final report

Project Code:	UNE.45
Prepared by:	Mark Trotter and Brian Sindel
	University of New England
Date published:	June 2007
ISBN:	9781741914528

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Delivery of best weed management practices for sheep meat producers

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

Weeds are a major impediment to the production of quality animal products through their effects on the quality and quantity of the pasture resource base, physical animal injury and plant toxins consumed in the grazing process. Recent research has advanced the science of weed management in grazed pastures, but adoption of integrated strategies apparently lags well behind technology. This project uniquely obtains and validates a producer perspective on the integration and implementation of best weed management practices for livestock production in southern Australia. Across all weeds the producers that have most success with weeds are those that integrate both proactive, pasture-promoting controls (e.g. grazing management, fertiliser application and sowing pastures) with reactive, weed-removing controls (e.g. boom spraying, spray grazing and spot spraying). The following questions are the minimum to be asked to help with the adoption of a new management strategy. What resources or infrastructure will be required for a producer to implement this strategy? Are there any adverse effects of this control on other farm systems, particularly livestock? Is this weed management strategy profitable? How might the ecology of the weed overcome the strategy? This project demonstrates the value of producer knowledge in assessing weed management strategies.

Executive Summary

Background

Weeds are known to have a great financial impact on the Australian grazing industry. Integrated weed management is widely considered to be the solution to the pasture weed problem.

Aims and objectives

Through surveying the indigenous knowledge of graziers this project sought to identify the best management practices for pasture weeds of southern Australia and the challenges that producers face in implementing them. In addition, this project also aimed to validate the producer perceptions which were relied upon for much of this study and identify the pasture weeds of most concern to graziers throughout southern Australia.

Methods

The project consisted of five major research activities which were: key informant interviews; a postal survey sent to 7,000 graziers; an on-farm validation study; telephone interviews; and producer focus groups.

Project findings

Although preliminary in nature, the results of the validation study indicated that producers are able to report most weed densities to within 5% canopy cover. However, many producers were unable to identify the annual grass weed vulpia.

Respondents to the postal survey reported an estimated 328 plants as undesirable species, dominated by annual broadleaf weeds. The most commonly reported species included capeweed, Paterson's curse, saffron thistle, blackberry and barley grass.

The best management practices were examined for the most commonly reported weeds in four functional groups. The key to successful control of capeweed (annual broadleaf) appears to be the integration of proactive (e.g. promoting pasture competition) and reactive controls (e.g. boom spraying and spray grazing) in a strategic way to control established infestations and reduce future establishment through pasture competition.

The most successful control of blackberry (perennial broadleaf) appears to involve the diligent and persistent application of spot spraying and where possible the strategic integration of burning and proactive control methods.

The key to the successful control of barley grass (annual grass) appears to be maintaining a competitive pasture.

Success in serrated tussock (perennial grass) control involves the maintenance of competitive pastures and the diligent monitoring and control of isolated infestations by spot spraying or chipping.

Across all these different weeds the producers that incorporate both proactive, pasture-promoting controls (e.g. grazing management, fertiliser application and sowing pastures) as well as reactive, weed-removing controls (e.g. boom spraying, spray grazing, spot spraying) appear to have more success than those reliant on only reactive methods.

The key challenges to the adoption of weed management strategies identified in this study included: resources and infrastructure limitations; the impact of the control on other parts of the farm system; a reduced profitability or expense involved in the control, or the availability of funds; the requirement for the control to be integrated with other methods; the influence of government regulation; a lack of extension programs; weed ecological influences; an incompatibility of the control with the beliefs and objectives of the producer; and climatic variability. These factors need to be taken into consideration when researching management strategies for pasture weeds, as well as when designing extension programs to encourage adoption.

Conclusions and recommendations

This project demonstrates the value of producer knowledge to provide a unique assessment of a range of integrated weed management strategies.

Full details of this project are found in the PhD thesis of Mark Trotter (Trotter 2007), a copy of which has been provided to MLA. A summary of the contents of the thesis is given in Appendix 1.

Contents

1 Background

Weeds are a major problem in the Australian grazing industry. Weeds compete with desirable species reducing available pasture, poison livestock, inhibit stock movement and cause physical injury. For those producers involved in the livestock industry, weeds have been estimated to cost $315 million in direct costs and $1,870 in lost production (Sinden *et al.* 2004). This combined cost of nearly 2.2 billion dollars represents 7% of Australia's gross value of production for all agricultural industries ($30 billion). There is clearly a need to improve the management of weeds in the Australian grazing industry.

It has been widely suggested that integrated weed management strategies are required to sustainably overcome the weed problems facing Australian graziers (Dowling *et al.* 2000; Huwer *et al.* 2002; Sindel 2006). Despite this belief, the integration of weed management methods in Australian pastoral systems has not been widely researched, developed or extended. Little is known about how graziers currently integrate controls or the rates of adoption of those few integrated weed management strategies developed through empirical science. Indeed, empirical scientific research faces many obstacles in its endeavours to examine the potentially innumerable combinations of control options that could be used in an integrated weed management strategy. An alternative research methodology which has been slowly gaining credibility is the harvesting of local knowledge through the concept of best management practice, a process which seeks to capture and distil producer perceptions on the most effective weed control techniques and strategies.

2 Project Objectives

This project primarily sought to:

1. validate the producer perceptions which were relied upon for much of this study;
2. identify the pasture weeds of most concern to graziers throughout southern Australia;
3. identify potentially successful control methods and better understand the ways producers integrate such methods; and
4. examine the potential challenges to adoption of some of the controls and integrated weed management strategies identified in this study.

As well as having these objectives, the project involved training a student (Mark Trotter) in research to PhD level. The project therefore had educational as well as applied objectives.

3 Methodology

To achieve these four main objectives this project involved five major research activities.

1. The first involved interviewing key informants to gain an understanding of the issues involved in pasture weed management.

2. The information acquired in these interviews was used to shape the next stage of the project, the postal survey. The postal survey was the major research component of this project and involved formulating the survey instrument which was used to gather information on a number of weed related issues, including changes in weed infestation levels over time in relation to the use of certain weed management practices. The postal survey was effectively a number of surveys combined into one questionnaire, allowing relationships to be examined between the issues of interest. The survey form was piloted twice and then mailed out to 7,000 graziers throughout southern Australia.

3. Following the postal survey, a ground-truthing study was undertaken to assess the ability of producers to accurately report the weed situation on their property. This test involved case study paddock assessments where producers selected a representative part of an average paddock and reported the composition of weeds and desirable plants in this area. This area was then sampled using a 400 point quadrat technique to determine the percent composition of the grasses, legumes and weeds present to make comparisons with the estimates of the respondent.

4. The postal survey results were analysed and a telephone survey was undertaken to provide a deeper understanding of the ways producers integrate weed management practices.

5. Finally, two focus groups on the Northern and Central Tablelands of NSW were used to further explore postal survey results examining the challenges to adoption of weed management strategies.

This project was initially targeted at meat sheep producers but was later broadened to include beef, wool and mixed grazing enterprises.

4 Results and Discussion

4.1 Validation of producer perceptions

From this preliminary study the majority of producers who reported decreasing weed infestation levels in the postal survey appeared able to accurately estimate weed canopy cover to within 5% in their own paddocks. Although it was not a completely random group of producers who participated in the validation farm visits, and the postal survey questions focused on the change in individual

weed status, we believe that the ability of these farmers to accurately report infestation levels at one point in time lends support to the idea that they can also be relied upon to accurately report changes in composition over time.

The results indicate that we can have particular confidence in the results of the postal survey for some weeds, for example, the four key weeds that are the focus of the best management practices. In contrast, the results for vulpia may need to be treated with more caution, as some producers failed to accurately identify and quantify the level of infestation of this annual grass weed.

On the whole, when reporting weeds, producers primarily cited more serious species rather than species which are not normally considered as important weeds, even though such minor weed species may have made up significant proportions of the canopy cover (up to 20%) compared with the more problematic species. Dellow *et al.* (2002) likewise found that minor broadleaf weed species such as flat weed and cud weed were present in the perennial pasture zone at often similar biomass levels to weeds such as spear thistle and saffron thistle.

Future studies will need to take into account these issues when attempting to ascertain the ability of producers to accurately report weed infestations. For example, it may be helpful to compare the ability of producers to identify and quantify a weed that is important to them against a weed of lesser importance. Information is also required on whether landholders are more able to quantify high level infestations than low level infestations. Ultimately, further trials may be able to examine the ability of producers to accurately report the change in weed infestations over time. Studies that focus on one weed species only are likely to be the easiest and most accurate.

The scientific and economic communities would benefit greatly from a study into the ability of producers to accurately report weeds at varying densities. Currently, landholder assessments of the impact and subsequent cost of weeds appear to be rarely based on economic thresholds. The development of a tool to enable producers to turn a self reported weed extent and density into an economic cost could greatly increase the economically rational control of weeds.

4.2 Weeds of southern Australian pastures

Graziers in southern Australia identified a vast array of species as weeds. There were 107 weed species that were reported by more than 0.5% (5) respondents to the survey and an estimated 328 species in total. This is more than double the 119 species listed as relevant to Australian grazing lands in the Weed CRC and MLA report on weeds of significance to the grazing industries of Australia (Grice 2002). Whilst many of the weeds recorded in this survey were only reported by a few respondents, it is worth noting the large number of plants that graziers have suggested as undesirable.

Despite this diversity, a number of key species are common problems for many graziers across the industry. Broadleaf weeds, and particularly the annual species, clearly dominate the most commonly reported weeds of graziers in southern Australia. Across all respondents the most commonly reported weeds were: capeweed, Paterson's curse, barley grass, saffron thistle and blackberry. Of these most frequently reported species, Paterson's curse is perhaps the most concerning with over 40% of respondents reporting this weed.

The most commonly reported weed species varied between the regions. Figure 1 shows the regions that were surveyed. The annual and perennial broadleaf species dominated the northern zone however the perennial and annual grass species appeared to be the most commonly reported increasing problems. The most commonly reported weed amongst graziers from the central pasture zone was serrated tussock, reported by 69%, whilst the most commonly reported weed of graziers from the southern pasture zone was capeweed. Paterson's curse was the most commonly increasing problem in this zone. Graziers from the western pasture zone also reported Paterson's curse as a commonly increasing weed.

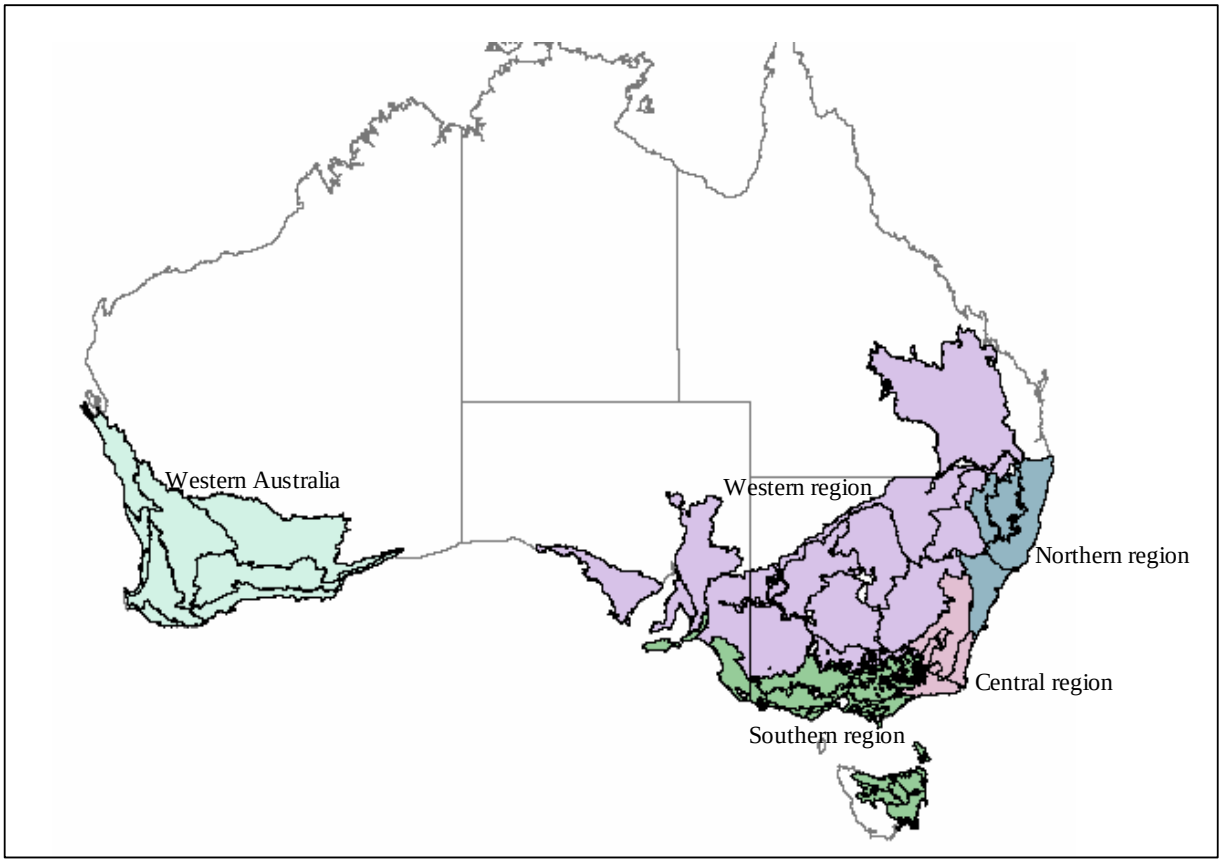

Figure 1 Regions developed for the analysis of postal survey results

The lesser reported most commonly increasing weeds were dominated by the perennial grasses such as Coolatai grass, Chilean needle grass and *Sporobolus* species. Viper's bugloss was also reported as a commonly increasing problem. In specific pasture zones spiny emex and cassinia were increasing.

Four key weeds were selected for further analysis, one from each of four functional groups - capeweed (annual broadleaf species), blackberry (perennial broadleaf), barley grass (annual grass)

and serrated tussock (perennial grass). These weeds were chosen as they were the most commonly reported species in each of these functional groups and the statistical analysis undertaken later in the project required species with the greatest number of respondents reporting them.

These four species were not amongst the most commonly reported increasing problems. However, the fact that more respondents reported them as stable or decreasing provided an opportunity to identify the controls that graziers were implementing to achieve these more favourable changes. The analysis of weeds that are predominantly increasing problems may provide valuable information too. However, this was not undertaken for the PhD thesis.

4.3 Best weed management practices and integration strategies

4.3.1 Capeweed

The survey results indicate that there are many and varied ways to successfully achieve longer term control of capeweed. Whilst a prescription for success for every producer cannot and should not be given, there are several key practices that appear to be providing a greater proportion of producers with more effective control. The results suggest that an integrated approach using both proactive, pasture-promoting and reactive, weed-removing methods that target different stages of the lifecycle of capeweed are best practice.

Producers looking to successfully control widespread capeweed infestations need to examine the possibility of integrating spray grazing and a grazing management strategy that involves managed paddock rotations. Obviously not all producers will have a suitable land class or fencing infrastructure to facilitate the application of spray grazing. Boom spraying with lethal herbicides will then be the next best option for the control of broad-acre infestations. Although this method has proven successful for many graziers it does not necessitate the integration of grazing management and consequently if not consolidated with managed paddock rotations may prove less successful in the longer term. Where lethal dose boom spraying is applied, timing is critical. In contrast to boom spraying, although only identified by a small number of respondents, winter cleaning was reported by all as successful. This technique requires early detection of infestations at the seedling stage, and the adoption of a paddock monitoring system that enables producers to identify these seedlings, could see a more effective use of herbicides. In addition to these methods, producers might consider the use of crop rotation to control capeweed. Although this technique will be more applicable to those involved in grain production, it could be successfully integrated into a pasture establishment phase of grazing properties.

The control methods reported by the majority of respondents as unsuccessful such as burning and slashing or mowing, may prove effective in isolated instances but should usually be avoided unless applied as a key component of a proven integrated strategy. This also applies to other less common control methods.

4.3.2 Blackberry

Spot spraying may be used with some success as a stand alone control method for blackberry. Despite this, the integration of a pre or post burning treatment with spot spraying can provide advantages. Although the results were not significantly different, it is worth noting that the group of graziers primarily practising spot spraying and burning had the second highest proportion of

respondents (58.6%) reporting a decreasing problem with blackberry. In addition, the integration of proactive controls such as grazing management, sowing pastures and fertiliser application are likely to provide some benefits. Again, although the results were not significantly different, those graziers promoting pasture had the highest proportion of respondents with a decreasing blackberry problem (64.3%). Control strategies targeting infestations on arable land can incorporate cultivation and short term crop or pasture rotation. However, consideration must be given to establishing a long term competitive pasture and maintaining this through fertilizer and grazing management.

4.3.3 Barley grass

The integration of control methods against barley grass would appear to be the best option for control. Respondents repeatedly reported the need for competitive pastures to proactively control barley grass. Any integrated management strategy for barley grass should consider this as the highest priority. In established pastures this will be achieved by a general grazing management strategy incorporating at least some paddock rotations which seek to promote desirable species. Fertilizer may provide benefits if pasture species are responsive. The addition of lime has been of benefit to some producers and any pH imbalances should be ameliorated as they may disadvantage the desirable grasses. If established pastures do become infested with barley grass, reactive control options such as winter cleaning, pasture topping and spray grazing should be considered. However, the potential negative effects of these methods on desirable species need to be carefully considered. Although limited in its application, the cutting of hay or silage from a heavily infested pasture may provide good results as an opportunistic control. The establishment of pastures on areas previously infested with barley grass needs to integrate several re-active controls to reduce the chance of reinfestation. The chemical controls of winter cleaning, pasture topping and spray grazing may be used as there is little need to consider the existing pasture. However, lethal dose boom spraying may provide the simplest and most effective control.

4.3.4 Serrated tussock

It is impossible to provide a prescription for success for the control of serrated tussock as it was apparent from this work that the recommended strategy will depend on each individual situation. However, this study provides direction for producers seeking to control this weed.

Although the result was not significantly different, the group of respondents reporting the highest proportion of graziers with a decreasing serrated tussock problem also had the greatest reported use of pasture-promoting controls. Although it appears that if producers are to successfully apply an integrated management strategy against serrated tussock they must incorporate activities to increase the competitiveness of pastures, this can be difficult to achieve when droughts and other production demands are opposed to the strategies required to maintain a competitive pasture. Whilst the reactive control methods of chipping and spot spraying are important in controlling mature plants, they will be of little long term use in the absence of a competitive pasture, maintained through grazing management, species manipulation and fertiliser application.

Where it is necessary to remove adult plants, spot spraying and chipping have both provided excellent results. It must be noted though that diligence in both the repeated treatment of infested areas and diligence in the way the chemical or chipping is undertaken is important. Treated areas need to be regularly checked and resprayed or chipped if necessary. When spot spraying, respondents suggest that careful application of the herbicide is essential to avoid non target species

damage and affect a good kill of the tussock. A chipping hoe or small chemical applicator should be carried on farm vehicles at all times to facilitate opportunistic removal of tussocks.

Larger infestations should be boom sprayed, however attention must be paid to the retention or re-sowing of competitive desirable species. On arable country the use of cultivation and fodder crop rotations has proven successful for many respondents.

4.3.5 Overall best management practice

In this project we examined four weeds in detail from four different functional groups. The most commonly used best management strategy for capeweed (annual broadleaf) and barley grass (annual grass) was boom spraying and for blackberry (perennial broadleaf) and serrated tussock (perennial grass) was spot spraying.

The annual weeds appeared to be controlled more by broad acre methods whilst the perennial weeds were controlled more often by techniques suited to isolated infestations. Whilst lifecycle is obviously a contributing factor, habit, size and the typical extent and density of infestations in which these species are found play a part in determining the most effective management practices. Practicality therefore seems to play a major role in perceived effectiveness of control techniques.

Legislation may also dictate that weeds like serrated tussock and blackberry be controlled even at low densities or in isolated infestations where spot spraying and chipping are more suited. In contrast, as legislation does not require the control of endemic species such as capeweed and barley grass, farmers may be less likely to control them when found in isolated infestations, but wait until they are widespread when boom spraying is appropriate. These trends are by no means universal, since some graziers reported extensive serrated tussock infestations and others isolated capeweed infestations.

The key to success with the use of controls for isolated weeds is the regularity and diligence in application. However, this does not exclude the need for integration with proactive pasture promoting controls which are required to increase pasture competition. Weed species that are extensively distributed but at low density need appropriate reactive controls such as boom spraying, spray grazing or pasture topping, but for long term success, they too must be integrated with proactive, pasture promoting measures.

Whilst it is apparent that some of the identified best management practices for the four case study weeds will be able to be transferred to other species within the relevant functional group, each species has its own unique ecology that may cause it to respond differently to the case study weed. For example, many of the best management strategies for capeweed may be applied to other commonly occurring annual broadleaf weeds such as Paterson’s curse and saffron thistle. But Paterson’s curse can also prove poisonous if crash grazed or spray grazed (Piggin and Sheppard 1995) and so this is an important distinction between the species that affects management practices. In contrast the best management practices for blackberry are likely to be able to be applied to sweet briar, those for barley grass to vulpia and those for serrated tussock to Chilean needle grass without the need for major changes. Although whether Chilean needle grass can be differentiated from the background pasture as well as serrated tussock can for chipping or spot spraying remains to be seen.

The clear finding from this part of the project is that producers that incorporate both proactive (pasture-promoting) and reactive (weed-removing) controls have more success with pasture weed management than those reliant on only reactive methods. Many of the clusters of graziers identified in this study that were pasture-promoters or more likely to use proactive controls were repeatedly populated by respondents reporting a decreasing weed problem. Whilst the individual results for these clusters may not have been significantly different, the trend across different functional groups is compelling. Despite the apparent effectiveness of proactive controls, it is essential that producers strategically integrate these with reactive controls to deal with established high density infestations or new incursions. Many producers are not in a position to maintain competitive pastures at all times and at least occasionally may need to sacrifice paddocks to sustain their livelihood because of issues such as drought. These reactive control methods play a key role in assisting the return of these paddocks to a competitive state when droughts break. Although not explored in depth, many of the respondents in this study also reported quarantine, containment and monitoring strategies as key elements of best practice weed management.

4.4 Challenges to adoption of weed management strategies

Producer perceptions of the relative importance of challenges to adoption of weed management are listed in Table 1. Amongst all the weed management strategies investigated in this study the most commonly reported challenges to adoption involved resources and infrastructure, intersystem impacts and profitability and expense. Focus group participants also commonly identified the challenges of integration, government regulation and lack of extension programs. Postal survey respondents also identified challenges posed by the ecology of some weeds, personal beliefs and objectives, and climatic variability.

Table 1 The top nine most frequently reported challenges to adoption, ranked by an index of the frequency that inferential codes were reported by respondents to the postal survey and by focus group participants.

	Postal survey index score (out of 5)	Focus group index score (out of 5)	TOTAL (out of 10)
Resources and infrastructure	4.8	2.5	7.3
Intersystem impacts	2.2	2.5	4.7
Profitability and expense	0.8	2.5	3.3
Integration required	0.0	3.0	3.0
Government regulation	0.0	2.5	2.5
Extension programs	0.0	2.5	2.5
Weed ecological influences	2.2	0.0	2.2
Beliefs and objectives	1.2	0.0	1.2
Climatic variability	1.0	0.0	1.0

These challenges will be specific to the control methods examined in this study. Other researchers examining similar problems have identified a different order or priority of challenges, e.g. Llewellyn *et al.* (2004) with integrated weed management for grain producers. It is important to note that the

challenges identified are producer perceptions and that less frequently reported challenges may still be important. In fact, many play key roles in the innovation adoption decision process. Despite this the producer perceptions of the most commonly reported challenges provide a valuable check list for organisations and individuals involved in the innovation and transfer of weed management strategies.

Appendix 2 lists the questions that might be asked of a weed management strategy targeted at graziers derived from the top nine most commonly reported challenges. The themes of relative advantage and trialability proposed by Pannell *et al.* (2006) become apparent in these questions. The questions can be used to guide the development and transfer of weed management strategies. The book Pasture Management for Weed Control (Burton and Dowling 2004) provides an example of extension material that presents some of these challenges. For example, with reference to spray grazing, it identifies the problem of non target species damage and the influence of weed ecology e.g. staggered germination, and provides suggestions for overcoming these challenges. Despite identifying these important problems, many other challenges reported by respondents in this study could be added to such extension literature along with possible solutions.

Innovation adoption is an important issue that continues to grow in significance in the ever changing world of research and development. All participants in the innovation, transfer and adoption process need to gain a better understanding of their roles and the potential challenges they face. If weed researchers are to act as effective innovators they need to develop an understanding of the challenges that adopters will face in attempting to implement their strategies. The challenges identified here and the questions posed have begun to elucidate the issues and provide a framework in which innovators can work. However, much more research is required to fully understand the challenges to adoption of specific weed management strategies amongst landholders. Still further study is required to assist in the development of techniques to enable the great variety of landholders to overcome these challenges.

Many of the experts in this area have pointed out that adoption of weed management practices is a dynamic and ongoing process. This study has demonstrated that the challenges that exist are diverse and have complex relationships. Looking for ways to overcome the challenges to weed management that have become apparent in this study must be the next step. However, when one considers that each farmer is unique it becomes difficult to provide prescriptive answers to the problem of adoption of weed management. An increased awareness of the value of local knowledge and an increased ability to capture and assess it is a step in the right direction.

5 Success in Achieving Objectives

The principal objectives of this project were achieved, as outlined above.

6 Impact on Meat and Livestock Industry – now & in five years time

This study, by identifying the elements of best weed management practice from a producer perspective, and by identifying the principal challenges to the adoption of improved weed management practices, has provided a framework for the delivery and adoption of better weed management strategies to the Australian meat and livestock industry now and into the future.

7 Conclusions and Recommendations

7.1 Validation of producer perceptions

Both biological and economic studies are often based on surveys of producers and so it is imperative that a better understanding is gained of the ability of producers to accurately report weed infestations. Although the study undertaken to validate a sub section of the postal survey results was preliminary in nature, the results indicate that producers can usually quantify weed canopy cover to within 5% in their own paddocks. However, for some weeds the results may be less accurate. For example, the reporting of the annual grass vulpia was plagued by the inability of producers to accurately identify this weed. Whilst credence should be given to producer perceptions of the density of weeds for most species, especially broadleaf weeds, studies using self reported data on vulpia and other “non-descript” annual grasses should be treated with caution.

One of the most convincing reasons for developing validation studies is the possible spin offs it might have for producers. If the ability of graziers to identify and quantify the weed species occurring in their paddocks can be measured, then steps can be put in place to improve their skills in this area. If producers can be effective assessors of the density of weeds in their pasture then they may be able to use this information to make more rational economic decisions about weed management. Ultimately, as computer models become available, producers may be able to assess a pasture paddock, and enter densities for a range of species into a program that will simulate the potential losses from these weeds and the benefits from various control options.

7.2 Pasture weeds of southern Australia

Graziers from southern Australia reported an estimated 328 undesirable species, dominated by annual broadleaf weeds. The most commonly reported species were capeweed, Paterson’s curse, saffron thistle, blackberry and barley grass. Whilst reported by fewer respondents, several perennial grasses - Coolatai grass, Chilean needle grass and *Sporobolus* spp.- were suggested to be key increasing problems for graziers. Viper’s bugloss was also reported as an increasing problem. Apart from barley grass, the annual grasses appear to be under-reported by graziers.

7.3 Best management practices

Due to their high rate of reported occurrence, capeweed, blackberry, barley grass and serrated tussock were chosen for assessment of their best management practices. Whilst a prescription for success for every producer cannot and should not be given, there are several key practices that appear to be providing a greater proportion of producers with more effective control.

7.3.1 Capeweed

The key to successful control of capeweed is the integration of proactive and reactive controls in a strategic way to control established infestations and reduce future establishment through pasture competition. For extensive and established infestations spray grazing should be used, however this short term control needs to be followed up with grazing management and other proactive controls to promote pasture competition. Where fencing infrastructure limits the application of spray grazing lethal dose boom spraying should be applied. Paddocks should be checked regularly in autumn so that timely winter cleaning can be carried out and if capeweed does establish and infestations are allowed to go to flower pasture topping may provide effective results. If the land is arable, paddock rotations and the sowing of pastures may be successful. Spot spraying will be of use to those producers struggling with new incursions or small infestations.

7.3.2 Blackberry

The key to the successful control of blackberry is the diligent and persistent application of spot spraying and where possible the strategic integration of burning and proactive control methods, though integration of control methods for the control of blackberry may not provide as much benefit as for other weeds. Essentially the diligent and regular application of spot spraying may be sufficient to provide success in blackberry control, particularly in rugged terrain where the implementation of proactive controls such as grazing management and the sowing of pastures is limited. However, the greatest proportion of respondents reporting a decreasing blackberry problem were those graziers integrating a range of proactive pasture promoting controls. Burning is integrated with success as both a pre-spraying operation to reduce thicket size and post-spraying to reduce the standing dead thicket. Producers are keen to see the release of a selective residual herbicide in granular form to allow for easy to application and ongoing control for re-establishing thickets. If, as it has been suggested, that blackberry may be removed from some noxious weed lists in the future, it could be very constructive to carry out monitoring to assess the effects of such changes in legislation on general infestation levels.

7.3.3 Barley grass

The key to the successful control of barley grass is maintaining a competitive pasture, which can be achieved through grazing management and promotion of vigorous species, and the integration of reactive control methods such as boom spraying, winter cleaning, pasture topping and spray grazing where pastures have become infested. Producers should pay particular attention to the opportunities that the establishment of new pastures or crop rotation provides for the control of barley grass.

7.3.4 Serrated tussock

The overall key to serrated tussock control is the maintenance of competitive pastures and the diligent monitoring and control of isolated infestations, though the best integrated weed management strategy for serrated tussock will vary from farm to farm. For producers facing extensive infestations, the diligent application of spot spraying and opportunistic chipping will provide good results. However, this will be of little value in the absence of a competitive pasture, maintained through grazing management, species manipulation and fertiliser application. Larger infestations on arable land may be successfully treated through the establishment of a sown pasture. Boom spraying, cultivation and crop rotation may be valuable components of this process. For those producers facing more isolated infestations the key to success will be the continued monitoring and control of infestations. Facilitating opportunistic control by chipping or small dose chemical applicators is an important component of control of serrated tussock when it occurs infrequently.

7.3.5 Overall best management practice

Producers that integrate proactive and reactive controls for weeds generally have more success than those reliant on only reactive controls. Many of the clusters of producers identified in this study that were identified as pasture promoters or more likely to use proactive controls were repeatedly populated by more respondents reporting a decreasing weed problem. Despite the apparent effectiveness of these proactive controls, it is essential to realise that most producers strategically integrate these with reactive controls to deal with established infestations or new incursions. In many cases the effectiveness of reactive methods appears to be linked with the diligence and regularity with which the control is applied. However, proactive controls also suffer if not regularly and diligently applied. Persistence in pasture weed control is a key factor in success.

7.4 Challenges to adoption

The key challenges to the adoption of weed management strategies identified in this study included: resources and infrastructure limitations; the impact of the control on other parts of the farm system; a reduced profitability or expense involved in the control, or the availability of funds; the requirement for the control to be integrated with other methods; the influence of government regulation; a lack of extension programs; weed ecological influences; an incompatibility of the control with the beliefs and objectives of the producer; and climatic variability. An understanding of these challenges is of prime importance to researchers and extension agents seeking to promote weed management strategies. The following questions are the minimum to be asked in considering the adoption challenges of a new management strategy. What resources or infrastructure will be required for a producer to implement this strategy? What are the possible adverse effects of this control on other farm systems, particularly livestock? Is this weed management strategy profitable? How might the ecology of the weed overcome the strategy?

7.5 Further research

This project has used producer knowledge to examine the best management practices for pasture weeds. The use of local or indigenous knowledge in developing countries is widespread and relatively well advanced (Raedeke and Rikoon 1996; Walker *et al.* 1999). In contrast, its use in

western cultures lags well behind developing nations (Millar and Curtis 1999). The local knowledge harvested through this study has proven very beneficial and so it is reasonable to assume that the same process could be applied to many other areas of agricultural research. However, the science of harvesting local knowledge, particularly in western cultures is lacking. Research is needed to develop techniques that can be applied across the fields of social and biological science so that the information collected is as accurate as possible.

This study has examined the innovation and adoption component of pasture weed management. In particular it has taken an alternative approach to innovation and examined the possible challenges to adoption. What remains unstudied is the transfer component of the innovation, transfer and adoption model. It would be worth while examining the issues surrounding the transfer of pasture weed management innovations. In particular, information gathered from producers through studies such as this may require a unique transfer process to maximise its application.

There remains a great need for detailed ecological studies of many pasture weeds. This project has demonstrated the value of local knowledge, however this process has its limitations and empirical research into the ecology and management of many existing and emerging weeds is urgently required, particularly when it is regarded as a major impediment to adoption of new weed management strategies.

Economic thresholds need to be developed for weed management in pasture systems. This fact has been reiterated by other authors (Revell *et al.* 2002). One of the key challenges to adoption of weed management strategies identified in this study was profitability and expense. However, little is known of the actual cost of weeds at the paddock level. Additionally, how producers decide what is a financially viable control is still not well understood.

This project has presented information produced through an examination of producer local knowledge. Whilst many researchers in this field baulk at the suggestion of making direct comparisons of producer knowledge with information from empirical scientific research (Millar and Curtis 1999; Leeuwis 2004), they agree that the amalgamation of the two can provide great benefits. Further research could examine ways in which the results produced in this study might be complemented by the relevant scientific literature. Indeed, the products of this process could prove highly valuable to both producers and researchers.

7.6 The final word

7.6.1 To farmers

Integrate proactive, pasture-promoting management strategies with reactive, weed-removing controls. Know your weeds. Practise quarantine, containment and monitoring strategies. Be diligent in the application of control methods. Look at what other farmers are doing. Don’t wait for researchers to come up with solutions. Somewhere, a farmer probably already has one!

7.6.2 To researchers and extensionists

Farmers have a great deal of experience in dealing with weeds. Although it is difficult, the harvesting of their knowledge can provide great insights into weeds and their management. Researchers need to take advantage of opportunities to interact with farmers. Researchers and extension personnel

also need to realise that farmers face many challenges in their attempts to manage weeds and they need to take these into account when developing their research and making recommendations.

8 Bibliography

Burton J. and Dowling P., (2004). 'Pasture Management for Weed Control. A Graziers Guide to Controlling Annual Weeds in Southern Australian Pastures' NSW Agriculture and the Cooperative Research Centre for Australian Weed Management (Orange).

Dellow J. J., Wilson G. C., King W. M. and Auld B. A., (2002). 'Occurrence of weeds in the perennial pasture zone of New South Wales', *Plant Protection Quarterly*, **17**, 12-16.

Dowling P. M., Michalk D. L. and Sindel B. M., (2000). 'Weed management in pasture systems'. In '*Australian Weed Management Systems*'. (Ed. B. M. Sindel) pp. 307-328. (R.G. and F.J. Richardson: Melbourne).

Grice T., (2002). 'Weeds of significance to the grazing industries of Australia', CRC for Australian Weed Management, Meat and Livestock Australia Ltd, Adelaide.

Huwer R. K., Neave M. J., Dowling P. M., Lonsdale W. M., Sheppard A. W., Briese D. T. and Michalk D. L., (2002). 'Integrated weed management (IWM) in perennial pasture using pasture and grazing management, herbicide strategies and biological control' In '13th Australian Weeds Conference: Weeds "Threats Now and Forever?"'. (Eds H. Spafford Jacob, J. Dodd and J. H. Moore). (Plant Protection Society of Western Australia).

Leeuwis C., (2004). 'Communication for rural innovation' Blackwell Science (Oxford, UK).

Llewellyn R. S., Linder R. K., Pannell D. J. and Powles S. B., (2004). 'Grain grower perceptions and use of integrated weed management', *Australian Journal of Experimental Agriculture*, **44**, 993-1001.

Millar J. and Curtis A., (1999). 'Challenging boundaries of local and scientific knowledge in Australia: Opportunities for social learning in managing temperate upland pastures', *Agriculture and Human Values*, **16**, 389-399.

Pannell D. J., Marshall G. R., Barr N., Curtis A., Vanclay F. and Wilkinson R., (2006). 'Understanding and promoting adoption of conservation practices by rural landholders', *Australian Journal of Experimental Agriculture*, **46**, 1407-1424.

Piggin C. M. and Sheppard A. W., (1995). '*Echium plantagineum* L.' In '*The Biology of Australian Weeds*'. (Eds R. H. Groves, R. C. H. Shepherd and R. G. Richardson) pp. 87-110. (R.G. and F.J. Richardson: Melbourne).

Raedeke A. H. and Rikoon J. S., (1996). 'Temporal and spatial dimensions of knowledge: Implications for sustainable agriculture', *Agriculture and Human Values*, **14**, 145-158.

Revell C., Moore J., Peirce J., Douglass A., Butler R. and Allen J., (2002). 'Weeds of significance to grazing industries of Southern Western Australia'. In '*Weeds of significance to the grazing industries*

of Australia'. (Ed. T. Grice). (CRC for Australian Weed Management and Meat and Livestock Australia: Adelaide).

Sindel B. M., (2006). 'Management of weeds in pasture systems'. In '*Handbook of Sustainable Weed Management*'. (Eds H. P. Singh, D. R. Batish and R. K. Kohli). (Food Products Press: New York).

Sinden J., Jones R., Hester S., Odom D., Kalisch C., James R. and Cacho O., (2004). 'The economic impact of weeds in Australia', CRC for Australian Weed Management: Adelaide, 8.

Trotter M.G. (2007). Best practice management of pasture weeds in southern Australia. PhD thesis, University of New England.

Walker D. H., Thorne P. J., Sonclair F. L., Thapa B., Wood C. and Subba D. B., (1999). 'A systems approach to comparing indigenous and scientific knowledge: consistency and discriminatory power of indigenous and laboratory assessment of the nutritive value of tree fodder.' *Agricultural Systems*, **62**, 87-103.

9 Appendices

9.1 Appendix 1 – PhD thesis outline

The project results are summarised above. In terms of the PhD student, the main outcome was their PhD thesis, an outline of which is given below. The full thesis has also been made available to MLA.

Chapter 1 provides a brief background to the project, outlines the major activities undertaken during the project and outlines the thesis format.

In chapter 2 a review of the relevant literature concerning integrated weed management (IWM), the innovation, transfer and adoption process, local knowledge, its harvest through best practice management (BPM) and the challenges to adoption of weed management strategies are presented. This review chapter seeks to introduce the background information necessary to understand this project. The overall objective of this review is to provide an understanding of the theory of knowledge systems in which this project is operating.

The methodology chapter (chapter 3) details the development of the various surveys and focus groups that were undertaken to achieve the four main objectives of this study. For each survey technique used a review of literature of the methodological issues is presented and then the methodology is outlined.

Chapter 4 reports on a study undertaken to validate producer perceptions. This part of the study was to determine whether the information provided by producers in survey form accurately represented the weed status of their properties. This study only begins to uncover the complexity of validation of producer perceptions; however it does provide insight into this vexed issue.

The broad results from the postal survey about the occurrence and distribution of weeds as reported by respondents are outlined in chapter 5. This chapter provides an understanding of the geographic, production and demographic characteristics of the respondents, identifies producer perceptions of

the most important pasture weed species and introduces four key weed species which will be investigated further in this thesis.

Having identified four key weeds in the previous chapter, chapter 6 seeks to identify best management practices for each of them. To achieve the above aim, a series of questions is asked leading from the most simple to the more complex concepts. Which controls do producers perceive to be successful? Is the use of individual controls on a farm correlated with the long term change in weed problem? If graziers use multiple control methods against weeds, what are the most frequently used combinations? What is the context in which different combinations of controls are used? Is there a correlation between the most frequently used combinations and the long term weed problem? And, are graziers integrating multiple control methods in a strategic way to manage weeds?

In chapter 7 the challenges to adoption of best weed management practices, as identified in chapter 6, are explored drawing on information from both the postal survey and focus groups. Through an in depth examination of the issues related to the adoption of one control method (spray grazing) and the barriers to adoption of controls for two nominated weeds, blackberry and serrated tussock, it is intended to clarify some of the challenges associated with adoption of weed management strategies.

The final chapter (chapter 8) draws conclusions from all the preceding chapters to provide a broad understanding of the validity of producer perception of weeds, the weeds of most concern to graziers in southern Australia, the best management practices for weeds and the challenges that producers will face in implementing these practices. This chapter also describes the direction that future research might take to investigate the issues raised in this thesis.

9.2 Appendix 2 –Producer challenges and extension questions

The top nine producer-perceived challenges and related questions that innovators or transfer personnel might ask concerning a weed management strategy, the answers to which might prove valuable for inclusion in extension material.

Challenge	Questions for innovators or transfer personnel to ask
Resources and infrastructure	What extra resources or infrastructure will be required to implement this weed management strategy? What is the cost of these? Is there a way of using or modifying current farm resources or infrastructure to allow trial or small scale adoption? What are the labour requirements in time and skills for this weed management strategy? How monotonous is this weed management strategy? Do target producers have suitable livestock classes to enable control? Do producers have suitable fencing infrastructure to facilitate implementation? Is there a simple and cheap way of fencing to allow trial or partial adoption?
Intersystem impacts	What are the possible adverse effects of this weed management strategy on livestock and what are the chances of these occurring? What are the possible adverse effects of this weed management strategy on desirable pasture species and what are the chances of these occurring?

Challenge	Questions for innovators or transfer personnel to ask
	Are there any possible benefits that might be gained in other farm systems from implementation?
Profitability and expense	Is this weed management strategy profitable in the short, medium or long term? Can you quantify the economic benefits of implementing this weed management strategy? Can you identify a density of weed infestation at which this weed management strategy becomes profitable?
Integration required	Does this weed management strategy require additional control processes for it to be successful? These will require review as well! Does this weed management strategy integrate several complex control methods (if so, it may not be extendable to all land managers)? If this weed management strategy integrates several controls, are they independent of or interdependent on each other for success? Integrated weed management strategies with a high level of interdependent controls are less trialable. The adoption of IWM strategies with independent controls might be encouraged by trial of the individual controls.
Government regulation	How might government regulations affect the implementation of this weed management strategy? (Although largely out of the control of the innovator or transfer personnel, changes in legislation and its enforcement might be used to advantage in encouraging adoption) (In the case of this study, government regulation and externality issues go hand in hand. Leading graziers will be interested in how a weed management strategy might assist in their externality issues)
Extension programs	Although this study does not focus on providing details for a successful extension program, producers highlighted two key issues: innovator and transfer personnel relationships are important (how can you establish or use existing relationships?); and conflicting information is a problem (what other information has already been extended or what myths exist?). These will need to be dealt with in extension programs.
Weed ecological influences	What are the ecological strengths of the target weed? How might it overcome this weed management strategy? When producers are armed with this information they will understand control failures, be less likely to dis-adopt and innovate around them.
Beliefs and objectives	How does this weed management strategy fit with grazier's personal beliefs and objectives? (Understand that graziers have personal values and subsequent farm objectives that are not entirely economically driven) For IWM strategies that incorporate herbicides is there an alternative non-chemical control that can be applied with comparative success for those formally or informally organic growers?
Climatic variability	How will drought affect the viability of this weed management strategy? How might short term climatic conditions (e.g. extreme temperatures, rainfall and frost) affect the implementation of parts or all of this weed management strategy?