final report

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Developing principles and priorities for the genetic improvement traits and species in pastures.

Report on a Priorisation Workshop

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Abstract

The investment profile and delivery structure for forage plant breeding and evaluation has been the subject of numerous reviews in recent years. There is an increased emphasis of examination of the role of government in investment and a desire for the private sector to invest in near market and commercial activities. This has seen an increase in the number of public:private partnerships and a focus of public sector and industry investment in generic technologies and areas of market failure. This report recommends some priority investment areas for pasture breeding and genetics in Australia that are aimed to provide Australian red meat producers with ready access to cultivars that have been selected for traits that add to the productivity and sustainability of the industry.

Executive Summary

The investment profile and delivery structure for forage plant breeding and evaluation has been the subject of numerous reviews in recent years. There is an increased emphasis of examination of the role of government in investment and a desire for the private sector to invest in near market and commercial activities. This has seen an increase in the number of public:private partnerships and a focus of public sector and industry investment in generic technologies and areas of market failure. This process has been endorsed by the PISC R, D & E process and is consistent with recent developments in plant breeding investment and delivery in the grains and horticulture industries.

A number of MLA reviews including the recent FIP have highlighted potential areas for MLA investment that are consistent with this overarching framework and have the potential to add value to the Australian red meat industries through the provision of improved forage genetics to an informed market place. These include:

- Development of objective evaluation programs
- Development of technologies to describe and increase genetic gain in forage species
- Development of programs that develop and utilise modern genetic tools (genomics, bioinformatics, quantitative genetics etc) to provide novel tools and traits for forage plants
- Extending the range of adaption of existing species through selection

Unfortunately, the implementation of changes to investment and activity in forage plant breeding has often occurred on a project by project basis as projects become eligible for renewed funding rather than an integrated strategic assessment of research priorities.

This workshop is an action from the Feedbase Investment Plan and has 4 main aims:

- To review and endorse a funding model for pasture plant breeding and evaluation in Australia that recognizes the respective roles of public and private sector agencies
- To develop a list of priority species by region based on adaptation, current and future use
- To develop a list of priority traits based on their likely benefit in red meat production systems
- To identify potential programs and project areas and recommend a path for developing and contracting these projects

Recommendations:

Processes and Policies

1. That MLA, research providers and the private sector invest in plant breeding activities in accordance with the principles outlined in Appendix 1.
2. That MLA, research providers and the private sector undertake an audit of key skills available among pasture plant breeding programs in Australia.

3. That MLA work with seed companies and the Australian Seed Federation to develop a new model for the commercialisation of non-international pasture species in Australia. This model to focus on maximising the availability of new cultivars to producers whilst avoiding duplication and the proliferation of poorly defined ‘me too’ cultivars. This discussion to include opportunities to assign a head licensee for finished cultivars with the provision of broad cross-licensing (this has been successful with some technologies such as endophyte in ryegrass and the Roundup Ready trait in crops) to ensure that the trait/genetic benefit is widely available.

Projects

Economic Value

4. That MLA initiate a project to measure the economic value of genetic gain pastures for red meat producers. This project will deliver estimates of the value of new pasture genetics but also serve as the basis for prioritising future investments.

Grasses

5. That MLA initiate the development of a project to ‘internationalise’ phalaris. This project will require contributions from research providers and seed companies. The aim of this project is to develop a self-sustaining phalaris breeding program so that future MLA investment can move upstream in the plant breeding pipeline.

6. That any research in perennial ryegrass, tall fescue, lucerne, white clover and cocksfoot complement existing commercial activities in these species and focus on either new traits or improved breeding methodologies. It is likely that in the short-term greater gains will be made by improving breeding methodologies as current rates of gain appear to be less than those obtained in other plant species rather than through selection for any individual trait. The workshop did not propose specific projects in this area rather that these principles should apply if any projects in these species were developed.

Legumes

7. The workshop noted that both sub-clover and annual medics were more important in Australian agriculture than overseas. However, there was less consensus on the key traits for improvement and the relative importance of sub-clover vs annual medics although winter yield was identified as a key agronomic trait for improvement. In the absence of consensus the need exists to determine the relative importance of these species for improvement and whether immediate needs are best addressed through the increased adoption of existing germplasm from NAPLIP and other programs.

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1. Background

The investment profile and delivery structure for forage plant breeding and evaluation has been the subject of numerous reviews in recent years. There is an increased emphasis of examination of the role of government in investment and a desire for the private sector to invest in near market and commercial activities. This has seen an increase in the number of public:private partnerships and a focus of public sector and industry investment in generic technologies and areas of market failure. This process has been endorsed by the PISC R, D & E process and is consistent with recent developments in plant breeding investment and delivery in the grains and horticulture industries.

A number of MLA reviews including the recent FIP have highlighted potential areas for MLA investment that are consistent with this overarching framework and have the potential to add value to the Australian red meat industries through the provision of improved forage genetics to an informed market place. These include:

- Development of objective evaluation programs
- Development of technologies to describe and increase genetic gain in forage species
- Development of programs that develop and utilise modern genetic tools (genomics, bioinformatics, quantitative genetics etc) to provide novel tools and traits for forage plants
- Extending the range of adaption of existing species through selection

Unfortunately, the implementation of changes to investment and activity in forage plant breeding has often occurred on a project by project basis as projects become eligible for renewed funding rather than an integrated strategic assessment of research priorities.

MLA, in conjunction with the Red Meat Co-investment Committee (RMCiC) is developing an investment plan for feedbase research and development with an aim of adding $25m on-farm value per year by 2020, with kilograms of meat per hectare rising at 2.5% per annum. This involves better decision/better management of (if appropriate) better plants but with no decline in sustainability indicators. The proposed investment is $5-7.5m pa over 5 years.

The following section is taken from the MLA feedbase investment plan document.

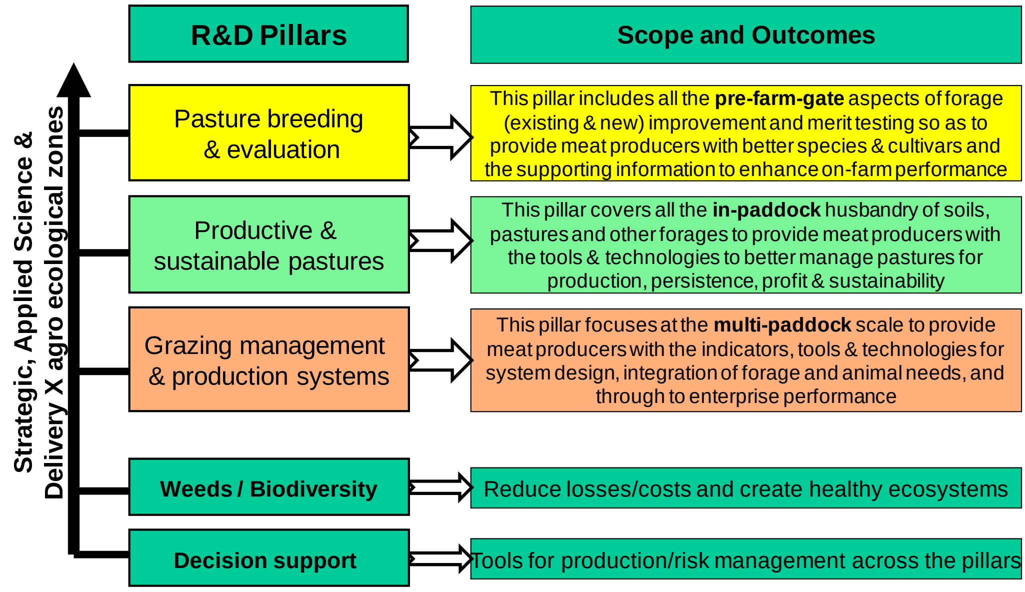

Figure 1. The research scope/outcomes for each of the 5 R&D pillars.

Pillar 1 - Pasture Breeding and Evaluation

The pasture breeding and evaluation process has been the subject of numerous reviews in recent years – as well as during the FIP consultation process. What these reports lack is an analysis of how well current pasture cultivars fit the requirements of leading producers who are the key target for this Feedbase R&D Plan. There is no 'industry agreed' priorities at either the species or the traits level on which to base industry investment decisions.

The meat industry has been moving towards the 'investment decision process' used in the grains industry (see Figure 2) where the private sector is primarily responsible for near market and commercial activities, while the industry and public sector invest in generic technologies and areas of market failure.

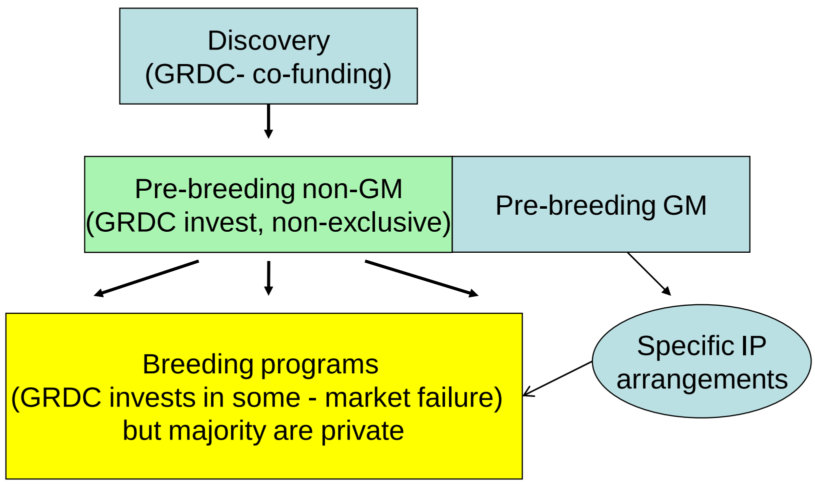

Figure 2. *The grains industry model that has been implemented by PISC agencies. In this model industry levies (and PISC agency investments) are concentrated on the discovery and pre-breeding stages of the R&D pipeline*

The overarching goal of this R&D pillar is to increase producer profit through delivery/development of superior cultivars, making them available faster, and providing objective information on performance to build confidence to invest in pastures. The outcome required is to have better (higher yield or quality, more persistent, better fit with animal system demands, etc) forage species and cultivars available to meat producers.

The FIP consultation process (FIP - see Appendix A) identified the key research deliverables for the Pasture breeding & evaluation pillar and these deliverables contain the key components of:

1. *Uniform and independent genetic evaluation (including persistence) and demonstration of pastures species and varieties.*
2. *Improvement in the base pasture traits identified as important to meat producers – viz persistence, forage production quality and timeliness, P efficiency, seedling vigour and animal health outcomes;*
   - *Pasture legumes with the additional features of tolerance to low pH, performance in mixed swards and adapted to shorter/more variable seasons and sub-tropical regions;*
   - *Pasture grasses with the additional features of reduced toxicity, better aluminium tolerance and adaptation to variable seasons and sub-tropical regions.*
3. *Tools and processes to assist meat producers and service providers access and utilise the most suitable pasture genetics.*

These deliverables are applicable to all agro-ecological regions other than the arid interior.

Some of the key challenges for this R&D pillar include:

→ *Adapting the grains industry model to suit the diversity of the forage industry;*

→ *Defining the industry priorities for both species/traits and production/NRM;*

→ *Clear definition of where market failure exists in breeding programs;*

→ *Development of a national variety evaluation program that both meets the objective information needs of leading producers and enables efficiency in pasture research;*

→ *Bringing the most advanced genetic technologies (eg molecular biology; genomics[1]) to focus on genetic gains in forage species of importance to Australian meat producers;*

→ *Building the case for pasture improvement in those areas where commercial returns are available, and thereby boosting the rate of pasture re-sowing.*

A summary of the investment recommendations for the Pasture Breeding & Evaluation pillar is presented in Figure 3. For a more detailed account, see section 8 of the MLA report.

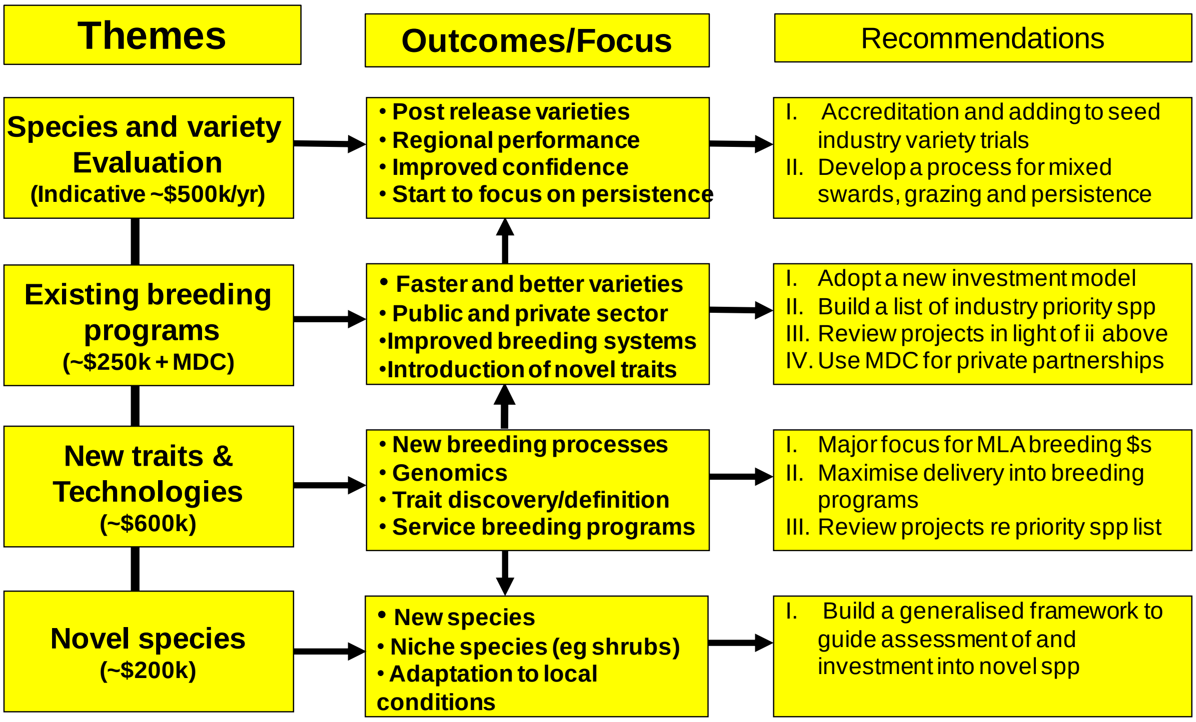

Figure 3. Summary of the Pasture Breeding and Evaluation pillar.

This workshop is an action from the Feedbase Investment Plan and has 4 main aims:

- To review and endorse a funding model for pasture plant breeding and evaluation in Australia that recognizes the respective roles of public and private sector agencies
- To develop a list of priority species by region based on adaptation, current and future use
- To develop a list of priority traits based on their likely benefit in red meat production systems
- To identify potential programs and project areas and recommend a path for developing and contracting these projects

2. Methodology

As part of the planning it was proposed that this project be focussed around a facilitated workshop. A list of attendees for the workshop (Appendix 2) was developed in conjunction with MLA and selected to include representation from:

- Universities
- State Government Research Agencies
- CSIRO
- Seed Companies
- Meat Producers

The group where selected based on their interest in pasture plant improvement and also experience across a range of relevant disciplines including:

- Plant Breeding
- Biotechnology
- Agronomy
- Economics
- Marketing
- Seed Production
- Meat Production

Prior to the meeting a paper was developed by AbacusBio (Appendix 1) to act as a discussion starter. This paper summarised recent developments in pasture plant breeding and the MLA Feedbase Investment Plan. The paper also placed these developments in context with national and international activities in plant breeding including developments in the structure and funding of plant breeding activities in crop and horticulture species.

The process of the workshop is described in the results section below. Following the workshop a draft report was circulated to attendees for feedback that was used in completion of this final report.

3. Results

Workshop Notes and Processes

Initial feedback

At the commencement of the workshop participants were asked to provide their initial responses to 4 questions:

What would you say has been the biggest success from pasture breeding for Australian meat producers?

What is the greatest disappointment/missed opportunity?

What is the greatest challenge facing pasture breeding for Australia?

What would you like to achieve from this workshop?

These responses are given in detail below but in general workshop attendees expressed views that articulated that progress had been made through plant breeding in Australia but there was a general frustration at the rate of uptake of new pasture cultivars and the inability of new cultivars to displace older cultivars from the market place.

What would you say has been the biggest success from pasture breeding for Australian meat producers?

- Using Australia's moderate/poor soils, variable climate, variable export markets and introducing pasture species (many) into a relatively prosperous livestock industry
- Lime and lucerne/clover for hay, grazing, N production in crops etc
- The identification of species suited to the Australian environment and breeding a variety in Australia for greater adaptation
- Discovery of the suitability of sub clover for the acid soils of southern Australia and the subsequent improvement of cultivars
- Adaptation of a range of grass and legume species to suit the various agroclimatic regions in the medium to high rainfall temperate zones
- Suite of species to cater for a diverse range of soils and environments
- Good range of cultivars for major agro-ecological zones that are significant improvements (in various ways) on old wild-type varieties
- Overall good identification/use of main pasture species for Australian environments
- Some good programs that have developed Australian cultivars – adapted to our conditions
- Introduction of perennial ryegrass
- NAPLIP
- Development of phalaris cultivars better suited to environment
- Continual incremental gain multiplied by occasional breakthroughs
- From a broad picture: taking exotic species (majority of pasture plants we use) an domesticating them for use in the Australian landscape
- The integration of exotic species of legumes (eg *Trifolium, Medicago* etc) into mixed cereal/livestock farming systems which has resulted in more stable, viable farm units with complementary benefits to both the livestock and cropping enterprise

- Introduction of sub clover and other legumes, high yielding perennial ryegrass
- Adaptation of exotic species to the Australian environment. Too many to mention but brining material from vastly different climates has often been the starting point
- The private:public relationships for pasture breeding that are delivering improved varieties (with little assistance from RDCs) that are being taken up by the market
- Nothing specific, just that growers currently have access to a terrific range of world-class cultivars in a number of important species – lucerne, sub clover, phalaris, cocksfoot, several other legumes
- Domestication and utilization of *Phalaris aquatic* and *Trifolium subterraneum*

What is the greatest disappointment/missed opportunity?

- Low uptake of new species
- General lack of management of Australian pastures
- Very limited new species to challenge lucerne, clover and phalaris in mainstream agriculture
- The loss of key development programs in pastures eg phalaris (CSIRO) & NAPLIP (DAFWA)
- Promotion of varieties/cultivars into unsuitable environments (eg Ellett ryegrass in the 1980's into <700mm rainfall zone)
- To have improved genetics replace rather than exist alongside clearly out-dated options
- Poor utilization of legumes; poor adoption
- That there have been a number of species/cultivars developed but very little uptake by producers – usually because of a lack of information to go with the new species/cultivar
- Focusing on what's working and united message across govt, RDCs, grower groups and industry
- Adoption. The frequency that outdated material is used
- Value creation for parties involved in breeding and marketing which then funds breeding
- Lack of support for practical plant breeding or linkage to basic research. Where are the future pasture plant breeders?
- Lack of opportunities for young pasture scientists
- Lack or loss of recognition by farmers of the multiple benefits of pastures in cropping systems
- Lack of breeding for alternative perennial grasses, bromes, cocksfoot
- Inability to convince farmers to plant new and improved varieties – can't convince them it is a critical and profitable activity
- The disproportionate amount of $ invested in genomics with not a single positive outcome for meat producers in Australia
- When AWI and MLA failed to invest in work on phalaris toxicity when the "time was right" ie a great collaborative team existed, an exciting hypothesis was there for the testing
- The failure to adequately develop the potential of Hispanica cocksfoots to extend them into the mixed farming zone

What is the greatest challenge facing pasture breeding for Australia?

- For all players (research, extension, private and public entities) to work together to 'raise the bar' of pasture management and production
- Animal efficiency and feed conversion efficiency
- Low-cost productive legumes in sheep/wheat belt

- Cheap, long term development of large areas of pastoral land
- How to keep the expertise it has without further erosion
- Persistent perennial grasses, improving management of perennial pastures, lack of long-term evaluations to give farmers confidence in newer cultivars
- To highlight the value to end users of the genetic gains achieved and to ensure that they have the management guidelines to achieve that extra value over the life of the pasture genetics
- Keep funding pasture breeding programs with the “omics” integrated into them, not running them
- Keeping legume breeding going until expanding adoption/utilization to the point where the market will sustain the variety development chain
- Identify the priority species and breeding programs that will provide the greatest bang for buck from investment by livestock industries
- Meeting the needs of livestock; pasture breeding needs to work closer with livestock scientists
- Funding and timeline to commercial outcome (probably the reason we are all here)
- Using the leverage that exists – public & private to generate benefits from a limited funding base
- Lack of trained pasture plant breeders
- Providing an interface between practical breeding and biotechnology
- Reducing public sector funding of agricultural research in general (including pasture improvement)
- Increased competition for diminishing RIRC funding (exacerbated by the withdrawal of some RIRCs)
- Loss of fundamental pasture plant breeding capacity (eg skills/infrastructure). This cannot be turned on/off like a tap.
- Where are the young scientists?
- Uptake of new cultivars
- Transition from developed cultivar to commercial product
- No doubt persistence (yield over time) is a challenge. Drought/climate change is a huge challenge
- Maintenance of capacity and resources required to respond to new challenges (ie new pests and diseases)
- Capacity to respond to requirement of increasing food production in response to increasing demand
- No succession planning; lack of future in Agricultural Science
- Funding competent, viable programs (including staff) for a sufficient time
- Address value proposition for breeding merit of individual plants in varietal development – that is transition to pedigree based system supported by genomic/phenomic characterisation or, build a selection ‘machine’ that can function like dairy cattle improvement
- Developing cultivars with adequate adaptation to increasing drought and high temperatures associated with climate change

What would you like to achieve from this workshop?

- Consensus that is simple in delivery and management
- To re-evaluate what our pastures are to be used for and where we are heading and integrate with other new technologies
- A joint program where public/private groups work together, with many seed companies involved so that the farmer is the one who has the greatest benefit
- Investment into the "total pasture package" – breeding, management, farmer education in establishment and management
- A clear role for MLA to fund step change technologies for the benefit of all producers via those agencies and private companies that want to come along for the ride
- MLA support to pasture breeding
- An agreed structure to achieve a market that will sustain the variety development chain
- A big picture framework for pasture breeding that can be underpinned by some good projects with regional outcomes
- 3 clear project streams to advance pasture improvement and productivity
- Efficiency, understanding, networks
- A broad consensus of major traits of importance
- Some string guidelines for project applications
- Development of a workable model for investment
- A greater recognition by MLA of the importance and relevance of the cereal/livestock zone for livestock production, ie the complementary benefits of pastures to both livestock and cereals
- Unified national breeding program
- Understanding of the groups knowledge/expertise in species and traits worth pursuing Evidence based, not promises will help our private company to work out where we invest
- Initiate a positive change that delivers base funding to applied plant breeding groups, whether they be public or private
- The realisation that the future level of investment is completely inadequate and needs to be revisited
- A clearer idea of how to proceed in future breeding ambitions
- Clear path forward to understand key pasture species for MLA (one will do), traits to improve and quantum of funds available to do the job
- That a pathway to achieve/attain research funding for me to be able to use my scientific knowledge and skills in the service of Australian farmers might be found.

What are the causes of market failure in Australian pasture plant breeding?

The group was then asked to discuss the causes of market failure in pasture plant breeding in Australia so that these could be addressed during project development. The following list is a consolidated list and commentary on the points raised.

1) *Returns funding breeding*

   The returns from plant variety sales are insufficient in most cases to fund plant breeding programs. This has seen a consolidation of breeding around key species with established markets in Australia and overseas.

2) *Is ROI undervalued or wrongly valued*

   The spread of value from pasture genetics is poorly understood and has not been partitioned along the value chain. How much of the benefit accrues to producers, seed companies etc?

3) *Variety of churn/running on the spot v's market size and size of pie and slice of pie*

   There are too many varieties in the market and their benefits are poorly understood. Companies are forced to provide a variety of each species and this leads to a proliferation of similar cultivars and poor information to producers.

4) *Benefits of new cultivars – to producers- KPI of profit drivers*

   The need exists to link the benefits of new cultivars to the profit drivers of red meat producers. This may be increased pasture yield, greater reliability, the ability to finish more lambs to specification without the use of supplementary feed or fodder crops etc.

5) *Aust markets small*

   In order to get scale it is necessary to focus on species with international markets.

6) *Should not expect farmers to assess all benefits individually*

   The need exists for a co-ordinated program to define the benefits of new pasture cultivars. If this is left to individual producers there will be no increase in sowing rates and there is a lack of drive to share the information as the individual producers are taking on all the risk of product verification.

7) *For part of the landscape products ok but information not to farm gate*

   Even when good varieties exist the information flow to producers may be poor.

8) *Farmer groups- interaction with breeders and seed companies*

   There is a great opportunity to increase this linkage.

9) *Trust*

   Not all producers trust seed company information but there has been a decline in sources of independent information.

10) *Application of technology*

   Not all species have benefited from new technology, some are every simple introductions. Even when technology is available it has not been applied in all breeding programs.

11) *Accounting for genetic gain*

   There is no simple and agreed method to measure and describe genetic gain in pastures. Should it be total yield, seasonal production, lifetime production, potential animal production etc.

12) *Adequate germplasm*

In some species there is adequate germplasm in others not so. The collection, description and curation of genetic resources does not always focus on the needs of those breeding for Australian conditions.

13) *Funds for exploitation*

Breeding programs have often only been funded to develop new cultivars, there has been insufficient attention on the development of packages to exploit the benefits of these new cultivars.

14) *Elimination of varieties*

There are still a large number of outdated cultivars in the Australian market. In many cases the defects of these cultivars are known yet they continue to be sold and marketed. In some cases this is because the seed is cheap and the market does not accept the value proposition for improved cultivars. In other cases producers may be actively returning to the use of outdated cultivars due to inadequate information on the management requirements of improved cultivars.

What are the priorities for MLA/Govt investment?

The workshop then discussed the priorities for investment based on an analysis around the following questions:

What if?

MLA and PISC agencies ceased funding today?

What would fall through the gaps?
Would it matter?
Would the private sector pick it up?
Is there a better way?

The general consensus was that the current reduction in government investment in cultivar development had led to some effective alliances between the private and public sector and that these would need to continue and be strengthened and that the major risk was for those species that are important for Australian agriculture (sub-clover, phalaris, annual medics) but less so internationally, or to the targeting of traits and technologies relevant to Australia in the major international species (Lucerne, ryegrass, tall fescue, white clover, cocksfoot). Some strategies to better manage the balance between public and private investment to deliver novel genetics to Australian producers were proposed and discussed.

a) Build on current successful public private partnerships

Eg Subterranean clover, perennial ryegrass, white clover. There are big opportunities to see new technologies and novel traits exploited in these species by expanding and strengthening current relationships.

b) Internationalise ‘Australian’ species

This is a novel concept and is based on giving scale to these species to allow resilient breeding programs. An example that was discussed was the problem that phalaris toxicity causes to its acceptance in international markets.

c) Demonstrate the value of novel genetics

The major opportunity in most grazing environments is not the replacement of one new cultivar with another, rather the displacement of outdated genetics and the potential to increase resowing and thereby grow the overall market and thus give scale to allow the breeding of species for Australian conditions. The New Zealand Pasture Renewal Trust is an example of an organisation with just this aim.

d) Negotiate with overseas/multinational companies

The seed market is an international business. Australia needs to be proactive in developing international partnerships to ensure that germplasm relevant to Australian conditions is being used during crossing and selection.

e) Develop novel business models for those species needed in Australia that are not widely used overseas

These species have benefitted from significant public investment in the past but have not proven to be attractive to private sector breeders. The opportunity exists to review marketing, royalty sharing and licensing to ensure that new cultivars are widely available yet still commercially attractive. It was agreed that this was not likely to be simple but worthwhile investigating.

In summary pasture breeding for meat producers faces some difficult challenges

- Declining investment
- Poor articulation of the value of novel genetics
- Rates of pasture renovation are too low to provide funds for development
- Too many cultivars lead to market fragmentation
- Restriction of resources further reduces genetic gain

f) Potential traits grouped according to species

The following traits were discussed at the workshop but in some cases time prevented an adequate assessment of the relative importance of traits (and species). The development of an economic assessment tool (Recommendation 4 of this report) would allow the assessment of priorities free of personal preferences and priorities but also to appropriately address issues such as risk.

Grasses

1. Phalaris

    a. ease of establishment,
    b. grazing tolerance in acid tolerant cultivar
    c. Toxicity as barrier to adoption.

2. Hispanica cocksfoots

    a. Seed
    b. Establishment

3. Winter Active tall fescue

    a. Late season Feed Value
    b. Establishment

4. Native

    a. Seed costs

Perennial legumes

5. Lucerne

    a. Acid soils tolerance (evaluation of new varieties and rhizobia, not breeding).
    b. Respond to new aphid biotypes
    c. Bloat. Availability from New Zealand. Impact on Australian programs discussed.

6. Tedera

    a. Agronomy
    b. Supported by FFI CRC

7. Annual legumes

    a. Early season feed
    b. Disease resistance (root rot causing 30-40% seedling mortality in sub and balansa)
    c. Powdery mildew – very high priority for medics
    d. Nitrogen fixation in subclover with background rhizobia – very high priority for subclover in NSW
    e. Bluegreen aphid tolerance in medics and subs to new virulent biotype

Recommendations for new projects

The following recommendations are based on the combination of discussion at this workshop and previous work in the Feedbase Invest Planning Process. In this workshop project needs were workshopped in the areas of:

- Perennial grasses
- Perennial legumes
- Annual legumes

Several other recommendations for improved processes are also proposed based on the discussions at this workshop.

Separately to this workshop MLA has been developing a new template and process for the assessment of project proposals in novel/niche species (forage herbs, some perennial grasses and many legume species could be assessed in this category). The recommendations of this workshop and report are consistent and complementary to these processes.

These recommendations are described below.

Processes and Policies

1. That MLA, research providers and the private sector invest in plant breeding activities in accordance with the principles outlined in Appendix 1.
2. That MLA, research providers and the private sector undertake an audit of key skills available among pasture plant breeding programs in Australia.
3. That MLA work with seed companies and the Australian Seed Federation to develop a new model for the commercialisation of non-international pasture species in Australia. This model to focus on maximising the availability of new cultivars to producers whilst avoiding duplication and the proliferation of poorly defined ‘me too’ cultivars. This discussion to include opportunities to assign a head licensee for finished cultivars with the provision of broad cross-licensing (this has been successful with some technologies such as endophyte in ryegrass and the Roundup Ready trait in crops) to ensure that the trait/genetic benefit is widely available.

Projects

Economic Value

4. That MLA initiate a project to measure the economic value of genetic gain pastures for red meat producers. This project will deliver estimates of the value of new pasture genetics but also serve as the basis for prioritising future investments.

It is envisaged that MLA employ a consultant to liaise with breeders to assess what datasets are available and that this consultant then work with economists and statisticians to determine the scope of the program and develop an investment case for MLA.

Grasses

5. That MLA initiate the development of a project to ‘internationalise’ phalaris. This project will require contributions from research providers and seed companies. The aim of this project

is to develop a self-sustaining phalaris breeding program so that future MLA investment can move upstream in the plant breeding pipeline.

It is critical that this research project is not merely a continuation of existing or previous investments. Regardless of whether it was a priority of these programs or not they have failed to develop the species to the point where its breeding can continue without financial support. The alternative is that phalaris improvement cease and it is likely that the species will be replaced to some extent by tall fescue and cocksfoot. This scenario is not ideal for the following reasons

- The species do not share exactly the same attributes and adaptation, although there is some overlap.
- Both cocksfoot and tall fescue have problems with adoption in the areas to which they are adapted and these are likely to be exacerbated in new regions or production systems.

It is the opinion of the author of this report that for this phalaris program to be successful it is essential that the program address the following criteria:

- What are the key factors that limit the 'internationalisation' of phalaris?
- What is the benefit of improving these features for Australian producers?
- What is the genetic correlation between these traits and persistence and quality of phalaris in Australian environments?
- What is the timeline for 'handover' of phalaris breeding to the private sector?
- What are the next traits that should be addressed for the direct benefit of Australian meat producers?

The author also recommends that the project should include partners and skills in the following areas

- Phalaris genetics and breeding
- Commercial plant breeding and marketing
- Toxicology and biochemistry
- Economics
- Molecular genetics and genomics

The exact balance of resourcing of elements of the project should be at the jurisdiction of the project investors and management team. However, both at the workshop and in feedback to the draft report many respondents have reinforced the complexity and risks associated with this project. This demonstrates that it is a departure from 'business as usual' and as such the scope and tools used in the project should be assessed accordingly.

The project should be managed by a management committee consisting of representatives of the project partners and an independent person/s with experience in pasture plant breeding and genetics. The author has seen the benefit of this management structure in large plant genetics projects in the past, particularly with respect to allowing these projects to evolve with changes in priority and technology. If it becomes clear that there are technological, commercial or market reasons whereby the major aim of 'internationalising' phalaris will not be achieved the need for this project should be reassessed and the cost-effectiveness of this option versus investing in trait development in tall fescue and cocksfoot to service the needs of those producers who use phalaris be determined.

6. That any research in perennial ryegrass, tall fescue and cocksfoot complement existing commercial activities in these species and focus on either new traits or improved breeding methodologies. It is likely that in the short-term greater gains will be made by improving breeding methodologies as current rates of gain appear to be less than those obtained in other plant species rather than through selection for any individual trait. (This recommendation applies equally to perennial legume species such as lucerne and white clover).

Published rates of genetic gain in forages vary widely (0-3%pa) but are mostly in the range of 0.5%pa. There is ample opportunity to treble this average rate of gain to 1.5% pa, through the integration of quantitative genetics, genomics and economics as has occurred in animals and forest trees. Tall fescue and lucerne are well placed to benefit from genomic research in perennial ryegrass and *Medicago* respectively. However, less research is occurring in applying quantitative genetic principles in pasture plant breeding.

Legumes

7. The workshop noted that both sub-clover and annual medics were more important in Australian agriculture than overseas. However, there was less consensus on the key traits for improvement and the relative importance of sub-clover vs annual medics although winter yield was identified as a key agronomic trait for improvement. In the absence of consensus the need exists to determine the relative importance of these species for improvement and whether immediate needs are best addressed through the increased adoption of existing germplasm from NAPLIP and other programs. The genetic basis of winter production is also unclear, with options including

- Disease resistance
- Early vigour (such as deployed by CSIRO in wheat)
- Increased root growth to allow early germination.

It is critical that this research project is not merely a continuation of existing or previous investments. Regardless of whether it was a priority of these programs or not they have failed to develop the species to the point where its breeding can continue without financial support.

It is recommended that further analysis of the priorities for annual legume occur and that these be based on producer requirements given the broad range of germplasm available. The proposed path forward is as follows:

- Comprehensive producer needs analysis (Jan – Mar 2012)
- Review of suitability of existing germplasm (April 2012)
- Development of new project/s (May 2012)

Appendix 1

Discussion Paper for
MLA Feedbase Plant Breeding Traits and Technologies
Prioritisation Workshop
North Sydney
26th and 27th October 2011

1. Executive/Plain English Summary

The investment profile and delivery structure for forage plant breeding and evaluation has been the subject of numerous reviews in recent years. There is an increased emphasis of examination of the role of government in investment and a desire for the private sector to invest in near market and commercial activities. This has seen an increase in the number of public:private partnerships and a focus of public sector and industry investment in generic technologies and areas of market failure. This process has been endorsed by the PISC R, D & E process and is consistent with recent developments in plant breeding investment and delivery in the grains and horticulture industries.

A number of MLA reviews including the recent FIP have highlighted potential areas for MLA investment that are consistent with this overarching framework and have the potential to add value to the Australian red meat industries through the provision of improved forage genetics to an informed market place. These include:

- Development of objective evaluation programs
- Development of technologies to describe and increase genetic gain in forage species
- Development of programs that develop and utilise modern genetic tools (genomics, bioinformatics, quantitative genetics etc) to provide novel tools and traits for forage plants
- Extending the range of adaption of existing species through selection

Unfortunately, the implementation of changes to investment and activity in forage plant breeding has often occurred on a project by project basis as projects become eligible for renewed funding rather than an integrated strategic assessment of research priorities.

This discussion paper will briefly outline principles and processes used when prioritising investment in pasture plant breeding. The purpose of the paper is to serve as a discussion paper for the forthcoming workshop and there are several key factors that the reader must consider

- Whilst the workshop is commissioned by MLA the views/options presented herein are not necessarily those of MLA and they may be endorsed, modified or refuted based on discussions or evidence presented at, or after, the workshop.
- The author is aware that in many cases that publicly available datasets may be incomplete and the provision of further data may influence discussions. In these cases workshop attendees are encouraged to provide further data at the workshop.
- In essence workshop attendees should view this document as a discussion starter and ‘strawman’ that can be built-up or burned-down based on debate at the workshop. The workshop convenors have requested such a document in the hope that it will stimulate debate and discussion thereby allowing maximum progress to be made during the workshop.

2. Background and Aims of the Workshop

MLA, in conjunction with the Red Meat Co-investment Committee (RMCiC) is developing an investment plan for feedbase research and development with an aim of adding $25m on-farm value per year by 2020, with kilograms of meat per hectare rising at 2.5% per annum. This involves better decision/better management of (if appropriate) better plants but with no decline in sustainability indicators. The proposed investment is $5-7.5m pa over 5 years.

The following section is taken from the MLA feedbase investment plan document.

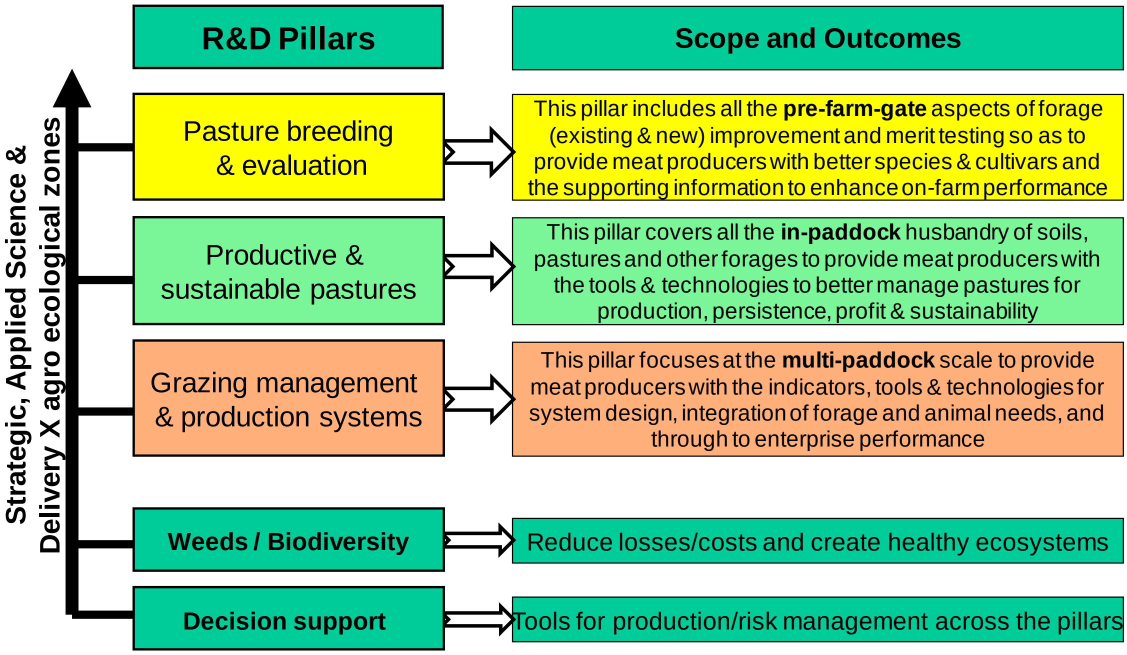

Figure 1. The research scope/outcomes for each of the 5 R&D pillars.

Pillar 1 - Pasture Breeding and Evaluation

The pasture breeding and evaluation process has been the subject of numerous reviews in recent years – as well as during the FIP consultation process. What these reports lack is an analysis of how well current pasture cultivars fit the requirements of leading producers who are the key target for this Feedbase R&D Plan. There is no 'industry agreed' priorities at either the species or the traits level on which to base industry investment decisions.

The meat industry has been moving towards the 'investment decision process' used in the grains industry (see Figure 2) where the private sector is primarily responsible for near market and commercial activities, while the industry and public sector invest in generic technologies and areas of market failure.

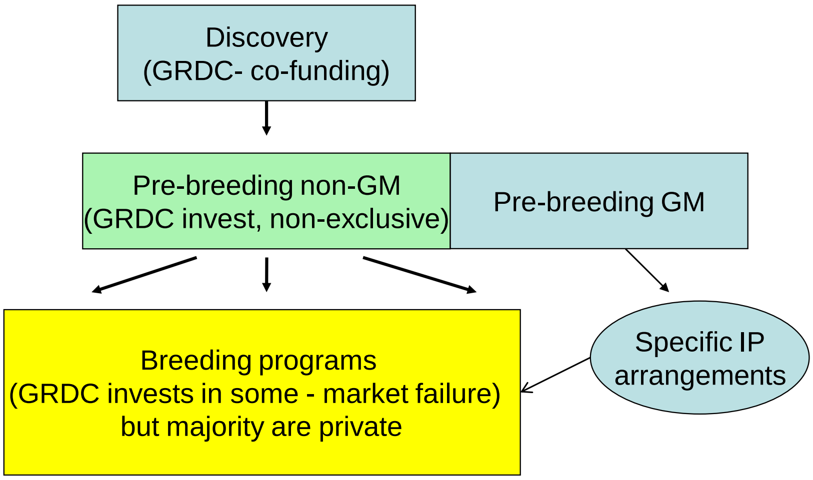

Figure 2. *The grains industry model that has been implemented by PISC agencies. In this model industry levies (and PISC agency investments) are concentrated on the discovery and pre-breeding stages of the R&D pipeline*

The overarching goal of this R&D pillar is to increase producer profit through delivery/development of superior cultivars, making them available faster, and providing objective information on performance to build confidence to invest in pastures. The outcome required is to have better (higher yield or quality, more persistent, better fit with animal system demands, etc) forage species and cultivars available to meat producers.

The FIP consultation process (FIP - see Appendix A) identified the key research deliverables for the Pasture breeding & evaluation pillar and these deliverables contain the key components of:

4. *Uniform and independent genetic evaluation (including persistence) and demonstration of pastures species and varieties.*

5. *Improvement in the base pasture traits identified as important to meat producers – viz persistence, forage production quality and timeliness, P efficiency, seedling vigour and animal health outcomes;*

   - *Pasture legumes with the additional features of tolerance to low pH, performance in mixed swards and adapted to shorter/more variable seasons and sub-tropical regions;*

   - *Pasture grasses with the additional features of reduced toxicity, better aluminium tolerance and adaptation to variable seasons and sub-tropical regions.*

6. *Tools and processes to assist meat producers and service providers access and utilise the most suitable pasture genetics.*

These deliverables are applicable to all agro-ecological regions other than the arid interior.

Some of the key challenges for this R&D pillar include:

- → *Adapting the grains industry model to suit the diversity of the forage industry;*
- → *Defining the industry priorities for both species/traits and production/NRM;*
- → *Clear definition of where market failure exists in breeding programs;*
- → *Development of a national variety evaluation program that both meets the objective information needs of leading producers and enables efficiency in pasture research;*
- → *Bringing the most advanced genetic technologies (eg molecular biology; genomics[2]) to focus on genetic gains in forage species of importance to Australian meat producers;*
- → *Building the case for pasture improvement in those areas where commercial returns are available, and thereby boosting the rate of pasture re-sowing.*

A summary of the investment recommendations for the Pasture Breeding & Evaluation pillar is presented in Figure 3. For a more detailed account, see section 8 of the MLA report.

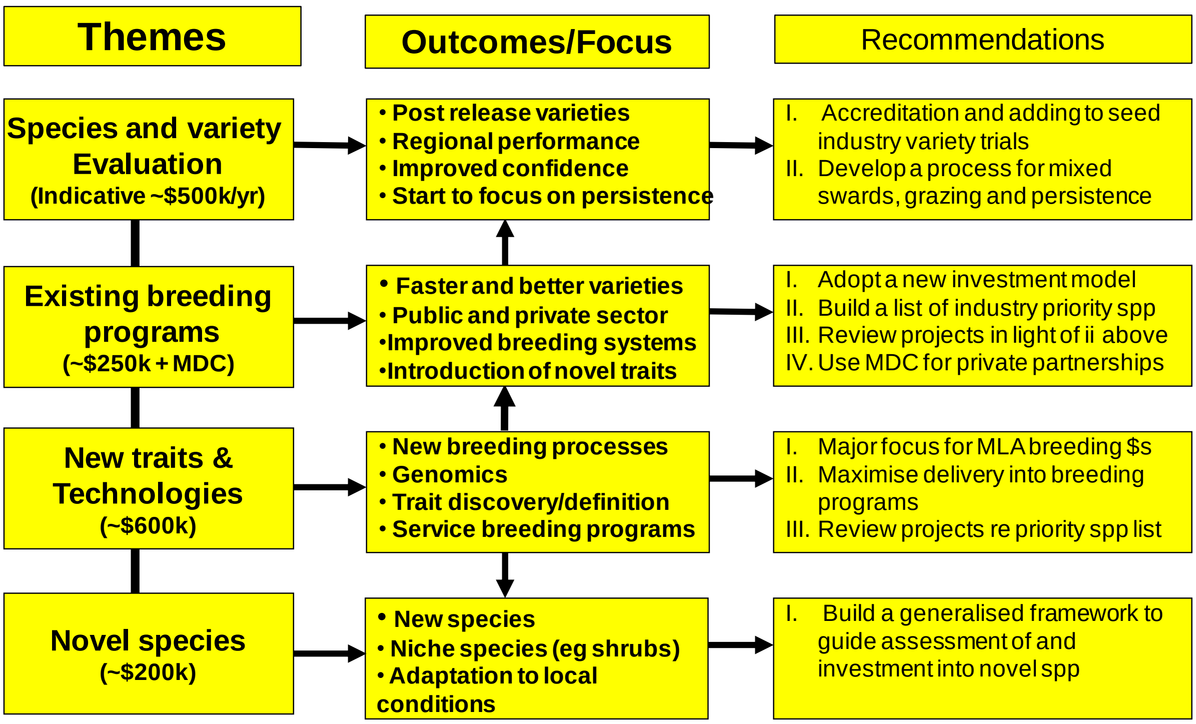

Figure 3. Summary of the Pasture Breeding and Evaluation pillar.

This workshop is an action from the Feedbase Investment Plan and has 4 main aims:

- To review and endorse a funding model for pasture plant breeding and evaluation in Australia that recognizes the respective roles of public and private sector agencies
- To develop a list of priority species by region based on adaptation, current and future use
- To develop a list of priority traits based on their likely benefit in red meat production systems
- To identify potential programs and project areas and recommend a path for developing and contracting these projects

3. Investment principles and guidelines

a. Background

There are generally three key drivers for investment in plant breeding research and development

1. The possibility for incremental gain (for instance a higher yielding replacement cultivar, or extension to the area of adaption for a cultivar/species)
2. The possibility of step-change technologies (such as genomics, GM etc) to radically change a pasture system
3. 'Market failure' in terms of providing novel genetics into a given environment or production system.

All of these are valid drivers for investment and have different levels of attraction depending on whether the investor is a Government department, MLA or private seed company. Area 1, is becoming widely accepted as a role for the private sector, with 2 & 3 the largely the domain of the public sector or private:public sector partnerships. The attraction of private sector funds into areas 2 & 3 can be limited by the size of the forage seed market relative to major food crops such as cereals, maize etc.

These investment principles have been articulated by DPI Victoria in their publication: *Plant Breeding: Policies and Principles for Investment* (DPI 2005; http://new.dpi.vic.gov.au/about-us/publications/economics-and-policy-research/2005-publications/plant-breeding-policies-and-principles-for-investment (accessed October 2011).

Market Failure in Plant Breeding (DPIV 2005)

Plant breeding programs are no longer seen as a complete entity or project but as a continuum of activities designed to improve plant varieties. The plant breeding continuum provides a framework to apply a market failure test. Precursors to plant breeding activities are 'knowledge and new enabling technologies', which includes the education of plant breeders and 'germplasm conservation and maintenance'. The plant breeding continuum can be divided into four main phases:

- Phase 1 - Technology Discovery *and* Development - strategic research to fast track and value-add to crop improvement processes. Outputs would include platform technologies and enabling tools.
- Phase 2 - *Germplasm Development* (ie strategic plant breeding) - includes germplasm trait identification and enhancement for developing cultivars.
- Phase 3 - Cultivar Development (ie applied plant breeding) - includes breeding, evaluation and commercialisation of superior cultivars.
- Phase 4 - Variety Exploitation (ie marketing and grower adoption).

Application of the principles of market failure to the plant breeding program reveals that there is, in general, a role for government in aspects of the early stages of the plant breeding continuum (phases 1 and 2), but less or no role in the latter stages (phases 3 and 4).

Market Failure in Plant Breeding

Plant breeding programs are no longer seen as a complete entity or project but as a continuum of activities designed to improve plant varieties.

These principles used by DPIV were further articulated in the following table (from DPIV 2005)

DPIV (2005) further mapped their investment policy according the stage of the plant breeding pipeline and suggested the role for industry and commercial funding to complement the government investment (see table 1 below – adapted from DPIV 2005)

Table 1. Role of Government in Plant Breeding Investment (DPIV 2005).

Area	**Role for Public $**	**Role for industry**	**Role for Private Companies**
Knowledge and New Enabling Technologies			
Development of new breeding techniques	High	Medium- High	Not Attractive
Germplasm Conservation and Maintenance			
Germplasm conservation and maintenance	Medium- High	Medium- High	Low
Phase 1: Technology Discovery and Development			
R&D to fast-track and add value to processes and outputs	Medium- High	Medium- High	Low
Phase2: Germplasm Development (Strategic Plant Breeding)			
2.1 Germplasm trait identification	Medium- High	Medium- High	Low
2.2.1 Germplasm enhancement for traits suitable for environmental situations	Medium- High	Medium- High	Low
2.2.2 Germplasm enhancement for traits for greater productivity only	None	High	High
Phase 3: Cultivar Development (Applied Plant Breeding)			
Breeding	Low-None	High	Medium
Evaluation	None	High	High
Commercialisation	None	High	High
Phase 4: Variety Exploitation			
Marketing, distribution etc	None	High	High

Assessing market failure in the Australian pasture seed market.

MLA has recently commissioned the development of a market failure assessment decision tree, which provides a sequence of key questions to help MLA make a decision as to whether to intervene or not based on evidence of market failure and whether the benefits of intervention would exceed the costs. The following points are taken from the draft report of this group (GHD 2011) and describe the process in general terms.

The market failure assessment guidelines shown in the next section provide further guidance to working through the decision tree.

Question 1: What is the problem being addressed?

This question is directed towards understanding the nature of the problem, including the background, extent of the problem, previous government involvement and consistency with MLA's strategic direction. Issues relevant to this question include:

- Is the interested driven by market forces or researcher interest?
- Which components of the pasture supply chain does it relate to?
- Has there been previous investment in this area?
- Is there fit with investment plans and strategies?

Question 2: What is the relevant market?

This question seeks to clarify the size and extent of the market and includes consideration of geographical spread, current private sector involvement and reasons for under-investment by the private sector. Issues relevant to this question include:

- Where in the supply chain?
- Which regions, environments?
- What is the likely uptake – are there competing products?
- What is the private sector involvement in the market?
- If the private sector is not involved then why?
    - Too small, availability of close substitutes, benefits too low

Question 3: What is the evidence of market failure in the relevant market?

This existence of market failure is an important pre-requisite for government intervention. This question is aimed at identifying the existence and causes of market failure in the relevant market. Issues relevant to this question include:

- Unable to appropriate returns on investment (public goods and private externalities)
- Lack of awareness of grower needs
- Lack of product information to growers
- Lack of access to enabling technologies

Question 4: Is there a case for government intervention in the relevant market based on market failure?

On the basis that market failure exists, this question aims firstly, to establish what actions should be

taken to correct market failure. Secondly, it is necessary to decide which organisation should undertake the intervention (including MLA). Thirdly, do the benefits of intervention exceed the costs (benefit cost test)? Issues relevant to this question include:

- Would the market failure correct itself?
- Is there a case for MLA intervention?
- Benefit:cost

Question 5: What form should MLA intervention take?

Eg. Research, cultivar development, extension activities, facilitation.

It is interesting to note that this process has not been applied in full to many prior plant breeding investments and there are many instances in Australian plant breeding where the initial promise of new species, lines, accessions, populations, synthetic varieties has not led to strong commercial success. This is in no small part due to the projects being driven from the basis of technical needs rather than a comprehensive market analysis. Too often the private sector has been engaged at the end of the process, by which time it may be too late to cost-effectively address the issues of market failure. An alternative model is proposed below:

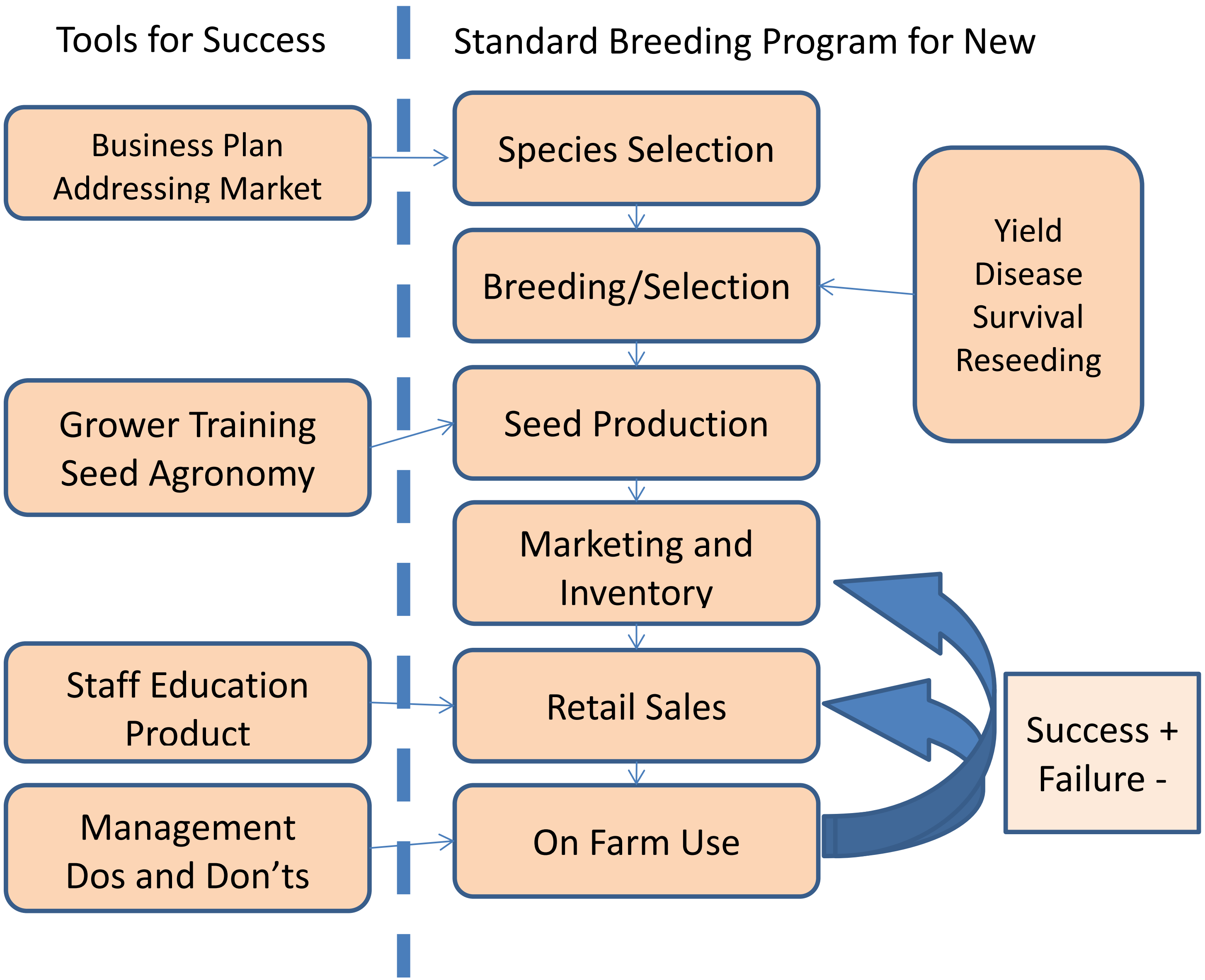

Figure 4. Schematic outline of breeding and commercialisation of new species, cultivars or traits

b. Discussion Points for Workshop

- What is the evidence for market failure in the delivery of pasture cultivars for red meat production?
  - Is it a lack of adapted cultivars/lines?
  - Is it the lack of an informed marketplace?
  - Is there variation across regions?
  - Can the models described above work for pastures?

4. Species use and adaption in Australia

a. Background

Breeding of novel species or adapting existing species to stress environments has long been a feature and success of pasture breeding in Australia, with some notable successes such as the domestication of *Phalaris aquatica* in the CSIRO Canberra program (Oram and Lodge 2003, Culvenor 2009) and the successful commercialisation of medics, subterranean clover, Persian and balansa clovers from a long running range of initiatives that have culminated in the recent NAPLIP and Future Farm Industries CRC programs (eg Dear *et al.* 2003; Dear *et al.* 2008). Australia has led the world in the domestication, breeding and commercialization of these species. However, despite significant government investment a number of other species have failed to find commercial success despite showing good promise in trials and selection, such as summer dormant perennial ryegrass (Reed *et al.* 1999), sainfoin, lotus and sulla (Dear *et al.* 2003; Dear *et al.* 2008) with the potential value of these species known since at least the 1960s. Despite the large and concerted effort has been placed on alternative legume breeding and selection and the number of cultivars released the market remains small with only a few cultivars successfully commercialised (Table 2). Whilst this can be expected to some extent due to investment in an area of market failure there is rarely an attempt to understand the cause of market failure before a breeding program is undertaken. The assumption is sometimes that the market will grow once suitable cultivars are developed.

An analysis of the Australian seed market (Table 2) demonstrates that the temperate seed market is dominated by several major species perennial ryegrass, short term ryegrass, tall fescue, sub clover and lucerne and as there are active private sector breeding programs in these species there has been a reduction in government support for private sector breeding programs starting with the reduction of MLA and DA funding to perennial ryegrass in Victoria in the late 1990s.

Table 2 also demonstrates that whilst there are large numbers of cultivars in the market, a relatively small number of cultivars dominate the market in each species. Recent reviews in wheat and barley have also shown this to be true and in both instances it is broadly adapted cultivars that dominate the market despite many programs breeding for regional and sub-regional adaptation. This point is critical as it is clear that companies currently strongly market broadly adapted cultivars whether they are bred in the private or public sector.

Table 2. Australian Pasture Seed Market (Source Gout Report to Pastures Australia 2006)

Species	Cultivars	Sales (t/pa)	Value ($M)	Top Cultivars	Market Share (%)
Perennial ryegrass	44	2400	9.6	8	56
Short term ryegrass	48	7000	21.0	13	82
Tall fescue	20	650	3.9	7	81
Cocksfoot	8	210	1.3	2	64
Phalaris	9	180	1.1	4	69
White clover	20	600	4.2	8	56
Red Clover	8	150	1.4	3	69
Sub clover	27	1700	7.7	6	61
Other clover	28	800	2.4	4	70
Medic & serradella	33	1000	5.0		
Brassicas	30	490	2.9	5	65
Herbs	12	200	2.0	2	65
Lucerne	43	2100	14.7	7	51
Tropical Grasses	30	1100	8.8		
Tropical Legumes	26	1400	7.2		
Total	386	19980	93.2		

An alternative approach to the use of seed sales is the use of the potential adaptation and surveys to assess the relative importance of pasture species (such an approach was used by the Australian Pastures Database (Hill and Donald). These data are summarized in the following tables and show that although seed sales broadly map to those species with broad adaptation there are some notable points:

- The relatively poor uptake of tall fescue given the number of cultivars available and the range of adaptation of these cultivars (eg continental and Mediterranean) a similar situation exists for phalaris and cocksfoot.
- The presence of a alternative species may limit the uptake of species with areas of common adaptation eg white clover and red clover share a broad overlap in their adaptation but red clover is seen as more of a specialty crop.
- The potential for productivity gains through greater uptake of existing cultivars, assuming these cultivars have been shown to be better than the *status quo.*

b. Discussion Points for Workshop

- Are these statistics a true reflection of the current rate of pasture resowing?
- Are there likely to be changes in the future?
- Should MLA focus on the development of an informed market place rather than breeding new species or cultivars?
- What new species/cultivars are in the pipeline? Are there any significant gaps?

Table 3. Potential area of adaptation of sown pasture species (Mha) (Hill and Donald)

State	Sub. clover	Balansa clover	Persian clover	Barrel medic	Serra della	White clover	Lucerne	Red clover	Phalaris	Per. Ryegrass	Cocks foot	Tall fescue
NSW	27.9	9.6	13.8	12.7	27.0	8.0	31.3	8.8	15.5	5.3	9.9	8.6
QLD	1.1	0.8	1.1	0	1.1	2.9	19.9	2.5	2.3	2.6	2.9	1.1
SA	9	3.8	4.3	6.8	9.2	0.4	7.8	1.2	1.6	0	2.2	0.9
VIC	12.5	5.6	6.6	5.0	9.3	3.1	12.2	4.7	7.4	4.3	4.2	5.1
WA	18.0	4.3	4.8	15.1	16.9	0.2	7.7	0.8	2.2	0	0.5	0
TAS	2.0	0.6	0.6	0	1.0	1.4	2.0	1.7	1.7	2.1	2.5	2.0

Table 4. Estimated total area containing pasture species (Mha) (Hill and Donald)

	Sub clover	Balansa clover	Persian clover	All medics	Barrel medic	Strand medic	Burr medic	Serra-della	White clover	Lucerne	Red clover	Phalaris	Per. ryegrass	Coocks-foot	Tall fescue
NSW	8.4	0.3	0.05	14.7	1.2	0.02	6.0	1935	4.1	2.6	0.5	2.2	1.2	1.5	0.9
QLD	0	0	0.02	2.7	0.2	0	0	0	0.06	0.1	0	0	0	0	0
SA	1.8	0.4	0.1	3.3	2.2	0.8	1.8	20	0.1	0.5	0	0.7	0.3	0.5	0.09
VIC	6.2	0.1	0.03	1.2	0.4	0	0.05	0	1.6	0.3	0	0.8	2.3	1.0	0.04
WA	10.0	0.6	0	1.6	0.6	0.4	0.5	7605	0.04	0.05	0	0.06	0.1	0.05	0.03
TAS	2.9	0	0	0	0	0	0	0	1.9	0	0	1.0	2.0	1.1	0

5. Traits and Technologies

a. Background

New traits in pasture breeding in Australia

This area seeks to both increase the range of traits of economic or environmental importance under selection and also the rate of genetic gain in pasture plant breeding.

One major program of investment in this area has been the suite of activities within the CRCPBMDS/FFICRC which has sought to develop a range of pasture plants targeted to either particular (stress) environments or to extend the range of adaptation of existing species. The following table illustrates part of the process that the CRC partners used to prioritise their research activities.

Table 5. Summary of current perennial legume and grass breeding activities for recharge areas, and identification of gaps in the target areas.

Breeding activities	Current knowledge	Gaps
Perennial legumes		
Lucerne	Cultivars available for neutral to alkaline soils, resistance available for common pests and diseases	Water-logging tolerance, salinity tolerance and cultivars for acidic soils
Birdsfoot trefoil	Cultivars available for high rainfall areas of southern Australia. Tolerant of water-logging and acid soils	Medium to low rainfall areas, better persistence under drought conditions
White clover	Successful in areas with more than 800mm annual rainfall	Medium to low rainfall areas (below 800mm/ yr)
Sulla	Breeding almost limited to mediterranean Europe. Good drought tolerance in alkaline areas	Neutral to acid soils, Tolerance to heavy grazing, prostrate types.
Perennial grasses	*Management is an issue in all grasses: weed control, soil fertility, grazing tolerance. Need species for medium to low rainfall areas with better drought and acidity tolerance and increased persistence*	
Perennial ryegrass	Suitable for high rainfall, fertile areas - dairy areas of Australia	Drought tolerance, benefits of 'safe' endophyte, increase into medium rainfall areas
Tall Fescue	Long growing season. Some tolerance to waterlogging and soil acidity	Benefit of 'safe' endophyte, increased drought and acidity tolerance
Cocksfoot	Reliable on acidic sandy hill country of low fertility	Enhanced performance in low-medium rainfall including wheatbelt
Tall wheat grass	Good summer activity. Developed for discharge regions, some salt tolerance	Better cool season activity
Phalaris	Deep-rooted, therefore dries out soil profile. Drought tolerant	Sensitive to heavy stocking, contains undesirable alkaloids, intolerant of acid soils
Native grasses	Number of elite lines selected for medium - high rainfall environments	Species/ ecotypes for medium to low rainfall environments. Improved seed yield and ease of harvesting required.

Cultivars from some of these programs are either reaching the market or are the subject of proposals for further work on agronomic evaluation. This table illustrates biological/agronomic gaps and imperatives that were used to prioritise activities within the CRC.

There are a number of other initiatives to develop cultivars of novel species and for greater ranges of adaptation within both the public and private sectors. It is outside the scope of this document to review all of these initiatives.

Another significant factor in this area is the number of cultivars developed in isoclimatic regions internationally that are starting to find their way into the Australasian market. In some cases these are the result of joint efforts between Australasian research agencies or companies and partners in Mediterranean Europe, USA, Argentina and Uruguay and reflect the global nature of the global seed industry and a significant potential for Australian investors and researchers to partner to achieve outcomes in pasture plant breeding.

Development of novel tools and technologies in pasture breeding

An example of this area of science that has involved MLA co-investment is the projects with DPIV/MPBCRC/DFCRC/DA/GGDF to develop molecular marker technologies for forage species. This project commenced with the development of a toolbox of marker technologies

- AFLP
- SSR
- SNP

in white clover and perennial ryegrass in all cases this was world-leading research conducted in germplasm relevant to Australian conditions and focussed on traits related to forage quality and stress tolerance.

Once these marker technologies were developed it became possible to utilise the markers for a range of activities that would form part of the strategy for implementing candidate gene based markers in forage plant breeding including

- Designing novel breeding strategies
- Understanding the basis of self-incompatibility
- Identifying genes involved in forage quality and genetic variation within these genes
- Using DNA fingerprints to identify and discriminate white clover cultivars

This program is now funded through a donor company project piloting the application of these technologies in a world's first application of candidate gene based markers in a commercial forage breeding program.

Assessing the relative importance of new traits.

Just as it is difficult to assess the relative importance of breeding of individual species it is also difficult to assess the relative importance of specific traits. Because of this it is common to see a wish list of traits rather than an assessment of how traits contribute to the productivity and sustainability of pastures.

Therefore in an attempt to assess the relative value given to traits by breeders, we have assessed the usefulness of discrete choice experiment techniques in the development of weightings for specific traits in forage plant improvement based on the views of an expert panel (plant breeders and non-breeders - agronomists, nutritionists, senior managers in breeding companies and consultants) asked to consider the requirements in four species (white clover, lucerne, perennial ryegrass and tall fescue) (Smith and Fennessy 2011).

The survey results indicate that, in general terms, criteria related to abiotic stress tolerance, adaptation or the costs of pasture (*Root growth, Drought tolerance, Persistence, Resistance to invertebrate pests, Tolerance of hostile soil conditions*) were deemed to be particularly important for both legume species. For perennial ryegrass, three of the five highest-weighted criteria (*Drought tolerance, Root growth, Rate of recovery of pasture after water*) are related to yield in environments where water is a problem, highlighting the importance that the experts placed on the ability of the plant to withstand this important abiotic stress. For tall fescue, the highest-rated criteria were *Drought tolerance, Seedling vigour, Persistence,* and *Root growth.* Some of the nutritive value criteria are weighted more highly with fescue than with other species; this is not surprising given the widespread concerns about this issue in fescues. Overall the preference weightings tend to reflect the perceived limitations of the various species, such as the priority of seedling vigour in tall fescue. This focus on the importance of abiotic stress is especially interesting as previous attempts to identify priorities have focussed on the forage quality traits rather than analysing their importance relative to traits related to herbage yield or stress tolerance. Given their direct involvement in the genetic improvement of pasture plants, responses of plant breeders were compared with those of non-breeders. The only substantive difference in weightings for legumes was in the importance attached to *Seed production* by breeders over non-breeders (statistically significant for lucerne, P=0.0, and P=0.09 for white clover), and that attached to *Resistance to invertebrate pests* by breeders for white clover (P=0.06). In the case of the grasses, the major difference in weightings was in the importance attached to *Drought tolerance* by breeders for ryegrass (P=0.08), while *Resistance to rust* (P=0.03), *Resistance to fungal and/or bacterial diseases* (P=0.0), and *Resistance to invertebrate pests* (P=0.05), were considered more important by breeders for tall fescue.

Whilst the above study gave an assessment of the relative weighting given to traits by breeders it does not give an idea of the level of expression that a trait requires to have value (eg how much persistence is required to have an effect on pasture profitability and/or acceptance of a new cultivar) nor how much the traits contribute to overall profitability. These assessments are critical when breeders attempt to select for traits simultaneously as they affect the technical difficulty of a program, the cost of the program and the decision as to when a commercial product has been developed.

In animal breeding (and more recently in forest trees) the use of breeding objectives overcomes these issues by mapping the economic value of genetic improvement. There are no insurmountable technical difficulties to the development and implementation of selection indices and breeding objectives in pasture plant breeding, rather the issue has been defining how the components contribute to the overall profitability of pastures. For instance, the lifetime potential value of a pasture for animal production will be a factor of lifespan, seasonal productivity and forage quality but the weightings of these components will vary according to production system and environment. Once these weightings are defined then all traits can be mapped against these components.

For instance disease resistance may increase longevity by an average of 1yr, give 10% more late season production and increase the metabolisable energy of the pasture by an average of 0.25MJ/kg dry matter. An increase in root growth may increase persistence by an average of 2yr, increase late season production by 15% with no change in average quality. Which would be the more important trait to breed for?

The following equation describes a breeding objective for perennial ryegrass at Gatton Qld (Woollaston *et al.* unpublished)

Breeding objective:

Y =		***153*** * spring production of DM (tonnes/ha)
	+	***157*** * summer production of DM (tonnes/ha)
	+	***154*** * autumn production of DM (tonnes/ha)
	+	***160*** * winter production of DM (tonnes/ha)
	+	***119*** * additional years at peak production (per year)
	+	***59*** * additional year to decline to 50% production (per year)
	–	***0.17*** * establishment cost ($/ha)
	–	***0.69*** * fertilizer requirement ($/ha in year 3)
	+	***27*** * percentage of DM utilized

Breeding objectives for a range of regions/environments were developed by Smith and Fennessy (unpublished) based on the relative importance of seasonal yield of nutrients (ME), cost of establishment and persistence and are presented below where Y equals yield, C = cost of establishment and P = persistence.

High rainfall: BO = $250[**0.20**δSpY + **0.20**δSuY + **1.00**δAY + **0.96**δWY] **- [1.08**δC - **$115**δP]

Temperate (inland): BO = $250[**0.32**δSpY + **0.32**δSuY + **1.00**δAY + **1.18**δWY] **- [1.85**δC - **$95**δP]

Mediterranean: BO = $250[**0.11**δSpY + **0.55**δSuY + **1.00**δAY + **1.00**δWY] **- [2.12**δC - **$52.5**δP]

Sub-tropical: BO = $250[**0.99**δSpY + **0.21**δSuY + **1.00**δAY + **0.89**δWY] **- [4.27**δC - **$113**δP]

These indices were then used to assess the value of a range of individual traits (here as with Woollaston value is assessed relative to buying an equivalent amount of nutrients as grain). For instance a high rainfall meat producer:

1. Would be willing to embrace a much more complex pasture management system[3] if the increased yield was equivalent to $263 per year (equivalent to 1.05 tonnes) in autumn (which is also equivalent to 1.00 tonnes of grain in winter).
2. If the following benefits were guaranteed, I would be prepared to trade-off a gain in annual pasture productivity thus:

[3] Note that this is expressed in relative terms such that the most complex management system for a pasture species being bred for a particular application (e.g. region) has an arbitrary value of 1.0

   a. guaranteed survival in adverse conditions (salt, aluminium, water-logging): $120 or 0.48 tonnes;

   b. extremely resistant to rust and pests: $202 or 0.81 tonnes;

   c. guaranteed survival in a hot, dry summer: $510 or 2.04 tonnes.

3. Hence these reflect the expected value of:

   a. guaranteed survival in adverse conditions (salt, aluminium, water-logging) is that pasture will persist for a further 1.04 years ($120/$115= 1.04 years);

   b. extreme resistance to rust and pests is that pasture will persist for a further 1.8 years ($202/$115 = 1.8 years);

   c. guaranteed survival in hot, dry summer is that pasture will persist for a further 4.4 years ($510/$115 = 4.4 years).

b. Discussion Points for Workshop

- What are the key drivers of pasture profitability?
- Are there likely to be changes in the future?
- What are the priority traits for improvement and what level of improvement is required?
- What data/research is required to validate these assumptions?
- What species are the most suitable vehicles to deliver these traits to industry?
- What tools, technology and infrastructure are required to breed for these traits?

Appendix 2

Attendees:

Dr Kevin Smith – AbacusBio (Facilitator)

Cameron Ludemann – AbacusBio (notes)

Dr Greg Bender – Consultant

Dr Warren Mason - Consultant

Cameron Allan – MLA

Tim Pepper – Seed Mark

Julie Brien – Producer

Neil Smith – Producer

Jake Howie – SARDI

Rob Shea – Producer

Alan Humphries – SARDI

John Forster – DPIV

Mike Gout – Seed Force

Eric Hall – TIAR

Richard Culvenor CSIRO

Richard Simpson – CSIRO

Carol Harris – DPI NSW

Mark Norton – DPI NSW

Graeme Sandral – DPI NSW

Anthony Leddin – Valley Seeds

Bill Malcom – UofM

Phil Nichols – DAFWA

Daniel Real – DAFWA

Andrew Lake – Pristine Forage Genetics

Alan Newman – Heritage Seeds

Rob Salmon – PGGWrightson Seeds