final report

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Sheep CRC

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Sheep CRC Exit Report

1. Summary of the CRC

The Sheep CRC was established to deliver transformational changes to the sheep industry through breeding well adapted sheep, developing new quality control systems for comfortable next-to-skin knitwear and ensuring lamb production includes the appropriate balance for improved lean meat yield and eating quality for consumers.

The CRC is a collaboration of 21 Participant organisations representing all sectors of the Australian sheep industry:

- Producers and producer groups, represented by the Sheepmeat Council and by WoolProducers Australia;
- the Rural R&D corporations, represented by MLA, AWI and AMPC, as major investors contributing over $21M cash over the seven years of the program;
- researchers from universities (UNE, Murdoch, Deakin, UTAS and UWA) as well as State Departments of Primary Industry (NSW, WA, Victoria, Queensland, Tasmania and South Australia) and CSIRO;
- farm consultants, represented by (Hall & Co, MS&A and Holmes Sackett); and
- companies, represented by Allfex and Australian Wool Testing Authority.

Over the seven year term, the CRC Participants contributed over $125 M through in-kind allocation of staff and provision of laboratories, farms, livestock and other facilities. Together with the cash investment of $64.4M the total budget for the program was $189.7M allocated across research, education and training. The estimated benefit to end-users from the CRC's programs associated with using the new technologies, is $605M.

Benefits were delivered through;

- improved on-farm productivity
- the impact of new quality assurance systems for next-to-skin knitwear, and the anticipated effect on the demand for finer micron wools, and
- through new technologies to support improved lean meat yield and increased eating quality.

The CRC's education program saw 37 new research professionals undertake postgraduate degrees and approximately 70% found jobs in the sheep and cattle industries which will contribute to their ongoing development after graduation. The CRC has also had considerable success in training agricultural consultants and developing partnership programs with private sector service providers to deliver new information and training to their clients.

The governance of the CRC via a skills-based Board has been a most successful mechanism to maintain clear focus on delivering the agreed Commonwealth outcomes, managing the expectations of our Participants and ensuring effective coordination of research and training activities.

2. Direct impacts

2a. The economic benefit to end-users through the development of new or improved products and processes

The benefits of the CRC's major research programs to end users have been estimated using the CRC Program's Impact Tool. Assumptions about usage of CRC products and information were updated using results from the 2014 National Survey of sheep producers commissioned

by the CRC to determine awareness of CRC information and the extent to which producers had changed practices as a result of accessing that information or attending CRC-initiated training programs. Estimated benefits and costs of using the new technologies were reviewed by a number of independent sheep industry consultants to ensure that they were consistent with real costs and returns from various sheep production enterprises in different regions of Australia.

The benefits delivered from Program 1 "Sheep and their management" were estimated at $314M with an expected benefit:cost ratio of 1.88.

There were three components of activities and benefits arising from the research program to improve sheep and their management:

- The initiative to breed sheep that are better adapted to the environment and more productive, involved a range of activities to increase the use of Australian Sheep Breeding Values (ASBVs) in the process of selecting the best ram source and making individual ram selections. Between 2011 and 2014 the number of producers using ASBVs to select their ram source increased from 11% to 18% and the number of producers using ASBVs to select rams for the flock increased from 38% to 48%. Faster genetic gain associated with this level of industry change was estimated to have a benefit of around $10M in 2014 alone.

- The second activity within Program 1 was to target improved reproductive efficiency. The 2014 National Survey of 1,000 producers provided an estimate of 6,000 producers participating in the CRC's workshop and training programs targeting better ewe management. The estimated benefit of these initiatives was estimated to be around $74M/year by 2014.

- The third component of Program 1 to improve sheep parasite management resulted in development of flagship ParaBoss program. This web-based information product developed by the CRC provides best-practice advice on parasite management. ParaBoss is an interactive resource with recommendations for worm, fly and lice management. Around 30% of sheep industry consultants use ParaBoss information as the basis for advising their clients. The program is also actively used by around 11% of producers, with between 50 and 70% of these producers basing management decisions on the advice. A benefit of $3.7M/year in 2014 was estimated to result from better parasite management by following ParaBoss recommendations.

Program 2 "Wool – quality assurance for next-to-skin knitwear" had an expected benefit of $174M and a benefit:cost ratio of 3.08.

The CRC's wool research Program focused on quality assurance for next-to-skin knitwear and delivered two new measurement systems. The new instruments and related research results provide innovative quality assurance for next-to-skin comfort and luxurious handle of wool relative to other fabrics. The CRC's research also showed clear functional benefits for finer micron wools in terms of reducing the risk of prickle and itch and improving water buffering properties. Understanding the functional benefits of finer diameter wools and being able to objectively measure the desired properties in finished fabric and garments is expected to increase demand for these wools and re-establish the micron price premiums for fibre under 19 micron in diameter. The expected premium of 100c for each micron decrease in fibre diameter will provide an extra 88c/kg per micron compared to the existing premium of 12 c/micron below 19 micron. Achieving a 100c/micron premium for superfine wools equates to an increase in the value of the Australian wool clip by $126M by 2018.

Program 3 "Meat – improving both lean meat yield and eating quality" is expected to deliver a benefit of $118M and a benefit:cost ratio of 2.58.

Benefits from the CRC's research in meat production and eating quality result from the new capability to select breeding animals with superior genetics for both lean meat yield and eating quality. The CRC's initial objective was to increase the rate of lean meaty yield by an additional 20% per year, while keeping a 'watching brief' on eating quality. However, the CRC's research showed that if the focus was only to improve lean meat yield, the result, over the next 10 years, would be a consistent decline in prices by around 3c/kg/year (based on extensive data from consumer testing and research into "willingness to pay").

This important finding was responsible for changing sheep industry breeding objectives to put more emphasis on consumer eating quality. The CRC's research in fields of genetics, genomics and meat science has now delivered new knowledge and new technologies that allow simultaneous improvement in lean meat yield and eating quality adding around $9M/year on a cumulative basis to the value of Australian lamb production.

2b. Other economic benefits - risk mitigation and capability enhancement

The CRC has made significant progress in improving the sheep industry's understanding of factors affecting reproductive efficiency and particularly lamb and weaner survival. The improved management systems and better monitoring programs now in place on many Australian farms to improve reproductive efficiency, reduce the risk that lamb and weaner mortality and animal welfare issues in future years. This is seen as a very important long-term benefit for the sheep industry as consumer concerns with welfare and animal management continue to develop in Australia and amongst our major trading partners.

The Sheep CRC's focus on building capacity amongst the private sector service providers in the sheep industry is set to deliver long term benefits for the sheep industry. One of the major changes in agricultural funding and technical support over the last five years has been a significant decrease in State Government investment in agricultural extension and advisory services. Recognising the potential impact of this sudden change in policy, the Sheep CRC has actively pursued two initiatives expected to make a major contribution towards filling the gap created by the demise of State Department extension and advisory services. The first was to develop, through UNE, a Graduate Certificate Program to train agricultural consultants. The second initiative has been to actively support private sector consultants and service providers to develop specific skills in aspects of sheep production and management – specifically targeting the delivery of CRC products and information. Examples of training programs developed by the CRC in conjunction with private sector service providers include the award winning RamSelect training workshop and the Pregnancy Scanner workshop series recognised for effective SME engagement.

2c. Case Study - successful commercialisation and utilisation of CRC research

The CRC's most significant achievement has been to take the application of genomic technologies from a research plan through to the delivery of a range of commercial genomic products – all within six years. At the start of the Sheep CRC in 2007 the sheep industry was considered to be around 10 years behind the beef cattle industry in terms of the capability of using genomic technologies. By the end of the CRC, in 2014, most experts consider that the Australian sheep industry is 2-3 years ahead of the beef industry in capitalizing on the commercial utilization of genomic technologies to increase genetic gain. This transformational change was accomplished through the success of the Information Nucleus program and the commercialisation arrangements for delivery of new genetic information through the Sheep Genetics organisation.

The Information Nucleus program is widely recognised as one of the most ambitious and innovative integrated livestock research programs ever. The program was conducted over a period of five years (FY08-FY12) in nine locations and resulted in intensive measurement of over 20,000 animals representing a diverse range of genetics and representing all aspects of

the Australian sheep population. The data provided the basis for developing genomic predictions of breeding values that were delivered for the first time as a Pilot Project in FY11. A further two Pilot Projects were conducted in FY12 and FY13 using the research 50k SNP test as the basis for DNA testing and provision of Estimated Breeding Values.

During FY13 the CRC developed a new 12k DNA test that was provided as a full commercial service in FY14. Sales of the 12k Sheep Genomic Test reached 1,660 tests by 30 September 2014. As producers become more familiar with the technology through the application of the Parentage test it is expected sales of the 12k Sheep Genomic Test will significantly increase over time.

The Information Nucleus Program also provided a data set for developing a new genomic parentage and poll/horn DNA test. This new product was first released in July 2012 and to 30 September 2014, a total of 22,350 tests have been purchased by commercial sheep breeders. The pattern of monthly sales is summarised in Fig 2 c.

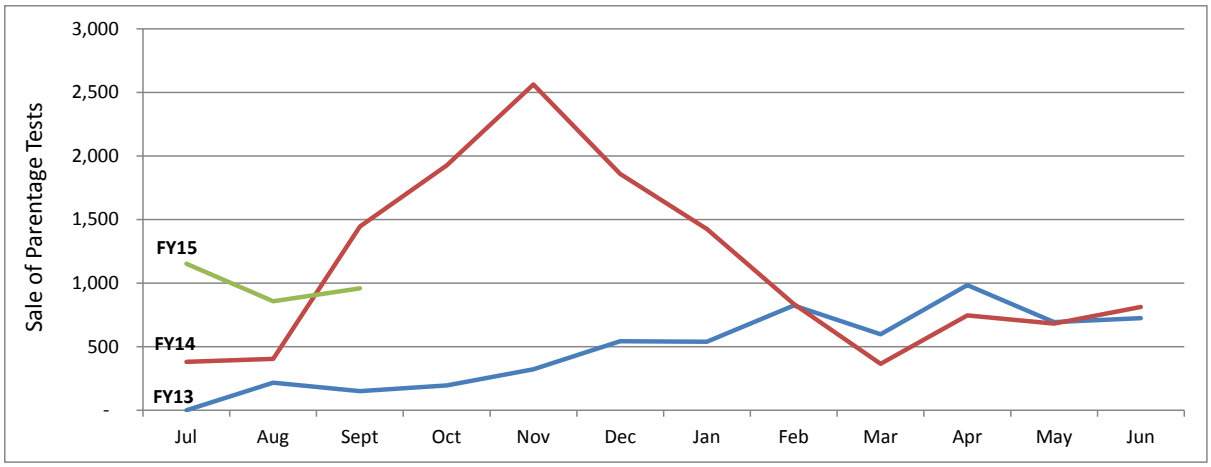

Fig 2c. Summary of the monthly sales of genomic parentage and poll tests to commercial ram breeders since the launch of the new product in July 2012.

The arrangement for delivery of genetic information and new genomic products via the Sheep Genetics organisation was fully negotiated prior to the start of the CRC. This arrangement meant that as soon as any new genetic information was available it was immediately "commercialised" and used by ram breeders. Therefore the commercial benefits of faster genetic gain, the ability to select for difficult to measure traits in order to enhance adaptation of sheep to their environments and to improve hard-to-measure traits such as meat eating quality are immediately transferred to the 80% of terminal rams and 30% of Merino rams that are benchmarked in Sheep Genetics and used in industry.

Not only was this program a significant example of successful commercialisation but of the benefits of an effective collaboration amongst researchers and industry partners throughout the sheep industry.

An important development arising from the Information Nucleus Program and the follow-on Genomic Resource Flock Program funded by MLA is a new level of understanding regarding the central role of efficient and accurate data capture and management. An industry level genetic improvement program is an essentially an exercise in 'big data'. Consequently, the CRC is working with its new Participants and various data management specialists to develop plans for more efficient on-farm and in abattoir data collection systems that are linked to cloud-based data management systems.

2d. Social benefits for end users utilising CRC research outputs

One of the most difficult issues for Merino sheep producers to manage has been the pressure by consumer groups opposed to the practice of mulesing as a means of reducing the risk of flystrike in sheep. The CRC contributed two very important developments to reduce the dependence on mulesing and provide long term solutions for flystrike management without the need for this practice.

As a result of the Information Nucleus research program, mentioned above, the CRC was able to provide estimated breeding values for breech and body wrinkle thereby enabling breeders to more quickly select for plain bodied animals with a reduced risk of flystrike. The second initiative was to develop the FlyBoss program and associated series of workshops on improved flystrike management. The computer based FlyBoss program provides interactive decision support enabling sheep producers to fine tune the set of management inputs required to minimise the risk of flystrike. The program is specific for various regions of Australia and different classes of sheep. Application of the new management and breeding information allowed many sheep producers to cease mulesing and this brought a significant feeling of relief to many producers that were very concerned about the dilemma of using mulesing to reduce the risk of flystrike while aware that it was not an appropriate long term solution for the industry.

2e. Meat supply chain case study – a non-monetary benefit for end users

The relationship between sheep producers and meat processors is generally one of mistrust and a reluctance to share information. The Sheep CRC recognised the importance of the supply chain relationships between processors and producers as a critical mechanism for developing new knowledge about products and technologies that would benefit both producers and processors as well as providing superior products for retailers and consumers. The supply chain group formed early in the CRC's term and provided co-investment for three supply chain officers to work with processors and their clients. The group also initiated regular meetings between processors, researchers and the supply chain officers to identify ways of introducing new products and technology and sharing the benefits of these innovations equitably between producers and processors.

The initiative took some time to gain momentum but is now recognised as a very important mechanism for both processors and producers to implement changes that will improve the long term stability and profitability of the sheep meat industry. While there has not yet been any monetary benefit for any of the Participants in the supply chain group, the value of the initiative is clearly demonstrated by the fact that three of the largest lamb processors have become Participants in the CRC's extension commencing July 2014.

The non-monetary benefit of the supply chain group is that it has established an important mechanism that all parties will be able to build on in developing new in-abattoir measurement systems and more detailed reporting of information that producers and breeders can respond to improved meat market specifications in the future.

3. Contributing to Australia's future research workforce

3a. Sheep CRC Postgraduate program

The Sheep CRC had an extensive postgraduate training program supporting research students enrolled in PhD and Masters degrees. Recruitment was based upon academic potential, and commitment to industry, but also involved the careful alignment of student

research projects with the CRCs priority research areas. This involved extensive facilitation between prospective students and supervisors, and the CRC research program leaders, ensuring the industry relevance of student projects which optimised the likelihood of success.

Additional training and professional development.

The postgraduate project involved an annual training event structured around a postgraduate student conference, and a professional development workshop. The conference has been run jointly, initially with Beef CRC postgraduate students, and in recent years also with postgraduate students from Meat and Livestock Australia, Australian Meat Packers Corporation, the Pork CRC, and Australian Pork Limited. CRC postgraduate students attend this event 3 times over the duration of their studies and are given the opportunity to present a component of their work as a 1 page conference abstract (compiled into a conference proceedings) and as a seminar delivered in a formal conference setting. Extensive verbal and written feedback is then provided by a panel of 10 senior scientists including the CEOs of the Beef and Sheep CRCs, and CRC research program leaders, with the make-up of this panel changing every year.

This process stimulates the analysis and write-up of data on an annual basis and also hones the students' writing and presentation skills. After the conference the students attend a professional development workshop targeting a range of topics rotated on a year to year basis. These topics have included scientific writing skills, delivering to an industry audience, science to optimise adoption and people management skills . A major outcome of this event is the facilitation of a national student network, enhancing ties between students and senior research scientists - many of whom become future employers.

In addition to attending the conference and professional development workshop the CRC has also supported the attendance of postgraduates at key industry conferences including the CRCs own national conference in Adelaide 2010 and LambEx in Bendigo 2012. Students were encouraged to present at these events, enhancing their connection to industry and developing their skill at presenting to an industry audience.

Contribution of the postgraduate program to the sheep industry.

In recent years there has been a growing concern amongst industry funding bodies about the value of their investment in postgraduate research and training. Initially, the rewards of their financial support could be easily identified with valuable research being conducted within the CRC research programs, contributing directly to the achievement of key experimental milestones. In fact it has been estimated that post graduate student researchers deliver a considerable proportion of the CRC's entire research output. However, a question has been raised regarding the retention rate of these highly-trained postgraduate specialists within the beef and sheep industries. To measure the success of this program for delivering trained scientists to industry, the CRC has undertaken a graduate tracking survey of all past Sheep and Beef CRC students. This task was completed in 2009, 2011, and 2013, and demonstrated that 70% of postgraduates had found employment directly within the sheep and cattle industries, and that 90% had been retained more broadly within agriculture. Furthermore, the bulk of graduates have been employed directly within senior research scientist or academic positions, emphasising the demand for highly trained research scientists within these industries. (See Fig 3a).

Postgraduate Student Details

There were a total of 37 Sheep CRCII postgraduate students of which five were enrolled in Masters and 32 were enrolled in PhD programs. Enrolments were at 9 institutions across 4 Australian states and one international institution. The University of New England in New South Wales and Murdoch University in Western Australia had the largest intakes of 16 and 7 students respectively.

One Masters and 13 PhDs have so far been awarded. Anadditional Masters and three PhD theses have been submitted and are under examination. The average time from commencement to completion for the postgraduates who have been awarded a Masters was 3 years and 1 month and for a PhD was 3 years and 10 months.

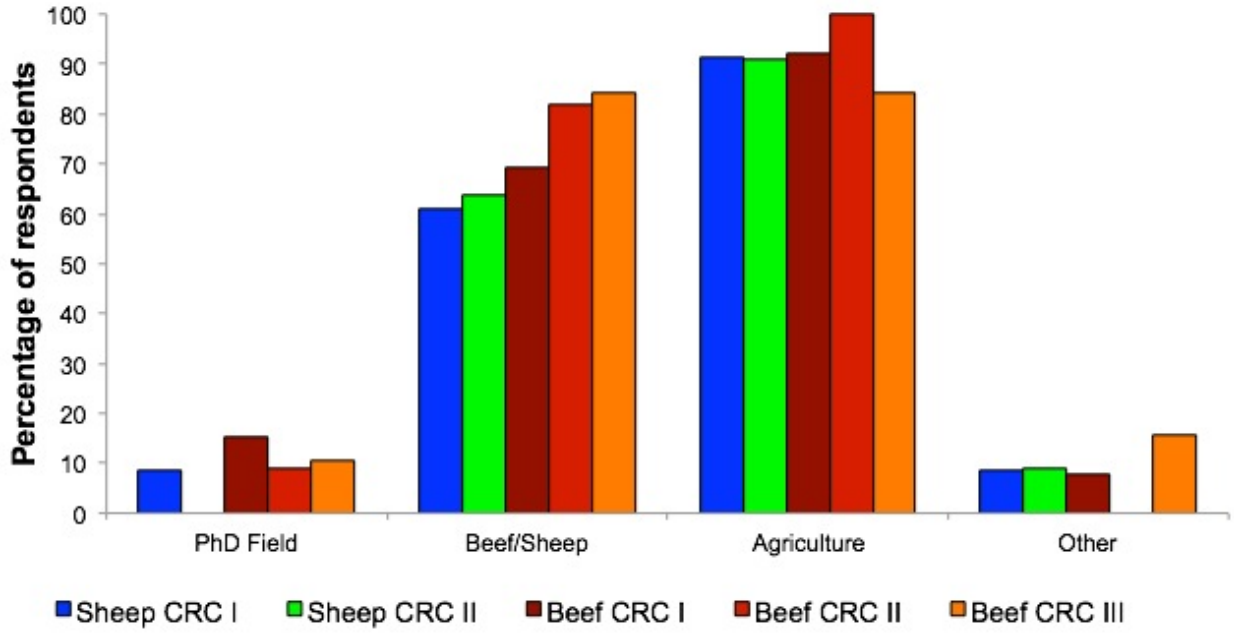

Figure 3a. Percentage of postgraduate students taking up careers in different end-user sectors

Graduate Employment Destination

The postgraduate students who have completed their studies are employed in government, university and industry positions heavily focused on agricultural and animal research. Examples include:

Government	-	National institute of, agricultural and animal research in Mexico
	-	CSIRO research
University	-	Postdoctoral fellow with the Sheep CRC
	-	Postdoctoral fellow with the Pork CRC
	-	Postdoctoral fellow at Melbourne University
	-	Postgraduate coursework adviser
	-	Lecturer positions (Sheep and Wool, Livestock Production, Animal Breeding and Genetics)
	-	Research positions
Industry	-	Mike Stephens and Associates
	-	Holmes Sackett

Six of the postgraduate students who have not completed their studies are currently employed in government and industry positions. While this has delayed their thesis completion, the fact that they are already embedded in industry and planning to complete their degrees is viewed a positive.

Government	-	DPI research
	-	DAFWA – Sheep Industry Extension officer
	-	SARDI
Industry	-	Wellards

Intended Employment Destination

Of the postgraduate students who have not completed their studies the majority have expressed an interest in research careers (including the areas of agriculture and meat quality) or academia. These students are all currently enrolled and finishing their studies.

3b. Key educational outputs including details of courses developed

The CRC realised the importance of private sector consultants and advisors that would be needed in the industry as State Departments withdrew from providing these services. A specific course for training new consultants was developed through UNE. The Graduate Certificate program was designed around two specialised courses for consultants: one dealing with the skills required by consultants; and the second with how to establish and manage a consulting business. Graduates of the program also had to complete two additional units covering areas of their proposed specialisation.

The course, first offered in 2009 was intended to train 160 students over a period of five years. The course has attracted well over this target and by December 2013, 204 students had completed the course with an additional cohort of 30 students enrolled to June 2014. UNE has taken over the management and the promotion of the course following the CRC's responsibility during the first three years of the program.

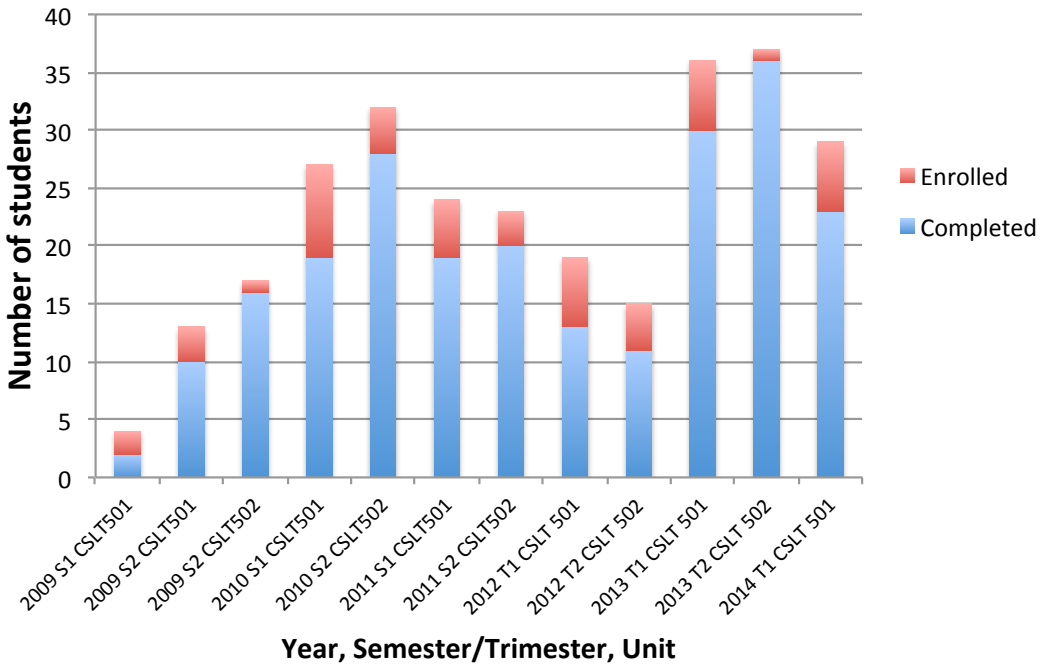

Figure 3b. Enrolments and completion in the specialised Graduate Certificate agricultural consultant units at UNE.

Industry training programs developed by the CRC

- *Lifetime Ewe Management* developed in conjunction with RIST
  The program was designed to train producers to manage pregnant ewes with scheduled monitoring and improved nutritional management in order to ensure improved reproductive performance and reduced lamb losses. The course has proven to be very successful and following the CRC's initial promotion has been supported by AWI and the Department of Agriculture in WA.
- *Managing Scanned Ewes Workshop*
  The CRC delivered a series of workshops with a range of contractors in the sheep industry focusing on ultrasound pregnancy scanning. The purpose of the workshop was to help the scanners clients make better use of the scan results to improve

management of twin bearing ewes to ensure higher levels of lamb survival from this group. A further benefit of the program has been the improved skill of pregnancy scanners who now generally report multiple births as well as a simple diagnosis of pregnancy.

- *High Performance Weaners*
  A new course was developed, again with input from RIST in Victoria, to provide information and training for producers in order to obtain better growth rates and high levels of survival from their weaner animals.
- *Electronic ID Training Program*
  The CRC, in conjunction with GoTAFE have developed a course to develop appropriate skills in setting up electronic data capture systems for on-farm recording and the necessary knowledge to utilise data effectively for better decision making.
- *Bred Well Fed Well Workshop*
  This workshop series focuses on selecting sheep that are well adapted to different environments and then managing them to achieve their potential. The course was initially established as part of the CRC's program and once it gained momentum, funding for its continued delivery was provided by MLA and AWI. MLA continues to promote and co-invest in the delivery of the course.
- *Ram Select Workshop*
  This initiative was developed following a detailed analysis of the skill sets required for using best practice genetic selection and specifically to help sheep producers purchase rams most suitable for their breeding objectives. The program has involved a series of Train the Trainer events and with a network of private sector service providers now presenting the workshop to their clients, the uptake of the course and use of the new information has become very wide spread throughout the sheep industry.

3c. Impact of education and training programs

The two-pronged approach taken by the CRC: firstly to train and support private sector service providers and consultants; and secondly to develop appropriate courses for developing skills that will enable producers and ram breeders to utilise CRC outputs effectively, has been very effective.

Working with AgriFood Skills Australia, the CRC undertook a comprehensive analysis of the skills required for a productive and innovative sheep industry. This project reviewed current university and TAFE courses as well as the specific skills required to make the most out of genetic improvement and better on-farm selection and management decisions.

It was as a result of this research initiative with AgriFood Skills that the CRC established the new eID course and the RamSelect program. The results of the analysis also encouraged the CRC to put further resources into encouraging private sector service providers to promote and deliver other workshops and training programs developed by the CRC and described above. In total the CRC delivered 256 workshops to 4,900 producers and industry personnel and additionally supported the delivery of LTEM to some 1,400 producers.

The impact of this integrated approach to industry training has seen very widespread participation and very high levels of practice change resulting from people attending CRC workshops and courses.

In 2011 and 2014 the CRC ran National Surveys involving 1,000 randomly selected sheep producers across Australia. These surveys identified the awareness of the CRC's training programs, levels of participation and resulting practice change. Table 3c taken from the survey report indicates the extent to which the industry was aware of the CRC initiative and the impact in terms of practice change resulting from participation.

Table 3c. Summary of sheep producer awareness of and use of Sheep CRC information and training programs including the impact on practice change

Producer responses	Not heard of it	Heard of but not attended	Attended (n)	Changed practice
Sheep CRC Conference or CRC Regional Updates	43%	49%	8% (78)	73%
Managing Flystrike workshop	56%	41%	4% (35)	51%
Managing Pregnant Ewes (or Pregnancy Scanning) workshop	48%	45%	8% (76)	82%
Worm control workshop	39%	49%	12% (119)	66%
Lifetime Ewe Management course	42%	43%	16% (156)	77%
High Performance Weaner course	65%	33%	2% (19)	79%
Precision Sheep Management workshop	70%	27%	2% (24)	71%
RamSelect workshop	45%	43%	12% (117)	53%
Bred Well Fed Well workshop	41%	46%	13% (129)	68%

One of the major factors responsible for the high levels of practice change in the CRC's training programs has been the engagement with private sector service providers. The linkage between researchers, consultants and their clients is a productive combination for the rapid dissemination and utilisation of new information. These estimated participation rates and levels of practice change from the National Survey have been used in the Impact Tool to assess overall benefits to the industry resulting from CRC R&D and associated education and training programs. The expected benefit of $314M and the benefit:cost ratio of 1.88 confirm the significant impact of this approach.

3d. Case study - Innovative training program to improve sheep management

At the outset of the Sheep CRC, one our most challenging and ambitious goals was to improve the reproductive performance of the national flock and thereby bolster productivity. In 2007 the average reproductive performance across the Australian flock was around 75% (that is, three lambs weaned for every four ewes joined) and hadn't improved during the preceding 20 years.

An innovative approach to tackling this persistent low level of performance was to partner with a group of small businesses that provide pregnancy scanning services to large numbers of sheep producers. The core activity of these scanning businesses is to identify ewes that are pregnant. This information allows for non-pregnant ewes to be sold, while ewes carrying single or twin lambs can be separated to provide appropriate nutritional support for their pregnancy status - best practice management and monitoring of ewes during their final trimester of pregnancy can significantly improve reproductive efficiency.

The strategic partnership involved the CRC and a number of pregnancy scanning businesses working together to provide a new information service to producers, 'Managing Scanned Ewes'. The project was implemented by the scanning businesses organising information workshops for their clients and the CRC providing a specialist in the field of sheep reproduction management to contribute to each workshop. The CRC provided further support for the new approach by organising publicity for events and media coverage with key technical messages and relevant case studies. To contribute to the professional development of scanner businesses, the CRC coordinated two training conferences for SMEs operating

pregnancy scanning services. The skills development program for these SMEs included technical updates, as well as communication and public speaking training.

This partnership approach has been highly effective. Forty SME pregnancy scanning businesses have sponsored 88 Managing Scanned Ewes workshops, attended by 1,800 sheep producers responsible for more than 3.3M ewes. Independent surveys have shown that more than 80% of producers attending the information workshops have consequently changed their management practice to improve reproductive efficiency. The percent of producers using information on multiple versus single lambs to manage ewe nutrition has increased from 64% to 71%. The initiative has also had significant benefits for the SMEs (these outcomes are described in other sections of the application).

The level of engagement between the CRC and the scanner SMEs has been comprehensive. The initiative was first planned with input from a number of scanner SMEs who went on to work with the CRC in running a number of pilot workshops. During the pilot project, the format, content and activities were jointly planned and evaluated. This format was then used as the basis for all future workshops.

Every training workshop involves seamless integration and coordination between the SME hosting the day and the CRC's coordinator.

- SME and CRC set the date and agree on target audience
- Invitation to existing clients - SME; media promotion and case study - Sheep CRC
- Program development and delivery - joint SME and CRC
- Follow up scanning activities and technical advice to clients - scanner SME;
- Survey of impact and workshop assessment - CRC

The main impact of this high level of engagement with SMEs has been through the achievement of important synergies. Pregnancy scanners are highly respected professionals within the sheep industry and the CRC is highly regarded as a source of independent and reliable technical and research information (ranked 4 out of a possible maximum 5 in a national survey). The industry credibility provided by involvement of the pregnancy scanners combined with the research profile of the CRC technical expert has achieved the extraordinary outcome of more than 80% of information workshop attendees indicating that they changed their management practice as a result of attending the workshop.

There have been two major benefits for the Sheep CRC through its collaboration with the scanner business SMEs. The first has been the significant contribution that this initiative has made to achieving one of our key outcome targets - increasing the number of lambs weaned each year by 1M. The second benefit for the CRC has been the establishment of a new model for industry participation and engagement.

The impact of increased use of pregnancy scanning data and the improved management practice in response to the information workshops is estimated to have improved the efficiency of reproduction by approximately 15% and this translates to an additional 500,000 lambs per year.

The CRC's other activity to increase reproductive efficiency - the LifeTime Ewe Management program - has been responsible for meeting the other 50% of realising our target outcome.

Perhaps the most important benefit for the CRC and for the sheep industry is that this collaboration with pregnancy scanner SMEs has created a model for accelerating the utilisation and increasing the impact of new research information and new technologies. Recognising the value of close collaboration and comprehensive engagement with SMEs involved in supporting sheep producers and ram breeders forms an integral component of the business plan developed for the CRC's application for a five-year extension.

4. Collaboration

4a. Participant collaboration over the life of the CRC

The Sheep CRC has a policy that all research and adoption projects must involve more than one Participant. This is designed to ensure that the CRC only tackles projects that require collaboration between a number of research providers and a number of end users. All 11 out of 11 active CRC projects in 2014 involve collaboration between at least one research provider Participant and at least one end user. This approach ensures that the following levels of collaboration are achieved:

- collaboration between researcher Participants;
- collaboration between researcher Participants and end user Participants;
- collaboration between end user Participants; and
- external parties being engaged wherever appropriate.

The Sheep CRC's Information Nucleus Program and the associated utilisation of the results in the fields of genetics, meat science, parasite management and improved reproductive performance, is the CRC's broadest and effective collaboration. Practically all of the CRC's Participants have been directly involved in the Information Nucleus Program and utilisation of the outputs extend across large numbers of ram breeders, sheep producers and processors.

The CRC has a policy of open engagement and this has resulted in a number of important linkages being developed that have strengthened our capabilities in research and in commercial development. The relationship with the Dairy CRC continues to grow stronger as many of the research opportunities involve overlap between the sheep and dairy industries. Sharing of research staff and their knowledge between both CRCs is proving to be very valuable. In addition, our links with wool manufacturing companies located in China and Mauritius have been important in understanding the commercial application of our new measurement systems – the Wool ComfortMeter and Wool HandleMeter.

The nature of collaborations and how they add value to the Sheep CRC are best understood by the analogy of sharing a taxi. The Participants "sharing the ride" gain from clearly defining the common destination or goal and developing a shared vision. The cost saving through "sharing the fare" is a direct benefit to all parties and, thirdly, the productive experience of working together on common problems results in expanded professional networks that deliver long-term benefits to researchers and end-users.

Perhaps the most important aspect of constructive collaboration experienced by the Sheep CRC is the deep engagement of end users in each project. The ownership of the outputs and outcomes starts with their involvement in planning the program and assisting in the conduct and evaluation of the research. The involvement of end users provides a practical approach to designing the programs and ensures that the research is clearly focused on delivering outcomes for the end user.

4b. Evidence of increased collaboration between researchers and end-users

Over the last seven years of the CRC, collaboration in all research, development and training activities is now becoming accepted as the norm within the sheep industry. The massive collaboration in the Information Nucleus program brought together researchers, ram breeders, meat processors and producers in a productive working arrangement that clearly established the benefits of working together.

Evidence of the increased level of collaboration within the sheep industry was seen in the planning process as part of developing the application for the CRC's five year extension. The number of organisations joining the CRC as Participants increased from around 20 to 38 for the new program. New Participants joining the CRC included all of the major ram breeding

associations, the main producer groups representing sheep meat and wool specialists, the major meat processors and the major retailers. Also keen to participate were the State Departments and universities that have worked together effectively over the last six to seven years.

4c. The value participants place on being part of the CRC

One of the ways of identifying commitment by Participants to the CRC and the value that they place on working collaboratively within the CRC program is the amount of in-kind staff support that is provided for CRC activities. Out of the total CRC budget of $189.7M, $125.3M was in the form of in-kind contributions. It is significant that the amount of in-kind contributed over the seven year term of the CRC was higher than initially committed despite the very significant reduction in in-kind contributions from State Departments of Primary Industry during the latter years of the CRC when their extension and advisory programs were severely cut.

Clear alignment of objectives between Participants and the accurate description of anticipated outcomes, outputs and activities are essential in order to ensure that Participants clearly understand the programs to which their staff and facilities are applied and the value of the outcomes delivered through their participation.

4d. Case study – effective collaboration in the Information Nucleus Program

The Information Nucleus program has been central to the Sheep CRC's portfolio. Of the 21 CRC Participants, 18 organisations were directly involved in the program. The trial design involved mating 4,500 ewes each year to 100 carefully selected rams from commercial studs for five years. The ewes were run on eight research farms under the control of five different organisations located in four states. The 18,000 lambs were measured for over 150 traits in addition to analysis of DNA from 10,000 selected animals. A central database has been used to develop improved genetic parameters and genetic predictions of breeding value based on DNA profiles. The 75 researchers involved in the program have already published 37 research papers in addition to technical reports and training material based on the research database. (See Fig 4d summarising the work flow).

Collaboration across different discipline and cultures.

The synergies developed through cross discipline research components have produced new understanding of constraints and opportunities within the production system and developed new approaches to genetic selection. In this Program, data from any single discipline is of little value on its own. All of the value is derived from combined analyses, particularly in comparing the genomic and phenotypic data in the association analysis to develop DNA predictions of breeding values.
On-farm measurement of the progeny includes regular weighing and ultrasound scanning for fat and muscle, parasite load, assessment of visual traits, wool production and reproductive efficiency. Laboratory measurements include parasitology tests, wool measurements and DNA analysis. Carcase data are recorded in collaboration with commercial abattoirs and there is a full analysis of meat characteristics. The collaboration between researchers representing disciplines of sheep management, reproduction biology, wool and meat science, parasitology and genetics has been essential. The multi-disciplinary team has developed detailed measurement protocols to ensure robust scientific and commercial interpretation of results. The value of all data has been greatly enhanced through genetic definition of all progeny and the ability to cross correlate data between discipline groups.

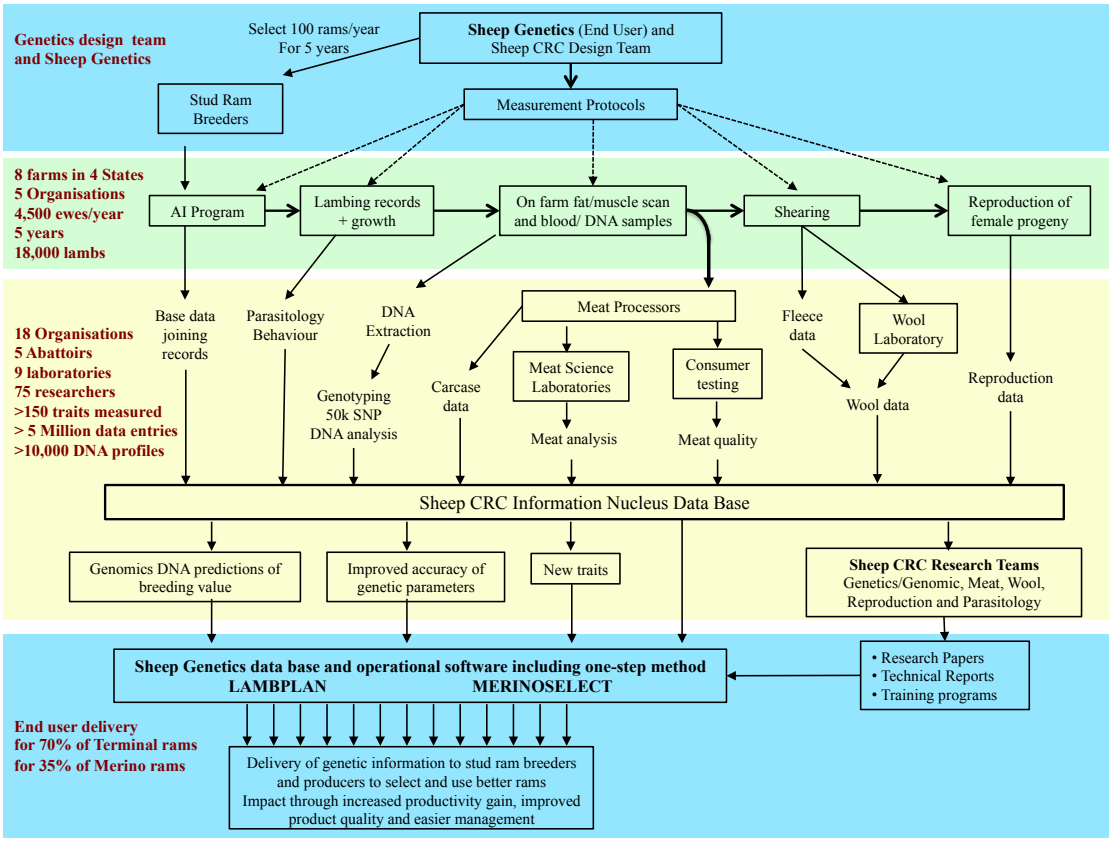

Fig 4d. Summary of the collaboration and workflow involved in the Sheep CRC's Information Nucleus Program

Collaboration across organisations.

The fact that eight research farms all managed their sheep flocks according to exactly the same clearly defined protocols, collected data with precise timing and prescribed techniques and then shared data in a common database is evidence of deep collaboration across organisations. Further collaboration was required to analyse the numerous samples in a range of laboratories throughout Australia. Sharing all data in a single database is also a significant measure of trust and collaboration. The protocols for use of data, joint publications and appropriate acknowledgement have been effective. Most research publications have been jointly authored by researchers in different organisations. This provides further evidence of deep collaboration. The collaboration between organisations, in this ambitious program, was coordinated by the CRC's Management Team with Board oversight and input from industry advisory groups at each site.

End user involvement in collaboration and impact.

Sheep Genetics was identified as the end user organisation responsible for commercial delivery of the outputs and products of the Information Nucleus Program. They were closely involved in designing the trial and in purchasing semen from designated rams for the artificial insemination (AI) program. Sheep Genetics has ensured that information provided by the program has been made available to ram breeders as soon as possible. Sheep Genetics markets data for improved genetic gain through MERINOSELECT and LAMBPLAN.

The impact of the Information Nucleus Program is captured by the sheep industry through improved genetic gain, which is estimated by calculating the additional meat and wool produced by sheep of superior genetic merit. Increased value through improved product quality is important for traits such as sheep meat eating quality.

5. Permissions and contact details

The Sheep CRC grants permission for the Department to use the information and images within this Exit Report for public release and for the communications objectives of the Department.

Further enquiries about the CRC should be directed to Professor James Rowe, sheepcrc@sheepcrc.org.au.

Documents referred to and used in preparing this report

The following documents were prepared by the Sheep CRC as part of the process of monitoring progress towards achieving our objectives. The details provided in various surveys and analyses have been aggregated to provide an overview of the CRC's achievements in this Exit Report.

1. Report on the National Producers and Service Providers Surveys 2014, Anne Jones, Mandy Curnow and Andrew van Burgel. Sheep CRC document pp55.
2. Impact Tracker prepared for Sheep CRC (September 2014), pp56.
3. Review of Outcome 2 – Improved reproductive efficiency (December 2013), RNCG Report pp41.
4. Sheep CRC National Farmer Survey Results 2011, Anne Jones and Mandy Curnow, Sheep CRC document pp57.
5. Media Coverage Report, May 2013 to May 2014 (iSENTIA May 2014) pp11.
6. Survey of the Agricultural Consulting Unit and Course (July 2013), Deborah Maxwell, pp16.
7. Sheep CRC Postgraduate Tracking Report 2013, Graham Gardner, pp23.

Summary of Sheep CRC's Major Achievements and Highlights

Major Achievements

- *Genetics and Genomics*. The most important achievement of the Sheep CRC was to develop and deliver new genomic technologies to the sheep industry to allow faster and better balanced genetic gain as a major driver of productivity and profit. Training programs have increased industry usage of Australian Sheep Breeding Values as the mechanism to select superior genetics for breeding programs.
- *Gaining industry support for continuous support of the Genomics Resource Flock.* At the CRC's mid-term review the value of the CRC's Information Nucleus program was recognised and the CRC was challenged to secure industry support for its continuation. With MLA's support and in-kind contributions from UNE, DAFWA and AWTA the ongoing program continues to provide the data required to keep genomic estimates of breeding value accurate and relevant.
- *Wool measurement systems for next-to-skin knitwear*. The development of new measurement systems to underpin wool's position in the base layer fabric market will have long term consequences implications for fine wool demand based on the functional benefits of improved water buffering and guaranteed comfort and handle.
- *Meat industry development*. Providing new information and tools to manage the dual objectives of improved lean meat yield and eating quality will improve both productivity and consumer demand based on quality.
- *Reproductive efficiency.* The CRC's programs to improve the management of pregnant ewes via the Scanned Ewe Workshops and Lifetime Ewe Management course have created widespread awareness of best practice and the benefits associated with closer monitoring and better nutritional care.
- *Parasite management.* The national ParaBoss program providing best practice advice on managing worm, fly and lice risks forms the basis of a national network of advisors, breeders and producers implementing better parasite management and reducing costs associated with treatment and lost production.
- *Communication and industry profile.* During the 12 month period to May 2014 a total of 1,143 media articles mentioned the CRC. This coverage reached a potential cumulative audience of over 13 M and had an overall advertising space rate of $2.5 M. The CRC's active communication program has achieved widespread awareness of the CRC's products and information and contributed to practice change, usage and industry impact.

Research

- The Information Nucleus program providing the new information for better genetic parameters and the development of genomic technologies has been widely recognised as one of the most important new approaches in livestock production research. Similar schemes are being designed and implemented for the beef and dairy industries in Australia.
- Meat science research has delivered a comprehensive understanding of the factors contributing to lean meat yield, human nutritional value (iron, zinc and Omega-3 levels) and to eating quality. Papers published by the meat science team include 18 peer reviewed papers in the international journal Meat Science published as a special edition.
- Wool comfort and objective measurement systems. The CRC's research into factors contributing to prickle, itch and water buffering of wool fabrics has underpinned the calibration of the new objective measurement systems and the research is the subject of two special editions of peer reviewed textile journals, each with 10 papers contributed by the CRC's wool team.
- Parasite research focused on the potential of targeted treatment as a means of reducing the onset of resistance by parasites to chemical treatment. The principle of treating only animals in identified risk categories results in less chemical use without any adverse

effects on production parameters. Papers on the targeted treatment approach and the anticipated impact on the extended life of chemicals used to control parasites have been published in international peer reviewed journals.

Commercialisation/Utilisation

- New genetic information and genomic technologies have been commercialised through the Sheep Genetics organisation under arrangements established at the outset of the CRC. This has been a spectacularly successful commercialisation process with improved information available to ram breeders within three to four months of new data being available.
- New genomic products (12k sheep genotyping test and new parentage/poll test). These new tests were developed and commercialised by the CRC in collaboration with Sheep Genetics and are now commercial products widely used by ram breeders throughout Australia.
- Commercialisation of the new information on meat eating quality and its relationship with lean meat yield has been commercialised as part of the genetic delivery chain. Many ram breeders, particularly meat terminal sire breeders, have altered their breeding objectives to include a balanced program of improving eating quality traits simultaneously with lean meat yield.
- Wool. New measurement systems have been commercialised via a licence agreement with AWTA that will ensure their availability and utilisation by yarn manufacturers, knitters, brand name companies and retailers that will increase the confidence in and demand for finer micron wools.
- ParaBoss developed by the CRC for the improved management of worms, flies and lice has been licensed to UNE and is being delivered nationally with support from MLA and AWI.
- Livestock Library. This national resource of information has been licensed to the Animal Genetic and Breeding Unit at UNE who have undertaken to continue hosting and delivery of this important resource.

Education and training

- The Postgraduate Program has met its target of 37 research specialists for the industry and indications are that around 70% of these graduates will be retained in the sheep and cattle industries.
- The Graduate Certificate for training consultants and advisors has delivered over 200 graduates with specialist qualifications in this key area for agricultural development.
- Industry training programs such as the Innovation Award winning RamSelect Program designed to achieve effective utilisation of CRC outputs and their rapid adoption has reached a wide cross section of the sheep industry and is having an impact on the capture of the benefits of innovation delivered by the CRC.

SME engagement

- The Information Nucleus program was recognised by the CRC Program STAR Award as an excellent example of effective SME engagement through the hundreds of commercial ram breeders contributing semen from key sires and associated information to the genetic improvement program.
- Managing Scanned Ewes workshop – this initiative of working with a network of private sector ultrasound pregnancy scanners to deliver new information on reproductive management was also the subject of a CRC Program STAR Award for the success in engaging with the SME pregnancy scanners in this successful initiative.
- Engagement in training programs such as Lifetime Ewe Management, Electronic ID, Ram Select workshops. Each of these initiatives relies on effective engagement with SMEs to deliver the course and workshop material while maintaining close engagement with the CRC program.

Inventions

- The Wool ComfortMeter was developed by the CRC and its Participants from concept to

a patented commercial product underpinning the quality assurance of next-to-skin wool knitwear.

- The Pedigree Matchmaker program was developed by the CRC as a means of identifying links between lambs and their ewes in order to use accurate pedigree information for purposes of genetic improvement. The Pedigree Matchmaker program was a winner of the ABC Television's "New Inventors" awards.
- Genomic products were developed from scratch during the life of the CRC. The identification of patterns of gene markers associated with different levels of genetic merit for different traits allowed the research team to design new DNA tests that would predict, in a cost effective way, genetic merit for a range of conventional and difficult to measure traits. These products have been commercially available for use by Australian breeders from 2014.

International engagement

- The meat science group has developed its research program to have very strong links with European researchers and this international collaboration has been most productive.
- The wool program has developed close links with yarn manufacturers and knitters in China, a large knitting company based in Mauritius and with wool testing houses in the UK and China.
- The development of new genomic tests has achieved effective collaboration with specialist companies in the US that have been able to provide technical expertise and access to volume product purchases to achieve cost effective price points for the Australian sheep industry tests.