# final report

Project code: B.PAS.0344

Prepared by: Dr J Virgona, R Salmon, and C de Kok

Australian Grassland Association

Date published: April 2012

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

## Australian Grassland Association Pasture Research Project

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

# Contents

**Abstract**

The Australian Legumes Symposium was the first in a series of regular technical symposia organised by the Australian Grasslands Association. The Australian Grassland Association is a joint partnership between the Grassland Society of Southern Australia and New South Wales Grassland Society with the sole purpose of working in collaboration to develop this series of symposia. The purpose of this symposium was to provide up-to-date reviews on issues related to pasture legume development, to provide a forum for current research to be presented and ideas to be exchanged *and* to set the agenda for research and development on pastures legumes over the medium to long-term.

**Executive Summary**

The Australian Legumes Symposium was the first in a series of regular technical symposia organised by the Australian Grasslands Association. The purpose of the symposium was to provide up-to-date reviews on issues related to pasture legume development, to provide a forum for current research to be presented and ideas to be exchanged *and* to set the agenda for research and development on pasture legumes over the medium to long-term.

A total of 108 delegates attended the conference consisting mainly of public and private sector R,D&E participants, agronomists and farmers, 28 of which took an optional bus tour the day prior. The international speakers were leveraged to a further audience of 69 farmers and agribusiness industry participants in separate events.

The symposium consisted of 24 oral papers and 22 poster papers were presented. Of the submitted oral papers 8 were commissioned by the symposium organisers to provide key reviews and/or explore challenges for pasture legumes in the various farming systems of southern Australia. A proceedings of the conference was published containing abstracts and poster papers, and full copies of presented papers will be published in the Journal of Crop and Pasture Science.

After the invited papers, summary and panel sessions were held to identify and expand upon constraints and future research and development opportunities. In the Summary session, session chairs provided an overview of content and reported on key questions from the symposium floor and summarised any issues that arose with speakers in a post-session debriefing (session contributors being asked to identify their key point and whether they could identify problems/deficiencies that were missed by the participant). In the following Panel session, the key constraints and opportunities were refined by an expert panel with participation from the audience through an interactive, real-time polling device.

It was clear that certain key issues were repeatedly raised and discussed and were drawn from a range of presentations, addressing capacity constraints in maintenance plant breeding and research, breeding to tackle significant problems such as acid tolerant perennial legumes for the higher rainfall zone, economic analysis at a paddock and farm scale, legume rhizobia delivery, the interaction of legumes with landscape, interactions of nitrogen from leguminous fixation and improving collaboration of public sector and private industry within Australian and internationally.

During the polling phase, feedback was sought from participants on the usefulness of the symposium and whether they would attend a similar event in the future. Those results are given below. Subsequent to the conference, the feedback received has been positive. One

comment from Dr. Derrik Moot from Lincoln University in New Zealand “AGA have hit the nail on the head in these subject driven scientific forums, well done.” 58 copies of the conference proceedings have been purchased subsequently.

The symposium budget was set at $95,000, which was achieved.

**Publishing Embargo until published in CSIRO Journal**

# Australian Legume Symposium - Synthesis and future directions.

JM Virgona C Harris S. Kemp, J. Evans and R Salmon

## *Abstract*

The Australian Legumes Symposium was the first in a series of regular technical symposia organised by the Australian Grasslands association. The aim was to provide researchers with the opportunity to interact, present research and participate in future planning in legume development (long and medium term). This paper is intended to be the key output of the forum – a summary of findings and highlights in reported research and review as well as identifying key research priorities for the future. In terms of the former reviews presented at the symposium provided an overview of the development and role of pasture legumes in temperate farming systems. Closely related topics including nitrogen fixation, nitrogen balance of farming systems and management of legume inoculation provided a focus on the importance of legumes in terms of N input and overall productivity. International perspective on lucerne – its improvement and adoption provided a noticeable contrast to the apparent paucity of research into this species in Australia – despite its widespread use in temperate farming systems. In terms of content there were many other papers delivered and the diversity of issues dealt with tended to suggest that current efforts at legume improvement and management are disparate.

With respect to determining research priorities, it was surprising that participants were more concerned that the way in which research is funded and conducted be addressed by reconsidering current arrangements. Also a greater role for economic analysis in determining

research priorities was foreshadowed. The identification and management of acid tolerant perennial legumes for higher rainfall zone permanent pastures was nominated as a major research priority as was the need to address problems related to pre-inoculation of legume seed. The clear message from the symposium was that there needs to be a reorganisation of legume improvement funding and research in order for gains to be effectively realised and to maintain R&D capacity.

## *Introduction*

The Australian Grassland Association was formed to promote scientific and technical development of pasture related issues in Australia. The establishment of a series of technical symposia was identified as a means to this end. The inaugural symposium, which is the subject of this paper focussed on pasture legumes. The purpose of the symposium was to provide up-to-date reviews on issues related to pasture legume development, to provide a forum for current research to be presented and ideas to be exchanges *and* to set the agenda for research and development on pasture legumes over the medium to long-term (Salmon 2012). As such 24 oral papers and 22 poster papers were presented. Of the submitted oral papers 8 were commissioned by the symposium organisers to provide key reviews and/or explore challenges for pasture legumes in the various farming systems of southern Australia. A proceedings of the conference was published (Harris 2012) and contains the papers that have not been published in this special issue.

It is not the purpose of this paper to summarise the content of each of the contributed papers but rather to identify (and develop) themes which became apparent in the Summary and Panel sessions. In these sessions, the constraints and future research and development opportunities were identified. In the Summary session, session chairs provided an overview of content and reported on key questions from the symposium floor and summarised any issues that arose with speakers in a post-session debriefing (session contributors being asked to identify their key point and whether they could identify problems/deficiencies that were missed by the participant). In the following Panel session, the key constraints and opportunities were refined by an expert panel with participation from the audience. Thus the aim of this paper is to present the content of these sessions and thereby give the reader a sense of being at the symposium and understanding the emphasis on the key issues that arose. In doing so, we readily acknowledge that it is not possible to reflect every comment made or question asked. However, it was clear that certain key issues were repeatedly raised and discussed and were drawn from a range of presentations. It is these we wish to address below.

The structure of this paper follows that of the symposium. Each of the sessions will be summarised in an overview of the content and key messages from speakers involved. The content of the Panel session is then presented, firstly addressing the major constraints that each panellist nominated and then the priorities for future R&D that arose to address these constraints. In a departure from conventional approaches, a further session invited participants to provide their views on issues that had been distilled in the previous sessions in a quantitative manner. All participants who attended the final Proposition session were

given access to individual electronic polling recorders. Propositions regarding key issues from the sessions were then put to the participants and results were collated instantaneously and the subject for further discussion and interpretation. Finally we will conclude the paper by identifying funding priorities in terms of the way in which R and D should be carried out and the subject matter

## *Overview*

*The Role of legumes in Australian farming systems*

There is a long history of research and development into pasture legumes in Australian farming systems. Their key roles being in pasture improvement, as agents of change in pasture community structure (Wolfe and Dear 2001) and boosting productivity of cropping systems (eg. Angus 2001) have been widely recognised. These features were also recognised by Nichols *et al.* (2012) who provided the historical context for the development of the wide array of pasture legume species that are currently available in temperate Australia. The list includes 49 exotic species (36 annual, 13 perennial) of which 34 had cultivars first developed In Australia. This in itself is testament to the unique combinations of farming system, climate and edaphic factors that are encountered in southern Australia. The prevalence of annual pasture legumes has been a feature of mixed farming systems and historically dominated by sub clover (Trifolium subterraneum) and a range of annual medic (Medicago spp.). Research and development over the past 30 years has increased the range of species available to farmers in this zone markedly. The main factors influencing this direction where identified by Nichols *et al.* (2012) as relating to deficiencies in traditional species with respect to edaphic limitations and/or changes in farming systems (eg. longer cropping sequences, see Wolfe, 2000). Likewise, alternate perennial legume species have attracted attention from researchers as limitations to lucerne (M. sativa), white clover (T. repens) and red clover (T. pratense) have become more apparent (eg for lucerne see Cocks 2001).

The suite of species available to farmers today is diverse. For instance, Lattimore *et al.* (2010) list 201 cultivars of 30 species of temperate annual and perennial legumes that could be used in NSW. However, while this array of species/cultivars is putatively available, it is not clear how many are actually used by farmers. Data on seed sales is difficult to obtain but that is not necessarily an indicator of what has been sown in a region and what has adequately persisted over the required life of the pasture. The scarcity of reliable information on what farmers are actually sowing means that it is difficult to gauge the extent to which alternate legumes have penetrated the market. In short, any attempt to evaluate the impact of pasture legume breeding and alternate species development will require sound data on

utilisation of the outcomes (cultivars) of these programs and yet it appears that the data required may be too difficult to obtain

In terms of future research, Nichols *et al.* (2012) identified a number of key issues. Firstly, a shortage of sufficiently skilled plant breeders may limit future improvement in legume performance. Hence the ability to continue improvement and integrate outcomes from biotechnological approaches may pose a significant capacity constraint in future. Secondly, that there is some uncertainty regarding the extent to which poor performance of some legume species could be attributed to genetic versus management limitations. Questions like this have arisen previously and have not been clearly resolved. The issue of legume decline loomed large over the industry in the 1980s and 1990s. The syndrome of low legume composition commonly found in pastures was attributed to a rage of factors (see Wilson and Simpson 1993) but mostly those that could be addressed by targeting soil fertility and soil acidity issues (eg. Hochman *et al.* 1990). A role for plant improvement was also clearly defined – especially where inherent characteristics (eg. hardseededness) and disease resistance could be targeted by breeders (eg. for sub clover in southern NSW - Dear *et al.* 1987). In recent times apparent failure of the traditional suite of species has led to an emphasis on alternate legumes. But was this failure more apparent than real? In a well fertilised pasture, with appropriate grazing management and having selected the most fit cultivar(s), would legume performance be problematic? There is not sufficient data available on a wide enough scale to answer these questions but it does remain an important issue to be resolved in order that emphasis of future effort into improvement in management and genotype be adequately resourced.

In a related sense, Nichols *et al.* (2012) also questioned the prioritisation of funding for future pasture legume development. Would more be achieved by addressing broad-scale problems and presumably those most widely adapted species *or* should a greater effort be made to address underperformance of legumes in niches? Indeed , having developed a suite of legume species, is there the capacity to fund and carry out the research and development to continue the production of cultivars by maintenance breeding? This issue will be further discussed below as it will become apparent that deficiencies at the organisational level will need to be addressed before it can be resolved.

The key role that legumes play in the nitrogen economy of agricultural systems in southern Australia farming systems was the focus of Angus and Peoples (2012). Updating previous estimates of N budgets for farming systems (Angus 2001), they calculated that when pastures (with lucerne as a component) comprised 40% of the area on a mixed farm then could be N balanced for the farm. In contrast, low levels of N exported in products from

higher rainfall zone (HRZ) pastures meant that N could be met by N fixation despite low legume content and fertiliser use. Management which aimed to considerably increase N fixation in this zone should be coupled with approaches to deal with likely environmental consequences. A trend towards higher cropping frequency in the mixed farming zone has meant that the contribution of N derived from pasture legumes has decreased and would not equate with those used in the hypothetical case study by Angus and Peoples (2012). Indeed they concluded that N fixation has decreased to a greater extent in the mixed farming zone than the higher rainfall zone over the 1990-2010 period. Importantly, an attempt was made to estimate the economic value of pasture sourced N in the mixed farming zone (MFZ) and accounted for 28% of the value from the pasture-based livestock enterprise. As nitrogen-based fertilisers become more expensive, the trend toward greater cropping frequencies may abate in order that pasture or some other source of N fixation be utilised to reduce expenditure on fertiliser and associated risk. If, however, the proportion of the farm under pasture does not increase, and the authors suggested the current trend is toward less pasture, then the likely consequences will be lower grain production and protein and/or reduced margins as the price of fertiliser increases relative to that of grain.

Discussion addressed the assumptions regarding the quality of pastures (in terms of legume proportion and growth) which were assumed to be better than commonly found. It was generally conceded that if the demand for N by cropping enterprises was to be met N fixed by pastures then improvements in legume production would have to be achieved. With respect to this, Angus and Peoples (2012) concluded that when the values of N was taken into account mixed farming was as profitable as continuous cropping and suggested that the underestimation of the values of N may partly explain the continued increases in cropping frequency in the zone. A more robust analysis of the value of N transferred from pastures to crops across the many different regions of the mixed farming zone may play a role in more informed decision making.

Dealing with higher rainfall zone dairy pastures Gourley and Weaver (2012) considered the environmental problems and regulatory issues associated with excess N and phosphorus (P) use. Relationships betwteen N input (and surplus N) and milk production per hectare have been found but too little is known about N balances in beef and sheep pastures to attempt the analysis. Pointing to likely higher levels of environmental standards, increases in the cost of N and demands from international markets they recommended greater priority be given to research that would increase nitrogen use efficiency and reduce losses. In further discussion, the implications of future rises in the cost of fertiliser N were further explored. It was proposed that “even” dairy production systems that relied on N from pasture legumes may have to be (re-)developed . Clearly, this will only be possible if the appropriate species,

cultivars and management packages are available to encourage adoption of pasture legumes into intensive dairy production systems.

Lucerne improvement, its history and future prospects, was the subject of the paper delivered by Bouton (2012a). This was fitting in that this species has long been seen as the solution to many of the production and environmental problems that have arisen in production systems based on annual legumes alone (eg. Wilson and Simpson 1993) and is assumed to be a pasture component when assessing the potential of contribution of N from pastures in the MFZ (Angus and Peoples 2012). The development of lucerne cultivars with improved grazing tolerance was described and prospects for producing cultivars with decreased lignin content, increasing condensed tannins and acid tolerance were outlined (see also Bouton 2012b). In addition lucerne has been genetically modified to produce glyphosate resistant ("roundup ready") cultivars. While providing enthusiasm for the future of development of this species, Bouton's key message was to "use it" a reference to the importance of ensuring that this species is widely adopted and profitably utilised by farmers. Providing an example of a coordinated approach to lucerne promotion, Moot (2012) detailed the research, development and extension that has underpinned the successful uptake of this species in the south island of New Zealand.

Deficiencies in organisation capacity to provide the necessary support for pasture legume improvement in Australia was a recurring issue at the symposium. Bouton (2012) described the Consortium for Alfalfa improvement (CAI) which is funding some of the developments listed above. It is a partnership of public, private non-profit and private for-profit stakeholders aiming to "advance long-term, high risk science". While it would not be possible to mimic the CAI in Australia (for instance the private non-profit funding in Australia is scarce), the focus and long term outlook are certainly features that would be desirable in the management of pasture research and development in Australia.

With a focus on lucerne development in Australia, Humphries (2012) outlined key opportunities for further research. Much of the lucerne used in Australia (particularly in the MFZ) is sown as a component in a pasture mix and not as a monoculture. This can be explained by the comparatively poor growth of lucerne over winter compared to annual species like sub clover. Recognising this, Humphries (2012) suggested that breeding and selecting lucerne and companion species for traits that conferred greater compatibility could improve the persistence and productivity. Moreover it could also increase the scope for the use of lucerne into more intensive production systems – for instance lucerne mixed with perennial ryegrass in dairy pastures.

*Current research to address gaps – Cropping zones*

Nutt and Loi (2012) predicted a greater role for pasture legumes in the MFZ as a response to the increase in profitability of livestock enterprises. The predominant issues that were raised in this session related to pasture establishment, the need to develop regional packages to improve pasture legume uptake and the need for a thorough economic analysis that would provide a system-wide assessment of the value of any changes in management related to pastures (eg. new species, longer pasture phases etc.) in this zone.

As farmers turn or return to a greater reliance on pasture legumes, establishment will become a key issues that needs to be addressed. The importance of establishment was emphasised by Peck and Howie (2012) who reported on the successful breeding selection of barrel medic (M. truncatula) lines that were resistant to damage from sulfonylurea herbicide residues. Potential subjects for research into establishment were not widely canvassed but these may be diverse necessitating the development of regional packages that combine appropriate species and establishment techniques.

Revell *et al.* (2012) addressing climate variability and climate change proposed that targeted trait selection could be used to enhance performance of annual legumes. In particular, selection for characteristics related to seed softening, nutrient uptake and drought tolerance would provide valuable improvements. They also suggested that research at the system level where opportunities to integrate annual legume pasture systems with alternate feed supplied from sources such as winter grazing crops and shrub belts should be explored in an effort to improve regeneration and winter production of annual legumes. In further discussion, it was suggested that research and development to address predicted changes in climate may not be as important as maintaining active research programs which could adapt to changing climate over the longer term.

The third major issue to arise in this session related to the need to develop an economic framework to provide an estimate of system-wide impacts of changes in pasture management. Such an analysis could extend beyond profitability of livestock and crop enterprises and also take into account labour use and availability. Calculating payback periods for pasture establishment (eg. Scott *et al.* 2000) would be an important component of such an analysis and could play a role in encouraging farmers to adopt legume pasture technology. Such an economic framework would have to have the capacity to include interactions between different component of the farming systems – as Angus and Peoples (2012) demonstrated by adding the value of pasture sourced N to the livestock gross margin. However, limitations of average gross margins analyses (eg. climate driven production variability, impacts on cash flow etc.) add impetus for the development of a more robust

framework. Interestingly this issue is brought up repeatedly at the symposium and is identified as a key opportunity (see below).

*Current research to address gaps – Permanent pasture zones*

The problem of legume persistence was identified by Sandral (2012) and the key issue that needs attention in the permanent pasture zones (hereafter referred to as the HRZ). Deficiencies in the main species currently available such as sub clover (competition with perennial species), lucerne (soil acidity, waterlogging tolerance) and white clover (tolerance of drought and seasonal water deficit) partly explain the underperformance of legumes in the HRZ. Certainly historical survey data (summarised by Wilson and Simpson 1993) and more recent efforts (Virgona and Hildebrand 2007) provide circumstantial evidence of low legume production in HRZ pastures. Even if a successfully established, well fertilised and carefully grazed phalaris (Phalaris aquatica)-subclover pasture in the HRZ were to retain acceptable levels of legume then the opportunity to incorporate a perennial legume that could produce high quality feed in response to summer/autumn rainfall would be very attractive. Local (eg. Scott *et al.* 2008; Hayes *et al.* 2011) and international research (Bouton 2012a,b) aimed at increasing acid tolerance in lucerne is one approach to expanding the use of this species in the HRZ. Research on white clover that has brought together teams in New Zealand and Australia has also targeted on the limitations of this species in terms of drought tolerance (Jahufer *et al.* 2012). A range of conventional and molecular techniques are being employed to improve the rooting habit of white clover by incorporating characteristics from closely related species.

In addition to efforts targeting the shortcomings of lucerne and white clover, other speakers (and poster papers) explored the potential of alternate perennial legume species. Real *et al.* (2012) reported on the development of a lotus (Lotus corniculatus) a perennial acid and drought tolerant legume. Initial screening of popu7lationshave taken place in Western Australia and promising lines developed for broadscale testing in the HRZ. Most of the ensuing discussion centred around the search for a perennial acid tolerant legume for the HRZ – colourfully termed the “holy grail” of pasture development in the zone. If such a species were found, it was proposed that low rates of re-sowing in this zone would reduce the rate of uptake of this species or, indeed, of improved lucerne and white clover cultivars. However, the historical rates of re-sowing would reflect the perceived benefits of sowing a new pasture to the traditional suite of species/cultivars and may not be a guide to the response from graziers if the benefits were of a much greater magnitude. Certainly in the MFZ the addition of lucerne to annual pastures has a pronounced positive benefit (eg. Wolfe *et al.* 1980) and similar impacts in the HRZ could well stimulate higher rates of resowing.

*Research solutions for specific problems*

Peoples *et al.* (2012) updated previous reviews into nitrogen fixation by pasture (and other) legumes (Peoples *et al.* 1998; Peoples and Baldock 2001) and suggested a number of agronomic strategies to increase N fixation by increasing legume production. Total N fixation is a function of legume herbage production and the proportion of N fixed by the legume (%Ndfa). A number of common factors that influence herbage production were identified and included soil acidity, herbicides, nutritional constraints and legume species. Factors that influence %Ndfa include soil acidity, residual soil N and effective rhizobium. Lastly, many estimates of the contribution from N fixation in pastures have been made but few take into account the contribution of N from the roots. Addressing this deficiency in our current knowledge could lead to more accurate estimates of the contribution of N fixation.

Hartley *et al.* (2102) presented data from 3 surveys over 3 decades that demonstrated the ineffectiveness of pre-inoculating legume seed with Rhizobia – a practice commonly found today. They identified and examined a range of factors that could influence this outcome, these included: water quality, strain of rhizobium, age of peat and type of polymer. These complemented the emphasis placed on the effectiveness of the Rhizobium/legume symbiosis for N fixation by Peoples *et al.* (2012). Contrary positions were expressed in the ensuing discussion. On the one hand, the futility of pre-inoculation (and coating) was stressed while another view maintained that industry still demanded pre-inoculated coated seed. Further, the effect that coating had on the coast of seed was also raised – as seed coatings can account for a significant proportion of the weight of the product and necessitate an adjustment to sowing rates. Khumalo *et al.* (2012) reported results from field work in New Zealand on seed treatment of lucerne that showed greater establishment of coated seed compared to bare and conventionally inoculated seed but no impact on lucerne production.

*Breeding for specific problems and traits*

The five papers delivered in this session presented results of research on annual legumes and Boron tolerance, Mn toxicity, bean leaf roll virus, blue-green aphids and compatibility with lucerne. Many of the poster papers addressed issues relevant to this session. Hence this was a disparate collection of work which was subsequently discussed with respect to the organisation of research and development rather than the content of each of the talks per se. Given this was a session on breeding for specific problems it was noteworthy that only one of the presenters was a plant breeder. This illustrates the importance that legume improvement requires a team approach with expertise required in plant physiology, pathologists, genetic resources, agronomy, molecular biology and breeding itself. For success collaboration was required across state boundaries, institutions and between public

and private stakeholders. The diversity of work also drew comment with respect to prioritisation of research funding. Was research piecemeal and reactionary or carried out in accordance with a long-term vision or plant? The diversity of subjects addressed pointed to the importance of maintenance breeding (the terms maintenance research was also used) without which the required expertise would not be on hand to address these issues. With respect to abiotic stresses the need for scoping studies to examine the scale of problems like manganese toxicity was also raised. Overall, this was the second session in which institutional or organisational issues were at the forefront of concerns, a theme that will be dealt with below.

*Molecular breeding*

The symposium included a number of paper and poster presentations describing current work and the potential for biotechnology and genetic modification in legume development. Much of this work was related to improvements in white clover (Labandera *et al.* 2012; Lin *et al.* 2012; de Lucas Arbiza *et al.* 2012). In the summary session that the role of the techniques employed in these papers as just another “tool” for plant improvement was emphasised. The importance of fostering greater cooperation between molecular biologist and conventional breeders was also raised. Once again it was not the content but the structure and organisation of research and development that was foremost in deliberations. Maintaining capacity in biotechnology was stressed as a key to making gains in the future and remaining internationally competitive. At the organisational level the challenge for the industry is to develop a cost-effective role for biotechnology in legume improvement. It is interesting to note that there was no debate about market acceptability of genetically modified pasture species. A key questions being around when Australia is likely to be in a position to adopt a glyphosate resistant lucerne of a virus resistant white clover, and which will be first, if at all?

## *Panel Session*

In the panel session, four panellists were asked to identify what they regarded as the major constraints and opportunities arising from the symposium. Each was discussed in an open forum and participants asked to comment or add to either category. Below we have summarised the content of this session.

### Constraints

The low proportion of legumes in pastures was identified as a key constraint. The causes of the syndrome may vary between and within the HRZ and the MFZ and could include factors related to pasture establishment, grazing management, soil fertility (not just soil P – there

are situations when this is optimal but still legume production is poor), drought etc. The continued use of pre-incoulated seed despite clear evidence of its ineffectiveness (Hartley *et al.* 2012) could also contribute to the problem.

In accordance with earlier observations, a second constraint was the absence of an appropriate analytical framework that could be used to examine the value of benefits accruing from improvements in legume related technology (better germplasm, improved management etc.). Indeed three out of the four panellists identified constraints that were related to this. For instance, one panellist raised the cost-benefit of developing and introducing a new perennial species into the HRZ versus better management of existing pastures. In addition, analyses of impacts beyond paddock profitability would enable assessments of the whole-farm impacts and ensure that proposed improvements would address economic drivers within the target farming system. Given the wide array of skills and expertise associated with plant improvement (see list above) it was noticeable that economic skills were not included in the teams that were represented. If this constraint were appropriately addressed, prioritisation of resources would be more clearly linked to verifiable outcomes and potentially greater adoption of technologies would be achieved.

Other constraints were raised from the symposium participants. Many represented important but not industry-wide problems eg. impact of sulfonylurea herbicides on pasture legumes, human resource limitations, managing pastures for seed production and low rates of pasture re-sowing. The funding and organisation of legume improvement was proposed as a major constraint. One proposition was that a system similar to that develop for wheat and other grain species be developed. However it was pointed out that, Australia crops improvement programs are not an appropriate model due to the absence of end-point royalty collections systems for pasture species. Finally it was accepted that there was not sufficient knowledge about current species distribution and performance and that such information would be important in judging the success of pasture improvement programs. Two pertinent comments were made: firstly surveys are of limited value if they do not increase our understanding of the factors that explain distribution and performance; and secondly, it is likely that enough is known to achieve considerable improvements in legume production in pastures in farm now.

## Opportunities

The panel and participants were asked to identify future opportunities for pasture legume development. These were mostly aligned with constraints and were:

- The introduction of a perennial legume into annual legume-based systems (eg. see also Dear *et al.* 2008). Such a species would not need to be a replacement for annual legumes but rather could be included in currently available pasture mixes. This opportunity was described as being risky but worth it.

- A greater emphasis from funding bodies on maintenance research. This would ensure that threats are expediently dealt with and future innovations can be addressed by teams with the necessary skills and experience. Fewer graduates are being trained in research as there are limitations regarding career paths and financial returns. Greater emphasis on funding teams and maintaining research expertise will play a role in ensuring that research expertise can be fostered and retained.

- Development of methodology that delivers an economic assessment of legume development strategies. Risk, costs and whole system benefits need to be addressed.

- The need to develop a new model of collaboration. There was recognition that the current Pastures Australia model has not worked. A useful model would have to integrate private and public stakeholders to ensure that resulting products are "delivered to the farm gate". Hence, there was a call for the industry to reform and reorganise to ensure that optimal outcomes are achieved with the limited funding sources available. Several participants proposed that farmers should be actively involved in this process to make sure that on-farms problems were addressed

This is a surprising mix of technical and institutional aspirations. Clearly, a long list of plant improvement opportunities could have been developed but was not. The submitted papers and posters were testament to the breadth of work currently under way in Australia. Instead panellists and participants focussed on the organisation of research, justification of investment and the management of human resources.

## *Participant Poll*

Relating to the constraints, opportunities and other issues raised during the conference, a poll of conference attendees was taken in the final session. The questions were formulated in the final session of the conference without the benefit of hindsight. All participants who attended the final session were given access to individual electronic polling recorders which they used to anonymously respond. Propositions regarding key issues were then put to the participants and results were collated instantaneously and the subject for further discussion and interpretation. For each of the propositions participants were asked to respond using a 10 point scale. The extent to which they agreed or disagreed with the proposition could be

expressed by using the scale – extreme scores of 1 (disagree) or 10 (disagree) representing the limits. This holds for all propositions except two. In one, participants were asked whether they thought the current mix of research over emphasised genotype or management (Fig. 1a). The other asked participants to respond in a quantitative fashion to the proposition that 90% of the legume plant improvement budget should be spent on lucerne and sub clover (Fig. 1c). A score of 10 indicating total agreement ranging down in 10% steps to a score of 1 indicating no funding for lucerne and sub clover improvement. To present the results scores of 1-3 were aggregated and scores of 8-10 aggregated and assumed to signify strong disagreement or agreement with the proposition. Broad agreement or disagreement was measured by aggregating scores of 6-10 and 1-5, respectively (Figure 1).

The results showed that most participants thought that there was too much emphasis on legume improvement at the genotype level and not enough on management (Fig. 1a) with 37% of participants strongly agreeing and 76% of participant broadly agreeing with the proposition. There was a strong view that maintenance research be funded (Fig. 1b) – presumably for many of the reasons outlined above. Views on the priority given to lucerne and sub clover improvement were more mixed (Fig. 1c). The median score is more relevant to the nature of the question asked and indicated that participants thought that 50-60% of the plant improvement budget should be spent on these species. Two propositions relating to the likelihood of successfully using molecular markers improving cultivars used on farm in the next 10 years (Fig. 1d) or transgenic applications being used to improve legumes used on farm in the next 10 years (Fig. 1e) received overwhelmingly negative responses with over 50% or respondents decidedly in the negative. It is worth considering that an opportunity to poll participants on the likelihood of conventional techniques having an impact on farm over the same period was not taken. Participants believed that closer collaboration with New Zealand pasture scientists was desirable (Fig. 1f) but were split on the whether agriculture graduates and postgraduates faced a promising future. More research on species landscape interactions was viewed as desirable by most participants (Fig. 1g) who also agreed that Australian farmers faced a looming nitrogen crisis – a term that expressed the prospect of lower levels of N fixation due to higher cropping frequencies and higher prices for N-based fertilisers as energy prices increase.

Three further questions were asked of participants – they were relevant to the conduct and content of the symposium. Over 90% of participants broadly agreed that the conference was useful and that the content was relevant. Likewise, over 90% of participants agreed that they would like to return to a similar symposium (with a different focus) in future.

## *Recommendations and Conclusions*

The Australian Legume Symposium provided a forum for researchers to exchange ideas and report on their latest findings. It was also designed to consider future research and development priorities. The following list is a summary drawn from the discussions, panel sessions and participant polling. Therefore we offer the following as recommendations from the symposium:

1) Capacity constraints and maintenance research should be addressed in a reorganisation of pasture research as it related to legume improvement. This was a recurring theme throughout the symposium and was addressed by speakers, panellists and thoroughly endorsed by participants (Fig. 1a).
2) More research is required on acid tolerant perennial legumes for the higher rainfall zone. This was a recurring issue and despite low rates of pasture re-sowing in the HRZ was regarded as worthy of further investment.
3) An economic framework needs to be developed that extends to system-wide impacts of interventions at the paddock levels. Such a framework should extend to analyses of risk and cash flow implications. This could also include analysis of establishment costs and risks and associated problems.
4) More research into the problems and implications of pre-inoculating and coating legume seed is warranted. Current industry practices may be limiting N fixation and persistence of legume species. Alternate methods of effectively pre-inoculating seed need to be developed if industry wished to continue with the practice.
5) There is a need to better understand the interaction between legume performance and landscape position (at the paddock scale). There was broad agreement from the participants on this issue (Fig. 1h)
6) Studies are required to determine the current levels of N addition in cropping and permanent pasture systems. Most improvement will come through greater legume production but there is very little known about how legumes are actually performing in paddocks. Do we have a problem in well managed pastures ie if the P is right and the other aspect controlled and we haven't suffered 7/10 years of drought is there really a problem? The answer may depend on trends in crop/pasture balance and, again, there is precious little relevant data on a regional scale that is available. Also with respect to legume N transfer to crops – do we know enough at the paddock scale? How can arrive at a value for pasture N contribution if we can't estimate components at paddock scale?
7) Develop a better model of collaboration within Australia and internationally. Many comments made re failure of Pastures Australia, lack of capacity and need for

greater involvement between private and public,a cross regions, across institutions and between conventional and biotechnology approaches to improvement. Farmers also need to be brought in and routinely consulted at this level. Part of the role of such a body would be to gather information on current performance and distribution of legumes species/cultivars. In short a new organisation is required that can ensure continuity of research and promote innovation.

Acknowledgements. The authors are indebted to Clare de Kok for her organisation of the symposium. Likewise we also thank Bernie de Kok for help in conducting the participant poll session in particular. We especially would like to thanks our Panellists Prof Mike Ewing, Dr Richard Simpson Mr Jim Shovelton and Dr Kevin Smith for their contribution in identifying constraints and priorities. We also thank Mr Richard Green for chairing the Summary and panel sessions.

# References

Angus, JF (2001) Nitrogen supply and demand in Australian agriculture. *Australian Journal of Experimental Agriculture* **41**, 277-288.

Angus JF, Peoples MB (2012) Nitrogen from Australian pastures. This Volume

Bouton JH (2012a) Lucerne's Role in Pastoral Agriculture. This Volume

Bouton J (2012b) Persistence in lucerne. Crop and Pasture Science 63, 95-106.

Cocks PS (2001) Ecology of herbaceous perennial legumes: a review of characteristics that may provide management options for the control of salinity and waterlogging in dryland cropping systems Australian Journal of Agricultural Research 52(2) 137 - 151

de Lucas Arbiza A, Rochfort S, Panter S, Smith KF, Mouradov A, Spangenberg GC (2012) Biosafety studies for the release of alfalfa mosaic virus resistant transgenic white clover (Trifolium repens L.). In Proceedings of the Australian Legume Symposium. Editor C. Harris. Australian Grasslands Association Research Seried No. 1, Melbourne 2012 (Australian Grasslands Association, Tooboorac).

Dear el at 1987 – wool book

Dear BS, Ewing MA (2008) The search for new pasture plants to achieve more sustainable production systems in Australia. Australian Journal of Experimental Agriculture 48, 387-396.

Dear BS, Reed KFM, Craig AD (2008) Outcomes of the search for new perennial and salt tolerant pasture plants for southern Australia. Australian Journal of Experimental Agriculture 48, 578-588. NOT YET CITED

Gourley CJP, Weaver DM (2012) Policy approaches and difficult choices to reduce nutrient losses from grazing systems in Australia. This volume

Harris C (2012) Proceeding of the Australian Legume Symposium. Editor C. Harris. Australian Grasslands Association Research Series No. 1, Melbourne 2012 (Australian Grasslands Association, Tooborac).

Hartley EJ, Gemell LG, Deaker R (2012) Some factors that contribute to poor survival of rhizobia on preinoculated legume seed. This volume

Hayes RC, Scott BJ, Dear BS, Li GD, Auricht GCl (2011) Seedling validation of acid soil tolerance of lucerne populations selected in solution culture high in aluminium. Crop and Pasture Science 63, 803-811.

Hochman Z, Osborne GJ, Taylor PA, Cullis B (1990) Factors contributing to reduced productivity of subterranean clover (Trifolium subterraneum L.) pastures on acid soils. Australian Journal of Agricultural Reseach 41, 669-682.

Humphries AW (2012) Future trends in lucerne production and development for efficient livestock production in southern Australia. This volume

Jahufer MZZ, Ford JL, Widdup KH, Harris C, Cousins G, Ayres JF, Lane LA, Hofmann RW, Ballizany WL, Mercer CF, Crush JR, Williams WM, Woodfield DR, Barrett BA (2012) Improving White Clover for Australasia. This volume

Khumalo Q, Moot DY, Wigley K (2012) Yield, final population and emergenc3e of seed treated lucerne (Medica sativa L.) sown on five dates. In Proceedings of the Australian Legume Symposium. Editor C. Harris. Australian Grasslands Association Research Seried No. 1, Melbourne 2012 (Australian Grasslands Association, Tooboorac).

Labandera M, Rosello F, Panter S, John U, Mouradov A, Spangenberg GC (2012) Transgenic white clover (Trifolium repens L.) plants with modified organic acid biosynthesis for aluminium tolerance. In Proceedings of the Australian Legume Symposium. Editor C.

Harris. Australian Grasslands Association Research Seried No. 1, Melbourne 2012 (Australian Grasslands Association, Tooboorac).

Lattimore M, Christie J, McCormick L (2010) Pasture varieties used in NSW 2010-2011. NSW I&I and Grassland Society of NSW Inc. Bookbound Publishing P/L, Macksville?.

Lin YH, Ludlow E, Schrauf G, Rush P, Iannicelli M, Garcia A, Garcia J, Panter S, Mouradov A, Spangenberg, GC (2012) LXR$^{TM}$ transgenic white clover plants (Trifolium repens L.) with delayed lead senescence, increased seed yield and improved stress tolerance. In Proceedings of the Australian Legume Symposium. Editor C. Harris. Australian Grasslands Association Research Seried No. 1, Melbourne 2012 (Australian Grasslands Association, Tooboorac).

Moot DJ (2012) An overview of dryland legume research in New Zealand. This volume

Nutt and Loi (2012) Challenges for annual pasture legumes in crop rotations. This volume

Nichols *et al.* (2012) Temperate pasture legumes in Australia – their history, current use and future prospects. This Issue

Peck DM, Howie JH (2012) Development of an early season barrel medic (Medicago truncatula Gaertn.) eith tolerance to sulfonymurea herbicide residues. This volume

Peoples MB, Gault RR, Scammell GJ, Dear BS, Virgona J, Sandral GA, Paul J, Wolfe EC, Angus JF (1998) The effect of pasture management on the contributions of fixed N to the N-economy of ley-farming systems. Australian Journal of Agricultural Research 49, 459–474.

Peoples MB, Baldock JA (2001) Nitrogen dynamic of pastures: nitrogen fixation inputs, the impact of legumes on soil nitrogen fertility, and the contributions of fixed nitrogen to Australian farming systems. Australian Journal of Experimental Agriculture 41, 327-346.

Peoples MB, Brockwell J, Swan AD, Hayes RC, Li GD, Hackney B, Fillery IRP (2012) Factors affecting N2 fixation by pasture legumes. This volume

Real D, Sandral GA, Rebuffo M, Hughes SJ, Kelman WM, Mieres JM, Dods K, Cross J. (2012) Breeding of an early flowering and drought tolerant Lotus corniculatus variety for the high rainfall zone of southern Australia. This volume

Revell CK, Nutt BJ, Ewing MA (2012) How will pasture legumes cope with increasing climate variability in the south-west of Western Australia? This volume

Salmon RW (2012) Introduction. Proceedings of the Australian Legume Symposium. Editor C. Harris. Australian Grasslands Association Research Seried No. 1, Melbourne 2012 (Australian Grasslands Association, Tooboorac).

Sandral GA (2012) Challenges for legumes in permanent pastures of the high rainfall zone. This volume.

Scott BJ, Ewing MA, Williams R, Humphries AW, Coombes NE (2008) Tolerance of aluminium toxicity in annual Medicago species and lucerne. Australian Journal of Experimental Agriculture 48, 499–511.

Scott JF, Lodge GM, McCormick LH (2000) Economics of increasing the persistence of sown pastures: costs, stocking rate and cash flow. Australian Journal of Experimental Agriculture 40, 313–323.

Virgona J, Hildebrand S (2007) Biodiversity of sown pastures: what you sow is not what you get. In “From the Ground Up”, Proceedings of the 48$^{th}$ Annual Conference of the Grassland Society of Southern Australia. Murray Bridge, South Australia, pp. 33-39.

Wolfe EC, FitzGerald RD, Hall DG, Southwood OR (1980) Beef production from lucerne and subterranean clover pastures. 1. The effects of pasture, stocking rate and supplementary feeding. Australian Journal of experimental Agriculture and Animal Husbandry 20, 678-687.

Wolfe EC (2001) Nitrogen special issue: summing up of papers and recommendations for future research. Australian Journal of Experimental Agriculture 41, 459-463. CHECK IF CITED

Wolfe EC, Dear BS (2001). The population dynamics of pastures with particular reference to southern Australia. In 'Competition and succession in pastures'. (Eds P.G. Tow and A. Lazenby). pp. 119-148. (CAB International).

Wilson AD, Simpson RJ (1993 or 1994??) The pasture resource base: status and issues. In 'Pasture management: technology for the 21st century'. (Eds DR Kemp, DL Michalk) pp. 1–25. (CSIRO Publishing: Melbourne)

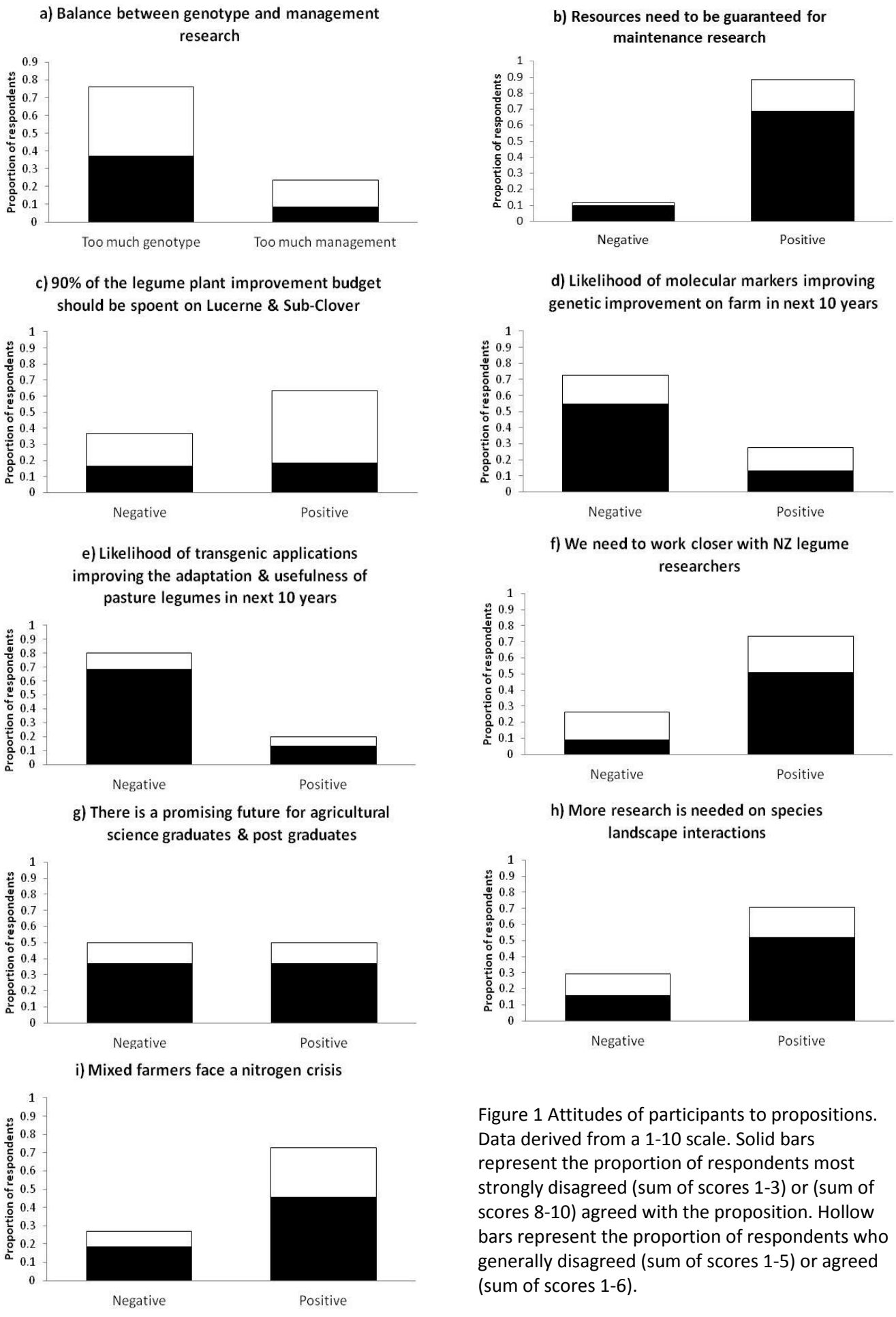


Figure 1 Attitudes of participants to propositions. Data derived from a 1-10 scale. Solid bars represent the proportion of respondents most strongly disagreed (sum of scores 1-3) or (sum of scores 8-10) agreed with the proposition. Hollow bars represent the proportion of respondents who generally disagreed (sum of scores 1-5) or agreed (sum of scores 1-6).