late spring early summer in 2003 and 2004 (one site represented only).

The decline in quality began in mid to late October and reached a point that would restrict animal production by mid to late December. Management strategies to maintain plants in a vegetative phase, especially tall fescue, should be implemented in November and December to extend the period of high feed quality. Increasing stock densities by reducing stocking rates on other lower priority pastures or pastures that can maintain a higher feeding value in late spring/early summer should be considered to both maintain feed quality and increase overall utilisation. Some of the collaborating producers implemented mechanical topping regimes during this period to maintain feeding value, but the economic feasibility of this strategy is not known given the extra cost of the mechanical operation and the potential trade off between quality and quantity of dry matter.

2.3.3 Animal production

The average ewe liveweight and condition score profile for all pasture systems are shown in Fig. 6. Ewe condition score was maintained between 3.5 and 4.0 for most of the demonstration period, which MIDAS predicts would be about $50/ha more profitable than running ewes a condition score lighter (see section 1.4.2.3). Ewes grazing system C had a higher liveweight and condition score profile, which was presumably the result of the increased feed quality and hence potential intake, but these differences were not statistically significant between systems or sites. There was little difference between Systems A and B. No supplement was used during the project except for isolated cases where lupins were used to create a flushing effect and this was abandoned after the initial year due to the high condition of the sheep. The minimal use of supplements may suggest that pastures were understocked, especially the enterprises lambing earlier and producing heavier lambs. The optimum management for these systems according to MIDAS would feed 20 to 50 kg supplement/DSE per year.

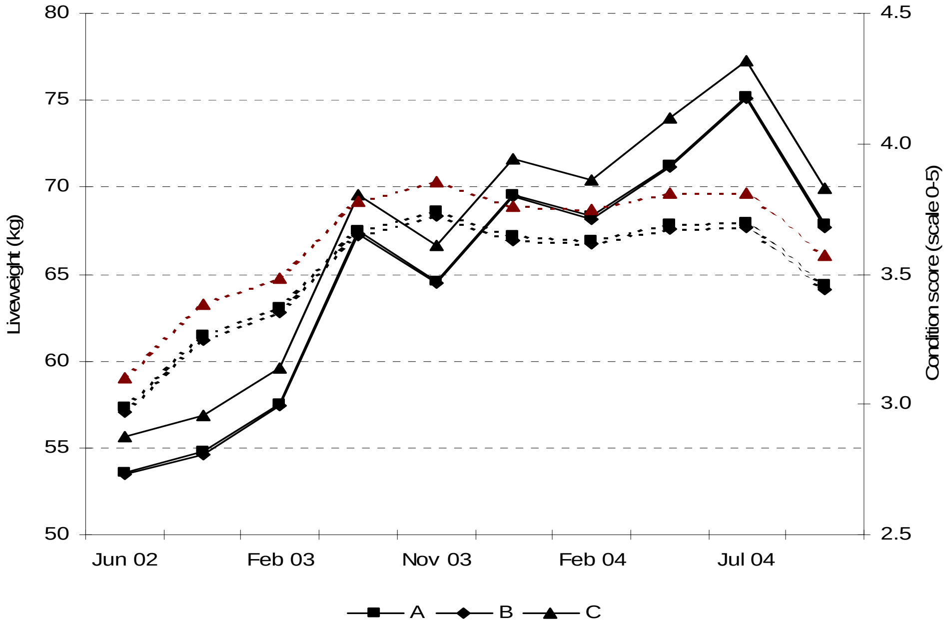

Figure 6. Average liveweight and condition score profile of ewes grazing pasture systems based on perennial ryegrass (◆), tall fescue (■) and short term ryegrasses (▲) over 2 years at five paddock scale sites across south west Victoria.

Across both years and all sites and pasture systems the total weight of lamb produced per hectare was more than 50% greater than that achieved on the rest of the collaborators farms and the top 20% of producers in the South West Monitor Farm Project (510 vs. 330 kg/ha). The differences in production between sites with the same enterprise were much greater than between pasture systems within site, reflecting differences in environment, land capability, sheep genotype, pasture management and other factors. Animals systems that focused on store lambs produced more lambs (16.0 *vs*. 13.4) but less liveweight (445 *vs*. 555 kg) per hectare than those that produced finished lambs. There was a reasonable match between MIDAS predicted benchmark production levels for high performance lamb flocks (see section 6, Table 24) and actual levels achieved at the demonstration sites (Table 12); 57 *vs*. 65 kg liveweight/ha/100 mm rainfall for store lamb systems and 71 *vs*. 84 kg liveweight/ha/100 mm rainfall for finishing systems, respectively.

Table 12. Ewe and lamb production and estimated gross income per hectare for three pasture systems based on perennial ryegrass (A), tall fescue (B) and short term ryegrasses (C) over 2 years at five paddock scale sites across south west Victoria. The data is presented separately for first cross ewe systems (n = 2) and composite ewe systems (n = 3).

Year	Ewe genotype	System	Mating date	Lambing date	Lamb wean or exit date	SR (ewes/ha)	Fertility rate (per 100 ewes mated)	Weaning rate (per 100 ewes mated)	Lamb number (ha)	Lamb weight (kg)	Total lamb weight (kg/ha)	Gross income ($/ha)
2003	BLM	A	06/02/03	06/07/03	22/12/03	9.5		129	12.8	42.9	549	1116
2004	BLM	A	21/02/03	20/07/04	17/12/04	10.7	160	124	13.8	39.2	543	1115
2003	BLM	B	06/02/03	06/07/03	22/12/03	8.5		135	11.9	40.9	490	1018
2004	BLM	B	21/02/03	20/07/04	17/12/04	9.2	175	130	11.8	39.4	466	982
2003	BLM	C	06/02/03	06/07/03	22/12/03	10.2		134	14.1	43.9	620	1232
2004	BLM	C	21/02/03	20/07/04	17/12/04	12.0	176	131	16.2	40.8	663	1318
						10.0	170	130	13.4	41.8	555	1130
2003	Comp	A	01/03/03	29/07/03	30/11/03	10.1	169	141	14.4	30.1	429	1081
2004	Comp	A	18/03/04	15/08/04	27/11/04	14.4	161	125	18.8	26.8	496	1326
2003	Comp	B	13/02/03	13/07/03	25/11/03	9.9	172	144	14.5	30.6	433	1100
2004	Comp	B	16/03/04	13/08/04	01/12/04	11.4	163	120	14.0	30.1	423	1083
2003	Comp	C	01/03/03	29/07/03	30/11/03	9.5	172	149	15.0	31.0	462	1172
2004	Comp	C	18/03/04	15/08/04	06/11/04	14.7	172	130	19.2	22.8	432	1254
						11.7	170	135	16.0	28.6	445	1169

It is apparent that the difference in lamb production between HPP systems was relatively small. Over 2 years the short term ryegrass based HPP (System C) produced 5% more lamb liveweight per hectare and the fescue based HPP (System B) produced 8% less lamb than the perennial ryegrass/subclover 'control' (System A) (Table 12). The differences between pasture systems were greater for finishing than store lamb enterprises. Not surprisingly, the gross margin analysis would suggest that there is little financial incentive for the introduction of the short term ryegrass or fescue based HPP (Table 13), but as already indicated this could in part be due to poor establishment and management of 'new' pastures at several sites, the manner in which the trial was managed (i.e. single pasture type with each system and stocked all year round) and the high performance of the perennial ryegrass/subclover 'control'.

The design of the demonstration sites did not allow the positive attributes of the different pastures to be exploited in a whole system context. Further work is needed to identify the strengths and weaknesses of the 'new' pastures in different seasons and years, and to determine if their inclusion in the mosaic of pastures at farm scale can improve output above that achieved from a simple perennial ryegrass/subclover system without increasing risk. Simple 'rules of thumb' indicating break-even levels of production for pastures with different resowing intervals would be useful. Nevertheless, all of the pasture systems returned a gross margin of $92-140 and $86-223/ha more than the overall farm averages for 2003 and 2004 respectively. Increasing subdivision to reduce patch grazing and trampling and rotational grazing to better allocate feed are likely to have increased pasture utilisation and lamb production per hectare compared to the remainder of the farm. The MIDAS modelling indicated that improving utilisation by 10% by these methods could improve the profitability of store lamb enterprises by $40 to $100/ha and finishing enterprises by $20 to $50/ha (section 1.4.2.2, Table 6).

Only 35% of the variation in gross margin per hectare between years, enterprises, sites and pasture systems was explained by the total amount of lamb produced per hectare. The data suggests that the key drivers of profit vary depending on enterprise type because store lambs are sold on a per head basis that does not necessarily relate to carcass weight values. The number of lambs produced per hectare was the most reliable predictor of gross margins per hectare, explaining 85% and 88% of the total variance in gross margins for store and finished lamb enterprises, respectively. Ewe stocking rate rather than weaning percentage had the greatest impact on the number of lambs weaned per hectare. Collaborating producers recognised the importance of increasing ewe stocking rates, and a case study is given in Appendix 4 to highlight the process some adopted to set ewe stocking rate and lamb production targets (Table A4.1).

Both ewe genotypes scanned at 170% (condition score 3.3 to 3.8 at joining) but 20 to 25% of lambs born died before marking. About 15 to 20% more lambs/ha were weaned from the demonstration sites than the remainder of the farms due mostly to lower rates of lamb mortality. Together with increasing stocking rate, reducing lamb mortality was identified by the store producers as a priority, rather than further increasing fecundity and number of triple born lambs. The MIDAS modelling (see section 1.4.2.4) indicated that profit could be increased by $60 to 70/ha for a 10% increase in number of lambs weaned by increasing survival. This implies a break-even point of about $6 per ewe to increase survival and overall weaning percentage by 10%. Other work has also indicated that weaning percentage is important once stocking rate has been optimised, and it is more economical to increase survival than fecundity (Warn 2006).

3 Evaluation of long season annual legumes

3.1 Background

The development of pastures that when properly managed can extend the pasture-growing season and provide high quality feed in late spring and summer could complement the strengths of perennial ryegrass and significantly improve the profitability of lamb production systems in southwest Victoria (section 1.4.2.1). Other work using whole farm systems modelling also predicts the inclusion of late season pastures in the perennial ryegrass based forage systems could increase profits by $100 to $200/ha, and the value was greater for production systems with an emphasis on meat production (Masters *et al*. 2006). The value of including late season legume pastures could be even greater, as it has long been accepted in ruminant nutrition that the feeding value of legumes is greater than that of grasses owing to their more rapid particle breakdown, faster rumen fermentation, and lower rumen mean retention time and consequently greater voluntary feed intake (Ulyatt 1973). Legumes are under utilised in many grazing systems and the legume component of most pastures is southwest Victoria seldom comprises more than 10 to 20% of the total forage available (Quigley *et al.* 1992).

An evaluation of alternative annual legumes in cropping rotations in southwest Victoria reported that arrowleaf clover *(Trifolium vesiculosum)* was late maturing and able to extend the growing season by several weeks beyond mid-season maturing species or cultivars such as subterranean clover, balansa clover and Persian clover (Zhang *et al*. 2004). Over three years, arrowleaf clover produced as much or more total pasture than these other annual legumes and more than 60% of its total pasture production for the year occurred from November onwards compared to 30% for the other legumes. Zhang *et al*. (2004) did not report the nutritive value of the different pastures. A new cultivar of arrowleaf clover (cv Arrotas) developed for extended growth and quality in late spring and summer, has not been evaluated under grazing conditions. In this component of 'Morelamb' we tested the hypothesis that arrowleaf clover (cv Arrotas) will maintain its digestibility higher than conventional subterranean clover and ryegrass mixtures during December and January and this would improve lamb growth rates.

3.2 Objectives

Objective #3a: By 30 June 2006 - Evaluate the impact on lamb production of a range of alternative pasture species that have the potential to extend the growing season and maintain digestibility of pasture available during December and January at least 5% units higher than currently recommended varieties.

Objective #3b: By 30 June 2006 - Development of grazing management guidelines for arrowleaf clover to optimise pasture and animal performance in a spring lambing production system.

3.3 Methodology

3.3.1 Experimental site and design

Experiments were conducted 2004/05 (Experiment 1) and 2005/06 (Experiment 2) on a commercial property near Hamilton in southwest Victoria[2]. The site experiences predominantly winter/spring rainfall and dry, hot summers, with a long-term average annual rainfall of 700 mm. The main soil types at the site were sandy clay loams, yellow chromosol (upper slope), brown chromosol (mid-slope) and brown sodosol (lower slope), derived from deeply weathered tertiary basalt. The soil nutrient status at sowing of subterranean clover and perennial ryegrass-based pastures in autumn/winter 2002 was as follows: pH in water 5.2; phosphorus (P-Olsen) 17.5 mg/kg; potassium (K-skene) 184 mg/kg; available sulphur 23 mg/kg; total carbon 4.2% and total nitrogen 0.34%. Fertiliser was applied to keep phosporus non-limiting (30 kg in 2003, 20 kg in 2004 and 2005) and 2.5 t lime/ha was applied in 2004.

The experiments were randomised block designs involving two or three replicates of different pastures and stocking rates, as described in Table 13. The pasture systems were: (a) Subterranean clover monoculture (T. subterannean, cv. Leura); (b) Perennial ryegrass (L. perenne, cv. Avalon and Fitzroy mixture) and subterranean clover mixture; and (c) Arrowleaf clover monoculture (T. vesiculosum cv. Arrowtas). In 2005/06, a perennial ryegrass/arrowleaf clover mix treatment stocked with 18 lambs/ha was also included.

Table 13. Pasture treatment, stocking rate, plot size and number of replicates for Experiment 1 and 2.

Pasture system	Experiment 1 (2004/05)		Experiment 2 (2005/06)	
	Stocking rate (/ha)	Replicates	Stocking rate (/ha)	Replicates
Subterranean clover	12	3	12	3
Subterranean clover	18	3	18	3
Perennial ryegrass/subclover mix	12	3	12	3
Perennial ryegrass/subclover mix	18	3	18	3
Perennial ryegrass/arrowleaf clover mix			18	3*
Arrowleaf clover	12	3	12	2
Arrowleaf clover	18	3	18	2
Arrowleaf clover	24	3	24	2
Arrowleaf clover			30	2
Arrowleaf clover			36	2

* 2 replicates were mistakenly crash grazed in early December which removed the arrowleaf component. The data reported for this treatment is therefore unreplicated.

There were 32 plots (24 x 1 ha and 8 x 0.5 ha) blocked into four groups of eight according to position in the landscape. Most plots were fenced across the contour and included a range of soil types. The arrowleaf clover plots were divided into six sub-plots (0.17 ha) and rotationally grazed. Pasture system by stocking rate treatments were randomly allocated in each of the three replicates. All plots were not used in each experiment and water was available in a trough in each plot.

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[2] Outcomes from pre-experimental activities in 2002/03 and 2003/04 included: (a) production of diffuse clover and arrowleaf clover seed in quantities sufficient for large grazing experiments; (ii) preliminary data indicated late season production and quality of diffuse clover was similar to subterranean clover therefore it was not included in Experiments 1 and 2; (iii) management guidelines for sowing and control of weeds in arrowleaf clover were developed; and (iv) impacts of grazing on growth of arrowleaf clover indicated that it was more suited to a rotational grazing system.

3.3.2 Pasture establishment and management

All pastures other than arrowleaf clover were established in winter 2002, following a brassica crop. A knockdown herbicide (2 L/ha roundup) was applied in late autumn, followed by a full cultivation and another knockdown herbicide pre-sowing. Subclover was direct drilled in early winter into a cultivated seed bed at 20 kg/ha for the monoculture treatment. The mixed pasture was sown with 10 kg/ha subclover and 6 kg/ha of perennial ryegrass. Subclover monoculture pastures were spray-grazed annually for broadleaf weed control, particularly capeweed. The arrowleaf pastures were sown in early winter 2004 and 2005 using a similar method of sowing. Arrotas seed was inoculated with Group C (WSM 409) and lime coated and direct drilled at 20 kg/ha with single super at 20 kg/ha to a depth of 5 mm. The perennial ryegrass/arrowleaf mixture was established by direct drilling 20 kg/ha of arrowleaf seed in an existing ryegrass pasture in early winter 2005. Broadleaf weeds were controlled post sowing using Tigrex at 1L/ha with 100ml/ha of Fastac for red legged earth mites.

All pasture systems were grazed by non-experimental sheep to achieve a target amount of feed on offer (FOO) of 2600 ± 500 kg DM/ha when experimental lamb entered the plots on 22 November 2004 or 2 November 2005. During the treatment period the perennial ryegrass/subclover mix and subclover monoculture systems were set stocked, whereas the arrowleaf clover treatments were rotationally grazed using a 6-paddock rotation. The rotation length and residual amounts of each subplot were managed to optimise whole plot pasture production.

3.3.3 Pasture measurements

Feed on offer for each of the perennial ryegrass/subclover mix and subclover monoculture plots was assessed fortnightly from the start of grazing until lambs were removed from the plots. FOO assessments for the arrowleaf plots were made on all cells at the start of the treatment period and then prior to lambs entering and exiting a cell (pre and post grazing). FOO was visually estimated with 30 observations per plot by two observers for the perennial ryegrass mixed pastures and subclover monoculture plots and 10-15 observations per sub-plot for the arrowleaf pastures. Each fortnight, visual assessments were calibrated as described in Section 2.3.4 using separate equations for perennial ryegrass-based and each of the legume pastures.

Dry matter digestibility (DMD), neutral detergent fibre content (NDF) and crude protein content (CP) was estimated for each plot at fortnightly intervals on samples collected using the toe-cut method described in section 2.3.4. At the start of the grazing period, a second sub-sample was sorted into principal species on the basis of sown species (perennial ryegrass and subterranean clover percentage in the mixture), annual grasses, broadleaf and dead components. The samples of individual species from each plot were dried at 100^{0}C for 24 hours and weighed to determine the dry matter percentage.

3.3.4 Lamb management and measurements

Weaned lambs (n = 300 in 2004 and 430 in 2005; 10-12 week old, 28-30 kg liveweight) were allocated to each plot on the basis of liveweight and sex. The lambs were from Coopworth/Corriedale ewes mated to terminal sires. The number of lambs per plot varied from 6 to 36. Lambs were drenched and vaccinated at weaning and allocation to ensure susceptibility to internal parasites and pulpy kidney were minimised. Faecal worm egg counts were collected from randomly selected plots at fortnightly intervals and all lambs were drenched if egg counts exceeded 300 eggs/g.

All lambs were weighed weekly from the time of allocation onto plots until slaughter. Once the average lamb growth rate declined to maintenance or below averaged over two consecutive weights lambs were removed from the plot and entered a feedlot. Lambs in the feedlot were fed *ad libitum* a processed pellet ration (11.0 MJ/kg and 16% CP) following a 5-day introduction where they were offered hay *ad libitum* and the amount of pellets offered was increased each day. The target was to finish lambs by the end of January at 45 kg liveweight and fat score 2 to 3.

3.3.5 Statistical Analyses

For the FOO, PGR and pasture quality data the method of restricted maximum likelihood (REML) was used with a variance-covariance structure selected in order to model repeated measurements over time. T he selection was via a sequence of likelihood ratio tests on the following nested models: (i) a power model in which the correlation between observations from the same plot decays as the time delay between the observations increases; (ii) heterogeneous power model in which the correlations follow the power model and the variances can be different at each time; and (iii) an unconstrained or unstructured variance-covariance model in which any correlation pattern is possible, and the pattern which best fits the observed data is selected. The power model was used for all. After the variance-covariance model had been selected, the appropriate main effects or interaction, were investigated via Wald tests. The results are reported as predicted means with the least significant difference (*P*=0.05) presented being calculated using the maximum standard error of differences (s.e.d.). Analysis of variance, ANOVA, was used to determine the effect of treatment and stocking rate on pasture composition.

The mean LW was modelled over time separately for each lamb using a random coefficient regression including a cubic spline for time. The final model fitted for the 2004/05 data was:

LW = μ + day + treat + sr + sr.day + treat.day + treat.sr + treat.sr.day + lamb + lamb.day + spline(day) + lamb.spline(day) + treat.spline(day) + treat.sr.spline(day).

The terms ‘day’, ‘treat’, ‘sr’, ’treat.day’, ‘treat.sr’ and ‘treat.sr.day’ were fitted as fixed factors or covariates while all other terms were fitted as random effects, with a covariance between the lamb intercept (lamb) and slope (lamb.day). The likelihood ratio test was used to assess any spline effects after the previously mentioned terms (day, treat, sr, treat.day, sr.day, treat.sr, treat.sr.day, lamb and lamb.day) had been fitted. The final model fitted for the 2005/06 data was:

LW = μ + day + treat + sr + sr.day + Sex + lamb + lamb.day + spline(day) + lamb.spline(day) + treat.spline(day) + treat.sr.spline(day).

The terms ‘day’, ‘treat’, ‘sr’, ’Sex’ and ‘sr.day’ were fitted as a fixed factors or covariates while all other terms were fitted as random effects, with a covariance between the lamb intercept (lamb) and slope (lamb.day). The likelihood ratio test was used to assess any spline effects after the previously mentioned terms (day, treat, sr, Sex, sr.day, lamb and lamb.day) had been fitted. All statistical analyses were performed using GenStat (GenStat Committee 2003).

3.4 Results and Discussion

3.4.1 Seasonal conditions

The average monthly rainfall and long-term averages are listed in Table 14. The total rainfall during 2004 (Experiment 1) was slightly above the long-term average for the locality, and was particularly wet in winter which adversely impacted arrowleaf clover pastures growing in low areas. Total rainfall in 2005 (Experiment 2) was 150 mm below the long term average. Rainfall from the start of September to end of January for both experiments was only 70 to 75% of the long term average, with extended periods (20-30 days) between major rainfall events (> 10 mm) in summer.

Table 14. Average monthly rainfall (mm) between January 2004 and February 2006 and long-term monthly rainfall (LTA; 1970 to 2006). Shaded areas show experimental period.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2004	46	28	64	40	46	139	75	104	52	34	62	39	728
2005	35	68	15	25	25	64	37	79	54	51	52	36	541
2006	37	41											
LTA	35	27	40	50	59	73	79	83	78	69	53	44	690

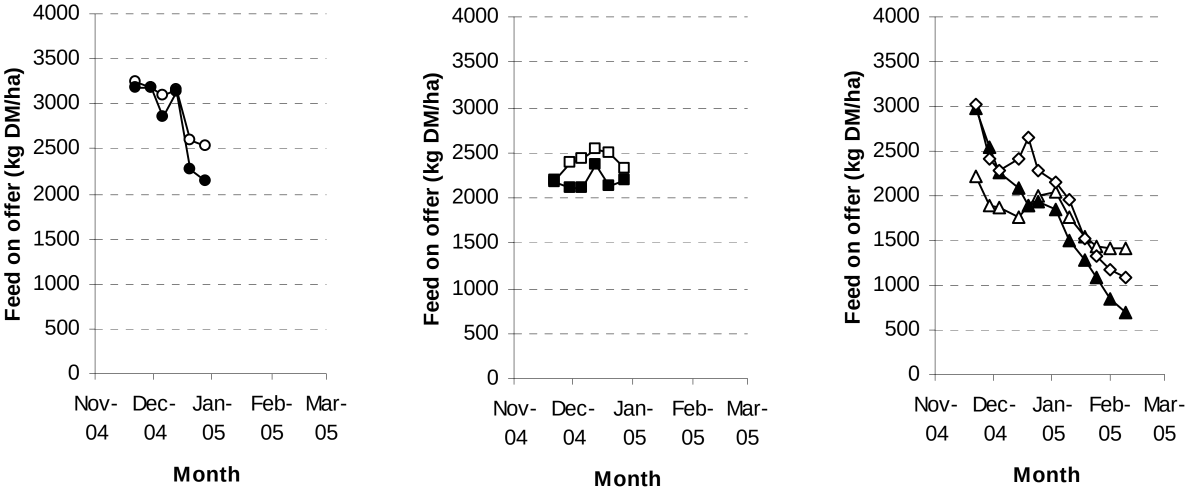
3.4.2 Feed on offer

The average FOO for the different pastures grazed at different stocking rates is shown in Fig. 7. FOO levels for subclover, perennial ryegrass mixed pastures and arrowleaf pastures at the start of the grazing treatments were more similar in Experiment 2 (2500, 2400 and 2800 kg DM/ha) than Experiment 1(3200, 2200 and 2700 kg DM/ha). FOO levels for subclover and perennial ryegrass /subclover mixed pastures was generally maintained above 2000 kg DM/ha even when lambs were removed because they could no longer maintain liveweight, and there were only small differences in FOO profiles between stocking rates. This indicates that declining pasture quality, rather than availability, was the major constraint on nutrient intake and lamb growth at this time. This finding suggests that these pastures were understocked at 18 lambs/ha during late spring/early summer. The recommendation to maximise utilisation of these pastures for lamb production in late spring is to adjust stocking rates to achieve a target FOO of about 1200-1500 kg DM/ha by mid December – *'use it or lose it'*. In these experiments this would have required a stocking rate of 20-25 lambs/ha.

The FOO profile for the perennial ryegrass/arrowleaf clover mixed pasture in Experiment 2 was similar to the perennial ryegrass/subclover pasture in November and December. Thereafter, the arrowleaf mixed pasture continued to be grazed for an extra month and FOO declined to about 1300 kg DM/ha when the lambs were removed in early February. Including arrowleaf clover in the mixture instead of subclover increased the utilisation of the low quality perennial ryegrass during early/mid summer by at least 1000 kg DM/ha.

For lambs grazing the arrowleaf monoculture pastures the average post grazing FOO was 64% and 60% of the pre-grazing FOO in Experiment 1 and 2, respectively. The average FOO declined during late spring/summer, particularly from mid-December onwards and at higher stocking rates. The average decline rate was 10-15 kg DM/ha/day at 12 lambs/ha, 20-25 kg DM/ha/d at 24 lambs/ha and 30-35 kg DM/ha/day at the highest stocking rate. The FOO during the week prior to removing lambs from the pastures was about 750 and 500 kg DM/ha in Experiments 1 and 2, regardless of whether this occurred in January or February. Critical FOO levels for arrowleaf pastures to minimise erosion during summer/autumn have not been defined, but there is a potential risk of over-grazing because it can maintain quality and animal performance well into summer.

Experiment 1



Experiment 2

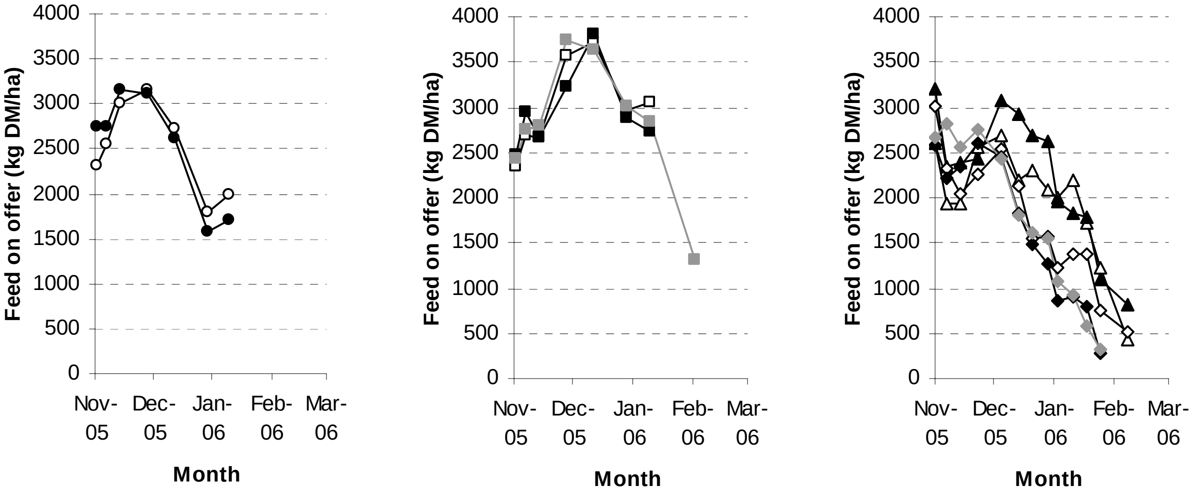


Figure 7. Average feed on offer for different pastures grazed at different stocking rates; (top) 2004/05, (a) subclover monoculture at 12 (○) or 18 lambs/ha (●), (b) subclover/perennial ryegrass mixture at 12 (☐) or 18 lambs/ha (■), and (c) arrowleaf clover monoculture at 12 (△), 18 (▲) or 24 (◆) lambs/ha; and (bottom) 2005/06, (a) subclover monoculture at 12 (○) or 18 lambs/ha (●), (b) subclover/perennial ryegrass mixture at 12 (☐) or 18 lambs/ha (■) and arrowleaf clover/perennial ryegrass mixture at 18 lambs/ha (■), and (c) arrowleaf clover monoculture at 12 (△), 18 (▲), 24 (◆), 30 (◇) or 36 (◆) lambs/ha.

3.4.3 Botanical composition and nutritive value

The proportion of subclover was 88% and 92% of total dry matter in the subclover monoculture treatment and 23% and 39% of the total dry matter in the perennial ryegrass mixed pasture treatment at the start of the grazing period in Experiment 1 and 2 respectively. The proportion of arrowleaf in the monoculture treatment was 57% and 44% in Experiments 1 and 2. In Experiment 2 arrowleaf increased to more than 70% over the first 30 days to the end of November and more than 80% by the end of December. Arrowleaf pastures lower in the landscape had more sorel and toad-rush than those higher areas which had more broadleaf weeds, largely capeweed. Arrowleaf clover was a major component (30-40%) of the arrowleaf/perennial ryegrass pasture during November and December, declining to 10% during January and less than 5% when the lamb were removed in early February[3].

Digestibility and protein content of all pasture species declined at different rates as the growing season progressed (Fig. 8). The DMD of arrowleaf clover was significantly higher than that of subclover from mid-December onwards in both experiments, the largest difference being in early January when arrowleaf was 60% to 70% digestible whereas subclover was only 45% to 50% digestible. In contrast to DMD, subclover had a higher CP content than arrowleaf clover from mid-December onwards. The results suggest that declining DMD was the major constraint on nutrient intake and growth of lambs grazing subclover pastures, whereas declining CP was the constraint on performance of lambs grazing ryegrass pastures.

There was no effect of stocking rate on the quality of any species in Experiment 1. In Experiment 2, the changes in pasture quality were greater at higher stocking rates [data not shown], presumably due to the removal of more leaf material, such that in early January pastures stocked with 36 lambs/ha had a lower DMD (58 vs. 66%) and CP (8.0 vs. 12.8%) than those grazed by 12 lambs/ha. The inclusion of higher stocking rate treatments in Experiment 2 partly explain the more rapid decline in DMD for the arrowleaf pastures than in Experiment 1 (Fig. 8). The quality of ungrazed arrowleaf in January is likely to be even higher than measured at the lowest stocking rate[4]. Together with the lamb liveweight profiles for the different pastures, we therefore recommend from this work that arrowleaf pastures be allowed to accumulate dry matter during late spring/early summer and only be grazed from mid to late December onwards or once lambs can no longer grow on other pastures.

Arrowleaf clover also contains moderate levels of condensed tannins (2-3%). Studies in NZ and the UK have shown that tannin containing forages reduce parasite infection and increase reproductive rate in sheep, reduce bloat risk in cattle and reduce methane emissions. Ramirez-Restrepo and Barry (2005) found that grazing *lotus corniculatus* which contains moderate levels of tannins for at least 6 weeks before joining increased weaning percentages by around 20%. Further work is needed to evaluate the role of specialist legumes in a whole farm context, especially those that contain bioactives such as tannins, but one option may be to graze arrowleaf clover with ewe lambs from late December/early January in preparation for mating at above 40 kg sometime in February

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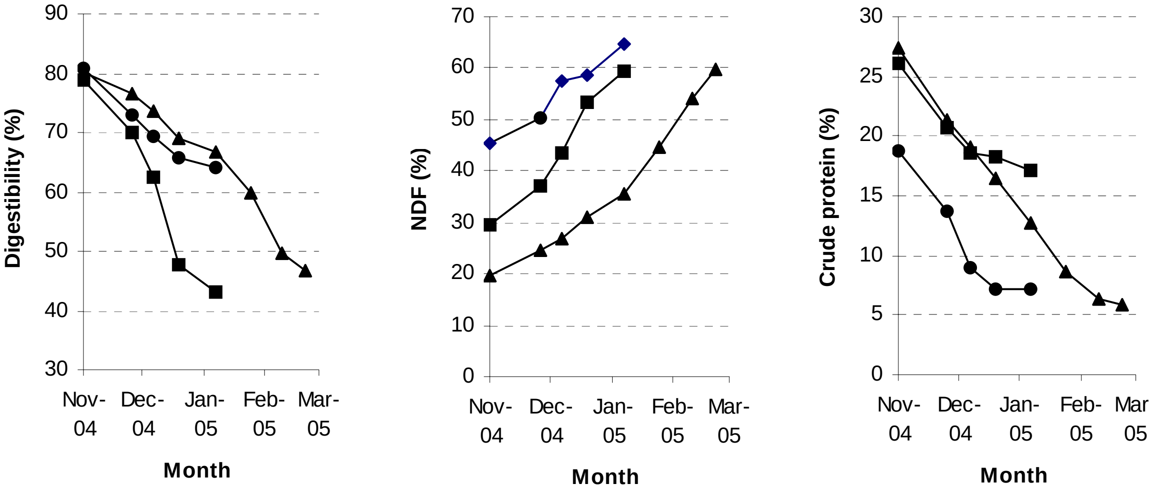
[3] Arrowleaf comprised more than 30% of the arrowleaf/perennial ryegrass pasture in spring 2006, 18 months after sowing. It is not known if this was due to plants that survived the summer/autumn, germination of seed set in February 2006 or seed that did not germinate following sowing in winter 2005. Further work on seed bank dynamics and persistence of arrowleaf in a grazing system is needed.

[4] Data from a pre-experimental evaluation of arrowleaf clover in 2001/02 showed that ungrazed arrowleaf maintained DMD at more than 70% during January.

Experiment 1



Experiment 2

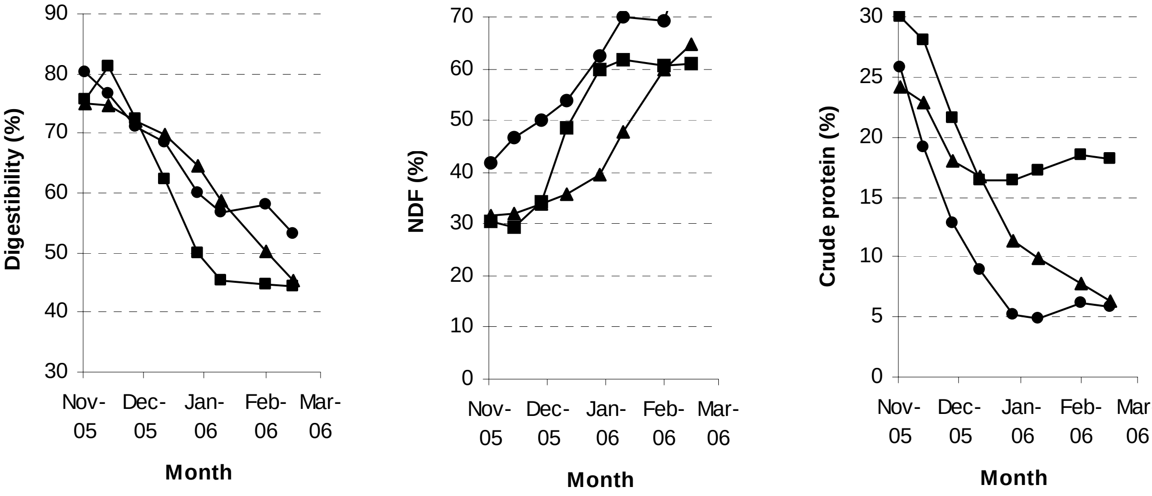
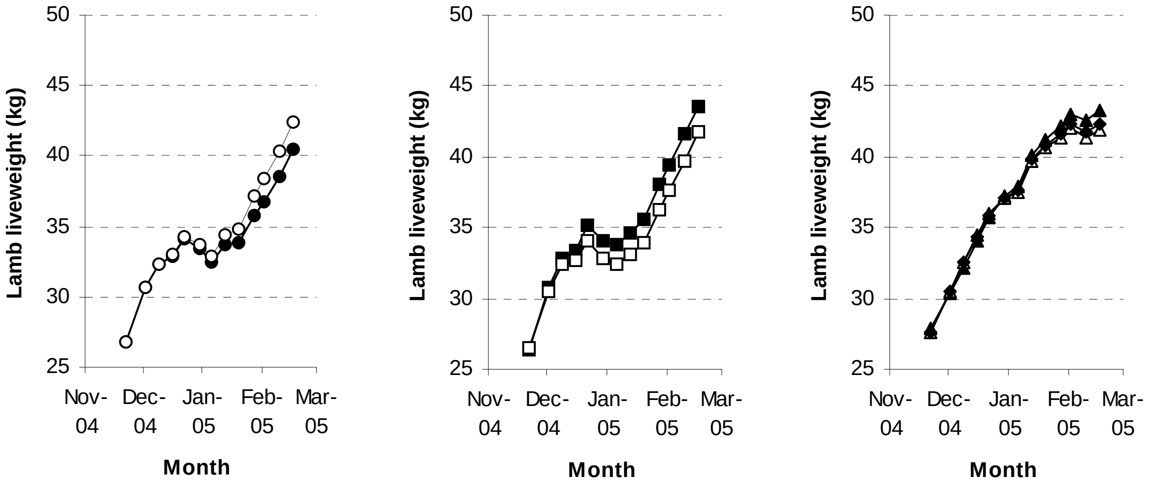


Figure 8. (a) Dry matter digestibility, (b) neutral detergent fibre content and (c) crude protein content for subclover monoculture (■), perennial ryegrass/subclover (●),and arrowleaf clover monoculture (▲) pastures grazed by cross bred lambs. The data represents the average across a range of stocking rates.

3.4.4 Lamb liveweights

Liveweight profiles for lambs grazed on different pastures at a range of stocking rates and finished in a feedlot are shown in Figure 9, and the final cubic spline models showing the significant effects on lamb liveweight are given in the section 3.3.5. In both experiments there was a significant (P<0.01) linear effect of day on lamb liveweight, and the average growth rate of lambs between allocation to pastures in November and exit from the feedlot was about 170 g/day.

Experiment 1 (a) **(b)** **(c)**



Experiment 2

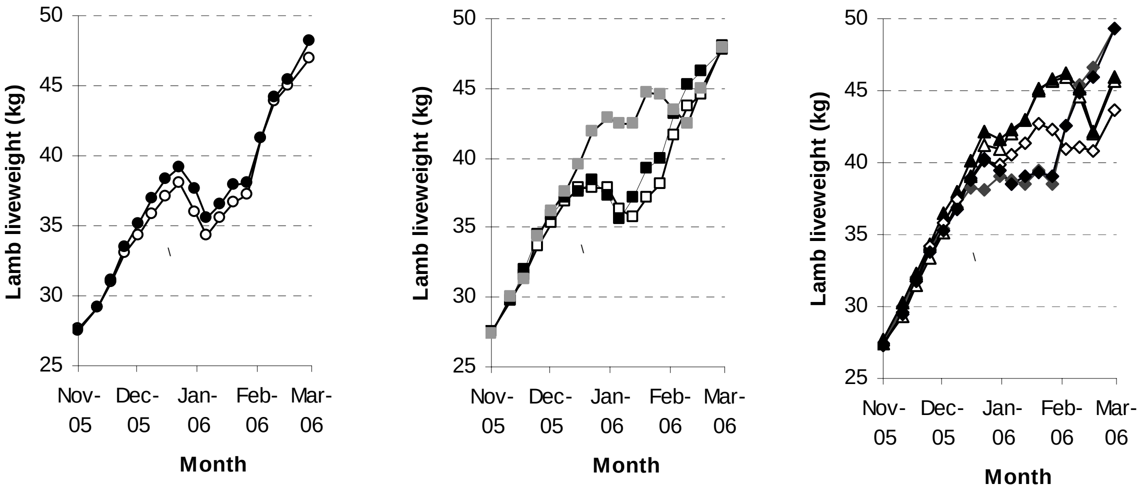


Figure 9. Average liveweight for lambs grazed on different pastures at different stocking rates and then finished in a feedlot; (top) 2004/05, (a) subclover monoculture at 12 (○) or 18 lambs/ha (●), (b) subclover/perennial ryegrass mixture at 12 (☐) or 18 lambs/ha (■), and (c) arrowleaf clover monoculture at 12 (△), 18 (▲) or 24 (◆) lambs/ha; and (bottom) 2005/06, (a) subclover monoculture at 12 (○) or 18 lambs/ha (●), (b) subclover/perennial ryegrass mixture at 12 (☐) or 18 lambs/ha (■) and arrowleaf clover/perennial ryegrass mixture at 18 lambs/ha (■), and (c) arrowleaf clover monoculture at 12 (△), 18 (▲), 24 (◆), 30 (◇) or 36 (◆) lambs/ha.

In both experiments lambs from all treatments gained weight at around 250 g/day until mid-December, but thereafter both pasture system and stocking rate had a significant effect on liveweight. These differences were reflected in significant ($P<0.001$) non-linear pasture treatment x day effects and pasture treatment x stocking rate x day effects. Lambs grazing the perennial ryegrass/subclover mix and subclover monoculture pastures gained minimal weight from mid-December onwards. In late December/early January when they could no longer maintain weight they were transferred to a feedlot at 33-34 kg in Experiment 1 and 36-37 kg in Experiment 2. Stocking rate had no significant effect on grazing period and liveweight profile, which supports the proposition that these pastures were understocked and FOO was not limiting even at 18 lambs/ha.

In comparison to these pastures, lambs grazing the arrowleaf/perennial ryegrass mixed pasture or the arrowleaf monoculture pastures at the same stocking rate continued to gain weight for an additional 35 to 49 days (Table 15) and entered the feedlot at 41 to 43 kg in Experiment 1 and 43 to 45 kg in Experiment 2. Higher stocking rates reduced the grazing period on arrowleaf pastures and the entry weight of lambs into the feedlot in Experiment 2, but in all cases they were greater than lambs grazing perennial ryegrass/subclover mix and subclover monoculture pastures.

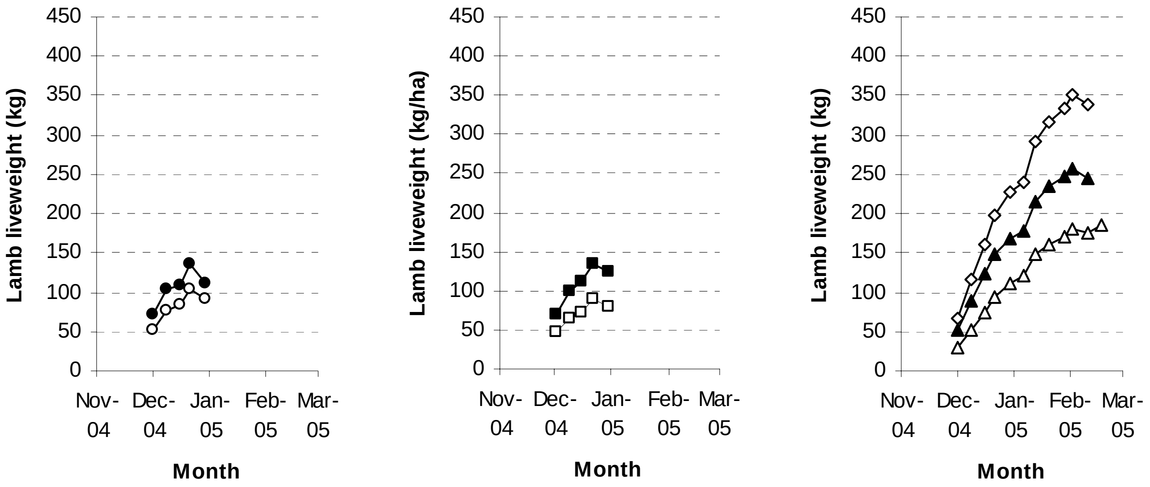
Table 15. Effects of pasture system and stocking rate on period (days) lambs spent grazing pasture and in the feedlot for Experiment 1 and 2.

Pasture system	Stocking rates (lambs/ha)	Experiment 1 (2004/05)		Experiment 2 (2005/06)	
		Pasture	Feedlot	Pasture	Feedlot
Subterranean clover	12	38	49	60	59
Subterranean clover	18	38	49	60	59
Perennial ryegrass/clover	12	38	49	66	53
Perennial ryegrass/clover	18	38	49	66	53
Perennial ryegrass / arrowleaf clover	18	-	-	94	25
Arrowleaf clover	12	87	0	101	18
Arrowleaf clover	18	80	7	101	18
Arrowleaf clover	24	80	7	94	25
Arrowleaf clover	30	-	-	73	46
Arrowleaf clover	36	-	-	73	46

Total lamb production per hectare of pasture for different treatments was reflected mostly by differences in stocking rate and to a lesser extent differences in grazing period and lamb growth rates (Fig. 10). Total production was similar for perennial ryegrass/subclover mix and subclover monoculture pastures being about 80 and 120 kg lamb liveweight/ha in Experiment 1 and 130 and 200 kg liveweight/ha in Experiment 2 for pastures stocked at 12 and 18 lambs/ha, respectively. As already indicated, had these pastures been stocked to maximise pasture utilisation before quality declined total production would have been about 150 and 250 kg liveweight/ha in Experiment 1 and 2 respectively.

Total lamb production at the same stocking rate on the arrowleaf/perennial ryegrass pasture was 310 kg liveweight/ha or 110 kg/ha more than the subclover/perennial ryegrass pasture. Total production from arrowleaf monoculture pastures stocked at 12 and 18 lambs/ha was 170 and 250 kg lamb/ha in Experiment 1 and 220 and 330 kg lamb/ha in Experiment 2, reflecting the longer grazing periods compared to the subclover and perennial ryegrass/subclover pastures. Total production for lambs grazing arrowleaf at 24 lambs/ha was about 350 kg/ha in both experiments, and over 400 kg lamb/ha at the higher stocking rates in Experiment 2. Taken together, over two years we believe the optimum stocking rate for the arrowleaf-based pastures was about 20-25 lambs/ha to finish lambs in late January/early February with little if any supplementation.

Experiment 1 (a) **(b)** **(c)**



Experiment 2

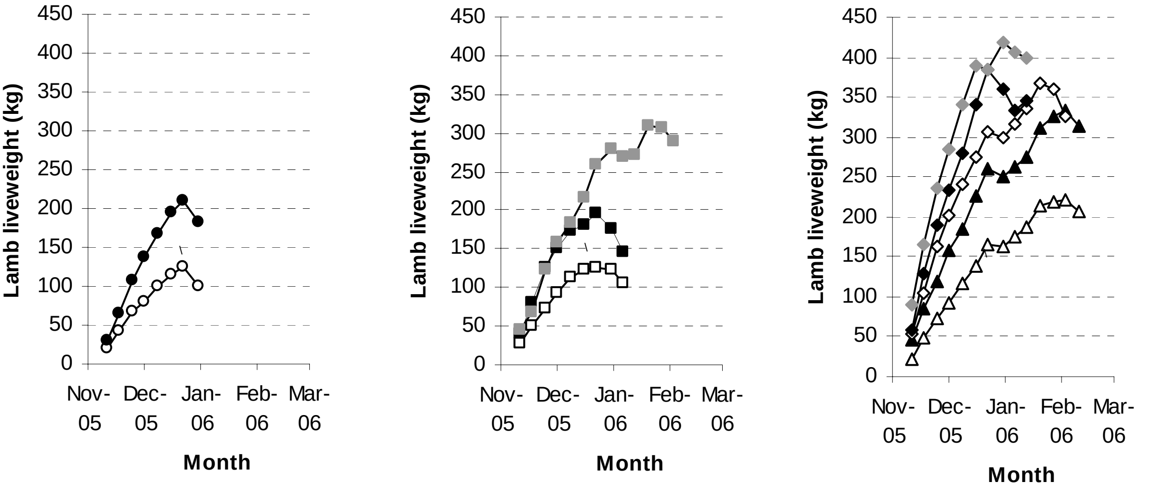


Figure 10. Total liveweight gain per hectare for cross bred lambs grazed on different pastures at different stocking rates until lambs could no longer maintain liveweight; (top) 2004/05, (a) subclover monoculture at 12 (○) or 18 lambs/ha (●), (b) subclover/perennial ryegrass mixture at 12 (□) or 18 lambs/ha (■), and (c) arrowleaf clover monoculture at 12 (△), 18 (▲) or 24 (◆) lambs/ha; and (bottom) 2005/06, (a) subclover monoculture at 12 (○) or 18 lambs/ha (●), (b) subclover/perennial ryegrass mixture at 12 (□) or 18 lambs/ha (■) and arrowleaf clover/perennial ryegrass mixture at 18 lambs/ha (■), and (c) arrowleaf clover monoculture at 12 (△), 18 (▲), 24 (◆), 30 (◇) or 36 (◆) lambs/ha.

The perennial ryegrass/arrowleaf mixed pasture produced a similar quantity of lamb per hectare as the arrowleaf monoculture pasture at the same stocking rate, but had greater pasture production and grazing value during winter and early spring. This highlights the potential value of direct drilling late maturing arrowleaf clover into existing perennial ryegrass pastures. Arrowleaf clover seed is likely to be relatively cheap as the seed can be harvested using conventional machinery and seed yields of up to 500 kg/ha were measured in 2002/03 and 2003/04.

3.4.5 Management guidelines for arrowleaf clover

Simple guidelines for the successful establishment and management of arrowleaf clover (cv. Arrotas) have been developed and are attached (Appendix 5 - attached). Most new pasture cultivars from breeding and selection programs are released into the market place without rigorous evaluation of animal performance at field scale and with minimal guidelines for management. It is clear that breeding and testing of new pasture cultivars should be supported by animal grazing trials if plant improvement is to maintain credibility, but protocols to achieve similar outcomes as the 'Morelamb' project at lesser cost need to be developed.

A companion project (ER220) found that these legume monocultures can be used for up to 2 years followed by a crop or pasture that can utilise the build up on N and therefore minimise the risk of nitrate leaching and acidification.

4 Novel grazing systems

4.1 Background

Pastures for sheep production are typically sown with mixtures of grasses and legumes. These species are complementary to each other in many ways. The legume fixes nitrogen from the atmosphere and supplies nitrogen to the grass. They are also complementary in nutritional attributes. Clover has a high concentration of protein, which is rapidly degraded in the rumen. Grass by comparison has a higher concentration of fibre. A combination of the two species should match the nutritional requirements of the sheep or cattle more closely than either species alone. In practice, grass-clover mixtures do not consistently perform to their theoretical potential because the clover content of mixed pastures is often less than 20% (Quigley *et al.* 1992). The proportion of clover in a sward varies within and across seasons, depending on the distribution of rainfall, climate, seed-bank content, nitrogen concentration, and phosphorous fertility (Parsons and Chapman 2000) and is also reduced by rotational grazing (Chapman *et al*. 2003).

When offered a free choice of grass and clover *ad libitum* both sheep and cattle consistently choose a diet containing around 70% clover and 30% grass. The high proportion of clover that they like to eat is in marked contrast to the proportion offered to them in mixed pastures. Selective grazing for clover may therefore be counterproductive as it decreases the presence of the preferred feed, but the processes that drive this preference are complex and not well defined. Aspects that influence preference include the previous grazing history of animals on pasture, the availability of pasture (spatial and temporal heterogeneity within the sward), pasture species and duration and method of evaluating choice (Parsons *et al.* 1994; Rook *et al.* 2002). Better knowledge of the factors motivating animals to select for certain dietary components should allow us to consider how pastures could be presented to grazing animals so they can acquire their preferred diet.

Growing grass and clover side by side in the same paddock may be an effective way to grow more clover and allow animals to select their preferred diet. A short-term study had suggested that increases in feed intake could be achieved by providing sheep a choice between adjacent monocultures of perennial ryegrass and white clover, compared to grazing these species as a mixed sward (Champion *et al*. 1998). This increase in feed intake should increase individual production and a study with lactating dairy cows reported a 11% increase in milk production from grazing grass and clover side by side (Cosgrove *et al.* 2001). The aim of this component of the 'Morelamb' project was to test this concept using perennial ryegrass and subterranean clover based pastures and examine the effects on ewe and lamb production over the longer-term.

4.2 Objectives

Objective #4: By 30 June 2005 - Determine the effects of allocating spatially separated forage choices on ewe and lamb production and define the mechanisms by which these novel grazing methods influence animal performance.

4.3 Methodology

4.3.1 Overview

Two grazing experiments examined ewe and lamb production, grazing behaviour and intake from four pasture arrangements of perennial ryegrass and/or subterranean clover. This work was conducted at 'Murroa' near Hamilton in southwest Victoria, the same location as described in section (3.3.1). A third animal house experiment examined the rumen conditions of fistulated wethers fed different ratios of perennial ryegrass and subterranean clover and how donor innoculum from these wethers responded to an additional six different ratios of ryegrass and subterranean clover.

4.3.2 Experiment 1 and 2

4.3.2.1 Experimental design and management

The effects of allocating spatially separated forages on grazing behaviour, intake and production were investigated using the following pasture treatments;

a) **Rye:** *Lolium perenne* monoculture, cvs. Avalon and Fitzroy mixture 70:30
b) **Sub:** *Trifolium subterranean* monoculture, cv. Leura
c) **Mix:** *Lolium perenne* and *Trifolium subterranean* sown as a traditional mixed pasture using the same cultivars as (a) and (b)
d) **Choice:** Lolium perenne and Trifolium subterranean sown in adjacent monocultures as per treatments (a) and (b).

The pastures were established in 2002 as described in Section 3.3.2, and the first experiment was conducted from 24th October to 9th December 2002 using three replicates of the four treatments. The plots were stocked with ten crossbred ewes (62.3 ± 0.69 kg), and their twin lambs (18.0 ± 0.23 kg; two months of age). The second experiment was performed between 25th July and 31st October 2003 using four replicates of the same treatments. The plots were stocked with 12 twin-bearing ewes (69 ± 5.1kg) that lambed in August. Ewes which failed to rear twin lambs were removed from the experiment.

The pastures were managed to maintain FOO around 2000 ± 1000 kg DM/ha. Plots were originally 1ha in size with the exception of the choice plots that were 2ha to allow sheep to obtain all their diet from either the ryegrass or subclover portion if they chose. Parts of plots were periodically sub-divided and grazed by non-experimental animals to maintain FOO levels. Pasture availability was estimated weekly with calibrated visual estimations in the first experiment and calibrated 'falling plate' meter measurements in Experiment 2. Botanical composition and quality were measured 2-4 weekly using the 'toe-cut' methods described in section 2.3.4.

4.3.2.2 Animal measurements

All ewes and lambs were weighed weekly in Experiment 1 and fortnightly in Experiment 2, with the exception of the period around lambing. Sheep were weighed direct of pasture in the morning. Ewes were condition scored using the 1-5 scale at the start and end of Experiment 1 and at each weighing session in Experiment 2.
Wool growth rates were measured on ewes in Experiment 2 using the method described by Wheeler *et al* (1977) with some modifications. A dyeband was applied at the start and end of the treatment period. Dyebanded staples were removed prior to shearing and the total weight of greasy wool from each ewe was weighed at shearing. Wool growth rates for the pre-experimental (tip), experimental (mid), and post-experimental (base) periods was calculated as described by Thompson et al. (1994). The fibre diameter profiles were measured on an OFDA 2000 prior to the staples being cut and weighed. Each staple was laid out on a glass slide, the relative positions of each dyeband recorded, and fibre diameter was measured at 2 mm intervals during each period.

Grazing behaviour between dawn and dusk was monitored by visual observation at strategic times through both experiments. At 5 minute intervals two observers recorded whether animals were grazing or not and if those on the choice treatment were grazing grass or clover. In Experiment 1 three ewes and three lambs from two replicates of the four treatments were observed on four separate days (24 animals per observer). In Experiment 2 five ewes from the four treatments on two replicates were observed on six separate days (20 animals per observer).

Short-term intake rates of pasture were determined on two replicates of the subclover, ryegrass and mix treatments in Experiment 1. These measurements were made on the same ewes from which grazing behaviour data was recorded. The short-term intake rates of pasture dry matter were determined by measuring weight changes of ewes during grazing in the afternoon, as described by Penning and Hooper (1985). Ewes were yarded and weighed (±0.02kg) prior to standing for 1 hour and being reweighed to calculate the insensible weight loss. Ewes were then released onto pasture for approximately 1 hour during which grazing behaviour was monitored at one minute intervals, before reweighing. The ewes were fitted with harnesses for the collection of faeces and urine, and udder cloths to prevent lambs suckling. Pasture samples were collected from the grazing horizon to calculate the dry matter content. Intake was calculated as the increase in weight during grazing minus the insensible weight loss, corrected for pasture dry matter content and grazing time.

Observations of grazing behaviour and measurement of the short-term intake rates allowed the calculation of intake. This was estimated by multiplying the daily grazing time by the intake rate. Animals on the choice treatment were assumed to have the same intake rates as animals on the monocultures (ryegrass and subclover). Intake was also measured using the alkane method described by Dove and Mayes (1991) with some modifications. All ewes were dosed with CAPTEC Alkane Controlled Release Capsules three times during each experiment. Fresh faecal samples were collected from the ewes over three days in two periods for each capsule. Daily faecal samples were bulked for each ewe on a volume basis to give two samples relating to faecal output 9 to 11 days and 16 to 18 days after each capsule was given. The bulked faecal samples were oven dried at 60ºC and ground through a 1 mm sieve on a Cyclotech grinder.

Plant samples from each plot were collected between the two faecal sampling periods for each capsule. A sub-sample was sorted into pasture species and dried at 60ºC, and ground through a 1 mm sieve on a Cyclotech grinder. The method used to estimate alkane concentrations is described briefly below. Pasture (up to 2 g) and faecal samples (1 g) were saponified with 15 ml of alcoholic potassium hydroxide (1.5M KOH) at 90ºC for 3.5 hours. After saponification, 8 ml n-heptane and 5 ml water was added to each tube and mixed thoroughly. The top phase was removed to a scintillation tube before another 5ml n-heptane was added. The mixing was repeated before the top phase was again added to the scintillation tube. The solution in the scintillation tube was transferred to a silica gel column and eluted with n-heptane. The eluate was evaporated under air flow before the alkanes were redissolved into 0.8 ml of n-heptane. The extract was analysed using a Perkin-Elmer Autosystem Gas Chromotagraph with built in autosampler. Tetratiacontane (C34) made up in n-heptane solution was used as an internal standard and added prior to the saponification process.

Faecal alkane concentrations were corrected for incomplete recovery using values published by Dove and Olivan (1998). Plant alkane concentrations were averaged for the subclover and ryegrass components of the diet. These values for C29, C31, and C33 were used in EatWhat© to calculate diet proportions on all treatments. The output from EatWhat© was used to calculate herbage alkane concentrations corresponding to each sheep at each sampling period. Raw faecal alkane concentrations were used in the calculation of intake. All samples where the faecal C32 or C36 alkane concentration was less than 40 mg/kg were removed as these indicated capsule errors. Intake was calculated based on the C31 and C32 pair as C33 herbage concentrations were low on the clover plots.

4.3.3 Experiment 3

4.3.3.1 Experimental design and management

Fourteen three-year old wethers were selected from 400 at the Department of Primary Industries Research Farm, Hamilton, on the basis of liveweight, condition score, temperament and general health. Experienced personnel surgically prepared these sheep for the experiment with the insertion of rumen cannula in the standard single stage rumen fistulation method. The sheep were allocated to treatments and adapted to the experimental diets four weeks post-surgery. Two sheep were selected as spares due to slower healing around the cannula site. The experimental diets were:

a) 100% perennial ryegrass (RR 100)
b) 67% perennial ryegrass and 33% subterranean clover (RR 67)
c) 33% perennial ryegrass and 67% subterranean clover (RR 37)
d) 100% subterranean clover (RR 0)

Subclover and perennial ryegrass samples were obtained from monoculture plots at 'Murroa'. They were harvested daily (between 1-3pm) using a sickle mower and collected in garbage bins. Sheep were feed twice daily at 4:30 pm and 9:00 am. Pasture was fed immediately after harvesting or stored overnight at 4ºC for the following morning. The amount to be fed was calculated to be at levels 1.3 x maintenance based on the weekly liveweight of each sheep and using estimates of dry matter content from the previous day and metabolisable energy content from the previous week.

4.3.3.2 In vivo rumen conditions

Rumen fluid samples (12-20 ml) were collected from fistulated sheep over two days at 8 am, 2 pm, 8 pm, 2 am, 11 am, 5 pm, and 11 pm consecutively by inserting a perforated polyethylene tube into the rumen to a consistent depth. The tube was attached via flexible tubing to a labelled collection bottle. A syringe attached to the top of this flask provided the suction to withdraw rumen fluid. The polyethylene tube was enclosed by a nylon bag with 40 µm pore size to prevent particular matter from blocking the tube and to seal the cannula entrance. The pH of each sample was tested before the rumen fluid was split into four vials for storage and further analysis including ammonia and volatile fatty acid concentrations.

4.3.3.3 In vitro rumen function

The intensive *in vitro* study of rumen function was conducted over 15 days prior to the measurements on rumen conditions as described above. The *in vitro* kit consisted of six 250 ml Schott bottles set into a water bath with automating pressure sensing and logging capabilities. Each flask was connected by 6 mm pneumatic tube to a 100 Kpa pressure sensor and a solenoid valve. Each valve acted as a closed device, but would open to vent gasses when energised if the sensor reached 50 kpa. A thermistor was also fitted to the system to monitor the temperature of the water bath. Fresh rumen fluid was bulked per treatment to use as donor innoculum within an *in vitro* digestion flask system. This innocula was challenged with six treatments:

(a) 100% subterranean clover (100 IVS)
(b) 84% subterranean clover and 16% perennial ryegrass (84 IVS)
(c) 67% subterranean clover and 33% perennial ryegrass (67 IVS)
(d) 50% subterranean clover and 50% perennial ryegrass (50 IVS)
(e) 33% subterranean clover and 67% perennial ryegrass (33 IVS)
(f) 100% perennial ryegrass (0 IVS)

The perennial ryegrass and subclover was collected from the same area used to feed to the fistulated wethers. This material was collected before the *in vitro* runs and frozen at -80ºC. While frozen it was ground with a mortar and pestle, weighed into aluminium foil packages and removed from the freezer on the day of use.

Each flask consisted of 21 ml fresh rumen fluid, 2 g pasture, and 100 ml solution (consisting of 20 ml buffer, 20 ml macro-mineral mix, 2 ml micro-mineral mix, and 58 ml water). The frozen pasture was added to the final solution and warmed to 39ºC prior to the addition of the rumen fluid. The *in vitro* incubation runs lasted 12 hours with measurements and samples taken at 0, 2, 4, 8 and 12 hours from the time at which the rumen fluid was added to the flask. At each sampling point the lid of each flask was removed and an 8 ml sub-sample collected. The pH of this was immediately recorded before the sample was split into four vials for storage and further analysis. These included pH, ammonia concentration and volatile fatty acid concentrations. The kit was fitted with a data logger programmed with Magpie software logging scheme to automatically record gas pressure within the flasks. Gas pressure was averaged across 5 minute intervals and the resulting data fitted with Gompertz functions. Four days of measurements were required to cover all combinations of the two factors – background diet (RR 0, RR 33, RR 67, RR 100) and the *in vitro* ratios (100 IVS, 84 IVS, 67 IVS, 50 IVS, 33 IVS, 100 IVS). Two background treatments and all *in vitro* ratios were tested each day (*i.e.* three *in vitro* ratios for each treatment). With these constraints treatments were allocated with a modified Latin square design for the 12 days.

4.3.3.4 Measurements of rumen fluid

A Denver pH probe was used to measure the pH. This was calibrated at least twice per day in pH 4 and 7 standards. Between measurement batches the probe was stored in saturated potassium chloride and was cleaned prior and between measurements with deionised water. To measure volatile fatty acids a sub-sample of rumen fluid (2 ml) was added to 0.5 ml of 25% metaphosphoric acid. The tubes were inverted to mix the contents, before freezing at -20ºC for storage. Prior to laboratory analysis, the samples were defrosted, inverted to mix, and 1 ml transferred to a centrifuge tube. This sub-sample was centrifuged at 3500 RPM for 15 minutes at 4ºC before removing 0.7 ml of the supernatant. This was analysed via gas chromatography. To measure rumen ammonia concentrations a sub-sample of rumen fluid (1 ml) was added to 4 ml of 0.1M HCl. The tubes were inverted to mix the contents, before freezing at -20ºC for storage. The samples were then defrosted prior to determining the ammonia concentration potentiometrically using an ion selective electrode and ion/pH meter (US EPA method 9212).

4.4 Results and Discussion

4.4.1 Experiment 1 and 2

4.4.1.1 Lamb liveweights

Lambs from treatments with high clover availability grew 20 to 30% faster than those from the ryegrass dominant treatments (Fig. 11). Lambs grazing the choice treatment grew at a similar rate to those grazing pure subclover (382 *vs*. 381 g/day in Experiment 1 and 329 *vs*. 309 g/day in Experiment 2) which was significantly faster than those grazing the conventional perennial ryegrass/subclover mixed pasture (303 and 269 g/day in Experiments 1 and 2, respectively). In both experiments lambs grazing the choice arrangement were about 5 kg heavier at weaning than those grazing the mixed pasture. Lambs grazing the mixed pasture grew faster than those grazing pure ryegrass in 2002 but not 2003. This was probably related to differences between years in clover content in the mixed pasture, which averaged 16% Experiment 1 and 11% in Experiment 2. The low proportions reflect the difficulty in maintaining high proportions of subclover in mixed pastures.

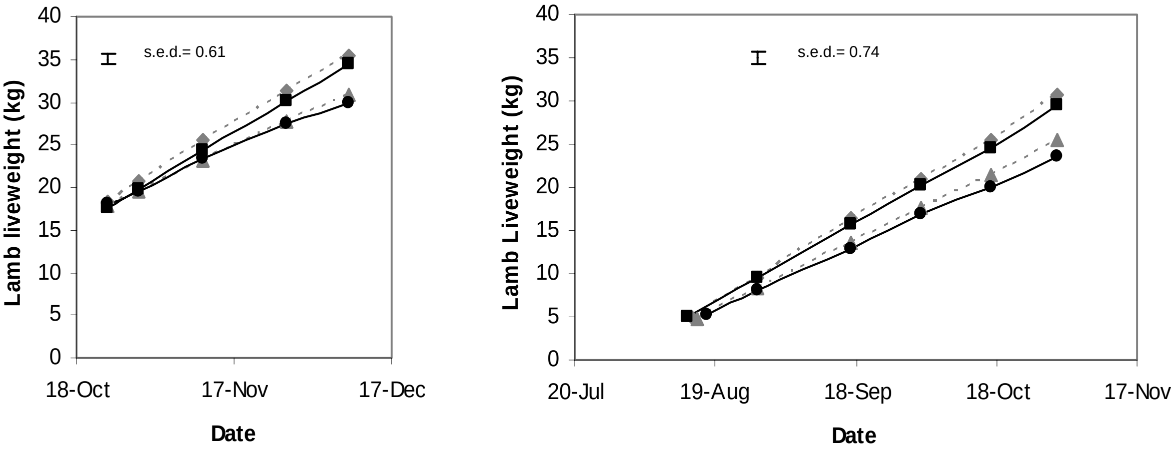


Figure 11. Liveweight of lambs grazing four different pasture treatments in Experiment 1 (left) and 2 (right); perennial ryegrass monoculture (●), subclover monoculture (■), perennial ryegrass/subclover mixture (▲--) and choice (◆).

4.4.1.2 Ewe liveweight and condition score

The differences in ewe liveweights between pasture treatments were similar to those described for their lambs. Ewes were significantly heavier on pastures with higher clover availability compared to the ryegrass dominant pastures in both years (Fig. 12). Ewes on the choice and subclover monoculture treatments were 5 to 8 kg heavier at weaning than those on the mixed pasture, which were 2 to 4 kg heavier than those on the pure ryegrass. The differences in liveweight between ewes grazing the mixed and ryegrass treatments were significant in Experiment 1 but not Experiment 2.
In Experiment 2, ewes on the choice pastures were significantly heavier during late pregnancy and early lactation than those from all other treatments. This difference was also evident in the condition score measurements [data not shown]. Ewes on the choice pastures actually gained about 0.3 of a condition score during late pregnancy and early lactation whereas those from the other three treatments maintained or lost condition during this same period. This result suggests the benefits from providing grass and clover side-by-side could be greatest at the time of highest nutritional demand. Increasing ewe liveweight and condition score at this time could be expected to increase lamb birth weight and survival, but no significant differences were evident in this work possibly due to limited numbers of animals. Further studies are required to identify the pasture and animal factors which contribute to positive animal production responses to providing dietary choices.

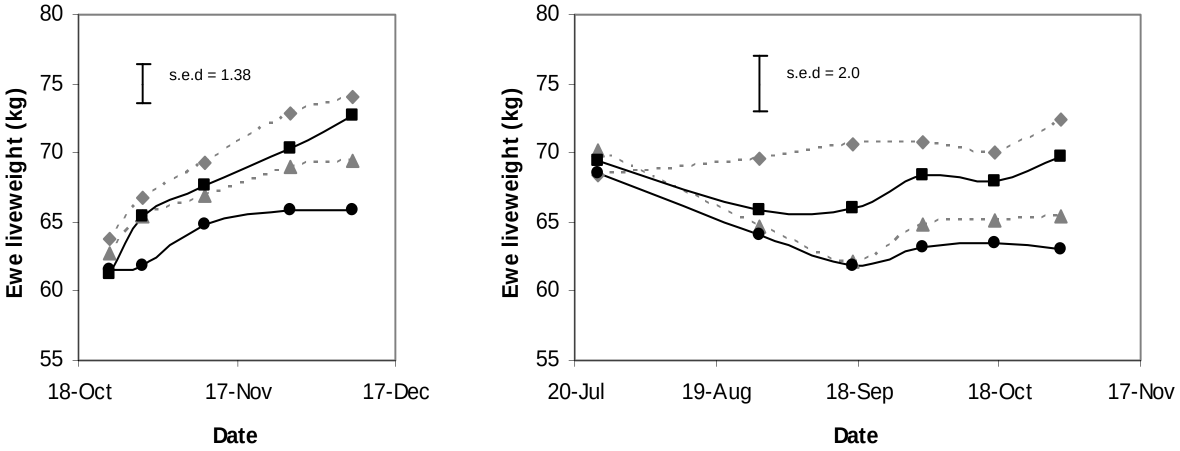


Figure 12. Liveweight of ewes grazing four different pasture treatments in Experiment 1 (left) and 2 (right); perennial ryegrass monoculture (●), subclover monoculture (■), perennial ryegrass/subclover mixture (▲--) and choice (◆). In Experiment 2, lambing occurred during August.

4.4.1.3 Ewe wool production

Ewes from the choice pasture grew more wool than those from the other pastures, even though the only statistically significant difference was between the choice and pure ryegrass treatments (Table 16). Treatment effects on wool growth were consistent with their effects on ewe liveweight profiles. The increase in wool growth could be attributed to increases in fibre diameter rather than staple length, with ewes on the choice treatment having a broader micron than those on the rye and mix treatments when fibre diameter prior to the experiment was used as a covariate.

Table 16. Growth rate and fibre diameter of wool from ewes grazing four pasture treatments in Experiment 2.

	Rye	Mix	Sub	Choice	p-value	s.e.d
Clean Wool Growth (g/day)	11.2 a	12.1 ab	12.9 ab	13.8 b	<0.05	0.78
Fibre Diameter	34.2 a	34.0 a	34.6 ab	35.2 b	<0.05	0.37

4.4.1.4 Grazing behaviour and intake

Ewes consumed subterranean clover significantly faster than perennial ryegrass (Table 18), which is consistent with other work. Ewes displayed a partial preference for subclover on the choice treatment with 69% and 78% of their time spent grazing subclover in 2002 and 2003 respectively. Estimation of partial preference for subclover using the alkane method gave a similar proportion of 70% and these proportions were maintained in the long-term (7-14 weeks). We conclude that because animals consistently include up to 30% grass in their diet when they could eat a 100% clover diet that they are not attempting to maximise intake rate – an outcome that would be achieved if they were to eat only clover and exclude grass altogether from their diet (Chapman *et al*. 2006). The inclusion of ryegrass in the diet raises questions regarding why sheep are selecting a mixed diets, but one proposition is that they are responding to rumen conditions in ways consistent with the satiety theory of Provenza (1995, 1996).

Ewes grazing ryegrass compensated for lower intake rates by grazing for 60% longer each day to achieve similar total intakes to those grazing subclover pastures in both years (Table 17). Ewes on the mix treatment appeared to have a higher intakes in 2002 but lower intakes in 2003 compared to the other treatments. The 2002 result is likely to be due to an error in the estimates of short-term intake rates which were quite variable. If we assume a diet of 10 to 20% clover, then the short term intake rate would be around 4.5 g DM/min and total intake about 2.3 kg DM/day. Intakes estimated by the alkane method in Experiment 2 showed that ewes grazing a free choice arrangement of adjacent monocultures of grass and clover had similar daily intakes to those grazing pure clover throughout lactation. These ewes had higher intakes than other treatments in early and mid lactation, however this difference between treatments disappeared in late lactation.

Table 17. Grazing behaviour, diet selection and intake of ewes grazing four pasture treatments during Experiment 1 and 2.

		Rye	Mix	Sub	Choice	*p- value*	s.e.d
Ewes	Short-term intake rate (g DM/min)	4.1 a	5.7 ab	7.2 b	-	<0.001	0.879
2002	Diet selection (% clover)	0	-	100	69		
	Grazing time (min/day) *	549 b	514 b	337 a	362 a	<0.001	46.1
	Intake (kg/day)[#]	2.4	2.9	2.3	2.3		
Ewes	Diet selection (% clover)*	0	-	100	78		
2003	Grazing time (min) *	505 b	523 b	407 a	412 a	<0.001	37.3
	Diet selection (% clover)[+]	0 a	5 a	93 c	70 b	<0.001	5
	Intake early lactation (kg/day) [+]	2.7 a	2.3 a	4.0 b	3.7 b	<0.001	0.33
	Intake mid lactation (kg/day) [+]	2.4 a	2.1 a	3.2 b	3.2 b		
	Intake late lactation (kg/day) [+]	2.5 a	2.0 a	2.4 a	2.5 a		

* Source: grazing observations
[+] Source: alkane method

It would be expected that ewes eating from the choice treatment would suffer a fall in daily intake in proportion to the difference between grass and clover intake rate, weighted for the time spent grazing on grass. Small compensatory increases in grazing time when animals are offered the free choice compared to animals offered pure subclover only, especially in Experiment 1, partly explains why daily intake was not reduced by including grass in their diet. Nevertheless, even at the same total intake, performance from the choice treatment would be expected to be less than the pure subclover in proportion to the difference in performance between animals grazing pure grass and clover pastures, weighted for the time spent grazing on grass. Again this was not the case and the performance of ewes and lambs on the choice treatment was 20% (198 *vs*. 165 g/day) and 12% (356 *vs*. 317 g/day) better than expected, suggesting improvements in feed conversion efficiency.

4.4.1.5 Meal patterns

Ewes grazing ryegrass had 25 to 40% fewer meals, but these were more than twice as long as those grazing pure subclover in both experiments (Table 18). Meal patterns for ewes grazing the mixed pasture were intermediate between pure ryegrass and subclover. There were minimal differences in meal patterns between the subclover and choice treatments in 2002, but in 2003 those offered free choice had fewer but longer meals. The lambs in 2002 displayed a similar characteristic with more frequent meals of shorter duration on the subclover treatment, and fewer, longer meals on the ryegrass treatment. Further insights into the factors controlling grazing behaviour are likely to be drawn from a breakdown of the meal patterns of animals grazing on the choice treatment (Marotti 2004), but we are yet to complete this analysis. However, a reasonable proposition from this and other work is that an accumulation of ammonia from the rapidly degradable protein fraction of clover constrains the length of time ruminants can eat from a pure clover pasture and that adding grass to the diet helps overcome this constraint (Chapman *et al.* 2006).

Table 18. Meal patterns of ewes and lambs grazing four pasture treatments during Experiment 1 and 2.

		Treatment				Significance[#]			
		Rye	Mix	Sub	Choice	Treat	Date	Int.	s.e.d
Ewes	Number of meals	11.0 a	12.5 ab	14.5 ab	15.4 b	***	NS	NS	1.99
2002	Meal length (min)	57.4 b	47.5 b	24.5 a	24.6 a	***	*	NS	10.3
Ewes	Number of meals	10.6 a	12.0 a	17.9 b	13.1 a	***	***	*	1.73
2003	Meal length (min)	60.2 b	50.3 b	24.6 a	34.9 a	***	***	**	9.60
Lambs	Number of meals	11.8 a	13.7 ab	15.6 b	15.2 ab	***	**	NS	1.77
2002	Meal length (min)	49.2 b	38.5 b	26.0 a	27.2 a	***	***	NS	5.56

[#] *** F-prob <0.001, ** F-prob <0.01, * F-prob <0.05, NS F-prob >0.05

4.4.2 Experiment 3

4.4.2.1 Rumen ammonia

The rumen ammonia concentration was closely related to the proportion of subterranean clover in the diet (Fig. 13). The time of measurement and interaction between time and treatment was also significant. After normalising the data for crude protein intake, sheep fed pure ryegrass had rumen ammonia concentrations consistently lower than 200 mmol/L/kg CPI. This suggests that ammonia produced from the degradation of ryegrass was either cleared from the rumen rapidly or incorporated into microbial protein. In contrast, the ammonia levels in sheep fed a pure subclover diet increased rapidly after the first meal of the day. This peak after the morning feed was also apparent on both mixed diets, but developed more slowly and the peak concentration was lower than for pure clover. The peak concentration of ammonia after feeding subclover was similar to those for white clover (Marotti 2004) and can be partially explained by the asynchronous nature of fermentable metabolisable and the soluble fraction of protein. Asynchrony in supply (under supply of fermentable energy and over supply of soluble protein) can lead to elevated concentrations of ammonia in rumen fluid. Furthermore, if the supply of fermentable energy and protein is not synchronised, the long term effect on the rumen ecosystem is to reduce microbial activity especially fibrolytic activity.

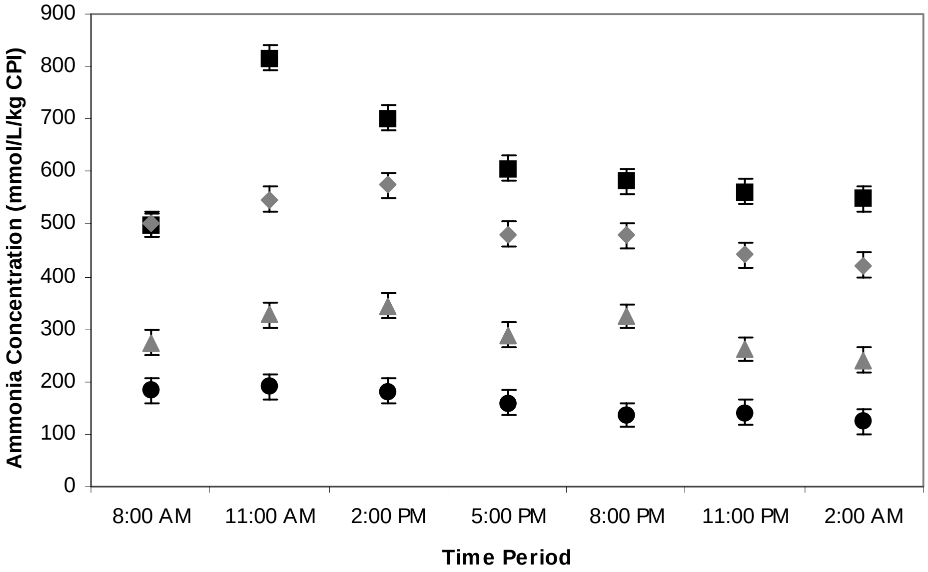


Figure 13. Daily fluctuations in the predicted mean ± sed of ammonia concentrations (mmol/L/kg CPI) of sheep fed twice daily fresh pasture diets of perennial ryegrass and subterranean clover in the following ratios, 100% sub (■), 100% rye (●), 67:33% sub:rye (◆) or 33:67% sub:rye (▲).

Sheep fed pure subclover did not have another peak corresponding to the afternoon feed. This reflects two factors: the ‘flooding’ of the rumen system with ammonia and behavioural changes during eating. The latter is difficult to identify when animals are offered two feeds per day (each approximately 0.5 of maintenance). This data set adds support to the hypothesis that animals select a mixed diet to avoid high ammonia levels in the rumen, which would lead to high blood ammonia levels and pose a toxicity threat to the animal. Confined feeding studies have observed that animals alter diet selection to balance protein intake (Kyriazakis and Oldham 1993), and it seems reasonable to propose that this could occur also in free-grazing ruminants. However this pen study was not designed to demonstrate a link between grazing behaviour for a partial clover diet and rumen conditions.

4.4.2.2 *Rumen pH*

Both the dietary treatment and the time of measurement had a highly significant influence on the pH values within the rumen. There was no significant interaction between the dietary treatment and time period within the day, indicating similar pH profiles through the day for the different treatments. Overall, the sheep fed 100% ryegrass in their diet had a lower pH than other treatments (Table 19).

Table 19. Predicted mean pH for sheep fed fresh diets twice daily of perennial ryegrass and subterranean clover in the following ratios, 100% subclover, 67:33 subclover:ryegrass, 33:67 subclover:ryegrass or 100% ryegrass.

	Diet				
	100% sub	67:33% sub:rye	33:67% sub:rye	100% rye	s.e.d.
pH	6.09 a	6.15 a	6.08 a	5.89 b	0.06

Prior to the morning feed at 8am, the rumen pH was quite high at 7.3 (Table 20). There were notable drops after feeding as evidenced by the 11am and 5pm measurements. However the pH takes longer to 'rebound' after the afternoon feed compared to the morning feed.

Table 20. Daily change in pH values for sheep fed fresh diets of ryegrass and clover twice daily at 8:30 am and 4:30 pm.

	Time of day							
	8 am	11 am	2 pm	5 pm	8 pm	11 pm	2 am	s.e.d.
pH	7.3 d	5.8 b	6.2 c	5.6 a	5.6 a	5.8 b	6.1 c	0.08

4.4.2.3 *Rumen volatile fatty acids*

Total VFA concentration fluctuated significantly throughout the day but the profile did not differ between dietary treatments. The time period effect on total VFA concentration in the rumen is presented in Fig. 14.

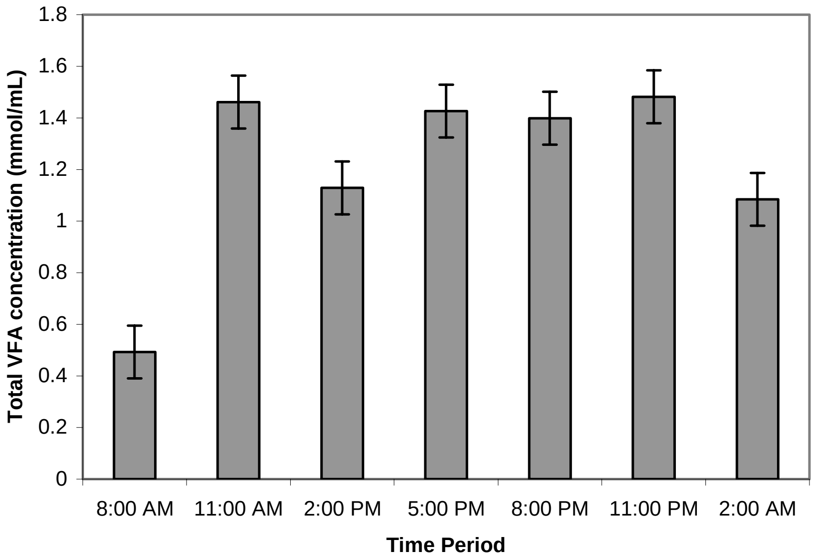


Figure 14. Daily fluctuations in mean ± s.e.d. of total VFA concentration (mmol/mL) of sheep fed twice daily fresh pasture diets of perennial ryegrass and subterranean clover.

The dietary treatments did however have a significant effect on the proportion of individual volatile fatty acids (Table 21). The percentage of acetate was lower on the 100% ryegrass treatment, while propionate was higher for the 33% and 100% ryegrass. An acetate:propionate ratio of greater than 3:1 indicates that energy is limiting microbial protein synthesis and this appears to be the case on 0% and 67% rye. A higher proportion of the branched chain fatty acids (i-butyrate and i-valerate) were present on the 100% subclover diet. Branched chain fatty acids are produced via amino acid catabolism, indicating a shift towards proteolytic microbes on the diets high in subclover. It is also important to note that the proportion of lactate increased with increasing ryegrass in the diet. The production of lactate reflects a move towards acidosis within the rumen. The lower pH on the ryegrass diet fits with this observation.

Table 21. Dietary treatment effects on the proportion of each volatile fatty acid.

	% Volatile fatty acid						
Dietary Treatment	Acetate	Propionate	n-Butyrate	i-Butyrate	n-Valerate	i-Valerate	Lactate*
100% subclover	61.5 b	19.4 a	13.2 ab	1.9 c	1.3 b	2.6 c	0.2 a
67:33% sub:rye	61.4 b	20.5 b	12.6 a	1.7 b	1.2 a	2.3 bc	0.4 b
33:67% sub:rye	62.4 b	19.7 a	12.7 a	1.5 a	1.1 a	2.0 ab	0.6 c
100% ryegrass	59.9 a	21.2 b	13.8 b	1.4 a	1.2 ab	1.9 a	0.7 d
lsd	1.4	0.7	0.8	0.2	0.1	0.3	0.1

*Interaction between period and treatment was significant.

These results suggest that mixed diets may have more stable fermentation patterns, as there are indications of sub-optimal conditions for both 100% ryegrass and 100% subclover. This was examined further in the *in vitro* measurements.

4.4.2.4 *In vitro gas production*

Samples of rumen fluid from each feeding group were used in an *in vitro* gas production experiment to examine extent and the rate of degradation of organic matter and the total gas produced (a measure of functionality). The experiment also examined the impact of feeding the rumen ecosystem with a contrasting feed source, an approach to try to explain why animals switch from one pasture species to another. The results suggest that the optimal rumen function results with a mixed diet of 16% ryegrass and 84% subclover, closely followed by the 33% ryegrass and 67% subclover. This conclusion is drawn from the rate functions, the total gas volume, the undegraded fraction and hence the effective degradability of the feed. The U_0 value is lowest of all treatments on 84:16% subclover:ryegrass, leading to the highest effective degradation.

Table 22. Total gas produced, extent and rate of degradation of organic matter from diets ranging from 100% ryegrass to 100% subclover fed to an *in vitro* system. Values are averaged across background diet effects.

Treatment	Y x S_0 (ml)	b (h^{-1})	c (h^{-1})	T (h)	U_0 (g/100 g)	E (%)	RSD
100% rye	287.4	0.0461	0.0032	2.1	20.9	43.7	40.7
33:67% sub:rye	306.1	0.0467	0.0033	1.7	20.6	45.4	31.9
67:33% sub:rye	330.6	0.0471	0.0035	1.4	18.7	47.3	40.4
84:16% sub:rye	346.7	0.0480	0.0036	1.6	17.6	47.7	27.6
100% sub	317.9	0.0471	0.0034	1.3	19.4	46.0	46.9

Y x S_0 = maximum gas produced (ml)
b and c = rate constants calculated from the Gompertz function
T = lag time
U_0 = undegraded fraction
E (%) = effective degradability at 0.03h^{-1} outflow

If the rumen ecosystem was challenged with a different feed compared to that offered originally *in vivo*, subtle changes in gas production and VFA production resulted. Table 23 outlines the positive and negative effects on Y x S_0, U_0 and E (%). A complete switch in diet to ryegrass or subclover reduces the effective degradation of the feed, while moving to a mixed meal increases the effective degradation. Adding portions of subclover to the rumen fluid of sheep adapted to pure ryegrass, increased the maximum gas production (ml), while adding portions of ryegrass to the rumen fluid of sheep adapted to pure subclover had the opposite effect. However, a complete switch in diet to ryegrass or subclover reduces the effective degradation of the feed. The effective degradation was improved by providing a mixed meal. The impact appears to be greater for animals as they leave pure ryegrass and enter subclover, than for animals adapted to pure subclover that enter ryegrass.

Table 23. The effect on gas production and organic matter degradation, of challenging rumen fluid from sheep fed 100% ryegrass or 100% subclover, with other ratios of ryegrass and subclover *in vitro*.

	Effect on Y x S_0	U_0	E (%)
100% Rye			
Challenge 100% Sub	+ 47.1	- 0.011	-3.7
Challenge 50:50 Rye: Sub	+ 40.1	+ 0.13	+1.1
Challenge 16:84 Rye : Sub	+ 26.3	+ 0.10	+0.6
100% Sub			
Challenge 100% Rye	- 31.1	- 0.26	- 1.6
Challenge 50:50 Rye: Sub	- 30.4	+ 0.17	+ 1.7
Challenge 16:84 Rye: Sub	- 4.7	+ 0.11	+ 3.0

More detailed studies are required to examine these responses when animals are adapted to *ad lib* systems (in housed studies) and are allowed to optimise their grazing behaviour. Definitive data sets that establish or disprove the link between rumen state and diet selection remain to be collected.

5 Success in Achieving Objectives

The 'Morelamb' project has successfully achieved all contracted objectives. These include:

(a) Identified critical control points for finisher and store ('feeder') lamb production systems in southwest Victoria

(b) Demonstrated 50% improvements in productivity per hectare at five on-farm sites from subdivision, improved grazing management and sowing commercially available high performance pasture mixtures.

(c) Conducted a rigorous evaluation of long season annual pastures and demonstrated that arrowleaf clover (cv *Arrotas*) extended the growing season by 4 to 6 weeks compared to subterranean clover (cv. *Leura*) and total production from arrowleaf clover in late spring/early summer approached 400 kg lamb liveweight/ha.

(d) Developed grazing management guidelines for arrowleaf clover that optimise pasture and animal performance in a spring lambing production system.

(e) Developed an innovative grazing system to improve the efficiency of production from existing legume pastures based on offering grass and clover monocultures side-by-side and allowing animals to choose their preferred diet.

(f) Demonstrated that mixed grass/clover diets resulted in a more stable rumen fermentation pattern and optimal rumen function occurred with a clover proportion between 67 and 84%.

(g) Provided information on project outcomes for incorporation into existing extension programs.

Further work contract is still planned. This includes:

(a) Work with MLA to package these outcomes with other projects within the Management Solutions portfolio.

(b) Complete analysis and publication of science outcomes in refereed journals and PhD thesis (K. Venning).

(c) Complete additional MIDAS modelling for 'critical control point' analysis following Management Solutions forum and feedback from lamb producers in March 2007.

(d) Complete additional MIDAS modelling to establish the economic value and potential fit of the high performance pastures and arrowleaf clover in a whole farm context with a forage system based on perennial ryegrass/subclover.

6 Impacts on Meat and Livestock Industry

There are a number of implications of these results for industry in the short term and the proposal is to work with MLA and consultants to package these with outcomes from other Management Solutions projects over the next 3 to 6 months. Key outcomes that have immediate application are summarised below.

1. A critical control point analysis using whole farm systems modelling identified the components of finishing and store lamb production systems that could be manipulated and their likely impacts on profitability. This information can assist producers (and funding bodies) in deciding where to invest time and resources to have maximum impact on profitability. Based on the assumptions used and factors examined the critical control points identified were: (a) matching ewe genotype and lamb turn-off system (finished or store); (b) pasture utilisation; and (c) pasture production. When producers have optimized these factors the second order control points were: (a) meeting market specifications; (b) ewe nutrition and condition score profile; (c) reproductive rate; and (d) ewe wool value. This is the first analysis to show that these critical control points vary for different enterprise types. For individual producers the management and production factors that will provide the greatest return on effort will depend on their current management and production levels, plus the ease and cost with which they can alter their management.

2. A flock based on a composite breed was more profitable than a flock based on producing 2nd cross lambs, the magnitude of the difference depending on the lamb turnoff system – changing from the best 2nd cross system to the best composite system increased profit by 50% or $100/ha. The relative profitability of different ewe genotype x lamb turn-off systems was sensitive to skin values of finished lamb and the cost of buying in replacement first cross ewes. Optimising pasture utilisation is a critical control point for all producers and increasing utilisation by 10% can increase whole farm profit by up to $100/ha. Improving feed utilisation requires producers being more informed about levels of pasture in different paddocks on the farm and making good decisions about allocating the pasture resource to the grazing animals. The cash costs associated with most of these decisions are low, however they require a high level of technical knowledge. Only when a high level of the pasture grown is consumed is it worth examining ways to increase pasture production. The first step to increase pasture growth is increasing fertilizer which increases the growth of the pasture throughout the growing season. The next step is to consider changing pasture species to alter the feed profile to better match the feed demand profile. The results show that a 10% increase in summer growth only has a moderate return, however the possible increase in summer growth rate from long season annuals and deep rooted perennials are in the range of 200 to 400% so the potential payoff is very large (up to $200/ha).

3. Farmer driven commercial scale sites demonstrated an average increase in lamb liveweight per hectare of 50% compared to the remainder of their farm or the top 20% of lamb producers in the South West Monitor Farm Project (510 *vs*. 330 kg/ha). These productivity gains can be attributed to increases in ewe stocking rates resulting from the combined effects of increased subdivision, better allocation of feed from rotational grazing and pasture improvement, plus reduced lamb mortality. The differences in productivity and profitability between sites managed by 'top producers' and running similar enterprises averaged 20 to

30%. This was greater than the differences between enterprises or pasture systems indicating the scope for individuals to fine tune their own enterprises to increase profits.

4. Whole farm systems modelling derived lamb production benchmarks that can be used by producers to assess which areas of their system might be improved. Table 24 includes the level of production that represents the "best bet" levels for lamb producing flocks at Hamilton. As with all benchmarks these values need to be interpreted with care because these standard figures don't account for the variation in resources between individual properties, such as variation in soil types present which impacts on the pasture production capacity of the farm. However, there was a good match between MIDAS predicted benchmark production levels and actual levels of production achieved at the five commercial scale demonstration sites across southwest Victoria; 57 *vs*. 65 kg liveweight/ha/100 mm rainfall for store lamb systems and 71 *vs*. 84 kg liveweight/ha/100 mm rainfall for finishing systems, respectively. This suggests that the MIDAS derived production benchmarks shown in Table 24 are achievable on farm.

Table 24. Benchmark production levels for high performance lamb flocks in Hamilton, southwest Victoria.

Benchmark	Units	Level
Weight of lamb	kg/ha	Finished: 500 Store: 400
Pasture growth	kg/ha	9000
Pasture consumed	kg/ha	5500
Pasture utilisation	%	61
Supplement fed	kg/ewe	Finished: 30-60 Store: 10-20
Lambing percentage	lambs marked / ewe joined	145%
Average lamb price	Average price / top prices	90%

5. There was minimal variation in lamb output between the three pasture systems compared at each demonstration site and the short term ryegrass based pastures did not persist beyond two years. Based on these results it is difficult to justify the investment in sowing short term ryegrass and longer term fescue based HPP. It is acknowledged that this result could in part be due to poor establishment and management of 'new' pastures at several sites, the manner in which the trial was managed (i.e. single pasture type with each system and stocked all year round) and the outstanding performance of the perennial ryegrass/subclover 'control'. Further work is needed to identify the strengths and weaknesses of the 'new' pastures in different seasons and years, and to determine if a matrix of different plant mixes and monocultures at farm scale can improve output above that achieved from a simple perennial ryegrass/subclover system without increasing risk. This work is in progress.

6. Pasture establishment was variable across sites and pasture systems and management during the pre and post establishment phases was a major factor contributing to the overall success and productivity of the demonstration sites. There was also a strong pattern for complex pasture mixtures to simplify to a few dominant species over a couple of years suggesting the practice of sowing 'shot-gun' mixtures is difficult to justify. The challenges to farm management skill associated with successfully using more complex feed base options

should not be under estimated and in our opinion a ‘hands-on’ extension program focusing on pasture selection and establishment strategies and targeted at farmers, consultants and pasture specialists would be a good investment for the sheep meat industry.

7. Simple guidelines for the successful establishment and management of arrowleaf clover (cv. Arrotas) were developed from rigorous science and published for producers and pasture specialists. Arrowleaf clover can extend the growing season by 4 to 6 weeks and maintain a digestibility of at least 5% higher than late maturing subterranean clover during December and January. At stocking rates up to 24 lambs/ha, August born lambs could be finished in late January/early February at 43 to 45 kg direct directly off arrowleaf pastures and without the need for any supplementation, whereas lambs grazing subclover and perennial ryegrass mixed pastures were removed into a feedlot situation by mid to late December at 33 to 36 kg. Total lamb production from arrowleaf monoculture pastures in late spring/early summer exceeded 400 kg liveweight/ha. A more economical option with less risk is to direct drill arrowleaf clover which has poor winter production into existing perennial ryegrass pastures, since perennial ryegrass/arrowleaf mixed pastures produced a similar quantity of lamb per hectare as arrowleaf monoculture pastures but had greater pasture production and grazing value during winter and early spring. Including arrowleaf clover in the mixture instead of subclover also increased the utilisation of the low quality perennial ryegrass during early/mid summer by at least 1000 kg DM/ha.

8. Opportunities exist to increase production and efficiency by growing complementary pastures as side-by-side monocultures rather than traditional mixtures. Spatial separation of subclover and perennial ryegrass increased ewe and lamb performance per head by 20 to 30% compared to traditional subclover/ryegrass mixtures, due largely to increased clover in the diet. Ewes and lambs offered a free choice of grass and clover *ad libitum* consistently included up to 30% grass in their diet but performed as well or better that those grazing pure clover. Thus all the feeding value benefits of clover are available when only 0.5 of the grazing area is sown to clover. The performance of ewes and lambs on the choice treatment was 20% (198 *vs*. 165 g/day) and 12% (356 *vs*. 317 g/day) better than expected based on their intake and diet composition, suggesting improvements in feed conversion efficiency. Ewes on the choice pastures actually gained liveweight and condition during late pregnancy and early lactation whereas those grazing pure clover maintained or lost weight and condition during this period. The feed conversion hypothesis was supported by *In vivo* studies showed that mixed grass /clover diets resulted in a more stable rumen fermentation pattern and *in vitro* work suggested optimal rumen function occurred on mixed diet with a clover proportion between 67 and 84%. This work indicates that farmers with existing pure legume pastures can make immediate productivity and efficiency gains by providing sheep with free access to clover and grass monocultures side by side. Opportunities also exist to establish new feedbase systems based on spatially aggregated grass and clover.

   There is no concrete evidence available to judge whether of not spatially separated monocultures would increase production per hectare, however it is reasonable to expect that it could if total dry matter production is similar for ryegrass and clover. Cocks (1974) found minimal differences in total production from ryegrass and clover when grown as monocultures and provided with adequate water and nutrients, and indeed clover produced more dry matter than grass when defoliated to maintain less than 2000 kg DM/ha. Separating grass and clover allows each species to be managed more specifically to maximise their production. This could include tactics such as targeting nitrogen fertilizer to the grass component of the paddock, phosphorus and potassium to the clover, and herbicide use for weed control to a broadleaf or grass species background.

7 Conclusions and recommendations

The first major recommendation in the short term is to work with MLA, consultants and producers to package key outcomes described in the previous sections. Further investment in the 'Critical Control Point Analysis' concept developed by 'Morelamb' to include other components of lamb production systems, regions and farming systems, and including a sensitivity analysis to a broader range of commodity prices should also be considered. A needs analysis of the target audience should be undertaken to establish if decision tools or 'check lists' would assist farmers to identify opportunities to increase the profitability of their enterprise while managing risk.

The second major recommendation concerns future research directions and building on outcomes from the 'Morelamb' project, remembering that some of these ideas have already contributed to the 'Evergraze – more meat from perennial' project. The design of cropping systems is now being approached with better appreciation of the functioning of landscapes, cropping systems themselves, and with the help of new technologies and tools. The same principles can be applied to develop more productive and sustainable livestock systems in Australia, but with the added complexity and challenges of providing complementary nutrients to achieve animal production and welfare objectives and being able to maintain desirable levels of plant diversity under grazing. We need to change the scale that we consider the role of plant diversity and expand our thinking from plant diversity at patch scale to across paddocks, farms and even landscapes. We know from previous projects such as Sustainable Grazing Systems how to manage pasture mixtures to optimise control of pasture regrowth for high per hectare production (Chapman et al. 2003), but it has proved almost impossible to maintain high proportions of the preferred feed of ruminants in the mixture at the same time. Spatial separation of different plant types to take advantage of spatial variability in land and soil types and allowing animals to select a mixed diet is one answer to deal with this dilemma.

The key to developing such systems resides in understanding complementarities among diverse plant species that differ in the kinds and amounts of nutrients and secondary compounds, phenology and tolerances to variable temperature and precipitation regimes. We need to better understand what plants we mix with what to match nutritional profiles for the animal, together with other attributes such as adaptation to the environment and water use efficiency, to develop profitable and sustainable animal production systems. We need to understand what level of complexity (species diversity, spatial structure) is appropriate, and the costs and benefits of different levels of complexity. Information on the metabolism of many toxins is currently inadequate and there is little information on how specific toxins may interact in the body. We need to gain a more comprehensive understanding of routes of detoxification of plant toxins to determine what combinations of toxins and plants may be complementary or non-complementary when offered as choices or in sequence. Better knowledge of the factors that are motivating animals to select for certain dietary components should allow us to consider how forages and other foods could be presented to grazing livestock so that they can acquire their optimal diet. In the short term, feeding trials involving different arrays of plants may be the only way to determine how foods containing different combinations of toxins and nutrients may interact to influence feed intake.

In summary, there would appear to be a number of benefits from designing forage systems based on multiple plant options, sown as simple mixes or monocultures spatially separated, as opposed to a ‘one pasture mix fits all’ approach to providing an all year round productive feed base. We also need to consider the use of forages in rotations over time [‘forage chains’] and develop and evaluate systems on a multiple year cycle, where the output is optimised over a cycle, rather than from each year. Increased understanding of the controls of intake and diet selection by ruminants is also vital for predicting the impacts of grazing animals on plant species dynamics, biodiversity and ultimately the functioning of ecosystems - in other words, it is an essential prerequisite to the development of sustainable grazing systems. Opportunities exist to design forage systems using complementary plants that not only meet animal nutrient requirements but also animal welfare benefits such as parasite control and environmental benefits such as reducing methane output.

A new paradigm is needed in how we ‘custom-design’ forage systems to deliver positive environmental, economic and social outcomes, and future-farming systems will need to consist of a mosaic of complementary vegetation-types across the landscape. A reasonable proposition is that in order to gain specific knowledge of achievable animal production and water use targets using novel combinations of plants, we must start building such systems and quantifying their performance. We should embrace this challenge, capitalising on the links formed with international scientists with expertise in components of forage system design, even whilst we have incomplete knowledge of how such systems will perform.

Suggested next steps are as follows:

1. Review of current forage systems to identify the system functions that are sub-optimal.

2. Review of current animal systems to identify critical control points, inefficiencies and practical and physiological barriers and opportunities.

3. Identify plant functional groups, including trees, shrubs, pastures and crops that could carry out these systems functions.

4. Improved understanding of diet selection – what are animal trying to achieve by mixing diets, and how can the answer to this question assist in designing mixed forage systems.

4\. Model new farm systems that incorporate different trees, shrubs, pastures and crops plus knowledge of diet selection and performance from offering complementary plants.

5\. Design radically different plant and animal systems to test. The challenge to determine the ‘optimum’ combinations of different plant components, their proportions and configurations within the system in relation to each other and the landscape will be enormous (and risky).

6\. Rank novel systems in order of degree of improvement achievable and feasibility of implementation, test systems and modify elements of systems to achieve economic, environmental and social objectives.

8 Communications and publications

The outcomes from this project have been communicated to sheep producers, consultants and scientific communities through seminars, conferences, field days and farming media.

8.1 Publications – Scientific Refereed Journals and reports

Chapman DF, Parson AJ, Cosgrove GP, Barker DJ, Marotti DM, Venning KJ, Rutter SM and Thompson AN (2006) Impacts of spatial patterns in pasture on animal grazing behaviour, intake and performance. *Crop Science (in press)*

Thompson, A.N. (2006). Integration of plant diversity and animal foraging behaviour to achieve multiple objectives'. Winston Churchill Fellowship Report, 41 pp.

8.2 Publications – Conference papers and posters

Gloag C, Thompson AN, Kennedy AJ, Venning, KJ (2003) Long-season annual legumes to increase lamb production. In 'Proceedings of the first joint conference of the Grasslands Societies of Victoria and NSW', June 11-13 Albury NSW, p. 93.

Kennedy AJ, Thompson AN, Gloag C, Venning KJ (2003) High performance pasture systems to increase lamb production in southwest Victoria. In 'Proceedings of the combined conference of the Grasslands Societies of Victoria and NSW', June 11-13 Albury NSW, pp. 83-84.

Venning KJ, Thompson AN, Kennedy AJ, Chapman DF (2003) Prime lamb production from adjacent monocultures of grass and clover. In 'Proceedings of the first joint conference of the Grasslands Societies of Victoria and NSW', June 11-13 Albury NSW pp. 81-82.

Venning KJ, Thompson AN, Chapman DF, Kearney G (2004) Ewe and lamb growth from adjacent monocultures of grass and clover. In 'Proceedings of the Australian Society of Animal Production', Vol 25, p. 336.

Holmes J, Kennedy AJ, Thompson AN (2005) Arrowleaf clover for growing lambs in late spring/early summer in southwest Victoria. In 'Proceedings of the 46th Annual Conference of the Grassland Society of Southern Australia', July 15-17, Ballarat, p. 120.

Kennedy AJ, Thompson AN (2005) Economic comparison of pasture based lamb production systems in southern Australia. In '*Proceedings of the International Grassland* Congress', Dublin, Ireland.

Schut AGT, Thompson AN, Gherardi SG, Metternicht G (2006) Seasonal changes in pasture quality in Mediterranean regions of Australia. In 'Proceedings of the 13th ASA Conference', 10-14th September, Perth, Western Australia (*in press*).

Venning KJ, Thompson AN (2006) Making better use of clover. Sheep Updates.

8.3 Media articles

MLA Prograzier Spring edition (2003)

- Arrowleaf boost for lamb, pg 10
- Fine-tuning high performance pastures, p. 11
- Clover crucial for good lamb growth, p. 11

MLA Prograzier Summer edition (2005)

- Menu choice lifts lamb growth by 30%, pp. 19-20
- Lamb production heads for 1000kg/ha on high performance pastures, pp. 14-18
- Mixed pastures give marketing flexibility, p. 15
- Livestock food preferences give clues to lifting growth, p16
- Kilomax mix boosts twinning rates, p17
- Rotational grazing benefits stand out, p18

MLA Prograzier Spring edition (2006)

- New pastures for a new prime lamb industry

Farming Ahead (Kondinin Group)

- Split clover and grass to lift lamb growth rates by 30%. Farming Ahead, No. 174, p. 64.

Other

- The Muster (2003) Management solutions for pasture-based lamb production, p. 22.
- On the Land (2003) *Research shows promise,* November edn.
- Stock and Land (2003) *Morelamb pushes the boundaries,* 13th November edn.
- The Hamilton Spectator (2004) *Novel Lamb Production System*.
- The Hamilton Spectator (2006) *Making better use of clover*.
- The Weekly Times (2003) *Pasture push ups lamb ante*, 28th March edn, p. 29.
- Western District Farmer (2003) *Morelamb*, December edn.
- Wrightson's newsletter (2003) *High performance pasture trial pointing to higher lamb productivity potential.*

8.4 Field Days, External Presentation and Workshops

Field Days and External Presentations
2002 • Holmes and Sackett producer group – 'Murroa' research site • Scientists from the CSIRO and University of WA – 'Murroa' research site • NAPLIP meeting delegates – 'Murroa' research site • Southern NSW Producer Group - HPP Demo site (Condah) • Kangaroo Island Producer Group - HPP Demo site (Condah) • SGS National field walk - HPP Demo site (Condah) • Science Group from PVI - 'Murroa' research site • DNRE Meat Team - 'Murroa' research site
2003 • CSIRO Perth Seminar (K Venning) • Bus tour for lamb producers – HPP Demonstration sites (Heywood, Digby and Hamilton) and 'Murroa' research site • Major field day - Murroa Research site • Field day - HPP Demonstration sites (Heywood) • Field day - HPP Demonstration sites (Camperdown)
2004 • South West Prime Lamb Group - Murroa Research site • Stephan Pasture Seeds/PGR Seeds - Murroa Research site • University of Melbourne students - Murroa Research site • Meat and Livestock Australia Southern Team Meeting 2004 - Murroa Research site
2005 • BestWool/BestLamb Group Contact Conference, Ballarat • DPI Secretary and Executive Team • MLA Prime Time (Mt Gambier, Adelaide and Warnambool) • International Grasslands Congress, Dublin • 'Beyond the plant: biodiversity impacts on the grazing animal' Symposium, Salt Lake City, US
2006 • BestWool/BestLamb Group Contact Conference, Ballarat • DPI Secretary and Executive Team • Southern Sheep School - • Finishing Systems Workshop - Camperdown • Sheep Update Conference, Perth • BEHAVE Symposium, Mid-way, Utah, US

8.5 International visitors

Eight international scientists from four countries also visited the site and held discussions with project staff.

- Mark Rutter, IGER International Grasslands Institute, North Wyke UK (2005)
- Prof Fred Provenza, University of Utah, USA (Jul 2005)
- David Christophe, Marc Benolt, Patrick Veyssett, INRA, France (Oct 2005)
- Fabio Porchile and Walter Ayala, Uruguay (Mar 2006)
- Mark Brunson, Utah State University, USA, (Nov 2006)

8.6 Project Awards

- Andrew Thompson: Churchill Fellowship (2004)
- Karen Venning: Best 'Young Scientist' for a poster presentation at the Australian Society of Animal Production conference (2004)
- Jayne Holmes: Best poster presentation at the Grassland Society of Southern Australia conference (2005)

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10 Appendices

10.1 Appendix 1 – Sheep Production and Price Assumptions

Table A1. Sheep production characteristics for different systems.

	'Composite'	'2nd cross lambs'	
Genetics	Composite breed with a Romney/Coopworth base	Merino Ewe mated to a merino ram or BL ram	Border Leicester x Merino ewe mated to a Dorset ram
Standard reference weight of ewes (kg)	55 kg	50 kg	55 kg
Standard reference weight of ewes of terminal sire breed (kg)	65	BL: 60 kg	65 kg
Clean fleece weight of ewes (kg)	3.0 kg	3.8 kg	3.0 kg
Fibre diameter of ewes (micron)	34.5 µm	20.5 µm	28.0 µm
Clean fleece weight of lambs (kg)			
Conception rate at CS 3.5 (%)	170% 6% Barren, 28% Single, 68% Twin	130% 10% Barren, 50% Single, 40% Twin	170% 6% Barren, 28% Single, 68% Twin
Lamb survival (scan to weaning)			
Singles		80	
Twins		60	
Calc. weaning %	134%	88%	134%

Table A2. Sheep management program for different systems

	'Early-Finished'		'Mid-Finished'		'Mid-Store'		'Late-Store'	
Lambing time	Mid-June		Mid-July		Mid-July		Mid August	
Weaning age			159 d				97 d	
Shearing time-ewes			15 Jan				15 Jan	
Crutching time-ewes			15 Nov				15 Nov	
Stock turn off date								
- wether lambs			19/12				22/11	
- ewe lambs			19/12				22/11	
- CFA ewes			Scanning and or marking/weaning				Scanning and or marking/weaning	
	Comp	2nd	Comp	2nd	Com	2nd	Com	2nd
Lamb growth rate (kg)			231				220	
Birth			5.0				5.0	
Weaning			41.1				25.8	
Sale (live)	45.0	30.0	41.1				30.0	
(dressed)	20.25		18.5					
Lamb Sale value			$3.50				$55 hd	
($/kg DW)			kg cwt				lwt	
or ($/kg LW)	-			-				
Lamb Skin value ($)	$1	$15	$1	$15	$1	$15	$1	$15

Other management comments:

- Buy in first cross ewe replacements for the "2nd cross Lamb" system as weaners in Nov/Dec for $150/hd (range 120-180) and mate at 19 months of age.
- Animal husbandry
  - Drenching (2 summer drenches for ewes, lambs drenched at marking or weaning)
  - Jetting (lambs get Click at marking)
- Crutching for all ewes (contract)
- Shearing annually (contract)
- Composite lambs turned off before requiring shearing and for 2nd X enterprise only lambs that are carried into late January/February are shorn)

10.2 Appendix 2 – Pasture productivity assumptions

Table A4. Initial growth or germination (kg/ha) of each pasture type on each soil class during the first feed period

	Ridges	Mid-slopes	Flats
High production Perennial Ryegrass	594	594	594

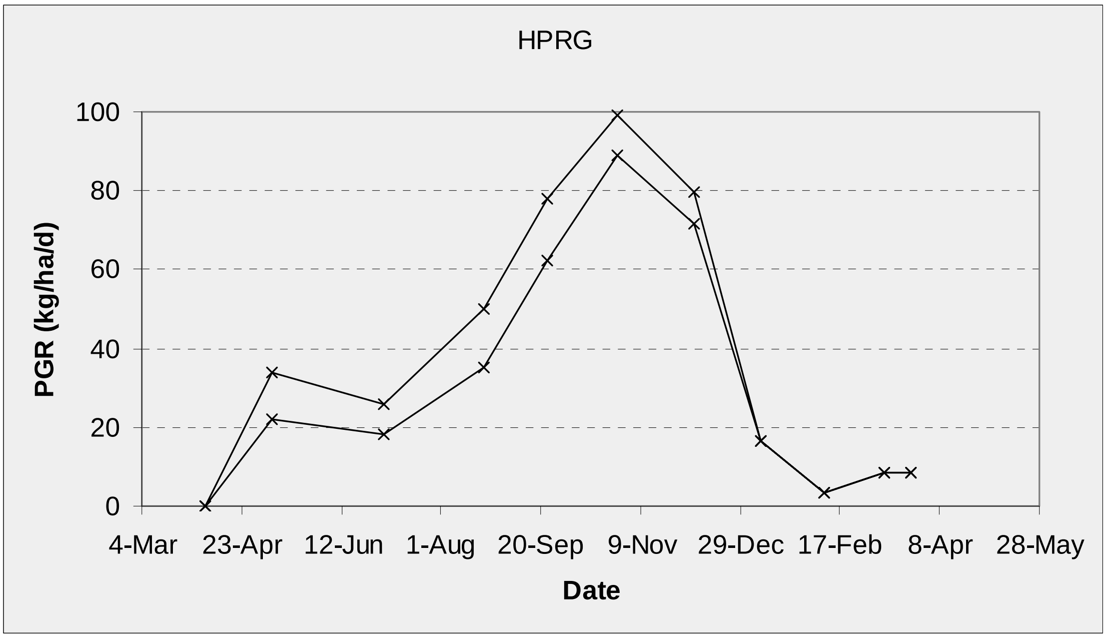

Figure A1. MIDAS inputs: Low and High pasture growth rate for high productivity perennial ryegrass pasture in each feed period (1 to 10). Note the low and high pasture growth rate relate to the low and high feed on offer levels in the following graph. The MIDAS optimization algorithm is able to vary grazing intensity which alters feed on offer which then affects pasture growth.

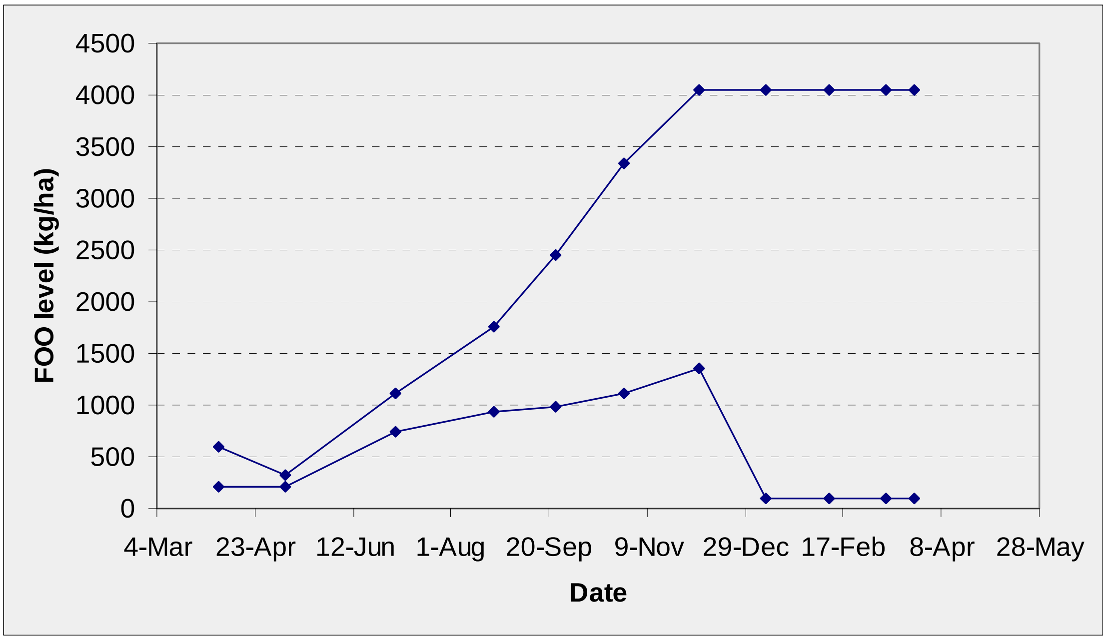

Figure A2. MIDAS inputs: Feed on offer levels for the two different pasture growth rate levels for all the pasture types.

10.3 Appendix 3 – Farmer case study; site preparation and grazing management during establishment of high performance pastures

Subtle differences in paddock preparation for pasture establishment and grazing management between two sites led to large differences in the composition of the fescue-based HPP (Table A3.1).

Table A3.1. The establishment processes employed by a successful and unsuccessful site for System B.

Site 3 'Successful'	Site 4 'Unsuccessful'
Knockdown herbicide in previous spring and Brassica crop sown. Full cultivation.	Mechanical topping of existing annual pasture in previous late spring period.
Knockdown herbicide in late autumn, full cultivation and another knockdown herbicide pre-sowing. Sown in early winter (late break of season).	Pre-sowing knockdown herbicide and sown in early winter (late break of season).
Direct drilled into cultivated seed bed.*	Direct drilled into non cultivated soil.

*It is generally recommended that cultivation increases the amount of seed disturbance leading to increased weed levels. In this circumstance it was used to increase germination to gain maximum kill of weed species with the knockdown herbicide.

The cultivation and three applications of knockdown herbicide conducted by Site 3 were substantially more effective in controlling annual weeds than the process employed by Site 4. Site 3 had a tall fescue content ranging from 26-72% of total sward mass compared to Site 4 that had 3-32% tall fescue (Fig. A3.1). Both sites had a quite low initial proportion of tall fescue and this is a result of its low vigour during establishment. Site 3 initially had a significant proportion of toad rush (*Juncus bufonius*) but used short duration high stocking rates (40-60 DSE/ha; Fig. A3.1) to graze the toad rush out of the pasture during late spring when the future growth potential of the toad rush was limited, but before it had become totally indigestible. Similarly, Site 4 used high stocking rates (30-120 DSE/ha) to reduce the amount of annual grasses (winter, barley grass), but overgrazed pastures with repeated grazing events that limited the potential of the tall fescue to dominate over the annual grasses.

A key difference between the two sites was the reduction of FOO levels below 1000 kg/ha at a particularly vulnerable time for the establishing tall fescue, but more importantly the sustained grazing of the pasture when it was below this level (Site 4; reached 600 kgDM/ha). The average duration of a grazing event during this establishment period was approximately 10 days for both sites, but Site 4 grazed these periods with 16 DSE more (69 vs. 53 DSE/ha) and had over double the frequency of grazing events during this period (16 vs. 7).

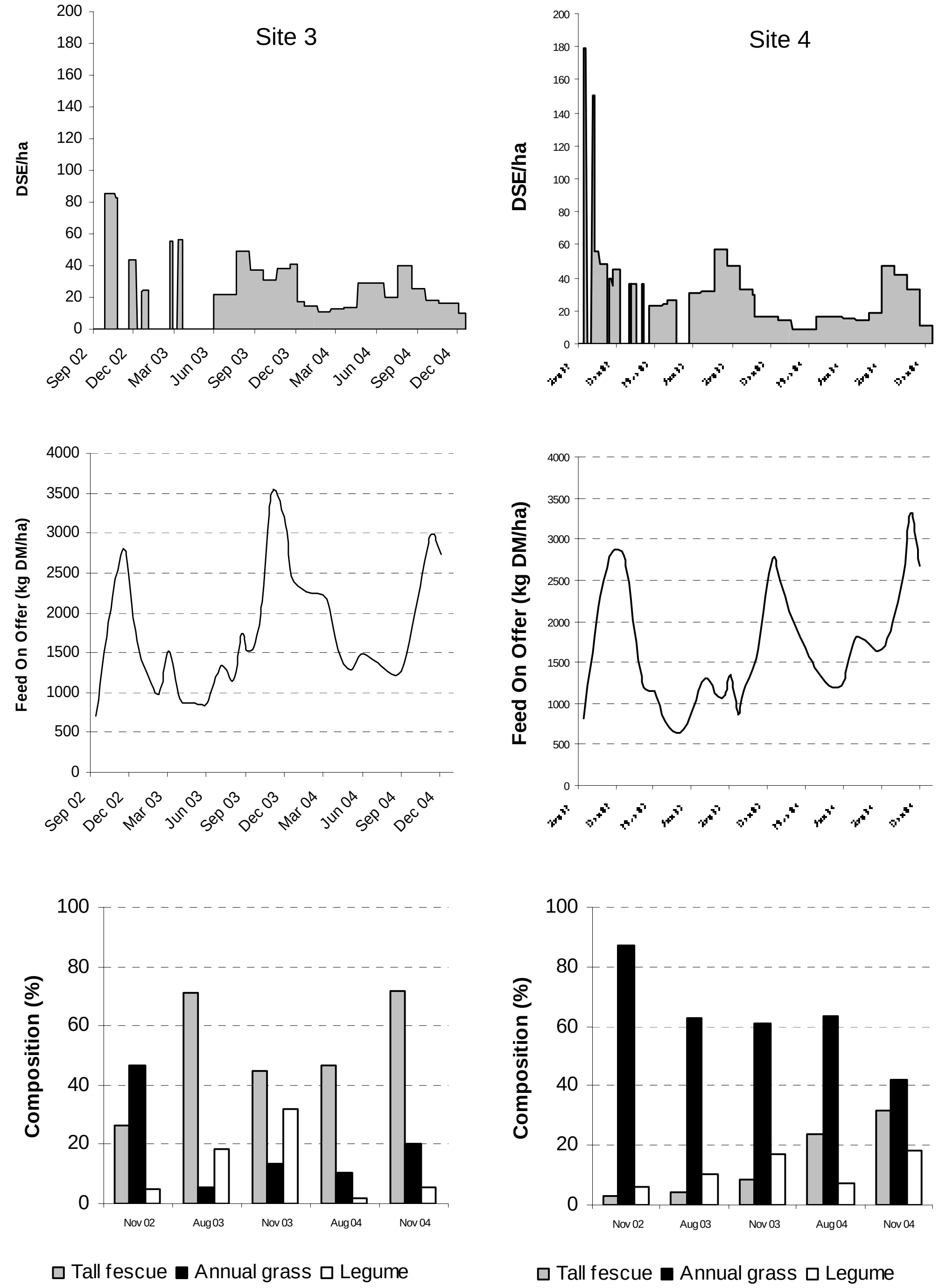

Figure A3.1. The grazing pressure (DSE/ha), feed on offer (FOO) and composition of System B from two sites that were considered either successful (Site 3) or unsuccessful (Site 4) in establishment of the pasture.

A hierarchy of events are summarised in Table A3.2 that details the critical control points to successfully establishing HPP.

Table A3.2. Summary of the critical control points to establishment of HPP

Critical control point	Action
Determine role and purpose of the proposed HPP establishment	Is the pasture a short term or long term venture? Is the pasture used to finish stock or maintain breeding animals or increase reproductive performance? HPP based on short term ryegrass have rapid establishment and produce large amounts of high quality forage during the growing season but require careful management out of season. Tall fescue based HPP have slow establishment and have a long lifespan with the possibility of out of season production.
Reduce annual grass and broadleaf seed set	Winter cleaning of existing pasture the year previous to establishment to reduce the winter active and early seed setting annual grass species (Winter grass – *poa annua* and silver grass). Apply broadleaf applications early to limit seed set and ensure effectiveness of application (capeweed, thistles). If onion grass is relevant issue then apply recommended applications during the specified time window (June and July in southwest Victoria)
Reduce annual grass and broadleaf seed set	Spray topping of pastures in mid to late spring the year previous to establishment to reduce seed set of annual species (Barley grass,)
Pre-sowing knockdown herbicide application	Areas for sowing should be grazed hard over summer and autumn to reduce residual biomass and expose bare ground prior to opening rainfall to encourage germination of seed. Apply herbicide when even cover of plants has occurred and utilise high water volume for maximum effectiveness of application.
Determine sowing rates and ratio of mixes	Consider seed size and number of seeds/kg and calculate potential plant density. Tetraploid grasses have larger seed size, less seeds per kilogram and lower plant density compared to diploid grasses. Formulate simple mixes based upon the purpose of pasture and endeavour to avoid mixing species or grazing regimes that are not compatible. For example, summer and winter active tall fescues require different grazing and spelling periods and one cultivar may be compromised by the specific requirements of the other. Consider the role that legumes will contribute to feed quality and production in short term mixtures, and if only a minor component then exclude from mixture and invest in the primary grass component. If the short term pasture is likely to undergo herbicide control of broadleaf weeds then exclude chicory from the mixture.
High intensity, short duration grazing during initial establishment period	High intensity short duration grazing is required to reduce animal selectivity for preferred species. Must alter grazing management to allow desired species to dominate over other undesirable species. Must consider the time of grazing; ensure that grazing occurs just before the point where annual species have limited capacity to regrow and before they have fully set seed.
Apply ongoing weed control	Tall fescue pastures that have a longer lifespan can be successfully winter cleaned to increase its proportion in the sward. This has been actively employed in the NSW New England and southwest slopes areas but not in southern Victorian regions.

* All herbicide applications and sowing methods discussed can be found in the latest edition of 'Greener Pastures for south west Victoria' It is assumed soil fertility is non-limiting in these situations.

10.4 Appendix 4 – Using the lamb profit map to set ewe stocking rate targets

The 'Morelamb' producers had an ambitious target to produce 1000 kg liveweight/ha**.** In the first year systems A, B and C produced 477, 461 and 525 respectively, about 50% of the target. In year 2 producers increased their stocking rate on the basis of how much lamb/ha they wanted to achieve. This was a simple process of working backwards from the target that defined critical points in the growing season that had to be met to achieve the required outcome. The process is documented below.

Target live weight per hectare / mean individual lamb live weight = Number lambs per hectare

Lamb number per hectare / (Ewe fertility rate – Lamb mortality) = Ewe stocking rate

Site 2 was a dedicated feeder lamb system and embraced the idea of setting targets. In 2003 the site produced 359 and 403 kg/ha from Systems A and C respectively (Table A4.1) (System B was excluded due to problems with establishment). In 2004 they set a target of 750 kg liveweight/ha and almost doubled ewe stocking rate (10 to 18 ewes/ha).

Table A4.1. Ewe stocking rate and lamb production from perennial ryegrass (A) and short term ryegrass (C) pasture systems at demonstration site 2.

Year	System	Stocking rate (ewes/ha)	Pregnancy Scanning (%)	Weaning rate (%)	Lamb number (ha)	Lamb LW (kg)	Lamb LW (kg/ha)
03	A	9.7	165	137	13.2	27.2	359
04	A	18.0	156	136	24.5	23.0	563
03	C	10.1	168	140	14.1	28.5	403
04	C	18.0	175	127	22.8	22.3	510

Production increased by 20 to 30% but was well short of the target by approximately 200-250 kg/ha. Increasing stocking rate reduced the live weight of lambs by approximately 4 to 6 kg and increased lamb mortality, particularly in System C that had a high fertility rate (28% vs. 13%). A major outcome for the site was the 60-80% increase in lamb numbers/ha from increasing stocking rate, and it highlighted that kilograms of lamb per hectare may not be a relevant productivity benchmark for a feeder lamb system.

The site managed to increase stocking rate and lamb numbers per hectare through simple calculation to achieve a given target. Although the targets may be rarely achieved it has given the producers a method and a series of control points during the lamb production cycle to benchmark their progress.