final report

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Fail safe guides for grazing pregnant and lambing ewes on cereals

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Key Points

1. This project uses a combination of literature review and surveys of producers and consultants to identify the benefits and risks of grazing young cereal crops with reproducing ewes.

2. Young growing crops have excellent nutritive value with high digestibility and protein levels. The plants can be grazed to fill a winter feed gap and availability coincides with increased feed requirements in pregnancy. Maintenance or liveweight gain is possible at much lower food on offer levels than would be required for pastures.

3. Management of ewes grazing cereals in is by trial and error as there has been limited evaluation of different grazing strategies. There is a lack of knowledge on how to manage sheep in large cropping paddocks and on the shelter benefits from lambing in crops.

4. Young growing crops contain an imbalance of potassium, sodium, magnesium and calcium that can cause metabolic disease (sodium deficiency, hypomagnesaemia or hypocalcaemia) and possible mortality in sheep. Risks of metabolic disturbance are higher for sheep grazing wheat than other young cereals. Preliminary evidence indicates risks are higher when grazing cereal crops in NSW, Vic and SA than in WA.

5. There is uncertainty around the benefits of mineral supplements. Producers using the recommended supplement have still reported metabolic disease and these supplements may even exacerbate the mineral imbalance problems in late pregnancy.

6. In interviews and through surveys it is apparent that significant numbers of producers avoid grazing young cereals with ewes in late pregnancy because of the apparent health risks. The risks were much more strongly expressed by producers in NSW, Vic and SA than those in WA.

7. Using a combination of census data and responses to web and phone surveys, it is estimated that the current cost of increased mortality in pregnant ewes resulting from grazing crops is approximately $15,700,000 pa. This is likely to be a significant underestimate of the benefits from providing fail safe grazing strategies.

8. We consider that addressing current losses is simply a fire-fighting strategy and does not take into account the losses from avoidance of grazing young cereals and benefits of adoption. An increase in utilisation of cereals by pregnant ewes together with the potential for an increase in sheep numbers in cropping zones provides an opportunity for AWI and MLA to re-establish sheep production in the wheat-sheep zones and significantly expand their client base.

9. High priority research and development.

    - A situation analysis of reproducing sheep grazing cereal crops to include:

        - ◊ Mineral composition of cereal crops to determine the concentration of minerals and the variation in minerals caused by crop genetics, geography, climate, fertiliser use and soil type,

    - ◊ Mineral status of ewes grazing young cereal crops and the relationship between crop mineral status and the mineral status of the ewe,
    - ◊ Mortality and other indicators of animal health (eg scouring) of ewes and lambs and the relationship between health and nutrition/management.

- ♦ Evaluation of the responses to mineral supplements in late pregnancy with particular emphasis on magnesium, calcium and sodium.
- ♦ Secondary priorities also identified by producers and consultants included: more quantification of livestock benefits; relationship between food on offer and production (optimised grazing management); shelter benefits for lambing; implications of patch grazing for crop and livestock production; and alternative crops.

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1. Introduction

There has been a dramatic decline in Australian sheep number over the past 25 years. This has coincided with expansion of crops into higher rainfall zone and movement towards cropping-only farming in low - medium rainfall zones. The decrease has been most marked in the wheat sheep zone where ewe numbers over the past 15 years have decreased by 25% or over 10 million (Figure 1). The decline in the Merino ewe population has been even more dramatic as the proportion of Merino ewes in the national sheep flock has declined from greater than 85% to about 67% since 2008.

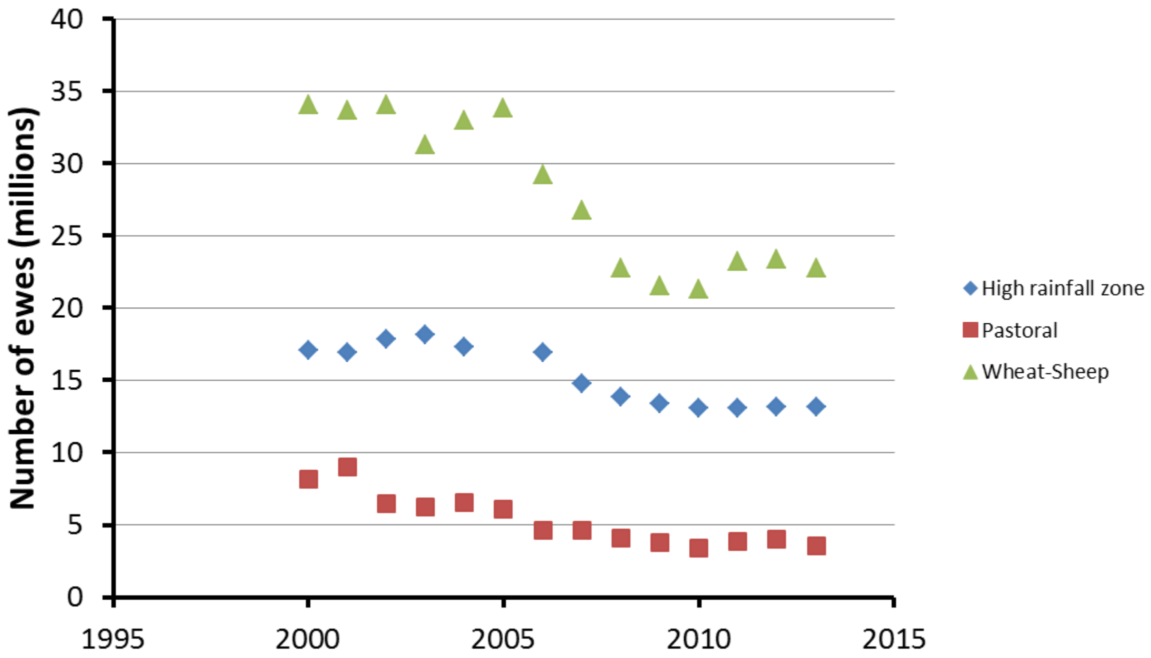

Figure 1. Changes in ewe numbers over the past 15 years (figure courtesy of K Curtis, Department of Agriculture and Food, WA)

This move towards more crops has been accompanied by increased financial risk and problems with acid soils, salinity, erosion and herbicide resistance. There is some movement back towards a higher mix of livestock within farming systems and whole farm modelling consistently shows that a mixture of crops and livestock is a more profitable long term farming option. Recent economic analysis indicates this is the case for low and medium as well as high rainfall zones (Kingwell and Squibb 2014[1]).

Cropping and livestock have always had synergies through the use of crop stubbles to provide feed for livestock in summer and the use of pasture phases to manage fertility, diseases and weeds in cropping paddocks. The changes in crop varieties and reintroduction of options to graze young crops in winter could further enhance that synergy and have the potential to transform the sheep industry, particularly in medium rainfall zones.

[1] Kingwell, R, Squibb, L (2014) The role and value of combining dual-purpose crops and lucerne in a mixed farming system. Crop & Pasture Science, Accepted.

Through the facilitation of this practice, AWI and MLA have an opportunity to significantly increase the numbers of livestock (and farm profit) within mixed farming systems and to improve whole farm conversion of feed resources into livestock products.

This project addresses the potential and needs of producers and consultants for the efficient utilisation of young growing crops for grazing sheep.

2. Background

The availability of accessible green forage in winter makes grazing crops an option with the potential to improve productivity and profitability of the entire farm system. The practice is quite simple to implement and does not require much preparation or prior investment. However it does not come with limitations and further work is needed before it can be incorporated into AWI-flagship producer training programs like Lifetime Ewe Management.

Anecdotal evidence from the increasing use of cereal crops for grazing indicates abnormally high rates of ewe death in some circumstances. These circumstances are not clear or well understood. To date, research has focussed on the agronomic effects of grazing cereals and the likely impact on crop yields and therefore profitability. There has been limited research with reproducing livestock grazing crops. McGrath et al (2013a, 2013b[2]) completed a grower survey investigating causes of ewe mortality rates. The growers with higher levels of ewe mortality from grazing young crops tended to have ewes with lower condition score, used less grain supplement and were less likely to provide calcium, magnesium and sodium supplements. Metabolic disease was a significant cause of death and higher mortality was reported in twin bearing ewes.

It is not surprising that metabolic disorders are implicated as a major part of the problem. Dove and McMullen (2009[3]) showed an increase in liveweight gain of 30 to 50% when salt, lime and causmag were supplied to growing sheep. They concluded that the response was likely due to the increased availability of sodium correcting an imbalance in the potassium to sodium ratio and allowing higher absorption of magnesium. The recommendations from this work were that young sheep grazing dual purpose wheat should be routinely provided with a 1:1:1 mix of salt, lime and causmag. In the only experiment with grazing ewes McGrath *et al.* (2011[4]) did not find difference in ewe health or metabolic disorders between supplemented and un-supplemented ewes. However there was a trend towards higher lamb survival in the supplemented flock and twin-born lambs from the supplemented ewes grew slightly faster than the controls

[2] McGrath, SR, Lievaart, JJ, Friend, MA (2013a) Extent of utilisation of dual-purpose wheat for grazing by late-pregnant and lambing ewes and producer-reported incidence of health issues in southern New South Wales. *Australian Veterinary Journal* 91, 432-436.
McGrath, SR, Lievaart, JJ, Virgona, JM, Bhanugopan, MS, Friend, MA (2013b) Factors involved in high ewe losses in winter lambing flocks grazing dual-purpose wheat in southern New South Wales: a producer survey. *Animal Production Science* 53, 458-463.
[3] Dove, H, McMullen, KG (2009) Diet selection, herbage intake and liveweight gain in young sheep grazing dual-purpose wheats and sheep responses to mineral supplements. *Animal Production Science* 49, 749-758.
[4] McGrath, SR, Bhanugopan, MS, Dove, H, Clayton, EH, Virgona, JM, Friend, MA (2014) Mineral supplementation of lambing ewes grazing dual-purpose wheat. *Animal Production Science* Online.

In addition to potential mineral issues, little appears to be known on optimal stocking rates (including feed on offer requirements), flock size or the relationships between crop height and lamb mortality.

The current project was designed to address the problems and opportunities initially through a review of the literature review and industry consultation followed by research on identified knowledge gaps.

This specific aims of the project are to increase the productivity of pregnant and lactating ewes grazing winter cereals in mixed farming enterprises of Western Australia (WA) by ensuring there is appropriate provision of supplements to reduce the risk of metabolic problems and to remove any other related or contributing risk factors. Part way through the first year the aims were expanded, at no cost to AWI or MLA, to incorporate mixed farming enterprises in South Australia (SA), Victoria (Vic) and New South Wales (NSW). The project aims to focus on applied research and demonstration that will:

- Test the effect of supplementing major minerals to pregnant and lactating ewes grazing winter cereals on ewe and lamb mortality and productivity. Supplementation with magnesium, sodium and calcium appear to be candidates to improve the performance of ewes grazing winter cereals during late pregnancy and lactation.

- Test the effect of lambing density and height of cereal crops on lamb mortality. Anecdotal evidence suggests that high levels of lamb mortality that can occur when grazing on winter cereals often results from ewes congregating around the edges of the crop rather than using the crop to provide protection and isolated lambing sites

The precise supplementary feeding strategies and experimental designs will be fine-tuned following a literature review and industry consultation. Outputs from the above activities will contribute towards the development of recommendations to be included in an easy guide to "grazing cereals". The guide will include the agronomic, sheep management and animal health factors that need to be managed to ensure grazing winter cereals has a positive influence on sheep and wool production systems in different environments.

Uptake of these guidelines by woolgrowers will be encouraged by developing clear messages to be "piloted" and evaluated within AWI and MLA funded networks of deliverers and producers and materials will be made available for including in Making More from Sheep, Lifetime Ewe Management grower groups and other extension programs

Project Activities

Activity 1: A literature review will be conducted covering the following topics.

- Mineral deficiency in animals grazing cereal plants
- Mean and range in plant tissue tests of Ca, Mg and Na
- Environmental and plants species/cultivar effects on Ca, Mg and Na
- Effective supplementation

Metabolic disorders of late pregnancy and lactation

- Predisposing factors leading to metabolic disorders of hypocalcaemia, pregnancy toxaemia and hypomagnesaemia

- Interactions between appetence, mineral deficiencies, condition score, grain feeding and pregnancy status on metabolic disorders
- Management factors to minimise losses

Grazing cereals with lambing ewes

- Implications for ewe performance and mortality
- Implications for lamb birth weight and survival
- Interactions of plant height, density, stocking rate, mob size and survival
- Impact of mineral supplementation on lamb survival and growth

Activity 2: Surveys.
Targeted interviews will be conducted with at least 10 consultants with clients that regularly graze cereal crops with pregnant ewes. The consultants will be selected from across a range of climatic zones in WA. In addition, in depth interviews will be conducted with at least 10 producers that regularly graze cereal crops. The information attained will be combined with information compiled during the literature review and with knowledge of project staff. These information sources will be combined to develop written management strategies to minimise ewe mortality and maximise lamb survival when grazing winter cereals.

The objectives of this project in Year 1 were:

1. To review literature and compile relevant information from in-depth interviews with producers and consultants about grazing cereals and pregnant ewes and the occurrence and management of metabolic disorders and overall performance.

2. Develop draft management strategies that must be followed to reduce the risk of ewes and lamb mortality and have these in a format to be road tested by the national delivery networks.

This report only addresses of objectives for Year 1 (Activities 1 and 2).

3. Literature review

The complete and now accepted journal version of the review is attached as Appendix 1. A brief summary is provided below.

Integration of crops and livestock has been revitalised in Australia, initially as an opportunity to increase cropping within the high rainfall grazing zones but more recently to improve enterprise diversification and profitability across the low, medium and high rainfall, and mixed farming zones. Young crops are highly digestible (>80% dry matter digestibility [DMD]) with a high energy density (>12 MJ/kg DM) and in much of southern Australia fill a winter feed gap.

The quality and time of feed availability also coincides with the high nutrient requirements of ewes in late pregnancy and lactation. In Western Australia and South Australia young crops are available for lactating ewes and young growing lambs (autumn lambing). For the smaller proportion of growers who lamb later in winter, young crops are available for the last 1-2 months of pregnancy. In the later lambing states of New South Wales and Victoria crops may be grazed by ewes at any stage of pregnancy and lactation and/or by young lambs. In Tasmania, crops are more likely to be available during early/mid gestation.

Limited studies on feed budgeting with grazing crops indicate that ewes can maintain or even increase liveweight with a much lower level of feed on offer that would be required with traditional pastures (<500 kg DM/ha). This has the potential to increase whole farm stocking rates and/or reduce fetal mortality, increase lamb birthweight and survival and improve lifetime production. Maintaining or increasing ewe liveweight during pregnancy and lactation may also result in heavier ewes the following year and higher ovulation rates.

Pregnancy and lactation are also periods of increased susceptibility to metabolic disturbances. The composition of young crops increases this susceptibility. Pregnancy toxaemia, hypocalcaemia and hypomagnesaemia can influence ewe health and fetal survival. Chronic acidosis and excessive ammonia absorption from rapid introduction of pregnant ewes onto young crops may risk appetite loss and increase susceptibility to pregnancy toxaemia. Low magnesium and sodium combined with high potassium increases the risk of grass tetany. Most young crops (except canola) also have a tetany index >2.2 indicating a high risk of grass tetany. The elevated potassium also contributes to a high dietary cation-anion difference of approximately +49 mEq/100g DM and this may cause metabolic alkalosis and hypocalcaemia. Pregnancy toxaemia, hypocalcaemia and grass tetany are all potential causes of increased ewe mortality.

Pregnancy and/or lactation outcomes will also be influenced by a deficiency of trace elements. Grazing young crops in areas with a history of selenium, copper, iodine and cobalt deficiency will increase susceptibility to deficiency by increasing growth and feed intake.

In conclusion, the grazing of young growing crops presents new opportunities for increased production and stocking rates in the mixed farming zones. The value of this feed source is well recognised by some producers. While growing crops have a highly productive potential, they also come with an increased risk of a range metabolic disturbances and nutritional imbalances. These risks can be minimised by regular monitoring of livestock and crop biomass and the provision of mineral supplements.

4. Interviews with producers and consultants

Activity 2 was initially described as targeted interviews with at least 10 consultants with clients that regularly graze cereal crops and at least 10 producers who also regularly graze cereal crops. The consultants and producers were to be selected from across a range of climatic zones in WA.

This activity was completed and a compiled report of the interviews is included as Appendix 2. However, the descriptions of use and problems in grazing crops were not consistent with expectations from the literature review or with preliminary anecdotal information gathered from consultants and producers in the south-east of Australia. To establish if this difference was real or simply a result of subjective assessment, the survey was expanded to include a further 10 producers and 10 consultants from South Australia, Victoria or New South Wales (abbreviated as ES) (Appendix 3).

This expansion identified striking differences in utilisation and problems in WA compared with those described in the ES.

This observation indicates that guidelines based on current knowledge for the use of crops for grazing by reproducing ewes needs to account for different experiences in different environments. It also indicates that research priorities are not the same across regions and that understanding why there are differences between States is, in itself, a priority.

Given the major differences in responses across the different geographical regions, the two interview reports have been kept separate (Appendices 2 and 3). The Appendices provide the names, contact details and location of the producers and consultants interviewed and a list of specific questions used in the survey. The key differences and similarities between the reports are summarised below.

Agricultural zones and grazing practice

The producers and consultants interviewed in both surveys were from mixed farming areas across low, medium and high rainfall zones. Across the country the proportions of producers grazing crops varied with estimates of between 5 and 25% in WA and 10 and 90% in the ES. On average approximately 15% grazed crops in WA with 60% in the ES. In WA grazing was more opportunistic depending on season with grazing of traditional grain varieties whereas in the ES more specialised dual-purpose crops were grazed. Nevertheless, all crop types (wheat, barley, oats and to a lesser extent canola) were grazed when required across all States.

Across both surveys the proportion of crop grazed in any one year normally ranged from 0 – 50% but occasionally extended to grazing 100% of available crops. Most of those interviewed identified some grazing management problems with large cropping paddocks and ewe flock sizes too small to ensure an even grazing pattern.

Time of grazing

Across both surveys, consultants and producers indicated crops were usually grazed in June, July and for part of August. In WA this meant that reproducing ewes grazed crops in the last few weeks of pregnancy and/or during early lactation. Some producers lambed on the crops and drifted ewes and lambs off into adjoining paddocks as the lamb was born. Others were not comfortable with this management and potential disturbance of ewes and lambs. The decision not to lamb on crops in WA was based the need for additional labour to monitor and move lambing ewes and the increased risks of lamb losses due to movement soon after lambing and not potential compromise of ewe health.

In the ES responses were quite different. Crops tended to be grazed by lactating ewes (early lambers), ewes in mid-pregnancy or carry-over lambs. Almost all producers and consultants indicated ewes were not grazed on crops in the last month of pregnancy due to the high risk of metabolic disease (see below).

Benefits of grazing crops by reproducing ewes

Across both surveys the primary benefits of grazing crops with reproducing ewes were identified as filling the winter feed gap and deferred grazing to improve spring pastures. In WA in particular a range of other benefits was also recognised, some of these were specific to livestock production and health (less supplement use, ewes in better condition prior to lambing, higher carrying capacity, reduced requirement for agistment and improved worm control) some specific to crop production (manipulate pastures to improve cropping in subsequent years, ability to crop a larger area without reducing livestock, improved water use efficiency, later flowering to avoid frost, less herbicide use and better control of crop disease and weeds) and some provided whole farm or environmental benefits (more flexibility, peace of mind and increased ground cover).

The benefits appeared to be equally recognised by producers and consultants in the ES, however, in WA, producers were usually enthusiastic but some consultants were sceptical and require more quantification of benefits before being convinced. Whether a producer grazed crops was often related to the consultant they used.

When consultants were asked why some clients did not graze crops and producers asked why some neighbours did not graze crops, most indicated a fear of yield loss or that clients or neighbours had left the sheep industry. In the ES the potential detrimental effects on livestock health (see below) were a major factor. This was not commonly recognised in WA.

Livestock problems with grazing cereal crops with reproducing ewes

There were clear differences in practice and concern between producers and consultants in WA and those in the ES.

All those interviewed in the ES identified metabolic diseases (hypocalcaemia, hypomagnesaemia, pregnancy toxaemia, nitrate poisoning and pulpy kidney) as major risks for ewes grazing young crops in late pregnancy. This was despite most producers using a mineral supplement consisting of causmag (or dolomite), lime and salt and also providing a roughage supplement (hay or cereal straw). Metabolic problems often resulted in 5-10% ewe mortality. As a consequence few producers grazed crops in late pregnancy.

In WA, there was less overall concern with ewes in late pregnancy grazing crops. Some reported scouring and others indicated they knew there were risks of hypocalcaemia and hypomagnesaemia but they were unaware of any incidence. Dr Danny Roberts, the DAFWA District Veterinary Officer in Albany stated metabolic disease was not a major issue in the south west of WA for ewes grazing crops. Use of mineral supplements was irregular and understanding of the relationship between calcium, magnesium and sodium and metabolic disease was poor.

Grazing management

Grazing was not initiated in either WA or the ES before plants were able to pass the anchor test. In the ES grazing usually ceased when plants reached growth stage 30, in WA grazing decisions were based more on time of the year (length of growing season remaining). In both WA and the ES crops were often grazed close to the ground and at FOO levels far lower than those applied to pastures. This is consistent with conclusions based on GrazFeed modelling that indicate the different plant height:FOO ratio between crops and pastures allows much higher feed intake at lower FOO when crops are grazed (see literature review). There has been no experimental evidence to support this conclusion, producers currently work from experience.

Knowledge gaps identified during the surveys

Western Australia

1. For those who remain unconvinced of the advantages, quantification of the benefits, possibly through on farm demonstrations is a priority. This would need to include measurement of crop losses (including impact of patch grazing) and livestock change (including stocking rate) under different scenarios (climate x soil x stocking rate x grazing intensity). It could also include some assessment of ancillary benefits such as delayed flowering, water use efficiency, worm management. This is a priority to convince consultants, not just producers – many are sceptical.

   Some consideration needs to be given to the practicalities of this approach as the potential combination of scenarios is high (both over time and space). A more realistic approach may be to cooperate with practicing farmers to quantify their benefits and use their properties for workshops/field days in combination with whole farm modelling.

   Alternatively, techniques are now available that would reduce the requirement for on ground activities. The use of satellite imagery to assess grazing combined with measured, within paddock crop yields would allow assessment of impact at scales ranging from sub-paddock to landscape. Data for this approach are already available.
2. Quantification of benefits of deferred pasture use. There were differences in opinion on whether this was simply more biomass in pasture paddocks or improved pasture quality.
3. Clarification of potential mineral deficiency problems to include:
   - Mineral composition of crops in WA.
   - Mineral status of sheep grazing young crops (to include nitrate toxicity indicators).
   - Documentation of losses from metabolic disease.
4. Introduction of stock to grazing crops – influence of previous feeding and condition on susceptibility to metabolic disorders.
5. Potential to use longer growing season varieties.
6. Implication of patch grazing on crop yields. Common observation that sheep do not graze crop paddocks evenly. How to manage sheep in large cropping paddocks (low stocking rates) with potential incidence of patch grazing.
7. Interaction with grower groups to possibly include bus trips to visit successful operations.
8. Causes of scouring in sheep grazing young crops.
9. Testing of alternative crops (eg sorghum) and alternative varieties (eg wedgetail wheat, oxford barley).
10. Withholding period for atrazine when used on canola.
11. Production of a ready reckoner (app) to predict crop/livestock trade-off and assist with decision making.

South Australia, Victoria and New South Wales

The producers interviewed from south-east Australia felt the management of sheep on grazing crops was all trial and error. The common gap that producers identified was the need for further investigation into the management of late pregnant and lambing ewes on grazing crops to inform more accurate solutions for supplementation with either minerals, grain or hay. The majority of the producers interviewed were no longer allocating grazing crops to ewes in late pregnancy or at the point of lambing because they lacked confidence in how to overcome health issues in a timely manner that reduced losses. Many had changed to grazing winter crops with lactating ewes instead, others delayed grazing until the crop was more mature and others used mineral and/or grain supplementation.

Consensus among consultants and producers was the need for research and/or demonstration on how to manage/mitigate ewe health issues, primarily hypocalcaemia, hypomagnesaemia, pregnancy toxaemia and nitrate poisoning. The outcome of the research/demonstration would be to lift producers' confidence and acumen for managing ewes on cereal crops by providing more accurate guidelines for supplementation, particularly mineral supplementation.

Consultants believed the investigation would need to explore the key risk factors for ewe health, perhaps in a hierarchy, including paddock factors (such as crop type, crop variety, stage of growth, soil nutrient status, plant nutrient status, fertiliser history, fibre source), animal factors (such as class of sheep, breed, age, stage of reproduction, parity) and prevailing weather conditions.

The challenge is how to best measure and manage ewe health signals. What to be aware of and how to mitigate the risks by addressing causes in a targeted manner. All consultants recognised their recommendations for managing ewe health on grazing crops was based on trial and error. If deficiencies are occurring, what are they? What is the root cause? How mineral supplements are best administered? One concern among the consultants is whether the standard provision of salt, lime and causmag is actually exacerbating problems, particularly calcium related issues due to excess supplementation in late pregnancy.

A key objective of this work according to consultants would be to reduce the mixed messages that are currently evident throughout south-east Australia in the industry on how to manage sheep, particularly late-pregnant and lambing ewes, on cereal crops. The need for such research is typified by the widespread avoidance of having late pregnant or lambing ewes on crop, which highlights that industry has not solved the underlying problem, instead just shifted to lower risk classes of sheep.

Another research interest would be to quantify sheep performance on crop compared to pasture, particularly lamb growth rates pre-weaning.

5. Management strategies for grazing young crops with pregnant or lactating sheep

Overview

Young crops have a high nutritive value and rapid growth rate– for these reasons they are suitable for grazing pregnant or lactating ewes. However, there are key differences between grazing crops and pastures. These differences require the implementation of specific grazing strategies relevant to young crops.

Strategies

These strategies are based on a review of the published literature and a series of interviews with consultants and producers experienced in grazing young crops with reproducing sheep. The strategies are for the management of livestock and should be used in conjunction with guidelines based on maintenance of crop yield and health[5]. Limitations and risks associated with these strategies are also shown within Table 1.

Table 1. Preliminary strategies and risks for grazing crops with reproducing ewes.

Current best practice or derived strategy[A]	Comment/gap
Crop grazing can commence when the crop is established to pass the anchor test.	Recognised by most consultants and producers, supported by Grain and Graze. Derived from - Free food for thought - grazing winter crops roadshow. (2008) Grain & Graze, workshop notes.
Intake of dry matter is predicted to reach its upper limit when Feed on Offer (FOO) is 0.6 t DM/ha for ewes in late pregnancy and 0.7 t DM/ha in early lactation. This is approximately equivalent to crop heights of 8.5 and 10 cm for pregnant and lactating ewes respectively[B].	No experimental evidence available for this estimation – derived from GrazFeed using manual adjustment for crop height. Is well known by producers that lower FOO levels can be used when grazing crops (compared to pasture) but current practice is based on trial and error. There is some research evidence that ewes can maintain weight and condition on as little as 100 kg DM/ha.
Crop growth can be expected to be 20 – 40 kg DM/ha/d. On the basis of 50% feed utilisation efficiency, these crops will support 10 – 20 DSE without a reduction in FOO[B].	Conservative estimate of carrying capacity – varies with rainfall.
Avoid rapid introduction of hungry ewes onto crops, particularly those previously feeding on high roughage diets. Ensure ewes are fed before introduction and preferably are accustomed to high soluble carbohydrates through grain supplements.	Recognised by some but not all producers.

[5] See Grain and Graze: http://www.grainandgraze2.com.au/

Current best practice or derived strategy[A]	Comment/gap
Offer a supplement of causmag:salt:ground limestone (1:1:1). This will provide additional magnesium, sodium and calcium. Magnesium is not stored in the body in a form that is readily mobilisable. Deficiency can become apparent in a short time.	Major uncertainty around this practice. Used by some producers (mostly in the ES). Problem is that calcium supplements may **increase** susceptibility to hypocalcaemia in late pregnancy (based on dairy cows). Therefore practice of magnesium and sodium supplements is sound but not calcium supplements with pregnant ewes. Major knowledge gap around predisposition to, and management of hypocalcaemia.
In South Australia, Victoria and New South Wales the risk of metabolic disease is increased and ewes should not graze young crops in the last month of pregnancy	This is a direct result of an inadequate strategy to deal with hypocalcaemia. Results in significant underutilisation of a feed source during a period of high feed requirement. This is not a long term solution.
Magnesium may also reduce the incidence of scouring.	Reported by some producers, may be an additional benefit to magnesium supplementation
Feeding hay or straw to ewes has been reported to reduce the incidence of scouring and may be considered if this is a problem.	Comments that this practice may improve gut health and calcium mobilisation. Not based on scientific evidence and not consistent with known interaction between fibre and calcium. Intake of straw/hay may reduce proportion of potassium in diet and improve both magnesium and calcium balance in the overall diet.
Nitrate poisoning is a risk if crops are grazed soon after application of nitrogen fertilisers. The Grain and Graze recommendation is not to graze crops for 3 weeks after application of fertiliser.	Seen as a problem by some producers and consultants but poorly characterised. Grain and Graze recommendation allows avoidance and may be very conservative.
Grazing crops may increase growth rates of ewes and increase the risk to trace element deficiencies in susceptible areas. Be alert to signs of deficiency in ewes and lambs or provide supplements to avoid the risk.	Good husbandry and knowledge of environment make this risk manageable.
Removal of ewes from the crop is usually a crop yield decision, not a livestock decision based on residual biomass or a date to allow crops to recover in a normal year and not on ewe condition.	Strategies in this table based on livestock production. This must be balanced with crop production but, is outside the scope of this study.

[A] Derived from a combination of review and experience.

[B] The information on both FOO and stocking rate are derived from experience or literature. There is no information on the interaction between stocking rates, paddock size and crop characteristics on lambing management.

6. Potential costs of strategy gaps and opportunities for industry expansion

Following the preliminary review of progress within the project with MLA and AWI on 29th September, 2014, a decision was made to extend the submission date of the milestone report to allow for a short term investigation into risks and potential benefits of solving the problems with grazing cereals. Given this was a short extension, information was collected opportunistically over one month and included:

1. Crop analysis data from CSBP. Three laboratories were contacted across states, but only CSBP were willing and able to make data available within the extension. This large dataset was for crops in WA only.

2. Survey of producers to quantify perceived risks and losses. This was through a simple 8 question web survey with the link distributed through a range of networks.

3. A preliminary assessment of the opportunities for expansion of the sheep industry back into the cereal-sheep zone that could be provided through fail safe grazing strategies for young cereals.

Quantification of risk

Minerals in crops

Results from chemical analysis of growing crops were sought from five laboratories across the country. All but two of these were unable to provide data within the extension period for this project. Nevertheless a significant dataset was obtained from WA, NSW, Vic and SA. The database for WA was supplied by a different company to that supplied for NSW, Vic and SA. For this reason they have been analysed separately.

Western Australia

Results from the analysis[6] of 5451 wheat samples, 328 oat samples, 2098 barley samples, 1109 canola samples, 83 lupin samples and 55 sub-clover samples collected across the low (≤400 mm), medium (401 – 549 mm) and high rainfall (≥500 mm) zones in WA in June, July or August 2014 were processed. The results are summarised in Table 2.

Given that WA producers appeared to be least concerned with the risk of metabolic disease when grazing young cereals, the analytical results are surprising. Across all rainfall zones, a high proportion of wheat samples were deficient in sodium (70.6%), calcium (26.4%), and had a high risk of causing grass tetany (67.8%) or sodium/magnesium imbalance (58.6%). There was also a high proportion of oat samples deficient in calcium (28.4%) and with a high grass tetany index (57.5%). For barley, grass tetany index often exceeded the at risk threshold (37.5%), but less than 10% of samples were deficient in any of the major minerals. Lupins were rarely deficient in any minerals and sub clover (included for comparative purposes) always provided sufficient minerals and indicated no risk of grass tetany or sodium/magnesium imbalance.

[6] Authors acknowledge and valuable support of CSBP in making analytical results available at short notice.

The conclusions from these results are that:

- Sheep grazing young wheat crops are at high risk of metabolic disease (hypocalcaemia and/or hypomagnesaemia) and sodium deficiency. There is also some risk with grazing oats or barley but this is a much lower than grazing wheat.
- The inconsistency in reports of metabolic disease from producers may be associated with grazing different cereals (eg wheat vs barley or oats).

New South Wales, Victoria and South Australia

Results from the analysis[7] of 1090 wheat samples, 28 oat samples and 122 barley samples collected across the NSW, Vic and SA in May, June, July, August or September (2008-2014) were processed. The results are summarised in Table 3. Given the smaller number of samples available for ES, analysis was by state and data was pooled across years and sample types. Some samples were whole tops while others were youngest emerging blade.

Across all states, a high proportion of wheat samples were deficient in sodium (52-87%), calcium (40-52%), and had a high risk of causing grass tetany (76-92%) or sodium/magnesium imbalance (52-58%). There were also a high proportion of oat samples deficient in calcium (44-71%) and with a high grass tetany index (67-77%) or sodium/magnesium imbalance (17-50%). A high proportion of oats samples (50%) from NSW were deficient in sodium, this was not apparent in other states.

For barley, a moderate proportion of samples from NSW were deficient in sodium (24%) and grass tetany index often exceeded the at risk threshold (52-72%), samples from NSW and SA also indicated a moderate risk of sodium/magnesium imbalance (29-33%).

The conclusion from these results is that:

- Sheep grazing young wheat crops are at high risk of metabolic disease (hypocalcaemia and/or hypomagnesemia) and sodium deficiency. There is also at high risk of metabolic disease in sheep grazing young oats in all states along with a high risk sodium deficiency when grazing oats in NSW. There are some risks with grazing barley but this is a much lower than grazing wheat.

In comparing WA with ES, there is some justification for a more detailed comparison. In the ES, a higher proportion of wheat samples were deficient in calcium and indicated high risk of grass tetany than in WA. Similarly, a higher proportion of oat samples in the ES indicated calcium deficiency than in WA.

These results should be taken as indicative of differences between regions only as samples from ES included those collected in May and September and were also sourced across seven years not one.

[7] Authors acknowledge and valuable support of Nutrient Advantage Laboratory (Incitec Pivot Ltd) in making analytical results available at short notice.

Table 2. Analysis of crop samples from low, medium and high rainfall zones in Western Australia. Data courtesy of James Easton, CSBP WA.

Crop type	Rainfall		Sample number	Potassium (% DM)	Sodium (% DM)	Calcium (% DM)	Magnesium (% DM)	Tetany index	K/(Mg+Na)
		Deficiency/at risk		< 0.5	<0.1	<0.3	<0.1	>2.2	>4.5[A]
Wheat	High		1032	4.07[B]	0.13	0.36	0.21	3.15	4.93
	Medium		1956	3.57	0.10	0.43	0.21	2.62	4.81
	Low		2463	3.51	0.07	0.41	0.20	2.69	5.15
		% samples deficient or at risk		0.0	70.6	26.4	0.5	67.8	58.6
Oats	High		84	3.65	0.64	0.45	0.20	2.50	2.79
	Medium		205	3.29	0.88	0.37	0.20	2.49	1.96
	Low		39	2.85	0.65	0.39	0.19	2.15	1.95
		% samples deficient or at risk		0.0	2.1	28.4	0.3	57.6	8.5
Barley	High		671	3.77	0.82	0.56	0.25	2.10	2.21
	Medium		786	3.63	0.59	0.61	0.25	1.93	2.50
	Low		641	3.45	0.57	0.56	0.24	1.97	2.41
		% samples deficient or at risk		0.0	2.9	9.1	0.1	37.5	7.8
Canola	High		268	4.11	0.81	1.44	0.40	1.03	1.83
	Medium		535	3.77	0.67	1.56	0.40	0.92	1.91
	Low		306	3.36	0.55	1.65	0.40	0.80	1.83
		% samples deficient or at risk		0.0	1.9	0.1	0.0	0.2	1.7
Lupins/Pulse	High		43	2.16	0.36	1.43	0.44	0.52	1.12
	Medium		6	2.63	0.64	0.83	0.28	1.47	1.36
	Low		34	2.38	0.21	1.61	0.52	0.56	1.40
		% samples deficient or at risk		0.0	7.2	1.2	0.0	1.2	2.4
Sub-Clover	High		45	2.57	0.57	0.94	0.26	1.05	1.48
	Medium		8	2.02	0.36	1.03	0.24	0.74	1.61
	Low		2	1.32	1.34	0.58	0.29	0.65	0.41
		% at risk		0.0	0.0	0.0	0.0	0.0	0.0

[A] Proposed risk ratio for K/Mg/Na imbalance (H. Dove pers comm.). [B] Mean of all samples.

Table 3. Analysis of crop samples from New South Wales, Victoria and South Australia. Data courtesy of Nigel Bodinnar, Nutrient Advantage Laboratory (Incitec Pivot Ltd).

Crop Type	Risk	State		Sample number	Potassium (% DM)	Sodium (% DM)	Calcium (% DM)	Magnesium (% DM)	Tetany index	K/(Mg+Na)
			Deficiency/at risk		< 0.5	<0.1	<0.3	<0.1	>2.2	>4.5
Wheat		NSW		644	4.00	0.26	0.34	0.19	3.29	5.57
		SA		188	3.31	0.05	0.31	0.14	3.44	6.64
		Vic		258	3.52	0.09	0.35	0.18	3.03	5.57
	% at risk	NSW			0.2	52.3	42.9	10.6	91.8	51.6
		SA			0.0	86.7	51.6	13.3	92.0	87.8
		Vic			0.0	79.5	39.5	1.9	76.4	65.9
Oats		NSW		34	2.91	0.14	0.27	0.16	3.26	5.28
		SA		9	3.33	0.29	0.33	0.16	2.83	3.61
		Vic		42	3.14	0.60	0.32	0.18	2.91	2.84
	% at risk	NSW			0.0	50.0	70.6	26.5	76.5	50.0
		SA			0.0	11.1	44.4	11.1	66.7	33.3
		Vic			0.0	4.8	54.8	7.1	69.0	16.7
Barley		NSW		143	4.08	0.74	0.44	0.23	2.72	3.78
		SA		83	3.73	0.39	0.50	0.17	2.57	3.59
		Vic		141	3.27	0.60	0.49	0.18	2.35	2.56
	% at risk	NSW			0.0	23.8	19.6	9.1	71.3	28.7
		SA			0.0	14.5	9.6	9.6	63.9	32.5
		Vic			0.0	5.0	17.7	2.1	51.8	6.4

Survey of producers

A simple eight question survey was set up using the Survey Monkey online survey tool. Questions were as follows:

1. Do you now or have you previously grazed young cereals with reproducing ewes?
2. Have you observed any metabolic disease or health problems when grazing reproducing ewes on young cereal crops? These problems may include hypocalcaemia, hypomagnesaemia (grass tetany), pregnancy toxaemia or acidosis.
3. In the most recent year that you grazed young cereals with late pregnant ewes, what percentage of the flock died or required treatment as a result of that grazing?
4. How many late pregnant ewes did you put onto young cereals in that year?
5. Over the last 5 years you grazed young crops what has been the average rate of mortality in reproducing ewes associated with this grazing practice?
6. Do you avoid grazing cereal crops with reproducing ewes because of the risk of the metabolic diseases described above?
7. Do you have any other concerns or problems with grazing late pregnant ewes on young cereals? Briefly describe …
8. What is the postcode of the site where you graze or have grazed crops the most?

The survey was open for 2.5 weeks and the link was circulated to farming groups. Primary circulation was through Rural Industries Skill Training Centre Inc to the Lifetime Ewe Management & High Performance Weaners network and through AWI and MLA to the Making More from Sheep network.

The survey was completed 186 times and after exclusion of repeat submissions, 179 responses were selected for further analysis (65 NSW/ACT, 49 Vic, 25 SA, 25 WA, 6 Tas, 1 Qld, 8 State not identified). A significant proportion of the surveys were incomplete but still provided useful data in some question fields. These data were included in the full analysis.

Key points from the responses were that 18% of those who graze cereals avoid grazing in late pregnancy because of the risk to health and increased mortality. Of those who avoid grazing in late pregnancy, 63% have had previous problems with sheep health when grazing young cereals (Table 4). Of those who continue to graze ewes on cereals during late pregnancy, 29% have had previous problems with sheep health. Of the 27 producers who avoided grazing crops during late pregnancy, all but four were from NSW, ACT or Victoria. Consistent with the producer and consultant interviews (see Section 4 above), 21 of the 22 producers from WA reported no problems with sheep health.

Quantification of mortality and/or sheep requiring treatment while grazing young cereals was not so straightforward. Many respondents included a range or provided a less than (<x) response. To quantify these responses some assumptions and rules were applied[8]. From the vagueness of many answers, it appeared that either the numbers were not available or the respondent did not have the time to inspect records. Many appeared to be guesses and ranged from 0.003% to 100%. After application of rules for data transformation (footnote 8),

[8] If answer was, “<x” applied as =x/2, if answer was “x to y” applied as =(x+y)/2, if answer was “blank” cell was left blank, if answer was “>x” applied as =x,

average losses were calculated as approximately 2%. From the average grazed flock of 930, this represents 18 ewes per flock.

Table 4. Summary of survey responses.

Survey topic	Response
Total responses from sheep producers who graze cereals	179
Producers who graze cereals but not with reproducing ewes	14%
Producers who graze cereals with reproducing ewes but avoid grazing in late pregnancy	18%
Producers who graze in late pregnancy and have problems with sheep health	29%
Producers who now avoid grazing in late pregnancy but have previously had problems with sheep health	63%
Average number of ewes grazed in late pregnancy (calculated from those who currently graze in late pregnancy only)	930
Estimated mortality or health problems with reproducing ewes in last year of grazing (estimated from those who have grazed or still graze ewes in late pregnancy)	2.0%

By compiling results from the survey with those from producer interviews and literature review a preliminary estimate of ewe losses can be made. The estimated cost of ewe losses is approximately $15,700,000 pa (Table 5). While there is a reasonable level of uncertainty around this estimate as it is reliant on a limited set of data collected it should be considered a significant underestimate.

The basis for this conclusion is that the cost of losses of ewes in late pregnancy takes no account of the potential production lost by those producers who graze crops but choose not to graze with late pregnant ewes, or, even more significant, the producers who choose not to graze crops at all because of perceived livestock problems or loss in crop yield (Industry opportunities below).

Table 5. Use of grazing cereals and calculated cost of mortality

Para-meter	Calculations used for estimate of financial cost	Number/$
A	Number of farms	34,896
B	Estimated number grazing cereal crops	6,979
C	Estimated number grazing cereal crops with ewes in late pregnancy	4,536
D	Total number of ewes grazing crops in late pregnancy (pa)	4,218,926
E	Mortality related to grazing young cereals (pa)	84,379
F	Cost of ewe mortality (pa)	**$15,694,406**
	Explanation and assumptions for calculations above	
A	Total high rainfall and wheat-sheep zones (ABARE 2011) in NSW, Vic and SA. WA and Tas omitted due to having no apparent problem.	
B	20% of total. Is a conservative estimate and is one third of the percentage (60%) provided from producer interviews in eastern states.	
C	65% of total crop grazers. Calculated from survey, excludes data from WA and Tas.	
D	Based on 920 ewes per farm. Calculated from survey excludes data from WA and Tas.	
E	Calculated as 2% of total ewes grazing cereals in late pregnancy – derived from survey. Conservative estimate as producer interviews suggested 5-10% and other research has indicated mortality up to 8% associated with crop grazing (Footnote 2).	
F	Value of ewe in late pregnancy ($186) sourced from Young et al[9].	

Industry opportunities

The cost as defined by responses from producers with experience and interest in grazing young cereals is important but also a significant underestimate of the potential benefits from providing a set of failsafe grazing strategies. There are many producers who will have never considered grazing young cereals because of anecdotal evidence of health problems and crop loss (these do not appear within the survey). Even more significant are the producers who have reduced sheep numbers or left the industry because of a perception that sheep do not contribute significantly to increased whole farm profit (see Section 1, Figure 1). The opportunity is now to convince these producers that sheep do increase whole farm profit and that grazing young crops significantly improves farm profitability.

While it is outside the scope of this project to quantify these benefits in full, they can be explored. The areas of cereal crops grown in the southern mainland states are shown in Table 6. In the wheat-sheep zone there were approximately 14.7 million ha of cereals grown in 2013. On the basis of our current understanding, in most years, this would provide between 20 and 40 kg DM/ha/d for at least 42 days without significant crop yield loss. For 14.7 million ha this represents 12,350 – 24,700 million kg DM available for grazing. Given most of the current crop grazing is in the high rainfall zones, most of the crop forage grown in the wheat-sheep zone is not grazed and is therefore a wasted resource.

Establishment of profitable and safe strategies for grazing young cereal provides an opportunity for AWI and MLA to re-establish sheep production in the wheat-sheep zone and to significantly expand their client base.

[9] Young, J.M., Trompf, A.J and Thompson, A.N. (2014) The critical control points for increasing reproductive performance can be used to inform research priorities. *Animal Production Science*, 54, 645–655.

Table 6 Areas (ha) of cereal crops grown in the southern mainland states in 2013 (table courtesy of Kimbal Curtis, Department of Agriculture and Food, WA).

Zone	State	Barley	Oats	Wheat	Total
High rainfall	New South Wales	11,168	72,592	39,088	122,848
	South Australia	75,145	15,029	111,644	201,818
	Victoria	53,224	19,959	166,325	239,508
	Western Australia	40,480	10,120	12,650	63,250
High rainfall Total		**180,017**	**117,700**	**329,707**	**627,424**
Wheat-Sheep	New South Wales	482,076	298,428	2,972,802	3,753,306
	South Australia	786,456	27,804	1,914,504	2,728,764
	Victoria	628,140	82,650	1,256,280	1,967,070
	Western Australia	1,398,303	227,286	4,684,068	6,309,657
Wheat-Sheep Total		**3,294,975**	**636,168**	**10,827,654**	**14,758,797**
Grand Total		**3,474,992**	**753,868**	**11,157,361**	**15,386,221**

7 Research and development priorities – summary of surveys and literature review

The grazing of young growing crops presents new opportunities in the mixed crop/livestock farming zone. The growing crops are excellent sources of both protein and energy for pregnant, lactating and growing sheep. Surveys of producers and consultants have confirmed that the value of this feed source is well recognised by producers and is becoming widely adopted.

While the growing crops have high production potential, they also come with an increased risk of metabolic disturbances and nutritional imbalances and a poor understanding of grazing management for crop and livestock benefits.

In reviewing the literature (Appendix 1) and surveys with producers and consultants in WA (Appendix 2) and the ES (Appendix 3) a long list of questions for potential R & D is apparent. These are compiled below into a prioritised list, with highest priority given to knowledge gaps that are currently limiting the use of crops for grazing or causing losses in production.

High priority - immediate influence on health and farm practice

1. A situation analysis of reproducing sheep grazing cereal crops to include:
    - Mineral composition of cereal crops to determine the concentration of minerals and the variation in minerals caused by crop genetics, geography, climate, fertiliser use and soil type,

- Mineral status of ewes grazing young cereal crops and the relationship between crop mineral status (see above) and the mineral status of the ewe,
- Mortality and other indicators of animal health (eg scouring) of ewes and lambs and the relationship between health and nutrition/management.

2. Evaluation of the responses to mineral supplements in late pregnancy with particular emphasis on magnesium, calcium and sodium. Supplements to include a comparison between:
    - Traditional calcium/sodium/magnesium supplement (33% each of causmag, lime and salt),
    - A sodium/magnesium supplement only (investigate options for a combination to increase DCAD - chloride/sulphate salts),
    - A supplement designed specifically to raise DCAD in the diet.

Other gaps - identified in review and interviews and considered a lower priority

1. Quantification of the benefits, possibly to include on farm demonstrations. This would need to include measurement of crop losses (including impact of patch grazing) and livestock change (including stocking rate) under different scenarios (climate x soil x stocking rate x grazing intensity). It could also include some assessment of ancillary benefits such as delayed flowering, water use efficiency, worm management. Possibly addressed through a combination of on-farm quantification, modelling and remote sensing.
2. Grazing management to optimise livestock production. Given the different relationship between feed on offer and plant height in young crops compared with traditional pasture plants, information on feed on offer and voluntary feed intake is required to establish guidelines for stocking rate and grazing times.
3. Implication of patch grazing on crop yields. Common observation that sheep do not graze crop paddocks evenly. How to manage sheep in large cropping paddocks (low stocking rates) with potential incidence of patch grazing.
4. The pre-crop grazing diet on adaptation to green crops by both young growing and reproducing sheep. Previous research into the susceptibility to both acidosis and ammonia load indicate that when sheep are introduced to lush pastures from a different diet, an adaption period may cause temporary metabolic disturbance and result in a lag in growth.
5. Potential benefits in providing shelter and improved maternal behaviour around parturition. To include optimisation of stocking rate, paddock size and crop characteristics for increased lamb survival
6. Interaction between grower groups to include bus trips to visit successful operations.
7. Potential to use longer growing season varieties In WA.
8. Testing of alternative crops (eg sorghum) and alternative varieties (eg Wedgetail wheat, Oxford barley) in WA.
9. Withholding period for Atrazine when used on canola.
10. Production of a ready reckoner (app) to predict crop/livestock trade-off and assist with decision making.

8. Appendices

Appendix 1 – Literature review[10]

Grazing crops – implications for reproducing sheep

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Short title: Grazing crops – implications for reproducing sheep

[10] Figure and Table numbers and headings in this section are retained in the format used for publication and numbering is exclusive to this appendix.

Abstract. Integration of crops and livestock has been revitalised in Australia, initially as an opportunity to increase cropping within the high rainfall grazing zones but more recently to improve enterprise diversification and profitability across the low, medium and high rainfall, and mixed farming zones. Young crops are highly digestible (>80% dry matter digestibility [DMD]) with a high energy density (>12 MJ/kg DM) and in much of southern Australia fill a winter feed gap.

The quality and time of feed availability also coincides with the high nutrient requirements of ewes in late pregnancy and lactation. In Western Australia and South Australia young crops are available for lactating ewes and young growing lambs (autumn lambing). For the smaller proportion of growers who lamb later in winter, young crops are available for the last 1-2 months of pregnancy. In the later lambing states of New South Wales and Victoria crops may be grazed by ewes at any stage of pregnancy and lactation and/or by young lambs. In Tasmania, crops are more likely to be available during early/mid gestation.

Limited studies on feed budgeting with grazing crops indicate that ewes can maintain or even increase liveweight with a much lower level of feed on offer that would be required with traditional pastures (<500 kg DM/ha). This has the potential to increase whole farm stocking rates and/or reduce fetal mortality, increase lamb birthweight and survival and improve lifetime production. Maintaining or increasing ewe liveweight during pregnancy and lactation may also result in heavier ewes the following year and higher ovulation rates.

Pregnancy and lactation are also periods of increased susceptibility to metabolic disturbances. The composition of young crops increases this susceptibility. Pregnancy toxaemia, hypocalcaemia and hypomagnesaemia can influence ewe health and fetal survival. Chronic acidosis and excessive ammonia absorption from rapid introduction of pregnant ewes onto young crops may risk appetite loss and increase susceptibility to pregnancy toxaemia. Low magnesium and sodium combined with high potassium increases the risk of grass tetany. Most young crops (except canola) also have a tetany index >2.2 indicating a high risk of grass tetany. The elevated potassium also contributes to a high dietary cation-anion difference of approximately +49 mEq/100g DM and this may cause metabolic alkalosis and hypocalcaemia. Pregnancy toxaemia, hypocalcaemia and grass tetany are all potential causes of increased ewe mortality.

Pregnancy and/or lactation outcomes will also be influenced by a deficiency of trace elements. Grazing young crops in areas with a history of selenium, copper, iodine and cobalt deficiency will increase susceptibility to deficiency by increasing growth and feed intake.

In conclusion, the grazing of young growing crops presents new opportunities for increased production and stocking rates in the mixed farming zones. The value of this feed source is well recognised by some producers. While growing crops have a highly productive potential, they also come with an increased risk of a range metabolic disturbances and nutritional imbalances. These risks can be minimised by regular monitoring of livestock and crop biomass and the provision of mineral supplements.

Introduction

Grazing crops is not a new concept and was used widely in Australia the 1930s (Forster and Vasey 1931). Livestock were introduced to the crop early during the growing phase and after a period of grazing, were removed to allow the crop to regrow and produce grain. During the 1960s and 70s, grazing oats, wheat, barley, rye, rape, lupins, vetch and peas were all evaluated (Axelsen *et al.* 1970; Spurway *et al.* 1974; Dann *et al.* 1977). Livestock weight gain and wool production were improved through grazing crops but economic value was dependent on the combination of returns from both crops and livestock (Axelsen *et al.* 1970; Cannon *et al.* 1978). Variability in seasonal conditions meant that the balance between benefits for livestock and the adverse effects of grazing on grain yield were difficult to predict and recommendations on grazing practices were tentative (Dann *et al.* 1977). For this reason, grazing during the growing phase remained a peripheral activity implemented on an opportunistic, rather than systematic basis. In 1972 only 1.6% of the high rainfall zone was used for grazing crops (Hoogvliet and Wheeler 1977), therefore use of forage crops over the larger mixed farming sector would have been negligible.

More recently, the integration of crops and livestock has been revisited, initially as an opportunity to increase cropping within the high rainfall traditional grazing zones. Dry matter from early autumn sown extreme spring wheat types yielded 8,000 – 10,000 kg DM during winter and this was potentially available for grazing (Davidson *et al.* 1987), however, these wheat varieties developed rapidly to ear emergence and all shoots in ear were susceptible to destruction by winter grazing and significant yield loss. Options to combine the early autumn sown wheat types with long-season late-flowering types were explored to assess the potential for both high grain production and dry matter production for livestock (Davidson *et al.* 1990). The development of long-season wheat varieties requiring winter vernalisation to flower meant these crops could now be grazed in winter without the risk of destruction of ears through earlier flowering. Grazing has become a much more attractive option (Virgona *et al.* 2006; Radcliffe *et al.* 2012; Dove and Kirkegaard 2014) and has now also expanded beyond the grazing of winter-sown or dual-purpose cereals to include opportunistic grazing of popular spring varieties managed to minimize yield penalties; sowing fodder crops to graze and not harvest and; the opportunistic sacrificial grazing of poor-performing crops (Radcliffe *et al.* 2012).

The time of availability of forage from young growing crops coincides with pregnancy, lactation and/or early weaner growth in southern Australia. The potentially large quantities of high-quality edible dry matter make grazing with reproducing ewes or growing weaners an attractive option. The purpose of this review is to summarise the opportunities and potential problems that may result from grazing crops at different stages in the sheep's reproductive cycle and identify knowledge gaps requiring further investigation. Information from grazing both dual-purpose crops (winter crops specifically planted for both grazing and grain production) and traditional spring varieties (used for either opportunistic or planned grazing) is included. The review focuses on southern Australia, primarily the winter-rainfall zone.

Grazing crops in different rainfall zones

The re-emergence of crop grazing has corresponded with significant change within the crop/ livestock zones in Australia. These zones are diverse with rainfall varying from 250 – 750 mm (Bell *et al.* 2013). In the higher rainfall zones, newer crops have provided an opportunity to take advantage of strong crop and weak wool and livestock prices. More recently, with improving livestock commodity prices, there has been renewed interest in improving sheep production. Grazing crops allows for an increase in grazing days and increase in carrying capacity with no loss in grain production (Bell *et al.* 2013).

In the lower rainfall areas the issues are quite different. With the introduction of no-till farming techniques, improved fertiliser options that are not dependent on pasture legumes and low wool prices, livestock have in some cases disappeared from the farming system. This has not been surprising; crops can be planted, managed and harvested with large and efficient machinery, labour requirements are decreased with fewer people required for a shorter period of time. This provides lifestyle benefits to balance the financial risk of reduced diversification. In some parts of the country cropping can even be carried out in combination with fly in/fly out off-farm work opportunities and labour shortages managed through the use of short-term itinerant labour. These changes in operations also provide an opportunity to live in larger regional centres and still efficiently conduct the farm business. As a cropping-only operation the technical skills required by management are also more focussed and far less complex (Kingwell 2011).

Added to this, livestock have been seen by some as a risk to crop yields and soil structure. Damaged topsoil structure, reduced water infiltration, increased bulk density and soil strength have all been attributed to livestock trampling with more damage to less well-structured soils than to better structured soils (Proffitt *et al.* 1993; Proffitt *et al.* 1995; Greenwood and McKenzie 2001). Most of the studies have focussed on soil damage to grazing land and have not assessed the impact on crop production or the potential relationship between trampling and tillage. This has now been addressed through a combination of review, modelling and experimentation (Bell *et al.* 2011). Overall conclusions from the study were that best-practice grazing has little impact on crop yields. Overgrazing should be avoided as this may cause long-term crop impacts.

While the balance between cropping and livestock varies across rainfall zones, recent temporal variability in climate favours diversity of enterprise to minimise financial and environmental risk (Kingwell and Pannell 2005; Bell *et al.* 2013). In the lower rainfall zone there have been problems in sustaining intensive cropping systems (Radcliffe *et al.* 2012) and these have contributed to increases in acid soils, salinity, herbicide resistance and wind and water erosion. Fear of more crop failures now means that livestock provide an option for a reduction in financial risk and a more financially and environmentally sustainable farming system.

Economic assessment

There are many economic assessments that now indicate grazing crops is profitable across a range of rainfall zones (Kelman and Dove 2007; Doole *et al.* 2009; Moore 2009; Hussein 2012; Kingwell and Squibb 2014). Studies near Canberra (>600 mm rainfall spread through the year) have demonstrated that gross margins can be increased by 9-30% by grazing crops in a forage brassica/cereal cropping rotation (Kelman and Dove 2007). Gross margins however, take no account of other changes that flow across the farm as a consequence of changes in feed supply and profit. As part of the re-evaluation of the relationship between cropping and grazing, the value of crop grazing has also been assessed within a whole farm systems context. Powerful new modelling tools have allowed the longer term benefits and costs to be explored over a range of climatic scenarios and model inputs have been improved through detailed field studies (Harrison *et al.* 2011a, 2011b). Moore (2009) assembled a whole farm systems simulation model (using APSIM soil and crop model together with and the GRAZPLAN pasture and animal models) to examine the benefits and costs of grazing cereal crops at 21 locations spanning four states and a range of rainfalls (290 – 655 mm). The author concluded that there may be scope for the expansion of dual-purpose cultivars into the 350 – 500 mm rainfall zone, although there is still uncertainty around the variation in benefits across years.

In a study directed specifically at the economic value of grazing wheat (*Triticum aestivum* L.), Doole *et al.* (2009) used the MIDAS whole farm model to conclude that farm profit can be increased by 10% by grazing vegetative wheat crops in high rainfall zones (~530 mm), however, grazing wheat in the lower rainfall zone (~ 360 mm) appeared to be unprofitable due to the longer feed gap and potential yield loss. The authors pointed out that these conclusions were based on the assumptions used within the model and suggested that a more attractive approach in the low rainfall zone may be to tactically graze wheat when good growing conditions are experienced. Kingwell and Squibb (2014) have argued that the Doole *et al.* (2009) study significantly underestimated the feed available from cropping and concluded use of dual-purpose crops is highly profitable in low to medium rainfall zones in Western Australia, even when crop yields are reduced. More recent studies using a combination of the GrassGro and APSIM models and 50 years of climate data have indicated that grazing spring and winter wheat will increase farm profit across low, medium and high rainfall zones. In this study, as with others, the practice was more profitable in the high rainfall zone (Hussein 2012).

Others have suggested options of sacrificially grazing crops in lower rainfall zones. When expected grain yield is low and/or livestock prices high, this provides flexibility in a crop-livestock zone that is not available within a single enterprise business (Bell *et al.* 2009; Bell *et al.* 2013). This is a risk management option, where the amount of early winter rainfall is used for decisions on fertiliser and post-emergent herbicide use for grain production versus the value of feed for livestock (Anonymous 2008).

Current use of crops for grazing

Crops are now grazed across all southern states in Australia. In 2011 it was estimated that dual-purpose crops were sown on 300, 000 ha across Australia. Of this, 130,000 ha were sown to wheat, 90,000 ha to oats and 60,000 ha to triticale. There were also small areas of barley and canola (Radcliffe *et al.* 2012). This summary does not provide the complete picture as grazing also occurs using locally preferred grain varieties on a more opportunistic basis. For example, Radcliffe *et al.* (2012) reported 700,000 ha of crops were being opportunistically grazed in South Australia and a further 600,000 ha in Western Australia, primarily within a farming system adapted to drier and more variable environments.

Availability of crops for grazing where the objective is to preserve crop yield, is highly dependent on location and climate. The balance between available time and the feed demand is important. The practice becomes much more valuable if it fills a winter feed gap (Moore *et al.* 2009), allows grazing pastures to be deferred until pastures are well established (Thomas *et al.* 2014), or changes the farm requirement for supplementary feeding (Thomas *et al.* 2012). For spring cereals, opportunistic grazing may only be possible for a few weeks, and not every season (Thomas *et al.* 2012; Thomas *et al.* 2014) while for long season dual-purpose cereals, months of grazing and high deferment benefits are possible (Dove *et al.* 2014). Deferred grazing may result in increased pasture available for spring and summer and this will potentially allow an increase in farm stocking rates (O'Connell *et al.* 2006).

In Temora, a medium rainfall site (528 mm), with rainfall distributed evenly through the year, dual-purpose crops were available for grazing as soon as the root system provided adequate anchorage across investigations over 26 years (1973 – 1999). Within this region, grazing commenced as early as February/March, usually finished in June but in some years continued until August (Radcliffe *et al.* 2012). In drier, more seasonal environments it is much more likely seeding will not commence before April or May and grazing would not extend past July.

Production and health implications for grazing crops

Dry matter production

The value of forage from young crops lies in both the increase in dry matter available for grazing and the time of availability. Crops provide dry matter for grazing when there is a winter feed gap from traditional pastures. Dry matter production is highly dependent on the same climatic and soil characteristics that also influence other agricultural plants in southern Australia. There is a significant amount of published literature on livestock production from grazed crops and the trade-off between animal and grain production, but very little on grazing behaviour and management for improving livestock performance. The information that is available on grazing management is primarily focussed on minimising the risk of grain yield loss. For example, it is recommended that grazing should not commence before the cereal plants are well anchored (passing the 'tug test'). The amount of biomass available for grazing at this time is unclear, Radcliffe et al. (2012) suggests forage exceeds 1000 - 1500 kg DM/ha by the time plants are anchored, others (Virgona *et al.* 2006), have measured 500 kg DM/ha "when the wheat plants had at least 5 leaves and could not be uprooted by grazing", while even more recent experience has indicated spring wheat in the Western Australian wheatbelt is anchored and can be grazed when biomass available is < 200 kgDM/ha (D.R. Thomas pers. comm.).

Estimates of forage available for grazing can be been made from forage growth measurements; dry matter production of between 20 and 40 kg/ha.day can be expected in June, July and August, but, depending on location and conditions this may vary from 0 to 100 kg/ha.day (Anonymous 2008). If 50% (Freer *et al.* 2012) of this growth is then utilised, stocking rates of 10 – 20 DSE could be expected, with 600 – 1200 sheep grazing days if grazed for 2 months (stocking rate * days grazed). This is supported by field studies in southern NSW where a commercial crop of wheat (*Triticum aestivum* var. EGA Wedgtail) was grazed at stocking rates of 32 or 40 DSE through July and August (Virgona *et al.* 2006). The shorter grazing periods of 15 -19 days (equivalent to 480 - 706 sheep grazing days) resulted in either no effect or increased grain yield. Estimated above ground dry matter at the start of grazing was approximately 500 kg DM/ha and this remained constant through grazing with 40 DSE/ha (25.6 pregnant ewes/ha). The authors estimated the crop growth rate at 51 kg/ha/day and suggested high stocking rates are required to ensure uniform grazing of crop canopy but excessive grazing will damage growing points (Virgona *et al.* 2006). Performance of livestock was not reported in this study, although estimates using GrazFeed (Freer *et al.* 1997) indicated plant growth matched livestock requirements. Under conditions where crop growth was constrained through low rainfall, stocking rates of 20 sheep/ha could not be supported, resulting in a rapid decline in herbage mass to levels that would constrain intake in grazing livestock (Dove and McMullen 2009).

Most other publications on livestock responses appear to be based on excess dry matter availability, for example, when testing mineral supplements for young sheep, grazing commenced when crop biomass ranged from 1274 – 2912 kg/ha (variation related to plot and crop type), with stocking rates set at approximately 50 kg of initial forage/sheep. Throughout the experiment biomass remained at > 1000 kg/ha for barley, oats, wheat and canola (Dove *et al.* 2012).

For tactical grazing programs, where stocking rate and movements are managed through feed budgeting (Trompf *et al.* 2011), estimates of dry matter availability or feed on offer are required. For crops, plant height has been used as an indicator of available biomass with each 1 cm of plant height estimated to indicate 60, 75 and 65 kg DM/ha for wheat, barley and triticale respectively (based on 20 cm row spacing sown at 100 kg/ha) (Anonymous 2008). In other studies, measurements on five different wheat cultivars indicated 1 cm of plant height was equivalent to 35 – 48 kg DM/ha (Dove and McMullen 2009). For a typical pasture 1 cm of plant height is indicative of 300 kg DM/ha (Weston 2002). As with current estimates of biomass available at the start of grazing (see above), there is also significant uncertainty around the relationship between plant height and biomass per hectare, this may be explained through differences in crop types, cultivars, seeding rate and row spacing. Improved understanding of this relationship is essential information for the efficient grazing management of reproducing ewes.

Protein and energy

Forage from crops is highly digestible (>80% dry matter digestibility [DMD]) resulting in a high energy density (>12 MJ ME/kg DM) (Table 1). These are high values for green feed and are primarily derived from analysis at two laboratories, while there are no comparable data from other published studies, other technical publications support these estimates of digestibility (Frischke 2011). With 80% DMD, there are no expected (low) energy limitations to intake, and, assuming abundant feed on offer, feed intake would be expected to reach its potential as defined by body size and physiological state (Freer *et al.* 2007). Similarly there are no expected constraints to intake or growth related to lack of protein. Data from a range of studies indicates that intake is constrained when crude protein (CP) in the diet is below 100-120 g CP/kg digestible organic matter (DOM) (Weston 2002). From the data shown in Table 1, it can estimated that 80% DMD is equivalent to approximately 750 g DOM/kg DM (Freer *et al.* 2007), therefore the minimum CP content of 212 g/kg DM (21.2% CP), reported in Table 1, is equivalent to 280 g CP/kg DOM. This is more than double the concentration required to avoid a constraint to intake.

TABLE 1 NEAR HERE

The high metabolisable energy and crude protein content have been reflected in livestock performance in most, but not all grazing experiments (Miller *et al.* 2010; Dove and Kirkegaard 2014). For example, Kelman and Dove (2007) reported growth rates of 358 g/day over a 22 day period of grazing Border Leicester x Merino lambs across plots of Mackellar wheat and Blackbutt oats. Similarly, young crossbred lambs with an initial liveweight of 39 kg gained 320 -369 g/day grazing Gordon and Tennant winter wheat and 282 g/day grazing Blackbutt oats in the first year of a two year experiment. In the second year however, liveweight gain of the crossbred lambs grazing Tennant wheat was less than the first (236 g/day) (Dove *et al.* 2002). Feed intake in the second year was lower than expected and lower than predicted from GrazFeed (Freer *et al.* 1997). Kirkegaard *et al.* (2008) also reported liveweight gain in young Merino hoggets grazing canola was less than expected (approx 210 g/d) and others have reported that variability in liveweight gain a common feature of brassica grazing (Dove and Milne 2006).

Metabolic disturbance

The high levels of soluble carbohydrate, while contributing to the high digestibility and energy content of young grazed crops, also increase the risk of acidosis. Acidosis occurs when carbohydrate supply is increased abruptly (Huntington 1993). This may take the form of overt illness following consumption of readily fermentable carbohydrates with reduced pH in the rumen or chronic acidosis where intake and performance are reduced without acute signs (Owens *et al.* 1998). While the condition is usually associated with rapid change to grain feeding from a low carbohydrate diet, the nature of the diet prior to introduction onto lush green forage may also influence the metabolic changes that occur in the rumen (Annison *et al.* 1959a).

Acidosis is usually associated with the fermentation of starch and sugars in the rumen as a consequence of grain feeding (Rowe 1997). Grains contain far more soluble carbohydrates than growing crops. Wheat for example, contains 60-70% starch and oat grain >40% (Ewing

1997; Shewry 2009) whereas cereals or forage rape for grazing have been reported to contain <20% total soluble carbohydrates (De Ruiter *et al.* 2002; Fulkerson 2008). Nevertheless, chronic acidosis has been reported in livestock grazing lush forage (Annison *et al.* 1959b; Bramley *et al.* 2008; Packer *et al.* 2011) and is seen as a risk for dairy cattle consuming forage rape (*Brassica napus*) (Fulkerson 2008); similar risks would be expected for grazing other crops. Chronic acidosis may cause short term inappetence in livestock. Short term fasting during pregnancy may increase the risk of ketosis, loss of condition, shortened pregnancy (West 1996) and precipitate acute pregnancy toxaemia.

The high digestibility of young crops may also be consistent with low fibre within the forage. The limited amount of data available indicates this is not a problem. Dove (2002) reported neutral detergent fibre in young wheat crops of 35-50% and in subsequent studies no responses to roughage were observed in young sheep grazing dual-purpose wheat.

The high concentrations of crude protein within these crops may also increase the risk of metabolic disturbance. Provision of too much soluble nitrogen in the rumen as urea will cause ammonia toxicosis (Roller *et al.* 1982) and ammonia can also be produced through microbial deamination of plant proteins in the rumen (McDonald 1948). As indicated through a GrazFeed simulation, the nitrogen provided by grazing crops is well in excess of that required for microbial protein synthesis and this excess protein would be a source of ammonia for absorption (Table 2). Excess digestible protein has been reported to cause a rapid increase in blood urea concentrations in sheep moved from hay/concentrate diets to grazing lush pastures, but adaptation to the new diets occurred quickly (Annison *et al.* 1959a). The tolerance of sheep to high doses of soluble nitrogen is also partially related to nitrogen in the previous diet. Sheep switched from a low protein diet will have lower concentrations of urea cycle enzymes in the liver and lower ability to metabolise and detoxify ammonia (Morris and Payne 1970).

TABLE 2 NEAR HERE

A risk of other metabolic disturbances has been reported from grazing crops including photosensitisation, bloat and nitrate poisoning (Hogan and Weston 1969; O'Hara and Fraser 1975; Morton and Campbell 1997; Kirkegaard *et al.* 2011). Nitrate poisoning is considered a risk by sheep producers growing crops (Masters and Thompson 2014) and is related to the increase in nitrate caused by the application of nitrogen fertiliser. Hogan and Weston (1969) reported no acute toxicity or changes in intake and digestion when sheep were fed forage oats fertilised with nitrogen. While these metabolic disturbances should all be considered as potential problems for livestock grazing crops, they have not been well investigated or reported in Australia.

Minerals

Variability in the growth of young sheep grazing dual-purpose wheat has led to investigations into the potential for mineral deficiencies and imbalances. In some experiments lower than expected weight gains have been measured even when forage supply and intake were adequate for rapid weight gains (Dove *et al.* 2002; Dove 2007). The primary cause of poor growth in these experiments was most likely an imbalance in the supply of magnesium, potassium, sodium and calcium resulting in a magnesium deficiency, possibly combined with a sodium deficiency.

Magnesium absorption is an active process and is highly susceptible to interference by some other elements (Greene *et al.* 1983). Increasing the potassium in forage from 2 to 5% can decrease absorption of magnesium by up to 75% (Fig 1). Similarly, high protein in the diet suppresses magnesium absorption. Conversely, high intakes of sodium both facilitate the absorption of magnesium directly and also lower the amount of potassium being recycled to the rumen in saliva (Suttle 2010).

FIGURE 1 NEAR HERE

Mineral analysis of wheat, oats, triticale, barley and canola have confirmed that magnesium and sodium content are low and potassium very high relative to requirements (Table 3) and crude protein is high (Table 1) So, while the picture is complex, some patterns are clear. Rapidly growing new young crops have all the ingredients to cause a mineral imbalance. An imbalance can induce a deficiency in minerals even though the concentration of that mineral in the diet exceeds, or is close to the minimum requirement (Suttle 2010).

TABLE 3 NEAR HERE

Subsequent studies in which young sheep grazing dual-purpose wheat were provided with mineral supplements confirmed the imbalance (Dove and McMullen 2009). In the first of two experiments, supplementing young cross-bred weaner sheep (initial liveweight 35Kg) with a mixture containing causmag (magnesium oxide), agricultural lime (primarily calcium carbonate) and salt (sodium chloride) (1:2:2) whilst grazing dual-purpose wheat (cv Wedgetail) resulted in a 54% increase in liveweight gain (compared to unsupplemented sheep). In the second supplementation experiment, a range of different mineral supplements were supplied to provide sodium alone or in combination with magnesium, calcium or roughage. Provision of sodium or magnesium resulted in an increase of liveweight gain of approximately 30%. The authors suggested the response to sodium was possibly via its influence on magnesium absorption (Dove and McMullen 2009). In subsequent experiments (H. Dove pers. comm.), responses to magnesium plus sodium has resulted in higher liveweight responses than to sodium when fed alone, indicating that responses may be a combination of imbalance (magnesium) and a simple dietary deficiency (sodium). These experiments have not included any collection or analysis of blood or urine to support the conclusions presented.

Experiments with grazing barley, oats and canola have not resulted in similar responses leading to the conclusions (Dove *et al.* 2012): that mineral supplements are not required for grazing oats; that there is a need for further work to define the mineral requirements when grazing barley and; there is no need to supplement minerals when grazing canola. The canola grazing experiments have, on one occasion, shown a negative response to mineral supplement (Dove *et al.* 2012). The lack of response to mineral supplements may be related to the higher concentrations of sodium reported for oats, barley and canola (Table 3). However, while these conclusions are supported by the results of experimentation, the number of experiments is small. A broader assessment is justified based on plant composition. In cattle the risk of magnesium deficiency created by an imbalance between magnesium, sodium and potassium is predicted using a tetany index (Elliot 2008; Dove and McMullen 2009). A value above 2.2 indicates an unacceptable risk of grass tetany (acute magnesium deficiency). Using this value as a reference for sheep, there appears to be a risk of magnesium deficiency in livestock grazing oats, triticale and barley on the basis of tetany ratios provided in Table 3.

Calcium supplements have also been provided to young sheep grazing dual-purpose wheat. The calcium supplement was combined with sodium and/or magnesium. Addition of calcium provided no additional liveweight responses above those measured for sodium and magnesium and the consumed diet contained more calcium than published requirements. For this reason it was concluded there was no need for calcium supplements in sheep grazing dual-purpose wheat (Dove and McMullen 2009). However, minimum calcium concentrations in all cereals shown in Table 3 are below recommended allowances for young growing sheep or ewes in late lactation and pregnancy. This would indicate more research is required with reproducing sheep to define risks and supplementation strategies.

Trace elements and vitamins

Australian animal agriculture has a history of trace element and vitamin deficiencies. These deficiencies are often associated with moderate to high rainfall zones (Judson *et al.* 1987) and the trend towards increasing crop production and grazing in the higher rainfall zones means the risk and potential changes in risk associated with crop grazing must be considered. The most common and economically significant include selenium, cobalt (manifest as vitamin B_{12} deficiency), copper, iodine and vitamin E (Judson and McFarlane 1998; Lee *et al.* 1999). Of these, selenium, cobalt, iodine and, to a lesser extent copper deficiency are primarily a consequence of low concentrations of the elements in the soil and therefore in growing plants. Copper deficiency is not simply due to low concentrations of copper in plant material. There is an interaction between copper, molybdenum, sulfur and iron meaning copper absorption is dependent on molybdenum, sulfur and iron in the diet as well as copper concentration (Bremner *et al.* 1987; Suttle 1991) Vitamin E deficiency is caused by long periods of dry feed intake (4-6 months) in mediterranean climates across southern Australia (White and Rewell 2007).

Iodine deficiency is most common in high altitude areas away from the coast, where iodine has been leached from the soil, but can also be caused by the consumption of goitrogens (Barry *et al.* 1983). Goitrogens are common in some brassica species. A deficiency in selenium may also interact with iodine activity by decreasing the conversion of the iodine hormone thyroxine (T4) to triiodothyronine (T3).

Livestock grazing crops will in most instances require the same trace element and vitamin management strategies that would be applied to grazing any other feed in the same location, although with some additional considerations including:

- Cobalt and selenium deficiency are often seen as a spring problem (Caple *et al.* 1980; Judson and McFarlane 1998). This is a time of rapid plant growth and, as plants have no requirement for either cobalt or selenium for growth, the available selenium and cobalt absorbed by the plant is diluted out by high plant dry matter production at this time. A similar situation may occur if crops grow rapidly prior to or during grazing. The risk of cobalt or selenium deficiency will be increased and may occur earlier in the season in areas already prone to deficiency of these elements.
- Increased susceptibility during rapid plant growth will be accentuated by rapid livestock growth and/or production (Judson and McFarlane 1998). Livestock most susceptible to selenium and cobalt deficiency are high growing/producing animals. If grazing crops increase rates of production they may also increase susceptibility to deficiency in livestock that have not been supplemented with trace elements.
- Grazing brassica crops may create crop specific issues that are not seen in grazed cereal crops.
    - Many brassica species contain high concentrations of goitrogens and consumption may disrupt iodine metabolism (Barry *et al.* 1983). Canola (*Brassica napus*) is the brassica species most commonly grazed in Australia, this is a plant bred for low goitrogens in the seed (Downey and Rimmer 1993), with an expected low concentration in the forage. While there is little analytical evidence from grazing experiments to support this conclusion, no health problems have been reported from grazing canola in Australia (Kirkegaard *et al.* 2008).
    - Brassica plants may also contain higher concentrations of sulfur (Table 3) and the sulfur amino acid S-methyl-L-cysteine sulfoxide (SMCO) than cereal crops. SMCO is converted to dimethyl sulfide in the rumen and is toxic when

absorbed (Barry *et al.* 1984). There is little evidence that SMCO is a problem in the more recently developed and grazed *Brassica napus* cultivars (Dove and Milne 2006; Kirkegaard *et al.* 2008), however the higher concentration of sulfur in the forage may still interfere with copper absorption and cause copper deficiency (Barry *et al.* 1981). Production responses to copper supplements have not been reported for livestock grazing forage rape (*Brassica napus*) (Dove and Milne 2006) but may need to be considered in copper deficient soils.

Implications for reproducing ewes and growing lambs

Time of grazing and reproduction

The times that crops are available for grazing and the length of time crops are grazed both have implications, not only for filling feed gaps and deferred grazing, but particularly for the class of livestock that will utilise the forage. This has implication for both production and health of livestock.

A wide ranging survey of lambing times in Australian sheep flocks has indicated that these predominantly range from March to September in the southern states with some extension into October in Tasmania and even into November in Queensland and New South Wales (Croker *et al.* 2009). Within the Mediterranean zone, lambing was usually from April to August with the distribution skewed towards autumn and early winter (March – June) in South Australia and Western Australia and more evenly spread between autumn and winter (March – August) in Victoria and New South Wales. These lambing patterns mean that crops in Western Australia and South Australia are most likely to be grazed by lactating ewes and young growing lambs. For the smaller proportion of growers who lamb later in winter, ewes may be grazing crops in the last 1-2 months of pregnancy. In New South Wales and Victoria crops may be grazed by ewes at any stage of pregnancy and lactation and/or by young lambs. In Tasmania, crops are more likely to be grazed during early/mid gestation.

From the point of view of any metabolic disturbance or nutritional imbalances that may occur from grazing crops in Australia, consideration must be given to both the implications for grazing in late pregnancy (winter and spring lambing) and for lactating ewes or young growing lambs (autumn lambing). The importance of any interactions between the physiological state of the animal and the nutritional and metabolic consequences of grazing crops will vary across states.

A further consequence is that the availability of feed from crops may lead to changes in time of lambing. The reasons for selection of lambing time in all these states are strongly influenced by three factors: feed availability relative to requirements; weather to improve lamb survival and; enterprise integration (management of crop and livestock programs). Almost all producers surveyed gave at least one of these reasons for choice of lambing time (Croker *et al.* 2009). A crop for grazing could provide additional feed early in the season or allow deferred grazing to provide more feed late in the season therefore providing an incentive towards more autumn lambing with a longer period to finish weaned lambs (Radcliffe *et al.* 2012).

Reproductive losses

Reproductive losses in the Australian sheep industry have long been a topic of research. In 1957 losses were classified as failure to mate, failure to lamb after mating and lamb mortality due to infectious and non-infectious causes (Watson 1957). These losses have in various publications been further categorised, for example, in a recent review Hinch and Brien (2014) categorise causes of lamb losses into dystocia, starvation, exposure and predation.

Often it is a combination of these factors that contribute to an unsuccessful lamb survival. There does not appear to be any useful publication that compiles or summarises the relative contributions of the specific metabolic, nutritional or environmental factors associated with reproductive losses.

Nutrition and reproduction

Mating and ovulation rates. Grazing dual-purpose crops will have only an indirect influence on mating success and ovulation rate. Mating is always in summer or autumn, at a time when dual-purpose crops are not available for grazing. However, the indirect influence may still be significant. Liveweight of ewes at the time of mating will influence ovulation rate - higher liveweight results in higher ovulation rate. For example, studies in Western Australia have indicated an additional 5 kg in liveweight at mating is associated with 5.9 extra ovulations per 100 ewes (Lindsay *et al.* 1975). This change can be translated into an improvement in ewe reproductive rate across different years and environments (Ferguson *et al.* 2011b). Ewes that are better fed during pregnancy and lactation tend to be heavier at the time of subsequent mating and have a higher reproductive rate (Ferguson *et al.* 2011b).

The availability of crops for grazing by lactating ewes and young ewe lambs may also provide an opportunity to increase the rate of weight gains in young ewes relative to traditional pasture feeding and shorten the time required to reach puberty. This will facilitate the option of mating at <12 months of age – higher liveweight in ewes mated at 8-10 months of age is positively associated with fertility, ovulation rate and reproductive rate at mating as a yearling (Ferguson *et al.* 2011a).

Pregnancy and lactation. The clear benefits of improved nutrition during mid and late pregnancy in grazing ewes have been well quantified. Paganoni *et al* (2014) reported increases in lamb weight associated with increased conception weight and weight gain during early and late pregnancy. The results were similar across breeds. Lamb birth weight is important because it is the single most important factor in determining lamb survival (Oldham *et al.* 2011). Lamb birth weight can be compromised when poor nutrition during mid-pregnancy restricts growth of the cotyledonary component of the placenta (Robinson 1983; Mellor 1987; Kelly 1992; Kelly *et al.* 1992) or when poor nutrition in late pregnancy restricts growth of the fetus (Robinson 1983). Poor nutrition in mid-pregnancy has also been associated with increased fetal mortality in ewes carrying twins (Kelly *et al.* 1989). Benefits of good nutrition during pregnancy go well beyond fetal mortality, lamb birth weights and lamb survival, weaning weights are also increased and there are lifetime benefits in wool production that include higher fleece weights and finer fibre diameter (Behrendt *et al.* 2011; Thompson *et al.* 2011) in growing lambs. Well fed ewes also have higher wool production (Kelly *et al.* 1992), improved staple strength in reproducing ewes (Masters and Mata 1998) and higher milk production during lactation (Dove *et al.* 1994).

Strategies to optimise grazing management of young crops to take advantage of potential benefits have not been developed. For pregnant ewes grazing pastures, feed on offer needed to achieve weight gains in excess of 90% of the maximum were 1500–1700 kg DM/ha at a Victorian site and 1100–1300 kg DM/ha at a site in Western Australia. The predicted feed on offer required for liveweight maintenance (feed on offer at zero change in liveweight) was 600–800 kg DM/ha at the Victorian site and 500–700 kg DM/ha at the Western Australian site (Ferguson *et al.* 2011b), however, 800 kg DM/ha has been associated with a reduction in lamb survival (Oldham *et al.* 2011). Comparable measurements have not been made with grazed crops although feed availability and therefore grazing strategies may be quite different. Virgona *et al.* (2006), for example grazed ewes in late pregnancy on winter wheat (*Triticum aestivum* var. EGA Wedgtail) to a constant above ground dry matter of 500 kg DM/ha. No measurements on the reproductive or growth performance of either ewes or lambs was reported in this study, although the maintenance of grazing for up to 60 days and a positive economic assessment presented with the paper would indicate animal health and production was not compromised. Similarly, McGrath *et al.* (2014) grazed ewes on crops with feed on offer less than 1000 kg DM/ha without any adverse effects on health or productivity.

This lower requirement for available biomass is likely to be related to the increased height of crop forage per unit of dry matter available compared with traditional pastures. Simulation using GrazFeed (Freer *et al.* 2012) indicates that pregnant and lactating ewes are able to maintain a voluntary feed intake close to potential intake even when green forage on offer is <500 kg/ha. For pregnant and lactating ewes consuming traditional forage, the model predicts feed on offer needs to exceed 1500 kg DM/ha to allow voluntary feed intake to reach potential intake (Figure 2).

FIGURE 2 NEAR HERE

So, the nutritional benefits of grazing crops during pregnancy and lactation are significant. However, pregnancy and lactation are also periods of increased susceptibility to metabolic disturbances. Pregnancy toxaemia, hypocalcaemia and grass tetany can influence ewe health and foetal survival.

Abrupt changes from dry, low nutritive value feeds to green rapidly growing crops present an increased risk of acidosis or a sudden increase in rumen ammonia. Such changes could result in a short term loss of appetite, ketosis and pregnancy toxaemia. The induced magnesium deficiency reported in young growing sheep would also be expected in pregnant and lactating ewes. Growth rates would be depressed but more importantly rates of grass tetany and potential mortality of ewes would increase. The risk of hypocalcaemia is also real. Hypocalcaemia may occur at times when sheep and cattle are subjected to a rapid increase in requirement or a sudden decrease in calcium supply. Normally, when requirements for calcium exceed supply, animals have a sophisticated internal control system that enables them to increase absorption, decrease excretion and mobilise the large store of calcium in bones to maintain metabolic stability (Suttle 2010). If the animal is unable to mobilise calcium quickly enough from bone it becomes listless, shows muscular weakness, twitching or convulsions and loss of appetite (Suttle 2010). This is termed hypocalcaemia or milk fever. Without treatment, death may result.

Susceptibility of ruminants to hypocalcaemia or milk fever is not simply a result of low calcium in the diet. In fact, low calcium leading up to late pregnancy has been associated with a decreased risk. The low dietary calcium is believed to stimulate the synthesis of vitamin D and improve the ability to respond to a drain on plasma calcium induced by late pregnancy and lactation (McNeill *et al.* 2002). The increased risk is more related to an inability to respond to a rapid increase in demand. In the dairy cow increasing importance has been placed on the cation to anion balance in the diet during the transition period 3-4 weeks pre partum to 3-4 weeks post partum (McNeill *et al.* 2002). A change in the cation-anion ratio alters the acid-base balance towards alkalosis and this reduces the ability of the cow to produce 1,25-dihydroxyvitamin D_3, the active form of vitamin D. High potassium (4-5% in May and June) has been identified as a major contributor to an increase in the cation-anion ratio in Victorian pastures (Jacobs and Rigby 1999). Similar high concentrations of potassium have been measured in grazed crops (Table 3). The elevated potassium contributes to a highly positive dietary cation-anion difference (DCAD) contributing to metabolic alkalosis. An estimate of DCAD (Tucker *et al.* 1991) using the average concentrations of sodium, potassium and sulfur for grazed wheat (Table 3) and unpublished average concentration of chloride (1.1%) in similar wheat plants (H. Dove pers comm.) provides a figure of +49 mEq/100g DM. DCAD of less than +15 mEq/100g DM has been associated with lower urine pH and a decreased risk of milk fever in dairy cattle (Roche *et al.* 2000). Less comparable data are available for sheep. Grant *el al.* (1988) reported that pregnant and lactating ewes had difficulty maintaining calcium status when grazing green pastures in winter and spring, even though these pastures contained calcium concentrations above published requirements. These authors subsequently concluded that a high, positive dietary cation-anion balance was a factor that predisposes ewes to hypocalcaemia (Grant *et al.* 1992). Takagi and Block (1991), reported that sheep fed a diet with a DCAD of +3.2 mEq/100g DM showed an increased ability to mobilise calcium during hypocalcaemia when compared with sheep fed +34.5 mEq/100g DM. On the basis of the cattle and sheep information there is a risk of hypocalcaemia in pregnant and lactating ewes grazing crops in winter.

In what appears to be the only published study on the use of mineral supplements for pregnant and lactating ewes grazing dual-purpose wheat (cv Wedgetail) in Australia, no clinical hypocalcaemia or hypomagnesaemia was observed in either supplemented or unsupplemented ewes (McGrath *et al.* 2014). This resulted even though calcium, sodium and magnesium concentrations in the forage were below ewe requirements. The only production response to supplements of magnesium, calcium and sodium was a higher growth rate in twin born lambs in one of the two experiments. Analysis of serum calcium and magnesium did identify ewes at risk of hypocalcaemia or hypomagnesaemia in both experiments but there was no relationship between serum mineral concentrations and mineral supplementation. The authors concluded that, the low mineral concentrations in wheat forage increased the potential for hypocalcaemia or hypomagnesaemia and indicated provision of mineral supplements would be prudent. This conclusion is supported by surveys of producers indicating there is a higher incidence of health issues in reproducing ewes grazing dual-purpose wheat in southern New South Wales and a lower incidence of ewe mortality in flocks provided with magnesium and sodium supplements (McGrath *et al.* 2013a; McGrath *et al.* 2013b). The authors concluded that a combination of mineral supplements and higher condition score at the start of lambing were associated with a 6.8% lower rate of ewe mortality and 2.4% lower rate of metabolic disease. While these numbers are significant, the results were derived from a survey of ewe losses and the survey was not designed to establish cause or measure response.

Pregnancy and/or lactation outcomes will also be influenced by a deficiency of all the trace elements. Selenium deficiency has been reported to cause significant reproductive losses in New Zealand (Hartley 1963). Responses in Australia have been inconsistent (Wilkins and Kilgour 1982; Langlands *et al.* 1991), most likely because pregnancy and often lambing tends to be in autumn or winter in most regions of Australia where selenium deficient soils are found. Autumn and winter are not traditionally times of low selenium status in livestock. Selenium deficiency in Australia is usually associated with rapid pasture growth in spring and is commonly apparent in young sheep. As a consequence, selenium supplements are not regularly provided to adult reproducing sheep. The availability of crops for grazing means that risk of selenium deficiency may be brought forward into winter or possibly even autumn. Under such circumstances an increase in selenium deficiency during pregnancy is more likely and supplementation of ewes grazing young crops in selenium deficient areas would be advisable.

Iodine deficiency in pregnancy will result in malformed lambs and lambs with increased susceptibility to cold stress, copper deficiency will cause in swayback and cobalt deficient ewes produce small weak lambs (Judson and McFarlane 1998) therefore, as with selenium all these elements should be provided as a supplement to pregnant and lactating ewes in areas pre-disposed to deficiencies. Particular attention to copper and iodine status should be considered for pregnant ewes grazing brassica species. Kale, a brassica plant with known high goitrogenic activity, has been associated with increased embryo mortality through a suspected reduction in iodine or copper status (Robinson 1983).

Weaner growth and survival. Recent experiments with young sheep have not provided consistent evidence that there are any metabolic adjustment problems associated with rapid introduction to grazing brassica (Dove and Milne 2006; Kelman and Dove 2007; Kirkegaard *et al.* 2008; Dove *et al.* 2012) or cereal (Dove *et al.* 2002; Dove and McMullen 2009; Dove *et al.* 2012) crops. Only in the study of Dove *et al.* (2012) was there a lag in growth when a group of sheep that had not previously grazed together were introduced to cereal forage. However, the majority of these experiments have been conducted in locations where green feed is available for most of the year. Where calves and lambs have been introduced to forage wheat from a hay-based diet, liveweight gain was lower than measured in animals that were introduced from a wheat pasture (Phillips and Horn 2008). A delayed liveweight and intake response to grazing may therefore be expected if there is an abrupt change from a previously low quality diet. The evidence is clear that an imbalance between magnesium, potassium, sodium and calcium may depress growth and increase susceptibility to hypocalcaemia and hypomagnesaemia in young sheep grazing wheat. There is less evidence of imbalance in young sheep grazing other crops. Further studies are required.

Growth and survival of young sheep will also be influenced by a deficiency of trace elements. Selenium deficiency results in slow growth, reduced wool production and potential mortality due to nutritional muscular dystrophy, iodine deficiency will result in poor growth increased and susceptibility to cold stress, cobalt deficiency causes loss of appetite, anaemia and slow growth while copper deficiency in young weaners causes steely wool and anaemia. Therefore all these elements should be provided as a supplement to young sheep.

Non-nutritional implication for reproduction

There are some potential, though unexplored, non-nutritional benefits associated with lambing on young crops. For any given level of feed on offer, it is likely that the plant height of crops will be 5-10 times higher than for traditional pasture (see above). With a plant height of 1 cm for each 60 kg DM/ha (Anonymous 2008), a feed on offer allowance of 1500 kg DM/ha would provide a canopy height of 25 cm. Others have reported that the use of erect plants to provide a wind break can reduce lamb losses in the 48 hours after birth by 10 – 32%, depending on the ambient conditions (Alexander *et al.* 1980).

Having a good feed supply and shelter at the birth site during lambing has also been associated with changes in ewe behaviour and the establishment of a bond between ewe and lamb resulting in improved lamb survival (Le Neindre and Poindron 1990; Lindsay *et al.* 1990). Improved survival, independent of birthweight differences, has been reported when lambing ewes have access to high levels of feed on offer (Oldham *et al.* 2011), this has not been confirmed in limited experimentation on ewes lambing within an oat crop (Glover *et al.* 2008).

Conclusions and proposed research priorities

The grazing of young growing crops presents new opportunities in the mixed crop/livestock farming zone. The growing crops are excellent sources of both protein and energy for pregnant, lactating and growing sheep. Surveys of producers and consultants have confirmed that the value of this feed source is well recognised by producers and is becoming widely adopted (Masters and Thompson 2014).

While the growing crops have high production potential, they also come with an increased risk of a range metabolic disturbances and nutritional imbalances. These risks, if identified, are controllable and with identification and management will not compromise the potential benefits of grazing young crops.

In considering possible consequences for reproduction further investigation is justified into the importance of:

11. Grazing management to optimise livestock production. Given the different relationship between feed on offer and plant height in young crops compared with traditional pasture plants, information on feed on offer and voluntary feed intake is required to establish guidelines for stocking rate and grazing times.
12. Milk fever (hypocalcaemia), grass tetany (hypomagnesaemia) and sodium deficiency in pregnant and/or lactating grazing green crops. The composition of the crop forage means these mineral related problems are likely.
13. The pre-crop grazing diet on adaptation to green crops by both young growing and reproducing sheep. Previous research into the susceptibility to both acidosis and ammonia load indicate that when sheep are introduced to lush pastures from a different diet, an adaption period may cause temporary metabolic disturbance and result in a lag in growth.
14. Short term metabolic disturbance from acidosis or ammonia load following rapid introduction to green crops in late pregnancy. This may cause temporary inappetence leading to ketosis or pregnancy toxaemia.
15. Mineral supplements, particularly magnesium and sodium, on production and health of young and reproducing sheep grazing crops other than young wheat (including barley, oats and canola), across a range of different growing environments;
16. Selenium, copper, iodine and cobalt (vitamin B_{12}) status of ewes and growing lambs grazing crops in autumn and winter in trace element deficient regions.
17. Potential benefits in providing shelter and improved maternal behaviour around parturition.

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TABLES

Table1. Crude protein, digestibility and metabolisable energy in young growing crops

Crop	Crude protein (CP. %)	Dry matter digestibility (DMD, %)	Metabolisable energy (MJ/kg DM)[A]	Reference
Mackellar winter wheat (*Triticum aestivum*)		91.2[B]	14.0	(Kelman and Dove 2007)
Blackbutt oats (*Avena sativa*)		93.6[B]	14.4	(Kelman and Dove 2007)
Brassica (*Brassica campestris* cv Hunter)		81.3[C]	12.3	(Kelman and Dove 2007)
Brassica (*Brassica napus*, various cv)		86	13.1	(Kirkegaard *et al.* 2008)
Tennant winter wheat (*Triticum aestivum*)	21.2-23.8 (decrease with plant aging)	80.4 – 87.8 (decrease with plant aging/ higher NDF)[C]	12.1 – 13.4	(Dove *et al.* 2002)
Lorikeet winter wheat (*Triticum aestivum*)	31.1	84.0[C]	12.7	(Dove and McMullen 2009)
Mackellar winter wheat (*Triticum aestivum*)	31.3	87.6[C]	13.4	(Dove and McMullen 2009)
Marombi winter wheat (*Triticum aestivum*)	29.4	83.9[C]	12.7	(Dove and McMullen 2009)
Wedgetail winter wheat (*Triticum aestivum*)	32.9	85.3[C]	13.0	(Dove and McMullen 2009)
Whistler winter wheat (*Triticum aestivum*)	29.7	84.8[C]	12.9	(Dove and McMullen 2009)
Wylah winter wheat (*Triticum aestivum*)	32.0	85.6[B]	13.0	(Dove and McMullen 2009)
Wedgetail winter wheat	22.1	76.3[D]	11.4	(McGrath *et al.* 2014)

Crop	Crude protein (CP. %)	Dry matter digestibility (DMD, %)	Metabolisable energy (MJ/kg DM)[A]	Reference
(*Triticum aestivum*)				
Wedgetail winter wheat (*Triticum aestivum*)	26.9	85.0[D]	12.9	(McGrath *et al.* 2014)

[A] Equation 1.12A (Freer *et al.* 2007)

[B] *in vivo* DMD (fresh material harvested and fed to penned sheep each day)

[C] *in vitro* DMD

[D]Estimated using near infrared spectroscopy. DMD calculated using equation 1.9B (Freer *et al.* 2007)

Table 2. Predicted intake, growth and protein surplus in sheep grazing crops. Crops assumed to have 80% DMD and contain 30% crude protein.

Potential and prediction for a 50 kg ewe, medium merino breed type, derived from GrazFeed (Freer *et al.* 1997)

Livestock class	Potential feed intake (kg/day)	Predicted feed intake (kg/day	Predicted growth rate (g/day)	Predicted metabolisable energy intake (MJ/day)	Predicted crude protein intake (g/day)	Predicted crude protein surplus (g/day)
Pregnant ewes (1 lamb, day 120 pregnancy)	1.40	1.40	162	16.2	419.4	261.2
Lactating ewe (1 lamb, day 20 lactation)	2.09	2.08	56	24.1	624.1	326.3
Growing ewe (4 months old)	1.08	1.08	125	12.5	323.9	201.2

Table 3. Mineral content of young growing crops

Data sources from Dove (2007), Dove and McMullan (2009), Dove *et al*. (2012) and McGrath *et al.* (2014). Maximum (Max), minimum (Min), average (Average) concentrations measured from a total of N samples, the two samples from McGrath et al. (2014) were derived from composite samples in different experiments averaged over two collection dates. Where a requirement range is shown, the higher values are for rapidly growing or lactating sheep.

		Magnesium (g/kg DM)	Calcium (g/kg DM)	Potassium (g/kg DM)	Sodium (g/kg DM)	Phosphorus (g/kg DM)	Sulfur (g/kg DM)	Tetany index	K:Na ratio
Requirement (sheep) (Freer *et al.* 2007)		0.9-1.2	1.4-7.0	5.0	0.7-1.0	0.9-3.0	2.0		
Wheat	Max	2.6	5.4	50.5	0.8	4.2	4.2	6.4	469
	Min	0.8	2.0	27.3	0.08	2.1	1.8	2.0	34
	Average	1.4	3.3	37.5	0.4	3.0	2.9	3.6	163
	N	12	12	12	12	5	5	12	12
Oats	Max	2.4	4.2	42.4	10.6	2.5	2.6	5.08	25
	Min	1.2	2.3	23.0	1.7	2.5	2.6	1.56	2
	Average	1.8	3.2	31.7	5.0	2.5	2.6	2.90	11
	N	4	4	4	4	1	1	4	4

		Magnesium (g/kg DM)	Calcium (g/kg DM)	Potassium (g/kg DM)	Sodium (g/kg DM)	Phosphorus (g/kg DM)	Sulfur (g/kg DM)	Tetany index	K:Na ratio
Triticale	Max	2.7	5.8	34.9	3.7			3.13	87
	Min	1.1	2.8	25.1	0.4			1.45	7
	Average	1.9	4.2	29.7	1.5			2.23	56
	N	3	3	3	3			3	3
Barley	Max	1.5	6.7	41.9	2.9	2.3	2.8	4.23	70
	Min	1.2	3.1	33.4	0.6	2.3	2.8	1.87	12
	Average	1.4	4.9	37.7	1.8	2.3	2.8	3.05	41
	N	2	2	2	2	1	1	2	2
Canola	Max	1.4	7.1	31.0	0.3	2.1	3.3	1.69	103
	Min	1.4	7.1	31.0	0.3	2.1	3.3	1.69	103
	Average	1.4	7.1	31.0	0.3	2.1	3.3	1.69	103
	N	1	1	1	1	1	1	1	1

FIGURES

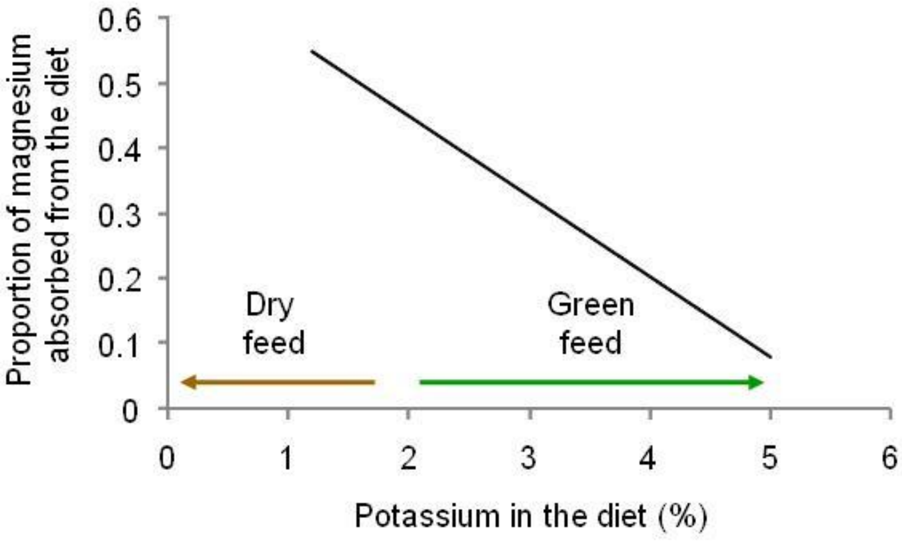

Fig 1. Influence of potassium intake on the absorption of magnesium by sheep (adapted from Suttle (2010).

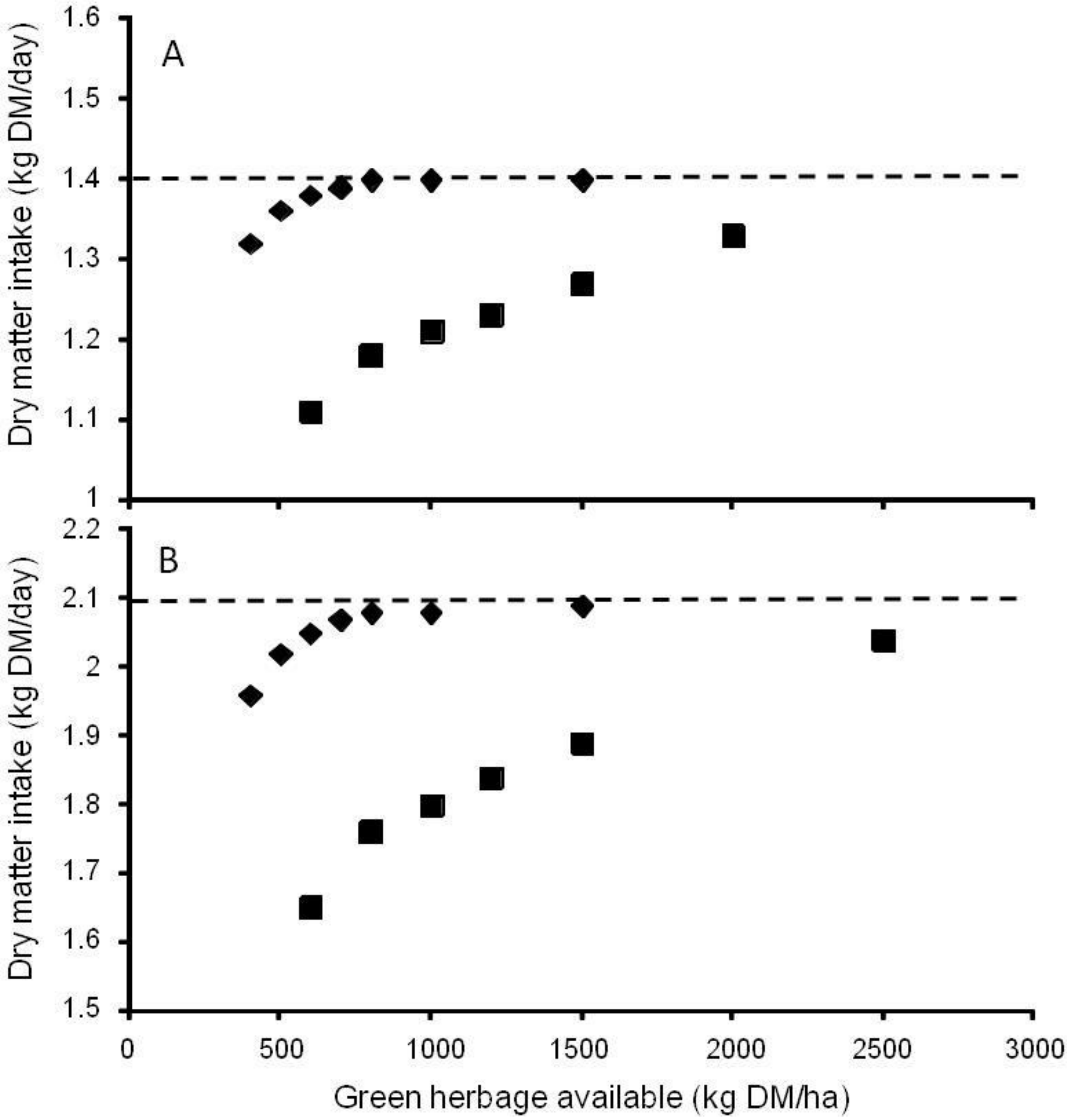

Fig 2. Predicted voluntary feed intake (Freer *et al.* 1997) of pregnant ewes (A - medium merino, 50 kg liveweight at day 120 of pregnancy and carrying one fetus) or lactating ewes (B - medium merino 50 kg liveweight at day 20 of lactation with one lamb) when grazing on green forage with height set as program default (■) or with forage height set manually as 1 cm per 60 kg DM (♦). Dotted line indicates potential dry matter intake for each class of animal and physiological state.

Appendix 2 – Producer and consultant interviews, Western Australia

Targeted interviews with consultants and producers in Western Australia with experience in grazing young crops

Compiled report

June 2014

Introduction

Activity 2 of the project "Fail safe guides to grazing pregnant and lambing ewes on cereals" is described as follows:

"Targeted interviews will be conducted with at least 10 consultants with clients that regularly graze cereal crops with pregnant ewes. The consultants will be selected from across a range of climatic zones in WA. In addition, in depth interviews will be conducted with at least 10 producers that regularly graze cereal crops. The information attained will be combined with information compiled during the literature review and with knowledge of project staff. These information sources will be combined to develop written management strategies to minimise ewe mortality and maximise lamb survival when grazing winter cereals."

This report addresses the first component of Activity 2 – interviews with consultants and producers

The interview process was carried out in three stages as follows:

1. A small workshop on researchers, development officers and consultants was held to discuss issues around grazing crops in Western Australia. During this workshop a set of interview questions was developed for producers and consultants and a preliminary list of appropriate consultants and producers was prepared from the knowledge of those attending the workshop.
2. Phone interviews were then carried out, initially with available consultants and producers from the preliminary list. Others were added or removed as a result of interview discussions or availability.
3. A post survey workshop attended by selected researchers and development officers was held at the end of the consultant/producers survey. The group was selected for their expertise in nutrition and reproduction with the aim drafting grazing strategies.

A report on the first workshop, together with the preliminary list of contacts was included in the Milestone 1 report and is not further described here.

Interview questions

The following list of questions was asked to each of interviewees from the two target groups.

Consultants

1. Do your clients graze young crops in winter?
2. Why do some of your clients choose not to graze crops?
3. What % clients graze crops and what % of their crops are grazed?
4. Why do your clients graze crops? What are the perceived/real benefits?
5. What class of animals are grazed on crops – pregnant ewes (i.e. removed before lambing); pregnant/lambing ewes; lactating ewes (ie, moved onto crop after lambing); finishing last year's lambs or dry stock?
6. If your clients graze crops with pregnant/lambing/lactating ewes, then:
    - When grazed – month, time in relation to lambing, period

- How is grazing managed? For example - what stocking rate, when are sheep moved on and off, are FOO levels managed, what decision rules are applied?
- Are mineral supplements used – if so, when, what, how much and how are they fed? If mineral supplements are not used, why not?
- Are other supplements provided (eg hay/straw)?
- What levels of animal production expected or achieved?

7. Animal health/welfare – are you aware if your clients experience any ill-health or deaths in sheep grazing crops? If so what is likely cause?
8. Gaps – do you or your clients see any need for research or demonstration to help build confidence in grazing crops with pregnant, lambing or lactating ewes – if so what are the priorities?
9. If the answer to question 8 is yes, would you or your clients be interested in participating is research or demonstration to address your concerns?
10. Do you have any other consultants/farmers that would be worthwhile contacting?

Producers

1. Do you graze young crops in winter?
2. What % or producers in your area graze crops? Why do some of your neighbours choose not to graze crops?
3. What % of your crops is grazed?
4. Why do you graze crops? What are the benefits?
5. What class of animals are grazed on crops – pregnant ewes (i.e. removed before lambing); pregnant/lambing ewes; lactating ewes (i.e. moved onto crop after lambing); finishing last year's lambs or dry stock?
6. If you graze crops with pregnant/lambing/lactating ewes, then:
    - When grazed – month, time in relation to lambing, period
    - How is grazing managed? For example - what stocking rate, when are sheep moved on and off, are FOO levels managed, what decision rules are applied?
    - Are mineral supplements used – if so, when, what, how much and how are they fed? If mineral supplements are not used, why not?
    - Are other supplements provided (eg hay/straw)?
    - What levels of animal production are expected or achieved?
7. Animal health/welfare – have you/do you experience any ill-health or deaths in sheep grazing crops? If so what is likely cause?
8. Gaps – do you see any need for research or demonstration to help build confidence in grazing crops with pregnant, lambing or lactating ewes – if so what are the priorities?
9. If the answer to question 8 is yes, would you or your clients be interested in participating is research or demonstration to address your concerns?

10. Do you have any other consultants/farmers that would be worthwhile contacting?

Interviews

Most interviews were conducted by phone after the consultant or producer had been sent the list of questions at least a week earlier. Interviews ranged from 25 – 50 minutes each. This sometimes followed an earlier call and preliminary discussion. Consultants and producers interviewed are listed in Table 7 and Table 8.

Table 7. Consultants interviewed and their area of influence

Consultant	Area of influence	Date interviewed
Paul Omodei	Manjimup based. Boyup Brook, Gnowangerup, Jerramungup	19/03/2014
John Milton	Perth based. Influence primarily south west	21/03/2014
Phil Barrett Lennard	Gingin based. Broad influence through Grain & Graze	25/03/2014
Allan Peggs	Southern, Northern and Central Agricultural regions	18/04/2014
Ashley Herbert	Katanning based. Southern and Central Agricultural regions	21/03/2014
Steve Curtin	Lake Grace based. Central Agricultural region. Low – medium rainfall	25/03/2014
Andrew Ritchie	Darkan based. Southern and Central Agricultural regions	04/04/2014
Eric Nankivell	Esperance based	07/04/2014
Bob Hall[A]	Darkan. Southern and Central Agricultural regions	01/04/2014
Jonathan England (DAFWA Development Officer)[A]	Narrogin based. Southern and Central Agricultural regions	25/02/2014
Dean Thomas (CSIRO Research Scientist - grazing crops)[A]	Perth based. Research in eastern wheatbelt	10/04/2014
Andrew Bathgate (Grazing systems economist)[A]	Albany based. Economic assessment for Grain and Graze	08/04/2014
Danny Roberts (DAFWA, District Veterinary Officer, Albany)[A]	District Veterinary Officer, Albany	27/5/2014

[A] Discussion were held with these individuals as they had information that was useful and relevant to this survey. They were usually asked for information on a relevant subset of the formal questions.

Table 8. Producers interviewed

Producers	Location	Agricultural Region	Rainfall zone[A]	Date interviewed
Rob Edgerton Warburton	Kojonup	Southern	Medium	01/04/2014
Kane Page	Pingelly	Central	Medium	26/03/2014
Simon Fowler	Esperance	Southern	High	03/04/2014
Don Nairn	Binnu	Northern	Low	08/04/2014
Marcus Sounness	Borden	Southern	Medium	26/03/2014
Andrew Watts	Wandering	Central	High	26/3/2014
Clayton South	Wagin	Central	Medium	09/04/2014
Tony York	Tammin	Central	Low	15/04/2014
Nathan Brown	Jerramungup	Southern	Low	03/04/2014

[A] Based on nearest town with rainfall records

Producers were selected to provide some representation of low, medium and high rainfall zones (Figure 2) and the major agricultural regions where both crops and sheep are grown (Figure 3).

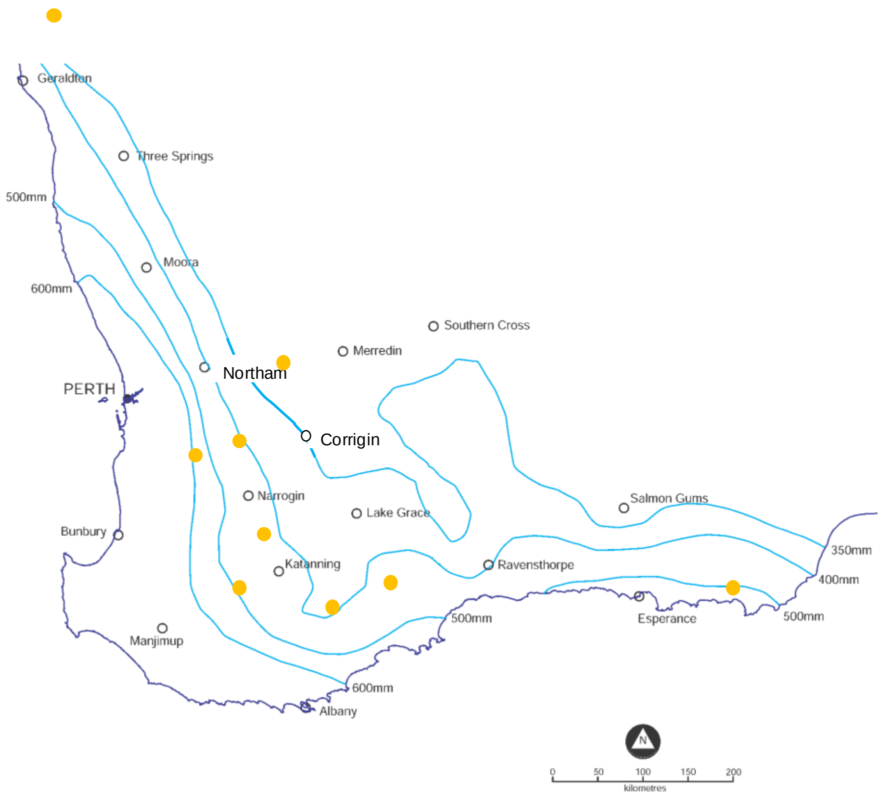

Figure 2. Rainfall isohyets and approximate location of interviewed farmers in Western Australia (map courtesy of G Doole, University of Western Australia)

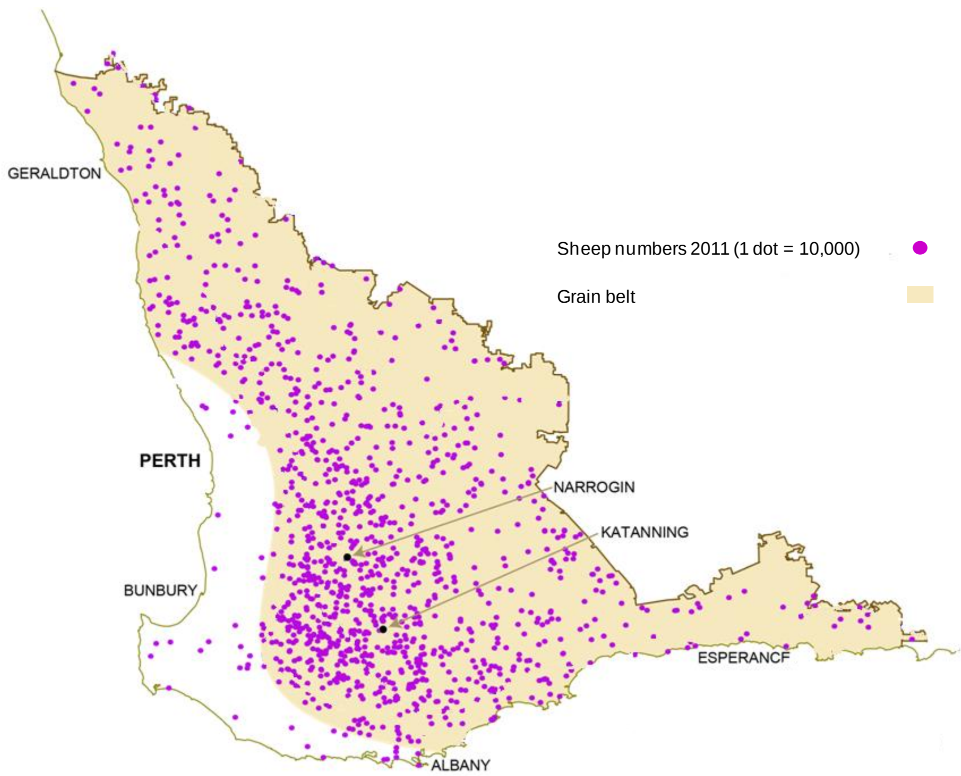

Figure 3. Distribution of sheep and grain growing zones in Western Australia (map courtesy of K Curtis, Department of Agriculture and Food, WA)

Consultant interviews

Do your clients graze young crops in winter?

Across the client base, the proportion of clients that grazed crops ranged between 0 and 50% with the most common proportion between 5 and 25%. For many producers, grazing crops was described as an opportunistic activity and depended on seasonal conditions with crop grazing used when pasture availability was poor or when poor expected crop yields resulted in sacrificial grazing of the crop.

Crops were grazed less in low and medium rainfall zones due to a perceived risk of yield loss and crop damage.

Why do some of your clients choose not to graze crops?

This question was directed to clients, but many consultants chose to provide their own opinions on crop grazing.

There were a range of answers to this question, in order of importance[11] they were:

1. Concern over yield loss. Particularly low and medium rainfall areas. Expectation that this feed is not free. Small yield loss will mean loss of overall farm profit.
2. Benefits have not been clearly quantified and communicated.
3. To be justified, the producer needs to be able to run more sheep, it is not worth the effort to simply save a small amount on supplement costs – not convinced more sheep can be carried.
4. Requires effort to set up paddocks to ensure they are weed free.
5. Tends to be less sheep and sheep are a lower priority on the farm. Reluctance to allocate the extra labour required for this. Prefer to de-intensify sheep enterprise.
6. Benefits from deferred grazing mean some additional pasture growth but little improvement in pasture quality.

What % clients graze crops and what % of their crops are grazed?

Response to first part of this question has been incorporated into first question above. The second part of the question was expanded to include a description of the type of crops grazed.

Proportion of the crop grazed was highly variably and depended on year/season, location and individual initiative. Most clients grazed small proportions of the crop (5 – 20%). Others grazed up to 50%, and, at the extreme end, one producer only had a crop/shrub farming system and in some years grazed 100% of the crop. Larger properties tended to graze crops on a larger scale, particularly around the Katanning area.

All crop species are used for grazing by some producers; this specifically includes wheat, barley, oats and canola. There is more grazing of cereals than canola.

The crops grazed are traditionally spring varieties although some producers (a minority) are experimenting with dual purpose winter varieties.

[11] Assessed as most commonly provided answers across the group.

Why do your clients graze crops? What are the perceived/real benefits?

A range of responses were given, in order of importance they were:

1. Filling the winter feed gap.
2. Deferred grazing of pasture paddocks – improved spring pastures.
3. Reduced requirement for supplements.
4. Manipulation (delay) of flowering time to avoid the risk of frost damage (location dependant).
5. Allows planting of a higher proportion of the farm to crop (without reducing livestock)
6. Increased production per head (wool and improved condition).
7. Management of poor seasons.
8. More flexibility in farm management.
9. Replacement for agistment.
10. Part of a weed control strategy.

It appears at this stage that many producers are still gaining confidence in a crop grazing strategy, many use it to improve the stock they have rather than increase farm stocking rate.

What class of animals are grazed on crops?

All classes of livestock were grazed on crops across different locations, specifically these included:

- Dry sheep/maiden ewes/wethers
- Pre-lambing ewes
- Ewes through late pregnancy and early lactation

Overall a smaller proportion of clients grazed dry sheep or finished lambs on crops. Most clients grazed pregnant ewes towards the end of pregnancy and removed the ewes prior to lambing, those with more confidence and interest continued to graze crops through lambing. Lambing on crops required some additional labour allocation with use of a strategy to drift ewes into adjoining paddocks as they lambed.

Lambing on crops was more common in the high rainfall areas and losses of lambs were claimed to be low with a drift lambing system (provided correct paddock preparation and management was applied).

Crops were usually grazed for 2 – 5 weeks.

If your clients graze crops with pregnant/lambing/lactating ewes, then:

When grazed – month, time in relation to lambing, period

Grazing mostly in June and July with some extending into August. Occasional grazing as early as May on the south coast.

How is grazing managed?

Management strategies very dependent on knowledge, goals, season and location. For most, grazing commenced when feed on offer (FOO) was between 250 and 800 kg DM/ha and plants passed the anchor test. Strategy from this point for some clients included a relatively high input strategy of grazing to match expected crop growth (eg 10+ DSE/ha for anticipated crop growth of 20 – 40 kg DM/ha/day) for others, strategy was simply to 'snip' graze, taking the top off the crop, low stocking rate and moving regularly to minimise leaf reduction. Those that grazed at the more intensive end of the spectrum grazed down close to the ground.

For most, residual biomass was around 3 – 5 cm crop height with a strong likelihood of variable (patch) grazing causing an uneven impact.

There was some lack of confidence around the Grain & Graze estimates that 1 cm of crop represented 60 kg DM/ha. This may also contribute to a conservative stocking rate and grazing strategy.

Are mineral supplements used – if so, when, what, how much and how are they fed?

Only one of the consultants interviewed indicated that a significant proportion of his clients used mineral supplements (about 50%). Lime, dolomite (or causmag) and salt were the supplements of choice, with less salt used in winter.

Others indicated that mineral use was not widespread, partly because they were difficult to manage, and many considered deficiencies were unlikely to develop in the very short length of the grazing period.

Where minerals were fed, they were provided in 200 L drums cut in half. Shelter was sometimes but not always provided.

It was not clear from these discussions whether the low use of minerals was true or whether this was a level of management detail that some consultants were not familiar with.

Are other supplements provided (eg hay/straw)?

As with mineral supplements, consultants indicated that other supplements such as straw and hay were also rarely used – this observation is not entirely consistent with responses from producers (see below).

What levels of animal production expected or achieved?

Few specific details of expected production could be provided, most expected benefits have been described in an earlier question (see above). Those with clients with more specific goals indicated achievement of a condition score increase of 0.1 in late pregnancy and a reduction of 0.1 in early lactation as an expected level of production improvement.

Animal health/welfare issues

Incidence of health issues was sporadic. Approximately 30% of the consultants described problems with occasional ketosis, hypocalcaemia and grass tetany or with undiagnosed health problems associated with rapid introduction onto crops, but most indicated they were unaware of problems.

Nitrate poisoning was identified as a risk but no examples of this occurring were provided.

Some examples were given of undiagnosed metabolic disturbance that had caused loss of livestock – these incidents had caused some loss of confidence by surrounding farmers and a reluctance to trial crop grazing.

Benefits identified included the ability to move livestock into a worm free paddock.

As with supplement use, it was not clear from these discussions whether low/isolated stock losses was a level of management detail that some consultants were not familiar with.

Possibility of unrecognised metabolic disease or disturbance was subsequently pursued in discussions with the DAFWA, District Veterinary Officer in Albany. In his experience, causmag supplements were sometimes used but often not consumed. He was not aware of any association between the grazing of young crops and either hypocalcaemia, grass tetany or acidosis.

Gaps in knowledge and confidence

1. For those who remain unconvinced of the advantages, quantification of the benefits, possibly through on farm demonstrations is a priority. This would need to include measurement of crop losses (including impact of patch grazing) and livestock change (including stocking rate) under different scenarios (climate x soil x stocking rate x grazing intensity). It could also include some assessment of ancillary benefits such as delayed flowering, water use efficiency, worm management. This is firstly a priority to convince consultants, not just producers – many are sceptical.

   Some consideration needs to be given to the practicalities of this approach as the potential combination of scenarios is high (both over time and space). A more realistic approach may be to cooperate with practicing farmers to quantify their benefits and use their properties for workshops/field days.

   Alternatively, techniques are now available that would reduce the requirement for on ground activities. The use of satellite imagery to assess grazing combined with measured, within paddock, crop yields would allow assessment of impact at scales ranging from sub-paddock to landscape. Data for this approach is already available.

2. Quantification of benefits of deferred pasture use. There were differences in opinion on whether this was simply more biomass in pasture paddocks or improved pasture quality.
3. Clarification of potential mineral deficiency problems to include:
   - Mineral composition of crops in WA.
   - Mineral status of sheep grazing young crops (to include nitrate toxicity indicators).
   - Documentation of losses from metabolic disease.
4. Introduction of stock to grazing crops – influence of previous feeding and condition on susceptibility to metabolic disorders.
5. Potential to use longer growing season varieties.
6. How to manage sheep in large cropping paddocks (low stocking rates) with potential incidence of patch grazing.

Participation in future research or demonstration

Table 9. Participation in future research or demonstrations - Consultants

Consultant	Possible client participation in future research/demonstration
Paul Omodei	Yes
John Milton	Possible
Phil Barrett Lennard	-[A]
Allan Peggs	Yes
Ashley Herbert	-
Steve Curtin	Already involved in research/demonstration
Andrew Ritchie	Yes
Eric Nankivell	Through Asheep
Bob Hall	-

[A]Dash does not necessarily indicate no participation, may depend on activity and perceived value.

Producer interviews

Do you graze young crops in winter?

The majority of those interviewed were from the medium – high rainfall zones in the southern or central agricultural regions (Figure 2) in areas with the highest sheep populations in the state (Figure 3). The properties ranged in size and most were 30 – 50% sheep and 50 – 70% crop. The property at Binnu was only 15% sheep.

All the producers interviewed grazed crops – this was expected as it was part of the selection criteria. Many had been grazing crops for 5 – 10 years, indicating for these producers at least this was a system change and not an experiment. Most indicated that crops were not grazed every year.

What % of producers in your area graze crops? Why do some of your neighbours choose not to graze crops?

The proportion of neighbours grazing crops ranged from 0 to 40%. The proportion was lower in the low rainfall areas.

The reasons for choosing to graze or not to graze were interesting. Primary concern was, as expected, potential damage to the crop and reduced yield, but there also appeared to be a strong influence of consultant used and possibly information from other local sources such as farmer groups (eg ASheep). A strong influence from one specific consultant appeared to have contributed to 30-40% of the producers in one area grazing crops. Conversely, another producer put the view that most consultants (particularly those based on low – medium rainfall cropping zones) dislike grazing crops and advise against it, these consultants focus on the negatives and overall are anti-sheep. The view was put that these advisors tend to be skilled in crop technology and lack sheep management knowledge.

Other reasons for avoiding crop grazing were:

1. They have few sheep and livestock are not seen as a priority.
2. There is a move towards low input livestock systems and grazing crops is too much effort for a small reward.
3. Crops must be very clean and weed free before grazing or these weeds will have a growth advantage when grazing ceases.
4. Lack of confidence.
5. Not comfortable with moving sheep during lambing.

For some of the producers, Grain & Graze had also influenced their decision to experiment with grazing crops.

What % of your crops is grazed?

All but one of the producers interviewed grazed a very high proportion of their crop in some years. Proportions ranged from 40 – 100% as a maximum. In some cases a lack of sheep was the limitation on grazing rather than concerns around yield loss. This indicated confidence in the system. At the other end of the scale, in years when feed was not in short supply, most producers grazed little or none of their crop.

Crops grazed were predominantly cereals – barley, wheat and oats. Canola was grazed much less. There were two reasons for this. The first was concern around the coincidence of grazing and herbicide spraying and uncertainty around withholding periods. The second related to the later growth of canola providing less grazing opportunity combined with a higher risk of delayed flowering causing yield loss.

Why do you graze crops? What are the benefits?

There were many benefits provided in the producer interviews, these are summarised in Table 10.

All producers recognised benefits to livestock – most of them specifically identified filling the winter feed gap with related responses including increased carrying capacity, better sheep production, less supplement use and reduced need for agistment. One producer indicated he had been able to double the number of stock carried on the farm. Most of the producers also believed there were benefits to pasture from deferred grazing and three of those interviewed used the availability of worm free crop paddocks as part of their worm control strategy.

Most but not all producers also described benefits to the cropping system, and, in particular, to crop health. Livestock were used to improve the control of weeds, fungus and insect pests and as a tool to delay flowering and avoid frost damage. A smaller proportion identified crop production benefits included the ability to plant a larger area to crop, improved water use efficiency (and higher crop yield) after dry winters and easier harvest through less stem bulk. Two of the producers identified deferment of grazing as an opportunity to manipulate pastures for improved crop production in upcoming years.

Three producers indicated grazing crops provided more flexibility on the farm and one planted crops on light soils to reduce erosion while maintaining a low level of production.

Table 10. Summary of benefits as identified by producers

Identified benefit	Type of benefit	Positive responses	Category compiled
Winter feed gap/more feed	Animal production	7	
Increased carrying capacity	Animal production	2	
Better sheep production	Animal production	4	
Less supplement use	Animal production	2	
Reduced need for winter agistment	Animal production	1	
Deferred grazing for improved pastures/less fertiliser for pasture required	Animal production	6	
Worm control	Animal health	3	25
Manipulate pastures for improved cropping in subsequent years	Crop production	2	
More crop planted	Crop production	2	
Improved water use efficiency	Crop production	2	
Easier harvest - less stem bulk with no yield loss	Crop production	2	
More efficient herbicide use	Crop health	2	
Better control of crop disease (fungus and/or insects)	Crop health	5	
Delayed flowering for frost avoidance	Crop health	3	18
More flexibility in production system - peace of mind	Whole farm benefit	3	3
Groundcover benefit - light soils	Environmental benefit	1	1

What class of animals are grazed on crops?

Crops are primarily grazed by ewes in the last few weeks of pregnancy or during lambing and into lactation although, depending on requirements, any class of sheep may be used.

Some of the producers interviewed were comfortable with ewes lambing on young crops and drifting the ewes and lambs into adjoining paddocks as feed becomes scarce, others prefer to graze in the last few weeks of pregnancy but avoid the (perceived) risk of moving ewes during lambing.

If you graze crops with pregnant/lambing/lactating ewes, then:

When grazed – month, time in relation to lambing, period

Grazing is usually in June and July with some extending as far as the second week of August.

How is grazing managed?

There are few standard rules followed by producers for grazing crops. There was consistency around the commencement of grazing where the crop needs to have been established long enough to pass the anchor test[12] .

Grazing after this time appeared to be subject to a range of personal preferences. Some grazing was at a high stocking rate (eg 50 - 60 DSE/ha) designed to provide additional feed to sheep but also to delay flowering. Crops may be grazed to ground levels. At the other extreme, grazing was light with the removal of only the top 30% of the leaf. Usually at least 2-3 cm of leaf would be left after grazing.

Grazing was often for short periods (days/weeks) with frequent rotation if longer grazing was required.

The majority of producers take a conservative approach as crop yield is still the first priority.

Managing the integration of crops and livestock also influenced grazing management where large cropping paddocks, combined with small and discrete ewe flocks, meant conservative grazing was inevitable. The alternative of combining ewe flocks (and later splitting) was not preferred.

Are mineral supplements used – if so, when, what, how much and how are they fed?

Mineral supplements are used by most of the interviewed producers but the content and timing was irregular and to some extent haphazard. The recommended mix of salt, limestone and causmag (or at least a variation of it) was used by four producers, but not necessarily for the full period of grazing. Three other used proprietary mixtures that were not specifically designed for crop grazing, some of these contained magnesium, and two producers used no mineral supplement.

There were some strong claims that magnesium was essential to reduce the incidence of scouring.

[12] Anchoring is defined as when plants have grown secondary roots and is tested using a pinch and twist test (see Grain & Graze, Free Food for Thought)

The opinion was expressed by some producers that, because grazing was for a short period, enough mineral would be stored in the body and a deficiency is unlikely. This logic is based on assumption the body has a readily and rapidly mobilisable store of sodium, magnesium and calcium stored that can meet short term demand and is incorrect.

Are other supplements provided (eg hay/straw)?

Use of straw and hay supplements was also irregular with the majority of producers providing some hay within the paddock.

What levels of animal production expected or achieved?

Most expected benefits have been described in an earlier question (see above). Those able to specifically address this question indicated that ewe's condition score could be improved leading up to parturition and loss minimised during lactation.

Animal health/welfare issues

Given the irregular use and composition of mineral supplements provided, and the known mineral content of crops analysed in the eastern states, some mineral associated health problems would be expected.

The expected health issues of hypocalcaemia (milk fever) and hypomagnesaemia (grass tetany) were not common. This may be due to different mineral composition of crops grown in WA or to alternative sources of minerals – for example, all those interviewed confirmed that sheep preferentially eat all weeds in the crop prior to consuming the crop. Alternatively mortality may be underestimated.

Scouring was the most common health problem identified. As indicated above this was believed to be related to a lack of magnesium.

One producer indicated there was a lag in growth during transition to crops and a second suggested it was important to ensure sheep were not introduced to crops when in poor condition or with an empty stomach. Both these observations are consistent with susceptibility to short term chronic acidosis caused by a sudden change in diet.

Gaps in knowledge and confidence

1. For those who remain unconvinced of the advantages, quantification of the benefits, possibly through on farm demonstrations were suggested. This would need to include activities in low rainfall areas. This should provide some hard data on livestock and crop benefits.
2. Interaction with grower groups to possibly include bus trips to visit successful operations.
3. Causes of scouring in sheep grazing young crops.
4. Implication of patch grazing on crop yields. Common observation that sheep do not graze crop paddocks evenly.
5. Testing of alternative crops (eg sorghum) and alternative varieties (eg wedgetail wheat, oxford barley).
6. Mineral status of sheep and mineral composition of crops in WA.

7. Withholding period for atrozine when used on canola.
8. Production of a ready reckoner (app) to predict crop/livestock trade-off and assist with decision making.

Participation in future research or demonstration

Table 11. Participation in future research or demonstration - Producers

Producer	Possible participation in research demonstration
Rob Edgerton Warburton	Probably not – previous experience not positive
Kane Page	Yes – small paddocks and lambs in small mobs
Simon Fowler	Possibly as part of ASheep alliance http://asheep.gga.org.au/
Don Nairn	Already involved
Marcus Sounness	Possibly
Andrew Watts	Yes – well set up with many paddocks
Clayton South	Yes
Tony York	Already involved in research
Nathan Brown	Yes

Post survey workshop

A second workshop attended by selected researchers and development officers was held at the end of the consultant/producers survey.

The aim was to review survey outcomes and provide input towards the development of management strategies and the identification of knowledge gaps. The workshop was held on 6 June 2014 and participants were primarily chosen because of research experience with the Lifetime Wool project and a high level of practical knowledge in the nutritional management of pregnant and lactating ewes on pastures.

Table 12. Post survey workshop participants

Name	Affiliation
David Masters	UWA/CSIRO
Andrew Thompson	Murdoch University
Chris Oldham	DAFWA
Beth Paganoni	DAFWA
Mandy Curnow	DAFWA
Jonathan England	DAFWA

Gaps identified by the project and workshop team

There were a number of knowledge gaps that were identified by the project team in the preparation of management strategies that were not explicitly recognised by either consultants or producers. These were deemed important in the establishment of feed availability and the intensity of sheep in lambing areas. The gaps were:

1. There was a clear gap in understanding the interaction between FOO, feed intake and livestock production. Under pasture conditions, FOO recommended for pregnant lactating ewes is at least 1200 kg DM/ha. Translating this to crops would mean crop height for grazing would need to be at least 17 cm high (1 cm = 70 kg biomass). Clearly crops are grazed at much lower heights and livestock production is not reported to suffer. Recommendation for grazing crops therefore require information on the relationship between FOO and intake (growth).
2. There is recent research that indicates lamb survival may be influenced by the intensity of sheep around the birth site. The option to graze large numbers of ewes in large cropping paddocks, combined with the tendency of ewes to aggregate and patch graze part of the paddock, means sheep intensity at the birth site may be high. This has the potential to influence early lamb survival.

Summary

This survey provides a valuable companion document to the scientific review “Grazing crops – implication for reproducing ewes”. Interviews with consultants and producers provided a significantly broader information base on the practical benefits and concerns. Many of these are not evident from review of the literature alone.

The proportion of producers grazing young crops is a minority (<25%). This is partly due to a decline in sheep in the mixed farming zones but also related to concerns around loss of crop yield. The concerns were most strongly expressed in interviews with consultants. There was clearly a lack of confidence in the strategy expressed by a high proportion of the consultants. If crop grazing is to be expanded then consultants will need to be presented with quantified and convincing information on the aggregated benefits.

Given the strong influence of consultants and the current anti-sheep sentiments of many consultants based in the low-medium rainfall zones, the evidence will need to be credible and the message compelling.

Crops grazed were predominantly cereals, wheat, barley and oats. Canola was grazed less due to concerns over withholding periods after spraying and a later growth pattern. The crops grazed were usually traditional crop varieties with only occasional planting of dual purpose varieties. Producers grazed up to 100% of the crop, but usually between 0 and 40%, depending on the availability of alternative fed sources.

It was clear from both sets of interviews that crops in Western Australia are predominantly grazed by reproducing ewes – either in late pregnancy and/or lactation. Some producers were confident in lambing on crops, others much less so. Management guidelines for pregnant and lactating ewes are therefore pertinent.

The benefits identified across the consultants and producers included a range of livestock and crop improvements. While most of these involved carrying more sheep or improved sheep production over winter, many producers had a more systems based view of grazing crops and identified improvements in crop health and ability to plant more crop as significant advantages. For some, grazing crops provided more management flexibility and less stress.

A reduction in crop yield appeared to be the primary concern for those not grazing crops, although the additional labour requirement and lack of perceived livestock and pasture benefits also contributed.

Grazing of crops was predominantly in June and July, most producers were reluctant to graze into August although some did. There were no standard grazing strategies. While all producers ensured crops were anchored before grazing, after this time stocking rates, length of grazing and the amount of crop left after grazing varied depending on objectives, location, season and confidence. The lack of a standard grazing strategy and variable objectives indicates guidelines may need to be based on some simple plant-focussed rules (eg date to stop grazing and minimum crop height), rather than livestock based decisions.

Overall there was a very poor understanding of the potential mineral deficiencies created by grazing crops and of the recommended composition of supplements. Few producers used the recommended sodium/calcium/magnesium supplement at the times when most required. This was at least partly related to two perceptions:

- Few producers (or consultants) could recall any major incidence of metabolic disease (grass tetany, hypocalcaemia). Therefore minerals were not seen as a priority.
- Many of those interviewed believed that, with the short grazing periods, livestock would have sufficient minerals stored in the body to provide for requirements.

While the second dot point is incorrect for the metabolic diseases of concern, the lack of observed health problems does require explanation. It may be that the spring crops grown in WA have more minerals than those analysed in the Eastern States, or it may be that minerals are being sourced from elsewhere. Some relatively low input survey work to analyse young crops and measure mineral status of grazing sheep would resolve the issue.

Observations that magnesium prevents scouring also requires some explanation and may be a component of future guidelines if correct.

Gaps in the knowledge can be partitioned into two categories:

- Those relevant to grazing crops by any class of livestock.
- Those relevant to grazing pregnant and lactating ewes.

Those in the first category are relevant to reproducing sheep, but to some extent are already covered by through other R & D programs (eg Grain and Graze 2).

Gaps that have specific relevance to reproducing ewes include:

- On farm demonstrations with reproducing ewes (including lambing ewes) to include quantification of system benefits and costs (livestock and crop).
- Mineral composition of crops and mineral status of reproducing ewes grazing crops (including assessment of magnesium and scouring).
- Preferred methods of introducing livestock onto crops – specifically ewes in late pregnancy that may be susceptible to pregnancy toxaemia.
- Information on the relationship between FOO, feed intake and livestock production – this is clearly different from annual pasture relationships.
- Relevance of sheep intensity around the birth site to lamb survival.

In conclusion, grazing young crops appears to have the potential to transform the mixed farming zones in Western Australia. Those that have adopted the practice are confident the benefits outweigh the costs The primary change will be an increase in the distribution of reproducing ewes back into areas that have become almost exclusively cropping. This change will be driven by an increase in whole farm profit and a reduction in seasonal risk. The consequence will be increase in production of both lambs and wool.

Appendix 3 – Producer and consultant interviews, South Australia, Victoria and New South Wales

Targeted interviews with consultants and producers in Victoria, South Australia and New South Wales with experience in grazing young crops

Compiled report

September 2014

Introduction

Activity 2 of the project “Fail safe guides to grazing pregnant and lambing ewes on cereals” is described as follows:

“Targeted interviews will be conducted with at least 10 consultants with clients that regularly graze cereal crops with pregnant ewes. The consultants will be selected from across a range of climatic zones in WA. In addition, in depth interviews will be conducted with at least 10 producers that regularly graze cereal crops. The information attained will be combined with information compiled during the literature review and with knowledge of project staff. These information sources will be combined to develop written management strategies to minimise ewe mortality and maximise lamb survival when grazing winter cereals.”

Following the completion of this activity in Western Australia there appeared to be inconsistencies between the interview results with the published literature and anecdotal evidence available from grazing studies and experience in the eastern states (South Australia, Victoria and New South Wales). On the basis that this information from other states was unstructured, a decision was made to extend the interviews to determine if perception and experiences were different across states.

The interview process was therefore repeated in southeast Australia with 10 consultants and 10 producers that regularly graze cereal crops, from South Australia, Victoria or New South Wales.

The interview process was carried out in two stages as follows:

4. One of the authors (JS) prepared a list of producers and consultants with experience in grazing young crops for interview. The list was primarily based on professional contacts and experience.
5. Phone interviews were then carried out with available consultants and producers.

Interview questions

The following list of questions was asked to each of interviewees from the two target groups. The questions were identical to those asked to Western Australian producers and consultants, with minor modifications around height of crops at the start and end of grazing.

Consultants

1. Do your clients graze young crops in winter?
2. Why do some of your clients choose not to graze crops?
3. What % clients graze crops and what % of their crops are grazed?
4. Why do your clients graze crops? What are the perceived/real benefits?
5. What class of animals are grazed on crops – pregnant ewes (i.e. removed before lambing); pregnant/lambing ewes; lactating ewes (ie, moved onto crop after lambing); finishing last year’s lambs or dry stock?
6. If your clients graze crops with pregnant/lambing/lactating ewes, then:
    - When grazed – month, time in relation to lambing, period

- How is grazing managed? For example - what stocking rate, when are sheep moved on and off, are FOO levels managed, what decision rules are applied?
- Are mineral supplements used – if so, when, what, how much and how are they fed? If mineral supplements are not used, why not?
- Are other supplements provided (eg hay/straw)?
- What levels of animal production expected or achieved?

7. Animal health/welfare – are you aware if your clients experience any ill-health or deaths in sheep grazing crops? If so what is likely cause?
8. Gaps – do you or your clients see any need for research or demonstration to help build confidence in grazing crops with pregnant, lambing or lactating ewes – if so what are the priorities?
9. If the answer to question 8 is yes, would you or your clients be interested in participating is research or demonstration to address your concerns?
10. Do you have any other consultants/farmers that would be worthwhile contacting?

Producers

1. Do you graze young crops in winter?
2. What % or producers in your area graze crops? Why do some of your neighbours choose not to graze crops?
3. What % of your crops is grazed?
4. Why do you graze crops? What are the benefits?
5. What class of animals are grazed on crops – pregnant ewes (i.e. removed before lambing); pregnant/lambing ewes; lactating ewes (i.e. moved onto crop after lambing); finishing last year's lambs or dry stock?
6. If you graze crops with pregnant/lambing/lactating ewes, then:
    - When grazed – month, time in relation to lambing, period
    - How is grazing managed? For example - what stocking rate, when are sheep moved on and off, are FOO levels managed, what decision rules are applied? What is the minimum height of the crop before grazing commences? What is the minimum height when sheep are removed?
    - Are mineral supplements used – if so, when, what, how much and how are they fed? If mineral supplements are not used, why not?
    - Are other supplements provided (eg hay/straw)?
    - What levels of animal production are expected or achieved?
7. Animal health/welfare – have you/do you experience any ill-health or deaths in sheep grazing crops? If so what is likely cause?
8. Gaps – do you see any need for research or demonstration to help build confidence in grazing crops with pregnant, lambing or lactating ewes – if so what are the priorities?

9. If the answer to question 8 is yes, would you or your clients be interested in participating is research or demonstration to address your concerns?
10. Do you have any other consultants/farmers that would be worthwhile contacting?

Interviews

Interviews were conducted by phone with the consultant s and producers. The interviews ranged from 25 to 50 minutes each. This sometimes followed an earlier call and preliminary discussion. Consultants and producers interviewed are listed in Table 13 and Table 14.

Table 13. Southeast Australian Consultants interviewed and their area of influence

Consultant	Area of influence	Date interviewed
Garry Armstrong	Northern Victoria, Riverina region of NSW	26/08/2014
Ken Solly	South east South Australia, Western Victoria	26/08/2014
Hamish Dickson	South Australia, western Victoria and Western NSW	27/08/2014
Rob Inglis	Southern NSW and Northern Victoria	29/08/2014
Megan Rogers	Central West of NSW	05/09/2014
Daniel Salmon	Riverina region of NSW	05/09/2014
Sally Martin	South West Slopes of NSW	06/09/2014
Cam Nicholson	Corangamite/Glenelg-Hopkins region of southern Victoria	08/09/2014
Simon Falkner	Geelong region	08/09/2014
Lyndon Kubeil	Benalla region	08/09/2014

Table 14. Southeast Australian producers interviewed

Producers	Location	Agricultural Region	Rainfall zone[A]	Date interviewed
Amanda Manifold	Mortlake	South West Victoria	High	27/08/2014
Charles de Fegely	Ararat	Western Victoria	Medium	04/09/2014
Marcus Wintercooke	Tahara	South West Victoria	High	04/09/2014
Andrew Boufler	Lockhart	Riverina region of NSW	Medium	05/09/2014
David Rogers	Forbes	Central West of NSW	Low	06/09/2014
Ray Norman	Illabo	South West slopes of NSW	Medium	06/09/14
Toby Jones	Junee	Riverina/south west slopes of NSW	Medium	06/09/14
John Rohde	Jamestown	Mid North of SA	Medium	07/09/14
Tim Ferguson	Hopetoun	Mallee	Low	08/09/14
Alistair Day	Bordertown	Tatiara region of SA	Medium	08/09/14

[A] Based on nearest town with rainfall records

Producers were selected to provide some representation of low, medium and high rainfall zones and the major agricultural regions where both crops and sheep are grown (Figure 4).

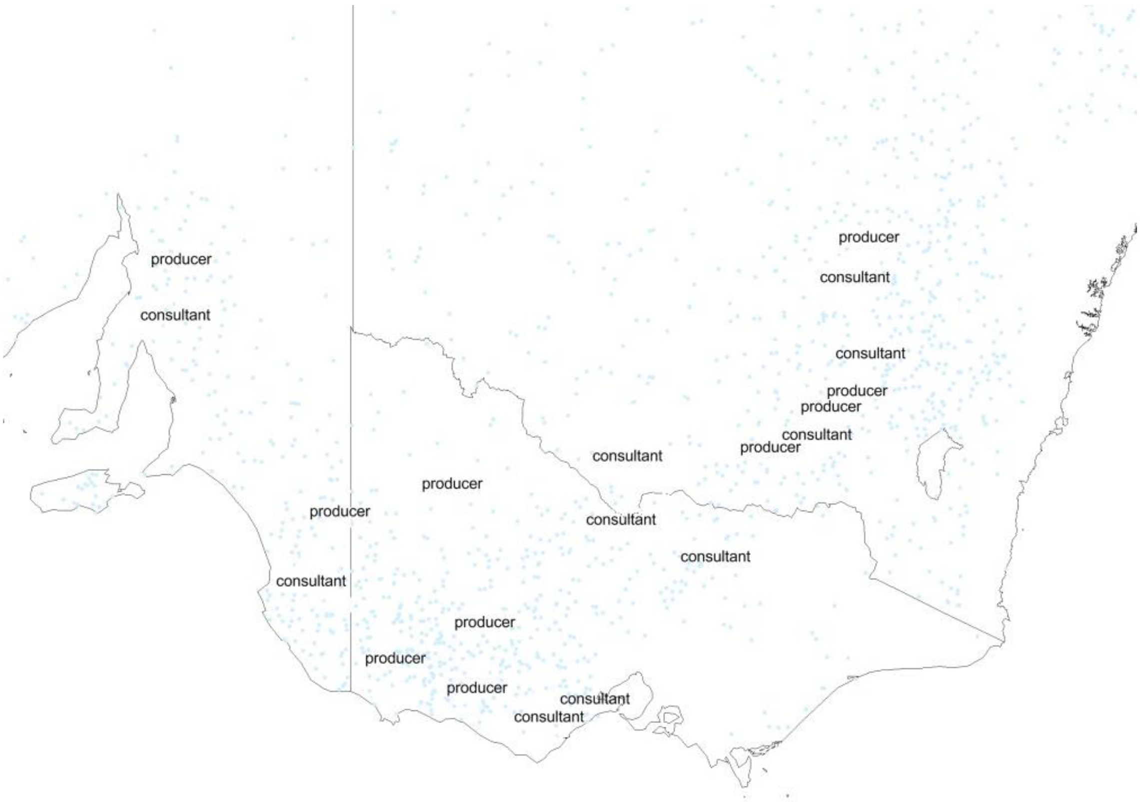

Figure 4. Approximate location of interviewed farmers and consultants in South Australia, Victoria and New South Wales (map courtesy of K Curtis, Department of Agriculture and Food, WA)

Consultant interviews

Do your clients graze young crops in winter?

The proportion of clients of the consultants interviewed that grazed crops was on average 60%, ranging from 10 to 90%. Several consultants commented that the majority of their clients that were mixed farmers and grazed their crops annually. What varied with seasonal conditions was the area of crop grazed in a given year.

Why do some of your clients choose not to graze crops?

There were a range of answers to this question:

1. All south east Australian consultants highlighted concerns over yield loss as the major reason some clients were not grazing crops.
2. Other issues identified by some consultants included:
    - Animal health concerns – specifically hypocalcaemia and hypomagnesaemia
    - Soil compaction
    - Weed seed disturbance

What % clients graze crops and what % of their crops are grazed?

Response to first part of this question has been incorporated into first question above. The second part of the question was expanded to include a description of the type of crops grazed.

The consultants interviewed provided a consistent estimate of the proportion of the crop grazed at 30% of the area cropped. Producers are grazing wheat, barley, oats and occasionally canola. The common crop varieties that were grazed include Wedge tail Wheat, Urambe Barley and grazing oats.

Why do your clients graze crops? What are the perceived/real benefits?

There were four reasons why client's grazed crops:

1. Filling feed gaps (in late autumn, winter and early spring).
2. Spelling pastures.
3. Ability to maintain stock numbers while increasing farm area cropped.
4. Assisting with weed control.

The first 2 reasons were considered the most important

What class of animals are grazed on crops?

Most classes of livestock were grazed on crops across different locations, specifically these included:

- Carry-over lambs.
- Ewe hoggets.
- Ewes in mid-pregnancy.

- Lactating ewes.

Most consultants indicated that their clients no longer graze ewes on crops in the last month of pregnancy or for lambing due to bad experiences with ewe health, primarily pregnancy toxaemia, hypocalcaemia or hypomagnesaemia. Even if their clients had not been directly affected they had heard of other producers that had and, as a result, had adjusted their grazing of crops away from ewes in late pregnancy or lambing.

If your clients graze crops with pregnant/lambing/lactating ewes, then:

When grazed – month, time in relation to lambing, period

Grazing of crops occurs typically from early June to mid-August. The time of lambing of each enterprise governs what class of stock were allocated to the crops during the grazing period. It was most common to be utilised by lactating ewes that had lambed prior to June or mid pregnant ewes on properties that were lambing in August/September. Alternatively some clients allocated dry sheep, primarily carry over lambs or ewe hoggets to the crop.

How is grazing managed?

Grazing management strategies for crops that were common to all consultants' clients were firstly the anchor test, ensuring that grazing only commenced once the crop seedling would not be pulled out of the ground. Second, in most cases grazing ceased once the crop had reached growth stage 30. Some consultants did indicate their clients typically grazed the crop when it had reached 10 cm in height or more, and grazed it down to about 3 cm high.

Are mineral supplements used – if so, when, what, how much and how are they fed?

The consultants interviewed indicated the majority of their clients were providing a mix of salt, causmag (or dolomite) and lime to sheep grazing crops. There was however, recognition that some (a small minority) grazed their crops without providing any mineral supplement. One consultant estimated the intake of the mineral mix would be 10-15g/head/day but acknowledged intake varies.

Are other supplements provided (eg hay/straw)?

The majority of consultants interviewed indicated most of their clients were providing a roughage source, usually either cereal hay or straw, although not everybody adhered to this practice. The provision of self-feeders with grain, typically barley or oats, occurs on a small portion of the clients' properties.

What levels of animal production expected or achieved?

The animal performance achieved when grazing crops varied. A couple of consultants highlighted their clients were selling early lambed suckers off grazing crops, achieving lamb growths rate up to 300 g/head/day. Other consultants estimated the lamb growth rates on crops was less than that achieved from pasture at an equivalent stage of growing season.

Even utilisation of the crop often required producers to stock their paddocks up to 30 ewes/ha, otherwise the crop would mature at varying rates across the paddock due to uneven grazing. The need for high stocking rates per ha on larger cropping paddocks, meant the required mob size was often unsuitable for lambing ewes due to the implications on miss-mothering.

Animal health/welfare issues

All consultants interviewed highlighted animal health issues were often, but not always, occurring when grazing cereal crops. The opinions of the consultants interviewed have been summarised in the table below. A range of animal health issues were identified when grazing crops but the one common to all was the occurrence of hypocalcaemia and hypomagnesaemia in late pregnant, lambing and lactating ewes (Table 15).

Table 15. Animal health issues occurring when cereal crops are grazed in southeast Australia

Consultant	Animal health issues identified
Garry Armstrong	• There have been a number of issues around grazing cereals with pregnant ewes in areas around the Mallee
Ken Solly	• Bad scouring • Milk fever (more so in cases where supplements and roughage not provided) • Increased incidence of prolapses
Hamish Dickson	• Animal health issues common but not all clients • Clients grazing pregnant ewes on cereal crops have had 4-5% mortality rates due to pregnancy toxaemia and most probably also have subclinical hypocalcaemia or hypomagnesaemia • Most issues are in late pregnancy or at the time of lambing, have had a couple of clients with a lot of ewe deaths during lambing on cereal crops
Rob Inglis	• 100% of clients had issues with grazing late pregnant ewes on cereal crops, no longer recommends it, 50% had problems with lactating ewes • Mostly acute nitrate poisoning grazing cereal crops in sultry conditions, with sheep staggering and gasping for breath • Hypocalcaemia or hypomagnesaemia • Many cases of pulpy kidney with sheep grazing crops
Megan Rogers	• Hypocalcaemia or hypomagnesaemia in late pregnant and lactating ewes
Daniel Salmon	• Hypocalcaemia or hypomagnesaemia- significant issues with both ewes and lambs with low blood calcium and magnesium, with up to 15% of ewes and lambs convulsing, and mortality rates up to 10% in late pregnant ewes • Lost ewes to pregnancy toxaemia on many occasions also
Sally Martin	• Pregnancy toxaemia due to a lack of energy in watery immature crops • Milk fever in point of lambing and lactating ewes • Lazy lambing- where ewes begin lambing and have weak contractions due a lack of calcium availability in feed or lack of calcium mobilisation • Lameness- possibly caused by ewes feet remaining wet in long feed, but nutritional imbalance may also be the cause
Cam Nicholson	• Metabolic disorders caused by mineral imbalance • High nitrate levels, particularly in cloudy weather
Simon Falkner	• Hypocalcaemia or hypomagnesaemia • Nitrate poisoning
Lyndon Kubeil	• Pregnancy toxaemia in late pregnant ewes, particularly on immature crops • Milk fever at point of lambing

Gaps in knowledge and confidence

Consensus among consultants was the need for research and/or demonstration on how to manage/mitigate ewe health issues, primarily hypocalcaemia, hypomagnesaemia, pregnancy toxaemia and nitrate poisoning. The outcome of the research/demonstration would be to lift producers' confidence and acumen for managing ewes on cereal crops by providing more accurate guidelines for supplementation, particularly mineral supplementation.

Consultants believe the investigation would need to explore the key risk factors for ewe health, perhaps in a hierarchy, including paddock factors (such as crop type, crop variety, stage of growth, soil nutrient status, plant nutrient status, fertiliser history, fibre source), animal factors (such as class of sheep, breed, age, stage of reproduction, parity) and prevailing weather conditions.

As one consultant outlined the challenge is how to best measure and manage ewe health signals. What to be aware of and how to mitigate the risks by addressing causes in a targeted manner. When asked, all consultants recognised their recommendations for managing ewe health on grazing crops was based on trial and error. If deficiencies are occurring, what are they? What is the root cause? How mineral supplements are best administered? One concern among the consultants is the standard provision of salt, lime and causmag is exacerbating problems, particularly calcium related issues due to excess supplementation in late pregnancy.

A key objective of this work according to consultants would be to reduce the mix messages that are currently evident throughout southeast Australia in the industry on how to manage sheep, particularly pregnant and lambing ewes, on cereal crops. The need for such research is typified by the widespread avoidance of having late pregnant or lambing ewes on crop, which highlights that industry has not solved the underlying problem, instead just shifted to lower risk classes of sheep.

Another research interest mention by a couple of consultants would be to quantify sheep performance on crop compared to pasture, particularly lamb growth rates pre-weaning.

Participation in future research or demonstration

All consultants interviewed in southeast Australia indicated they would be interested in participating in any future research and/or demonstration, and would have clients that would partake.

Additional names

Not required for south-eastern Australia component of project

Producer interviews

Do you graze young crops in winter?

All the producers interviewed were mixed farmers (crop and stock) and all grazed young crops in winter. All of the producers interviewed had been grazing crops for at least 5 years and they all indicated that crops were grazed annually to varying degrees depending on seasonal conditions.

What % of producers in your area graze crops? Why do some of your neighbours choose not to graze crops?

According to the producers interviewed the proportion of their neighbours grazing crops ranged from 5-85%, with an average of about 50%. The proportion of neighbours grazing crops was lower in the high rainfall regions.

The primary reasons for neighbouring producers choosing not to graze their crops were:

1. Concerns about the impact on yield,
2. Compaction due to grazing wet soils
3. Disturbance of weed seeds
4. Crop varieties sown not being suitable for grazing.
5. Many producers no longer have the stock numbers to warrant grazing crops or in many cases any stock left at all.

What % of your crops is grazed?

The percentage of crops grazed among the producers interviewed was on average 33%, ranging from 15 to 75%. A few producers indicated in years with limited feed availability all of their crops are grazed. The crops most commonly grazed were wheat, oats and barley, and occasionally canola.

Why do you graze crops? What are the benefits?

There were two key reasons why producers grazed crops, these were:

1. To fill the winter feed gaps
2. To spell/manipulate pastures.

It was highlighted that grazing crops with high winter growth rates can sustain high stocking rates and, simultaneously the carrying capacity of the pastures for late winter-spring is increased by building up leaf area. Several producers commented that high stocking rates were needed to evenly graze the crops in big paddocks and these often required large mobs of sheep. One example was given of 1000 ewes with lambs on 38ha for almost 4 weeks.

What class of animals are grazed on crops?

The producers interviewed indicated that crops were primarily grazed by lactating ewes or pregnant ewes up to 1 month before lambing, or dry sheep such as carry over lambs or ewe hoggets. Only one of the producers interviewed was still grazing crops with late pregnant and lambing ewes. A number of producers highlighted they are no longer grazing crops with ewes in very late pregnancy and lambing, particularly twin bearing ewes.

If you graze crops with pregnant/lambing/lactating ewes, then:

When grazed – month, time in relation to lambing, period

Grazing usually occurs in June and July with some extending as far as the middle of August.

How is grazing managed?

In southeast Australia the only grazing management strategy for grazing crops that was common to all producers interviewed was the anchor test, ensuring that grazing only commenced once the crop seedling was established enough not to be pulled out of the ground. Grazing ceased (if grain harvest was intended) once the crop had reached growth stage 30. Some producers preferred to use high stocking rates (30 ewes/ha plus their lambs) to eat the paddock down in 2-3 weeks, others used more conservative stocking rates for longer periods per paddock.

Are mineral supplements used – if so, when, what, how much and how are they fed?

All bar one of the producers in southeast Australia were providing mineral supplements to sheep when grazing crops. The standard mineral given was a mix of salt, causmag (or dolomite) and lime.

Are other supplements provided (eg hay/straw)?

Half the producers were providing cereal hay or straw *ad libitum* when grazing crops and the other half provided no hay or straw. One producer was feeding barley in self-feeders instead of providing hay or straw.

What levels of animal production expected or achieved?

In general the feedback from producers on the animal production achieved of grazing crops was positive. However a couple of producers highlighted concerns about lamb growth rates.

Animal health/welfare issues

With the exception of one producer, all of those interviewed had experienced issues with late pregnant, lambing or lactating ewes grazing cereal crop. The common problems according to producers were a combination of pregnancy toxaemia, hypocalcaemia and hypomagnesaemia. A few of producers reported losses of up to 10% of ewes.

The main adjustments producers had made to address the situation was, where possible, to avoid having very late pregnant and lambing ewes on grazing crops. In most cases where producers had changed the class of sheep or stage of pregnancy when grazing the crop the animal health issues were reduced. However it was hard to delineate the real cause and effect because most of these producers not only changed sheep type but also began to supplement ewes with salt, lime and causmag.

Gaps in knowledge and confidence

The producers interviewed from southeast Australia felt the management of sheep on grazing crops was all trial and error. The common gap identified that producers felt needed further investigation was the management of late pregnant and lambing ewes on grazing crops to inform more accurate solutions for supplementation with either minerals, grain or hay. The majority of the producers interviewed were no longer allocating grazing crops to ewes in late pregnancy or point of lambing because they lacked confidence in how to overcome health issues in a timely manner that reduced losses. Many had changed to grazing lactating ewes instead, others delayed grazing until the crop was more mature and others commenced mineral and/or grain supplementation.

Participation in future research or demonstration

All the producers interviewed in southeast Australia indicated they would be interested in participating in any ensuing research and/or demonstration that would improve the management and performance of sheep grazing crops.

Additional names

Not required for south-eastern Australia component of project

Summary

This survey provides a valuable companion document to the scientific review “Grazing crops – implication for reproducing ewes” and the survey of WA consultants and producers. Interviews with consultants and producers provided a significantly broader information base on the practical benefits and concerns. Many of these are not evident from review of the literature alone.

The proportion of producers grazing young crops is substantial (50 – 60%). This is a higher proportion that reported in WA indicating most consultants and producers were convinced of the benefits of filling the winter feed gap through crop grazing.

Crops grazed were predominantly cereals, wheat, barley and oats. Canola was grazed less. The crops grazed were often traditional crop varieties but there was also significant use of dual-purpose varieties. Producers grazed up to 100% of the crop, but usually between 30 and 50%, depending on the availability of alternative fed sources.

It was clear from interviews with both consultants and producers that crops were predominantly grazed by lactating ewes, ewes in mid pregnancy or carry-over lambs but not usually by ewes in late pregnancy. Most producers and consultants were aware of the high risk of metabolic disease in ewes grazing crops in late pregnancy. Management guidelines for pregnant and lactating ewes are therefore pertinent.

The benefits identified across the consultants and producers were primarily filling the winter feed gap and allowing pastures to be spelled before spring. Some also identified the ability to increase crop without reducing livestock and weed control as benefits.

A reduction in crop yield appeared to be the primary concern for those not grazing crops, although a reduction in the number of landowners growing sheep was also identified.

Grazing of crops was predominantly in June and July and early August. There were no standard grazing strategies. All producers ensured crops were anchored before grazing and usually ceased grazing at growth stage 30. The lack of a standard grazing strategy and variable objectives indicates guidelines may need to be based on some simple plant-focussed rules (eg growth stage), rather than livestock based decisions.

Overall there was a very good understanding of the potential mineral deficiencies created by grazing crops and of the recommended composition of supplements. Most producers used the recommended sodium/calcium/magnesium supplement. Many commented that hypocalcaemia or hypomagnesaemia results in ewe mortality of 5-10%

Gaps in the knowledge are clear and described below:

1. Consensus among consultants and producers was the need for research and/or demonstration on how to manage/mitigate ewe health issues, primarily hypocalcaemia, hypomagnesaemia, pregnancy toxaemia and nitrate poisoning. The outcome of the research/demonstration would be to lift producers' confidence and acumen for managing ewes on cereal crops by providing more accurate guidelines for supplementation, particularly mineral supplementation.

   The investigations would need to explore the key risk factors for ewe health, including paddock factors (such as crop type, crop variety, stage of growth, soil nutrient status, plant nutrient status, fertiliser history, fibre source), animal factors (such as class of sheep, breed, age, stage of reproduction, parity) and prevailing weather conditions.

   Both consultants and producers recognised managing ewe health on grazing crops was based on trial and error. Research is required to determine:

   - What deficiencies are occurring?
   - What is the cause?
   - How mineral supplements are best administered?
   - Do calcium supplements exacerbate the incidence of hypocalcaemia?

2. There is a need to reduce the mixed messages that are currently evident throughout southeast Australia on how to manage sheep, particularly pregnant and lambing ewes, on cereal crops. The need for such research is typified by the widespread avoidance of having late pregnant or lambing ewes on crop, which highlights that industry has not solved the underlying problem, instead just shifted to lower risk classes of sheep.

3. Another research interest is to quantify sheep performance on crop compared to pasture, particularly lamb growth rates pre-weaning.

In conclusion, grazing young crops appears to be providing significant benefits to the sheep industry. Poor understanding of grazing management and a recognised risk to animal health are major obstacles in the expansion of this practice to other growers and the most relevant class of livestock (pregnant ewes). Improving this understanding will enable producers to better integrate their cropping and sheep systems to increase whole farm profit and reduce seasonal risks.