final report

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Developing Supply Chain Capacity in Pastures

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Executive Summary

This project was aimed to propose methodologies and tools to develop supply chain capacity in pasture genetics. Specifically, the development of a manual of definitions of genetic terms that may be used to promote or describe new cultivars, the development of teaching tools for pasture plant genetics at undergraduate level and a review of the teaching of pasture plant breeding at undergraduate level.

The project involved consultation with a broad range of seed companies (PGGWrightson, NZ Agriseeds, Heritage Seeds, VicSeeds, Seed Disitributors, Stephen Pasture Seeds, Seed Force, VicSeeds and Valley Seeds) and universities (University of Melbourne, University of Adelaide, University of Western Australia, University of Queensland, University of Sydney).

There was generalised agreement among seed companies that a set of generalised terms and definitions would be of value to industry and ideally that these would be standardised and promoted by a forum such as the Australian Seeds Federation and be made available in a way that could be appended to company specific marketing information. A draft manual has been developed as part of this project along with example decision trees illustrating where and why the terms would be used when describing cultivars and during the choice of cultivars by producers.

There is no longer an active initiative to develop a uniform plant breeding curriculum at Australian universities and the majority of lectures (and lecturers) focus on the breeding of grains crops with little emphasis on pasture plant breeding (particular the breeding of cross pollinated plants) or on the integration of quantitative genetics into plant breeding courses. There are some exceptions to this general situation such as the teaching of quantitative genetics in plant breeding at the University of Queensland. There is also little integration of plant and animal genetics at advanced levels with these tending to be taught as stand-alone subjects or streams. The opportunity exists for MLA to influence this situation through the sponsoring of post-graduate student programs in quantitative genetics and plant breeding that bring together co-supervisors from plant and animal genetics.

One integrating initiative across universities was the “Plant Breeding by Example” project sponsored by the Australian government. In this project, led by the University of Adelaide, a set of teaching tools were scheduled for development that would be used to highlight plant breeding

principles in a practical context. In this project two units were developed that were focussed on pasture plant breeding; "*Using Estimated Breeding Values in Plant Breeding.*" and *"Breeding Wind Pollinated Grasses.".* These examples have already been used in teaching at the University of Adelaide and will be used at the University of Melbourne in October, with the tools made available to all other universities with plant breeding subjects.

Project Objectives

Objectives By 15 Dec 2010 have delivered to MLA:

1. A draft genetics manual for retailers and producers to explain and promote novel plant genetics

2. A draft module to develop pasture genetics skills in undergraduates through scoping a pasture genetics module in the "Plant Breeding in Theory and Practice Program" that has been developed in Australian universities.

3. Scoped a methodology to include a broader coverage of pasture plant breeding in the proposed national curriculum for plant breeding at undergraduate level.

Success in achieving project outcomes

1. Develop a Pasture Genetics Manual for Retailers and Producers.

This task has been achieved. Material has been assembled from PGGWrightson, NZ Agriseeds, Heritage Seeds, VicSeeds, Seed Disitributors, Stephen Pasture Seeds, Seed Force, VicSeeds and Valley Seeds.

In general this material focuses on selling individual company cultivars but often includes general information on topics such as endophytes, ploidy etc. In some cases the information is incomplete or inaccurate such as tetraploidy where some information implies that perennial ryegrass occurs naturally as both tetraploid and diploid forms.

manual (Appendix 1) has been prepared and submitted previously to MLA and in conjunction with MLA the decision was made to send to key seed industry contacts for review and in concert the development of a couple of examples of how the manual could be used. This manual can be updated as new terms come into use to describe novel cultivars and further examples of where the terms would be used in the 'decision tree' that producers use for cultivar choice. Examples of these decision trees for perennial ryegrass and tall fescue are given in figures 1 and 2.

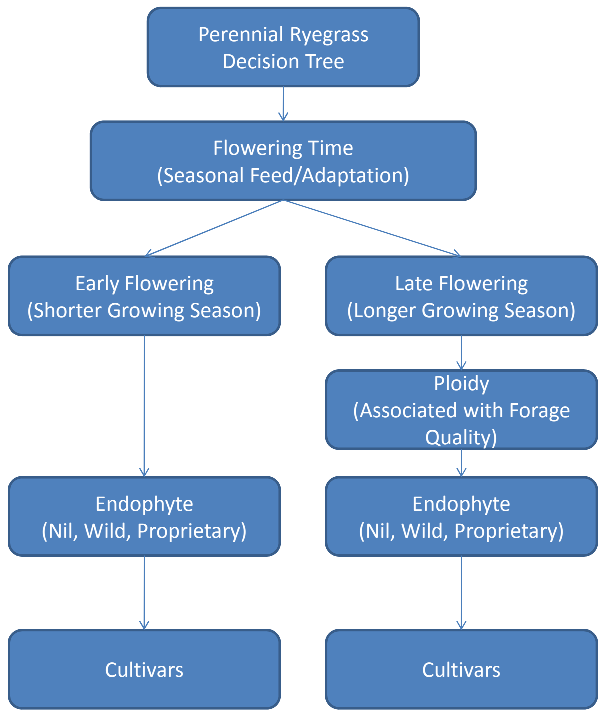

Figure 1 Descriptors used for perennial ryegrass cultivars

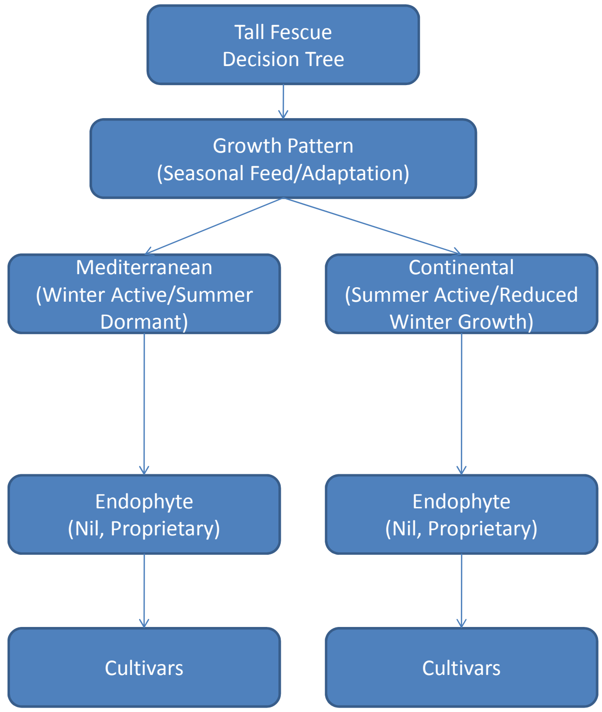

Figure 2 Descriptors used for tall fescue cultivars

Recommendation

Feedback has been sought from a limited number of seed industry sources. It is recommended that once MLA endorses this manual that MLA seek to have the manual endorsed by the Australian Seeds Federation and their members.

2. Developing Forage Plant Breeding by Example Units

Two units have been prepared (included as appendices 2 & 3) these units cover the use of breeding values in plant breeding and a generalised overview of the methodologies used in breeding wind pollinated grasses. These units have been circulated to all participating universities (University of Adelaide, University of Melbourne, University of Queensland, University of Sydney, University of Western Australia and Murdoch University). These units were used this year (2011) as part of the University of Adelaide undergraduate course in plant breeding. The units have been made available to all other universities with plant breeding subjects and will be used by the author at the University of Melbourne in October.

An evaluation of the effectiveness of the "Plant Breeding by Example" concept in raising student awareness of the range of species and technologies that are used by plant breeders in Australia was undertaken by the University of Adelaide (Bray *et al.* pers comm.). The following quotes were provided by students during a facilitated feedback workshop:

What did they think of the way they looked?

- The students liked the visual appeal of the handouts:
    - *"They were pretty easy to read ... just a good summary of the information ... not too much. It wasn't like you just got a sheet of writing, and that can put you off. It's good to have some pictures and tables in there that you can read easily."*
    - *"Sometimes with scientific papers, you get them and you see just all black and white writing ...references, references, references. You drift out a bit reading it."*
    - *"I found it just the perfect amount of information to be able to go through and say- Oh yeah- this is the stuff I need to go and look up."*

- Some students expressed difficulties finding/accessing references. Facilitator asked if the students knew that they were going to have to go and do more research. Response was that it was in the course outline. There was agreement that having references that could be found easily using the library catalogue was quite important.
    - *"Would have been useful. Even just to elaborate on <u>that</u> example more as well. Even if we still had to find further information for other examples, it would have been good to clarify some of the points in <u>that</u> example there, by being able to look at those specific references "*

Did they find the handouts interesting?

- Generally the students found them interesting:
    - *"I had a bit too much fun with mine"*
    - *"I liked it that we were randomly allocated them, because otherwise I think we all would have all been trying to pick something that we already knew about"*
    - *"Yeah, it's good having a broad range of different things, like blue gums to wheat. Like we knew about wheat but knew nothing about blue gums. It's good to learn a bit more about [different things]"*

- Facilitator wanted to draw out more comments from those who began their presentations with "I didn't know anything about this." Did that scare them at all? Did they think it would be interesting?
    - *"It did [scare me] at the start, especially because we hadn't gone through the stuff in lectures yet. Like with the actual science bit. That was where I put it off and [didn't do it], where I hadn't learned about it in lectures until two weeks ago"*

- *"For me today we had a lecture and then I'd already written my presentation and I was like - Oh no I'm so confused now, but I just stuck with it"*

Had the students discussed each other's example before today?

- There had been some discussion between students beforehand. They could tell that some were a bit more scientifically based than other ones, so they did know some of the things that the others were doing. Some had a bit of trouble getting their head around them and had to read them a few times
  - *"I think it's fair to say they weren't equally complicated"*
  - *"But in saying about that, mine was wheat, the complexity of the chromosome thing didn't make mine different than for .... blue gums which [student X] knew nothing about. Whereas I got wheat, but I got chromosomes of wheat"*

- Facilitator asked about barley example, given the familiarity:
  - *"I actually had probably a better chance of understanding what was going on due to the lectures. We had barley breeding basically given to us on a plate a week beforehand so what I'd already learned from my own research I had taught again in a different aspect or a more important aspect so that helped to know exactly which direction I should go in to."* [Student also expressed worry about the impact of going 'too scientific' on other people] "*Mine was a good balance between both [the science and the application]*"

When watching the presentations, did they find them engaging because of the topic area and the diversity of the examples?

- Students enjoyed the amount of diversity in the examples:
  - *"It was good that everyone had a different one. It didn't get monotonous ... kept you awake."*
  - *"You could see the relevance and the applications of each example, or the importance of them, the practical side."*
  - *"That's really important, them all being relevant and not just about the science."*

Did they enjoy the task?

- The students generally enjoyed the task:
  - *"As far as I'm concerned that was one of the better ones and I actually looked into the information more than I would because I didn't know much about lupins and it was interesting on the piece of paper so I looked into it a bit more. Whereas [with] orals you usually stress out heaps."*
  - *"It was left pretty open as well. Didn't have any guidelines in the thing which is ok in a way ..."*
  - "*Given that license where we can take any part of it and go down [any path], gave us a bit of freedom rather than ... instead of being given something and [told] do this. It was sort of now here's something, go and find something that relates."*

- Some students found the openness of the tasks a bit more ambiguous and were unsure of the expectations.

  - *"I was a bit unsure of what ... I mean obviously we had to cover the example but a bit unsure as to what ...what to expand on ... or how deep to go"*

- The conversation moved towards understanding expectations for the task:
  - *"I reckon a better marking scheme would have been helpful as well, so we knew how far we had to go"*
  - *"I think if it was confirmed that we could take any direction with it that would have just been good for myself because then I would have felt a bit more confident that I could choose what I thought was relevant"*

- There was general agreement that a rubric or similar that said they could look at an aspect of, for example, the science or the breeding program or how that crop is used in cultivation and that they could go in either direction, but they would be assessed on the depth, was a good idea.

Did they find the task it easy/challenging/about right?

- There was general agreement that the task was about right. Some had prepared at the last minute, others had spent more time because of their lack of familiarity with the topic and its complexity, the breadth of information covered in the handout, or the amount of research needed to extend the topic further:
  - *"I did the majority of mine last night to be honest."*
  - *"Mine took up a bit of time because I didn't know anything about the topic ... it was really broad."*
  - *"Yours* [to Blue gum student] *probably had a lot of variety of information. You had the reproductive biology plus what they use it for plus like the pin penetration traits where as mine I couldn't really find any other information on adaption, like that was the main example and I just explained that. I didn't really have any other ... like I couldn't find any other information on the net about it really. Lucky we'd had the field trip ... otherwise I would have just said - Oh yep, that's what the fact sheet says."*
  - *"I had to read mine [Blue gum] a few times before I understood it, like I could tell it was just chopped out of something massive, crammed into something ... and I was like - Where is this going?... I had to get [another student] to read the last couple of sentences because I was seeing it in so many different ways."*
  - *"And that's where the references would have been really helpful, although I couldn't get into a fair few of them ... Yeah they weren't really journal articles."*

- Facilitator explained some of the different approaches used in writing, for example the Blue gum vs the barley example and suggested that perhaps the flow and the story might have been lost in the process of compressing the information. Facilitator suggested reviewing the handouts should include ensuring that that are still telling the story and that they flow and that it's easy to read and that the references are there as trigger points for the students to know where to go and look further.
  - *"I found with mine that pretty much all I needed was in there, but the only thing I really needed was the history of almonds. But you still did have to go and look at it, to understand it a bit better, like what they do in the industry, but pretty much the science was all on the sheet."*

How have the handouts and the exercise (because it might be difficult to tease them apart) influence their learning? Has it influenced their thinking about other aspects of the course? Has it helped?

- There was general agreement that the handouts and the exercised had helped with their learning in the course. The facilitator asked specifically about the theoretical concepts:
  - *"When I read mine on the first day we got it, I was a bit lost with just the breeding programs and domesticating lupins and that stuff. Then I read it a few weeks later after a few more lectures and after Tony's* [Rathjen] *brief overview of plant breeding it sort of helped a bit more. As we went through a few more lectures, like with faba beans I understood yours* [to other student] *a bit more otherwise I wouldn't have known what you were talking about as much. So it depends on when the lectures are."*

- Facilitator asked if it would have been better to have received the handouts later. The students felt it was good to get them early.
  - *"It's good to get them at the start ... read 'em once ... then as you go through the lectures you can go - Oh, that actually applies to my example, which I found last week when Jeff Paull spoke to us"*
  - *"Yeah it's always in the back of your head if you've had it and you've read through it"*

- Facilitator suggested that in future students should be told to have a look at their example first.
  - *"And look at your lecture program and make a note that it is actually taught, like the stuff that's in here, so you know it's coming up"*

- Facilitator emphasised that the project is about linking what they are learning to the practice of plant breeding:
  - *"Yeah the concepts are applied to all different breeding programs"*

How did the student feel about the plant breeding course generally?

- The students generally enjoyed the plant breeding course
  - *"It's one of our best ones"*
  - *"Yep, everyone's favourite"*
  - *"Probably because of the field trips"*
  - *"But it's interesting to get out into the industry, where we haven't had that yet, like in our uni degree. But yeah now we get to see what we can actually do out there"*
  - *"And what we're learning, how it's applied"*
  - *"And it's really not that far off now that we're in our last year."*

- The students also valued being in a smaller group and being able to interact with the lecturers while travelling on field trips. The discussion turned to their experiences in the earlier years with generic subjects taught at faculty level with students doing other degrees which they didn't really like.
  - *"When you went through the first two years, doing botany and that, like I found it pretty boring and it doesn't give those people that are iffy of doing plants ... like it doesn't stimulate your interest into plants at all."*

- *"[Other student] and I were just saying over lunch ... all the sort of core subjects you do when you're in the massive(?) theatre with everyone else doing other subjects. It would be so much better if you had the contact with you know Jason and Glenn and Tony and if all those people could take small groups to teach us the basics and it would be more ag related."*
- *"Or even if you just had like a set tute with the rest of the ag kids, like if you did the lectures for botany with the rest, but then everyone who did ag had a tute with Jason or something like that and then within the tute it would be like still sort of run the same course but the tute would be more ag related."*
- *"There was probably about 20 of us to start with and I reckon a lot dropped out because of that."*
- *"But still you can see now why we've done it, like knowing different reproductive structures and flower types stuff. Yeah you still need it"*

- Facilitator clarified that it was not the subject but the way it's delivered and that the students would prefer a situation where they could develop more of an identity early on, particularly relating theory back to agriculture rather than other disciplines, for example geology.

Have the resources influenced their attitude towards the course in any way?

- The handouts and the plant breeding course generally had exposed them to a diversity of breeding programs and applications that they had not been aware of previously:
  - *"I don't know whether it's [the resources] or in combination with the course but it's probably opened my eyes to the importance of plant breeding generally in industry and agricultural food production, ornamentals, everything!"*
  - *"Like if you said to someone down the street, they'd probably look at you like - I don't care but it's such a large part ... of supporting the community."*
  - *"And we probably didn't realise how many breeding programs there [were] out there. Like if you'd said to me three years ago - Oh [are] you going to do ag science, [do] you want to be a plant breeder, I'd be like- Well isn't there only one in South Australia?"*
  - *"Yeah, Tony Rathjen, he's the main man!"*
  - *"Yeah I didn't realise how many opportunities there were out there ... or what they do ... and just the range of different like, not just wheat and barley. Well faba beans even, I didn't really realise ... Sturt pea ..."*
  - *"Yeah definitely ...I didn't realise there was a Sturt Pea breeding program."*

What's your general attitude towards plant breeding as a career, becoming plant breeders perhaps?

- The students were not particularly enthusiastic about being plant breeders, seeing it as potentially rewarding, but that it took a long time to achieve those rewards. They were also exposed to some of the uncertainties of funding, which potentially made the role unattractive.
  - *"Well I've thought about it a lot more since doing this subject.*
  - *"It definitely interests me, but whether I want to just trawl through all that data and look at, what was it, Agrobase. Yeah just sit at my computer and work Agrobase for the rest of my life, probably not."*
  - *"Could be pretty rewarding though."*

- *"Yeah it could be, if you were able to develop [something] or make improvements."*
- *"I think for me it still seems like really long term, like Tony [Rathjen] said that it's not as quick but it still seems like it takes ages to release a variety."*
- *"Even like the apricot breeder, like when he was talking to us ..."*
- *"Yeah he wasn't very positive at all."*
- *"Yeah he seemed a bit depressed about it all."*
- *"And everyone is fighting for funding, that's all they whinge about."*
- *"But every time we talk to a plant breeder about- Oh are you going to do plant breeding and we're like - Nah, looks a bit boring and takes too long and [they say] there's like well marker assisted selection and genetic modification and that sort of thing are sort of becoming more and more ... so yeah technology is increasing pretty rapidly."*
- *"Looking at the people outside of the government, [they] were quite passionate, like John, the AGT guys ... definitely ... I mean they all love it. But you talk to the blokes who are working with a SARDI shirt on and they're all* [depressed voice] *– Oh Mike Rann's going to pull my job out ... wondering whether they're going to be back there next week ...whether they're going to have any food on the table."*

Have the resources influenced your thinking about plant breeding as a career. Are you thinking about it a bit more than you did before?

- The students were already sceptical of careers in plant breeding and it seems as though the handouts didn't change this view. However the resources did emphasise the diversity of breeding programs and also seemed to get them thinking about opportunities outside of their local area.
  - *"Probably [we] also see that there's a lot more opportunities for [plant breeders] than what you thought that ... there's all these ... like each of us has got something that's very different and there's probably people who are looking for that ... people to undertake [plant breeding] and get into that sort of thing ... whether you would or not but ..."*
  - *"I was wondering like if you went into a plant breeding program I'd say you'd want to go to a place where you grow [the crop] the most or where it's .... like with the almonds, well 80% of its grown in America, obviously it's going to be massive over there and everyone would be talking about it and it would be a lot more interesting if you could go to America"*
  - *"And that's why we thought when we started it would just be wheat, barley, oats*
  - *"Even now we've seen a different range of breeding programs and wheat and barley are still the biggest ones ... because this is the local area for it I suppose."*
  - *"This provided something that we didn't get from lectures because no-one here would probably know about Blue gum either* [agreement from other students] *and even if they did know about it they probably wouldn't be passionate about it and so really get the point across"*

- The facilitator outlined the plans for the project especially the possibility of sharing internationally. Facilitator explained that sharing resources also kept things interesting for the lecturers

Are there any suggestions for improving the resources?

- Facilitator summarised points to date including making sure the story is still there, making sure it's well referenced and that those references are good trigger points, changing the colour of the beers, making sure that the references in the list are accessible. No other suggestions were made at this point

In terms of preparing the powerpoint presentation, did having some images help?

- The students agreed that being provided with images helped them prepare for the assessment task.
  - *"It helped with mine because it matches what's in the text. I could have had just all text and it [would have been] really boring to look at but with a picture of my lupins, one was germinating and the wild one wasn't. I could just point that out and it make it a little bit more interesting"*
  - *"I did notice with mine [barley] that the diagrams had ... um ... become modern. In a sense so they'd become coloured and pretty and things like that. Whereas the actual references were very dull, as usual, and so I think I wouldn't have been able to get my point across as well if they hadn't been updated. Cause I mean the information on the diagrams like the proteins and the graph were exactly the same, they just weren't in colour and I wouldn't have been able to access them in colour. So thank you for changing the colours."*
  - *"I found with mine that the pictures helped explain a lot more about what they did with their example, or what was in the example, so the help was there."*

- Facilitator related this back to some students being given extra images that weren't in the handout. Facilitator explained there would be an image library with the handouts at the completion of the project.

Are there any suggestions for other ways of using the resources in the course?

- The students agreed that having an assessment task around the handout made them read the ones that they were given. They enjoyed hearing about the other examples from their fellow students.
  - *"I thought with the sheets given to us and said - You have to read this and present something with it - actually made me read mine* [agreement from other students] *cause if you were just going to put it up on say MyUni saying this is additional I'm never going to read it"*
  - *"I never would have read all 9 if they'd just been up on MyUni and [told] - Here's a resource, it's pretty interesting. I would have gone - Hmph, no it's not interesting. But having everyone learn theirs and then present it gives you a good overview of each one plus it's a lot easier to sit and listen rather than read it yourself."*
  - *"Even if it was put into the lecture material I still probably wouldn't have looked at them until right before exams and we had to."*
  - *"I think having people at the same sort of level presenting the material makes it easy to understand rather than say a lecturer who just thinks that everything is fairly basic and sometimes forgets to explain things that makes sense to everyone else"*

- Facilitator asked if there was anything else. The students asked for some feedback on the presentations from the facilitator. General feedback, congratulating the students on their presentations was provided. There was also some general discussion on the future of the project. After another request for any more comments the facilitator thanked the participants for their time and responses.

These comments highlight some of the issues in attracting students to pursue plant breeding as a career including:

- The large amount of data analysis involved
- The influence of negative attitudes from lecturers that portray plant breeding as an area where funding opportunities are limited.

However, it is clear that the examples were effective tools in raising the awareness that there are opportunities to breed crops other than the major grains crops and that this opportunities exist throughout Australia.

Further work is required to maintain the links with lecturers to ensure that they are aware of the opportunities to receive support for postgraduate training in pasture plant breeding and that they make students who show an interest aware of these opportunities.

3. Incorporating Forage Plant Breeding into Undergraduate Courses

The Plant Breeding Education Group has been disbanded so it has been necessary to organise to discuss with members individually. With the disbanding of the national group there appears to be little opportunity to influence the curriculum at a national level at this stage rather it may be better to work with individual staff particularly those who are willing to work with quantitative geneticists.

Interviews were conducted with plant breeding lecturers at the University of Adelaide (Prof Diane Mather, Dr Hayden Kuchel), University of Queensland (Dr Mark Dieters), University of Western Australia (Dr Wallace Cowling), University of Sydney (Dr Richard Trethowan) and the University of Melbourne (Dr Phil Salisbury).

The majority of lectures (and lecturers) focus on the breeding of grains crops with little emphasis on pasture plant breeding (particular the breeding of cross pollinated plants) or on the integration of quantitative genetics into plant breeding courses. There are some exceptions to this general situation such as the teaching of quantitative genetics in plant breeding at the University of Queensland. There is also little integration of plant and animal genetics at advanced levels with these tending to be taught as stand-alone subjects or streams. The opportunity exists for MLA to influence this situation through the sponsoring of post-graduate student programs in quantitative genetics and plant breeding, that bring together co-supervisors from plant and animal genetics.

Most lecturers were receptive to the idea of support for summer scholarships or postgraduate scholarships as opposed to changing their lectures to include pasture plant breeding at the undergraduate level.

The incorporation of the plant breeding by example units into undergraduate curricula will help to raise the awareness of pasture plant breeding but it appears that in the short term there is little opportunity to increase the number of lectures specifically related to pasture plant breeding. Therefore it is recommended that MLA focus its efforts on supporting postgraduate training that my combine supervision from plant and animal genetics streams.

Appendix 1.

Pasture Genetics Manual

Prepared for

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By

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AbacusBio Limited

October 2010

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Every effort has been made to ensure the accuracy of the investigations, and the content and information within this document. However AbacusBio Limited expressly disclaims any and all liabilities contingent or otherwise that may arise from the use of the information or recommendations of this report.

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Contents

Summary

This manual provides a definition of terms that are used to describe pasture cultivars with an emphasis on those characters that effect plant performance on farm. The terms described have been identified in conjunction with seed industry representatives and farmers.

Background

AbacusBio Ltd was contracted by Meat and Livestock Australia (MLA) to investigate the industry demand for a set of agreed definitions for pasture genetics; a "*Pasture Genetics Manual*". During this project relevant documents have been collected from the following seed breeding companies and retailers

- PGGWrightson
- Agriseeds
- Heritage Seeds
- Seed Force
- CropMark
- Landmark
- Stephen Pasture Seeds

Many of these groups define some of the terms that are used to describe the difference between plant varieties but often use different language or may only define those terms that are relevant to the cultivars that they are marketing.

The general feeling of those surveyed was that an industry wide set of terms and definitions would be a positive development especially if this could be linked to their own websites or used as an addition/supplement in existing documentation.

List of relevant definitions requiring industry acceptance

A. Growth habit and plant characteristics

Aftermath Heading

The production of seed heads after the main flush of seed head production in spring. If grazing or cutting a pasture removes the seed head during the main period of seed head production, any further production of seed heads is called the 'aftermath heading'.

Aftermath heading may reduce feed quality due to the proportion of stems in the sward.

Annual

A plant which completes its full lifecycle from germination to fruiting in one year before dying off.

Annual plants either need to be resown every year or allowed to seed to build up seed reserves in the soil.

Anthesis

The time at which pasture flowers open and begin to shed pollen. Peak anthesis occurs on the day the greatest number of florets shed their pollen.

Biomass

The weight of a plant or animal.

Biomass is equal to the yield of the pasture at a given time.

Brown mid-rib (BMR)

Brown mid-rib or (BMR) is a naturally occurring variation in a range of tropical and sub-tropical grasses (eg maize and sorghum) that changes the lignin concentration of the grasses and increases their digestibility.

Ear emergence (AKA Inflorescence emergence)

The time at which the tip of the inflorescence (ear) appears out of the sheath of the flagleaf.

Florets

An individual flower on a plant. For instance a white clover flower is made up of many individual florets.

Flowering date, (mean)

In clovers and lucerne, the average date on which the first floret on each plant opens and is capable of being pollinated.

An early flowering date can mean extra winter or early spring growth, whereas late heading can provide higher pasture quality in late spring.

Heading date (AKA, inflorescence emergence)

For a pasture sward, inflorescence occurs on the date at which 50% of the inflorescences in fertile tillers have emerged. For a group of spaced plants or sward of a given variety, the mean date is when the third inflorescence of each plant first emerges.

An early heading date can mean early spring growth, whereas late heading can provide higher pasture quality in late spring.

Heading date classification in perennial ryegrass

Perennial ryegrass cultivars vary greatly in their flowering dates with average heading dates occurring over approximately 2 months. Early heading date cultivars tend to have better growth in winter and early spring, while late heading cultivars tend have better growth and feed quality in late spring and early summer.

A general heading date classification for perennial ryegrass is:

- ‘Early- cultivars heading more than 6 days before Nui/Bronsyn
- Mid-season- cultivars heading from 6 days before Nui/Bronsyn to 7 days after Nui/Bronsyn
- Late- cultivars heading from 8 to 21 days after Nui/Bronsyn
- Very late- cultivars heading from 22 to 35 days after Nui/Bronsyn
- Extremely late- cultivars heading more than 35 days after Nui/Bronsyn

The choice of a cultivar with an appropriate flowering time for a given system or environment is a key determinant of appropriate growth patterns and persistence.

Herbage

Plant material from the pasture sward characterising mass and nutritive value which accumulates above ground through growth.

Herbage refers to both the leaves and stems of a pasture.

Hybrid (ryegrass)

Plant offspring from parent plants which belong to different taxa i.e. different family, genus, species or any interspecific category.

Hybrid ryegrasses tend to be intermediate in performance between annual and perennial types.

Inflorescence

The arrangement of florets or flowers on a plant species. In grass the inflorescence may also be known as the seed head or spike.

Inflorescence emergence (AKA ear emergence)

The time at which the tip of the inflorescence appears out of the mouth of the sheath of the flagleaf.

Inflorescence emergence, mean date of (AKA Heading date)

For a pasture sward, inflorescence occurs on the date at which 50% of the inflorescences in fertile tillers have emerged. For a group of spaced plants of a given variety, the mean date is when the third inflorescence of each plant first emerges.

An early inflorescence emergence date can mean early increased winter and spring growth, whereas late heading can provide higher pasture quality in late spring and summer.

Italian ryegrass

Italian ryegrass (*Lolium multiflorum*) occurs in annual and short lived forms. In Australia the annual forms are sometimes marketed as annual ryegrass and should not be confused with annual ryegrass (*Lolium rigidum*) which is a widespread weed in cropping areas.

It is important when choosing between Italian ryegrass cultivars to ascertain the expected life span in the target environment. Italian ryegrass cultivars may be either diploid or tetraploid.

Long rotation ryegrass

A long rotation ryegrass is one that may be intermediate between Italian and Perennial ryegrass in terms of persistence.

Perennial

A plant which lives for more than two years. For most pasture species perennial usually describes a plant that is expected to survive for more than 3-4 years in suitable environments.

Persistence

The ability of a plant to remain in the pasture sward. Table 1 shows a persistence continuum for pasture types from the most persistent perennials which live for more than 2 years, to the least persistent annuals which completes its full lifecycle from germination to fruiting in one year before dying off.

Table 1: Relative persistence of ryegrass varieties

Most persistent	Perennial ryegrass
	Long rotation ryegrass
	Hybrid (Short rotation) ryegrass
Least persistent	Annual ryegrass

Persistence is generally estimated at least 3 years after a species has been sown using point analysis. Point analysis consists of counting how many plants touch the point analysis measuring tool.

The expression of persistency in pastures is influenced by climate, soil conditions and management and data relevant to the target environment are required to make choices between species and cultivars.

Regrowth

The quantity of biomass which accumulated above the height that the plant was last defoliated following grazing or cutting.

Regrowth rates determine the optimal grazing intervals for paddocks that are rotationally grazed.

Seed dormancy

The period of time when a seed is alive but unable to germinate until certain conditions are met. These conditions may include time, temperature or other factors.

Seedling emergence

Is when the first shoot of a seedling has appeared above ground.

Short rotation

A short rotation grass is one which is expected to survive between 2 and 4 years.

Spaced plant

Plants grown in a row or grid so that leaves do not touch or overlap any other plant. Plant breeders sow spaced plant trials to assess the genetic merit of individual plants, this task is difficult under sward conditions.

Taxon

A classificatory group of any rank. Ranks include family; genus; species; or any other infraspecific category.

Tiller

A singular unit of a grass plant with each unit comprising a single stem, roots and leaves.

Grass varieties with large numbers of tillers are sometimes more tolerant of grazing than those that with fewer tillers.

Undersowing

The process of drilling seed into an existing pasture without using sprays or cultivation. Undersowing is more successful when performed in pastures with low density, to boost pasture population and growth.

Vernalisation

The process by which seeds are subjected to a period of cold temperature to break the dormancy cycle of the seed or facilitate plant development and flowering.

Winter activity ratings

The winter activity (growth) of lucerne cultivars varies greatly and is related to the persistence, speed of regrowth, seedling vigour and appearance of lucerne cultivars. Lucerne cultivars are rated on a 1-10 scale with 1 being the least active and 10 the most active. However, the cultivars are often grouped as being winter dormant (3-5), winter-active 6-7) and highly winter active (8-10).

Winter activity ratings are key determinants in the choice between lucerne cultivars due to the correlation with seasonal growth. Cultivars with low winter activity also tend to be more tolerant of grazing.

Yield

Is the weight of biomass accumulated over a certain period of time. Yield is generally expressed in tonnes of dry matter (t DM). However, it may also be quantified as a number in relation to other varieties with 100 as the base variety (101 indicating a higher relative yield than the base) does, or it could be based on units above or below the average yield when the average is set to zero.

B. Breeding and variety testing

Chromosome

A structure in a living cell which is made up of DNA and protein which enables genetic information to be passed from one generation to the next.

Coefficient of variation (CV %)

A ratio of the standard deviation to the mean of a dataset. This quantifies how variable trial data is and hence the accuracy with which the average values of cultivars within a trial are measured. In plant yield trials (using a single cut) for instance, the CV is usually below 20%, and a CV below 10% indicates low variability.

The CV gives an indication of the reliability of an individual trial or experiment. Data from trial with a high CV should be treated with caution.

Confidence level

This statistical term is used to describe the degree of certainty with which a result has been obtained. For example if two cultivars are described as being different at a 95% confidence level there is only a 5% chance on average that is apparent difference would be seen by chance.

If no confidence level is presented for trial data there is no estimate of the likelihood that the observed differences are likely to be seen in further trials or are just a chance occurrence.

Cultivar

Cultivar is a scientific term used to describe a plant variety, for instance Holdfast and Sirosa are both phalaris cultivars.

Whilst pasture plants are marketed as cultivars it is the traits and characteristics of these cultivars that are important when determining pasture performance.

Diploid

A diploid plant contains two sets of chromosomes. Examples of naturally diploid plants include perennial ryegrass and cocksfoot.

DNA (Deoxyribonucleic acid)

A nucleic acid housing genetic information that combines to form the genetic code of a living organism.

F test

A statistical test to check the variability of trial data. The F test can be used to decide whether an LSD test can be used. The F test will either suggest that there is no significant differences (NS) in trial data so the LSD test cannot be applied. If the F test suggests the LSD can be used it will either be significant at the 5% level (*), significant at the 1% level (**) or significant at the 0.1% level (***).

Least significant difference (LSD)

This is a statistical test to provide an indication of whether differences in data are real or if differences in data can be attributed to random variability. An LSD test is determined at a 5% level meaning, there is 95% confidence that the differences in trial data are real. Table 2 provides an examples of an LSD test in use in a plant yield trial. The plant yield of treatment 1 is significantly different than the three other treatments indicated by the difference in letters after the value. Treatments 2 and 3 are not significantly different.

Table 2: Plant yield across four treatments, where treatments with different letters indicates significant differences

Treatment	Plant yield (tonnes of dry matter per annum)
1	9.00 a
2	9.50 b
3	9.60 b
4	10.0 c

The LSD may also be presented as a number, so in the example above an LSD of 0.2 would mean that the differences between treatments 1 & 2 are not likely to be significant. The LSD is influenced by how well a trial is undertaken and trials with a lot of variability will have a higher LSD.

Ploidy

Ploidy refers to the number of pairs of chromosomes within a plant cell. Some plants are diploid and contain two sets of chromosomes (similar to animals) whereas others are polyploid and contain more than two sets of chromosomes.

Standard deviation

A standard deviation provides an indication of the variation from the mean value. If data points in a data set are close to the mean, the standard deviation will be low. If data points are far away from the mean, there will be a high standard deviation.

Statistical significance

The statistical significance of a difference between two varieties is an estimate of the likelihood that they differences observed are real and not just due to errors or chance. For instance a statistical significance of 95% would suggest that there is a 95% chance that the measured difference is real based on the analysis of trial data. This level of significance is the usual level chosen by breeders and trial managers to assess the differences between varieties.

If differences between cultivars are not listed as being statistically significant then these differences should be treated with caution.

Tetraploid

Tetraploid plants contain four sets of chromosomes. Examples of naturally occurring tetraploid pasture plants include lucerne (*Medicago sativa*) and white clover (*Trifolium repens*).

Plant breeders have also developed tetraploid forms of Italian and perennial ryegrass using induced chromosome doubling. These tetraploid forms of ryegrass can have enhanced forage quality as they can have a higher proportion of highly digestible components than dilpoids. These tetraploid ryegrasses also tend to have larger seeds and therefore are often sown at higher rates (in kg/ha) to achieve adequate plant densities.

While tetraploid cultivars may be more nutritious the difference may vary from cultivar to cultivar. Therefore, data should be sought that relates to the performance of individual cultivars in the target environment.

D. Endophytes

Endophyte

Endophytes are a group of fungal organisms which have their entire lifecycle within the organs of the host grass. There is generally a symbiotic relationship between the endophyte and the grass species with the endophyte requiring the host plant to complete its lifecycle. In return the endophyte produces chemicals called alkaloids that confer resistance to insect and mammalian predation. In an agricultural context the alkaloids which confer plant resistance to mammalian grazing is a detrimental aspect of the particular endophyte. Whereas plant resistance to insect predation is a beneficial aspect of the .

Ryegrass endophytes and their production of alkaloid chemicals (NZ data needs Australian refinement)

	Alkaloid chemicals produced?			
Endophyte	Peramine	Lolitrem B	Ergovaline	Janthitrems

AR1	Yes			
NEA2	Yes	Very low	Low	
Endo5	Yes		Low	
AR37				Yes
Standard (SE)	Yes	High	High	

Insect resistance and livestock effects from a variety of endophytes (NZ data needs Australian refinement)

Endophyte	Resistance to which insects	Detrimental impacts to livestock	Comments
AR1	Argentine stem weevil (ASW), Pasture mealy bug (PMB)	Does not cause ryegrass staggers	
NEA2	ASW, PMB, Black beetle (BB), Root aphid	Does not cause ryegrass staggers	NEA2 is made up of two endophyte strains
AR37	ASW, PMB, Root aphid, Black beetle, Porina	May cause small reduction in dairy milk production in summer and it can cause ryegrass staggers but not as bad as SE.	
Standard endophyte (SE)		Severe ryegrass staggers, reduced lamb liveweigth gain, increased dags and flystrike	Provides good resistance to a number of insects but no better than some other endophytes

E. Forage Quality

Crude Protein

Crude protein content of a pasture can be calculated by quantifying the amount of nitrogen in the feed, then multiplying the nitrogen content value by 6.25 (as it is assumed protein is made up of 16% nitrogen). The crude protein may include some non-protein nitrogen but it is the most common form of protein measurement.

An excess of crude protein can be common in some parts of the year such as autumn, winter and spring. While there can be a lack of crude protein in: late spring/summer when ryegrass is heading and/or moisture stress causes leaf loss; leaves are lost due to severe frosting; and when stock are fed large quantities of low protein supplements.

Digestibility

Digestibility (or dry matter digestibility) is the proportion of the pasture that is ingested by a grazing animal and not excreted. It is estimated using a range of laboratory procedures and is a primary determinant of the quality of pastures. Digestibility varies between species and also according to management factors (overgrown and dry pastures are less digestible) and the stage of maturity of plants (mature stems are mostly less digestible than leaves).

Dry matter

Pasture plants have varying amounts of moisture content depending on species, stage of growth and a range of other factors. To correct for this variability in moisture content it is common to express all yield and forage quality factors on a dry matter basis. The dry matter of pasture is the proportion of the total fresh weight of the pasture that remains after drying.

Megajoules of metabolisable energy (MJME)

Metabolisable energy is the estimate of the energy yield of a given forage to a grazing animal allowing for energy loss in faeces, urine and methane. It is measured in megajoules of energy (MJ) per kilogram of dry matter in the feed (DM) to give MJME/kg DM.

Neutral detergent Fibre (NDF)

Neutral detergent fibre (NDF) is a laboratory estimate of the fibre content of a pasture sample. It approximates the cell wall content of the pasture. NDF is an important indicator of forage quality for two main reasons:

- Diets very low in NDF (such as grain and some lush pastures and fodder crops) can cause poor rumen function and acidosis
- Diets very high in NDF may reduce animal performance due to low rates of intake and slow digestion of this pasture in the rumen.

Non structural carbohydrates

Non structural carbohydrates (NSC) are either simple sugars in a feed, or carbohydrates that can be broken down by enzymes produced in the animal. NSC include glucose, fructose, lactose, sucrose and starch. A diet comprised of hay supplements will have very low quantities of NSC compared to a high grain-low fibre diet. See also water-soluble carbohydrates.

Palatability

The degree of preference an animal has to consuming a certain type of feed. Generally palatability is measured by assessing defoliation of pasture amongst plots of pasture that are next to each other. Lower residual pasture cover would indicate higher levels of palatability.

Water soluble carbohydrates

A component of feed very readily converted into energy by animals and includes sugars (glucose and fructose) and disaccharides (sucrose) and more complex carbohydrates such as fructan.

Using estimated breeding values in plant breeding

Plant Breeding by Example

Example 8

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What can plant breeders learn from animal breeding? This example discusses how methods that were developed for animal breeding can be applied in plant breeding.

Advancing multiple traits in a breeding program

In most plant breeding programs, multiple traits must be considered, and there can be 'trade-offs' between these traits. For example, in a pasture crop where both yield and nutritive value are important, the ideal plants are those that are high-yielding and very nutritious, but breedera may also employ less nutritious parents if they are very high yielding, and lower yielding parents that are particularly nutritious.

One way of balancing multiple traits in parental selection is to calculate a single number to represent the overall merit of an individual or its progeny. For example, the breeder may sum up the phenotypic values across all traits, using a formula that weights the traits according to their relative importance (a 'linear additive index'). For example, the Southern Tree Breeding Association (www.stba.com.au) has developed a four-trait profit index for *Pinus radiata* saw logs, as follows:

$NPV\$ = {}_{w1}Growth + {}_{w2}Branch + {}_{w3}Sweep + {}_{w4}Stiffness$

Typically such indices are updated as market specifications change or new traits become available to add to the index.

The use of selection indices is quite advanced in forest tree breeding, partly because relative economic values are quite easy to define for forest products. Also, the long generation intervals of trees and the high cost of forestry trials make it important to ensure that all of the information collected throughout the life cycle of the trees is effectively used in selection decisions for maximum genetic gain.

What is an Estimated Breeding Value (EBV)?

With appropriate statistical analysis, information on related plants and families (parents, siblings, progeny) can be used to improve this estimates of usefulness of possible parents. This provides 'estimated breeding values' (EBVs) that predict how useful each individual will be as a parent.

In livestock breeding, where there is often extensive information on the performance of relatives, EBVs are routinely used to improve selection decisions. In the dairy industry, EBVs are used to describe the relative genetic for traits related to milk production and milk composition. In the Australian sheep industry's Lamb Plan program (www.sheepgenetics.org.au), EBVs estimated using an index that includes economically important traits for prime lamb production can be used to select rams or ewes for matings.

Figure 1. EBVs enable sheep breeders to select individuals based on a range of economically important traits. Photo courtesy of Sheep Genetics.

The use of EBVs in Plant Breeding

Despite their broad use in animal breeding, EBVs are not commonly used in plant breeding. There are a number of possible reasons for this including:

> The relative economic values of traits to profitability are often poorly defined, making it difficult to develop a selection index.

> For some plant species, the industry requires minimal threshold values for certain traits (e.g. to meet malting specifications for barley, or milling specifications for wheat), so breeders apply 'independent culling' for each trait rather than practising index selection.

> Plant breeders often do not maintain the detailed pedigree information that is routinely maintained in animal breeding.

Extending the use of EBVs in plant breeding.

Forage plant breeding may be well placed to benefit from the use of EBVs due to:

- > The use of multiple parents
- > The need to balance many traits related to total yield, seasonal yield and forage quality
- > The absence of pre-defined threshold levels for variety release
- > Successful adoption of EBVs in forage plant breeding will require:
- > Relationship matrices that describe the relatedness of individuals
- > Better knowledge of the relative value of individual traits in the profitability of pastures

With DNA marker technologies, it is now possible to use molecular data to estimate the degree of relationship among plants (e.g., Wang et al 2009), in essence creating a pseudo-pedigree that can be used to derive a relationship matrix even if pedigree information has not been recorded.

It can be difficult, however, to assess the relative value of individual traits within a breeding objective due to the broad range of environments in which pasture species are grown and the lack of historical evidence of the relative importance of individual traits in determining the profitability of pastures. We have recently been addressing this issue by undertaking research on the use of analytical software (www.1000minds.com) to determine the relative importance of individual traits in forage breeding programs (Smith and Fennessy 2011). This methodology has allowed us to understand the relative emphasis that is placed on individual traits. We have recently extended this technology further to understand the balance between yield, persistence and quality in economic terms across a range of environments in Australia.

If this approach is successful, we will be able to define clear objectives for forage breeding and derive EBVs that will improve genetic gain towards those objectives

Web links

Southern Tree Breeding Association www.stba.com.au
The Australian Sheep Industry Lamb Plan program www.sheepgenetics.org.au
Analytical software www.1000minds.com

References

Wang J, Dobrowolski MP, Cogan NOI, Forster JW, Smith KF (2009) Assignment of individual genotypes to specific forage cultivars of perennial ryegrass based on SSR markers. *Crop Science* **49**, 49-58

Smith KF, Fennessy PF (2011) The use of conjoint analysis to determine the relative importance of specific traits as selection criteria for the improvement of perennial pasture species in Australia. *Crop and Pasture Science* **62**, 355-365.

Breeding in a wind-pollinated grass species

Plant Breeding by Example

Example 7

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A breeding program for perennial ryegrass illustrates the theoretical and practical basis of breeding methods that are used for wind-pollinated grasses.

Many of the grass species that are grown in temperate climates to feed grazing animals are self-incompatible, cross-pollinating species. Cultivars of these species are often 'synthetic' varieties that are formed by allowing multiple parents to pollinate each other in a process known as polycrossing. This paper describes a breeding program for perennial ryegrass as an example of how synthetic varieties are developed in a self-incompatible grass species.

Figure 1. Dairy farm in southern Victoria. The pasture is mainly perennial ryegrass. Photo courtesy of the Australian Dairy Herd Improvement Scheme.

Self-incompatibility and its consequences for grass breeding

Self-incompatibility is under genetic control. In grasses, this involves two unlinked loci called S and Z, each with multiple possible alleles. Recent genetic mapping studies in grasses have demonstrated that the location of these genes is conserved across grass genera (Figure 2). The mechanism of self-incompatibility is such that if a haploid pollen grain contains either an S or Z allele that is the same as one carried by the recipient plant then fertilisation will not result. Self-incompatible plants normally cannot be self pollinated and may not cross with close relatives. Polycrossing among unrelated parents is easy, and results in synthetic populations with enough diversity to support continued intercrossing.

A typical grass breeding program

Breeding programs for cross-pollinated grasses typically involve three stages:

Stage 1. Creating novel variation by growing different parent plants together and allowing them to intercross. Seeds harvested from these plants provide half-sib families; the plants within a family share the same maternal parent but have different paternal parents.

Stage 2. Measuring progeny performance (Years 2-6 in Figure 3). The half-sib families from these crosses are evaluated for target traits as spaced plants or in small drill rows. These plots may be grazed or ungrazed depending on the trait under selection and the availability of grazing animals.

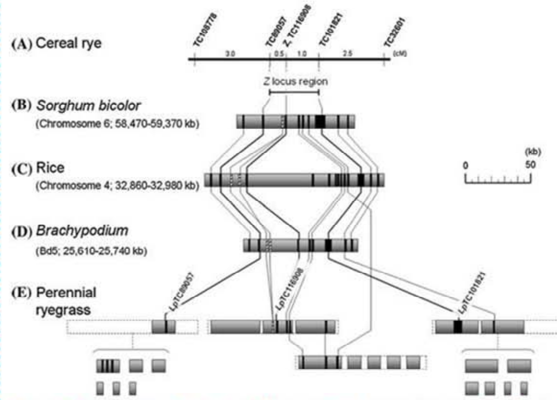

Figure 2. Conservation of location of Z locus position across grass species (from Shinozuka *et al.* 2010)

Stage 3. Creating and evaluating synthetic cultivars. The relative importance of each of these stages will vary according to the resources available to the breeding program, and the extent to which the species has already been domesticated and improved by breeding. For example, a program aimed at developing a new species for a niche environment may not include any progeny evaluation as the need for genetic gain may be less than for a program with species with a mature market and several competing cultivars.

Putting the theory into practice

The perennial ryegrass breeding program used by NZ Agriseeds is an example of a grass breeding program. In this program the breeders are seeking to develop new perennial ryegrass cultivars for target markets in Australia and New Zealand.

Stage 1. (Years 1 and 2 in Figure 3) Crosses are made to combine traits that are needed in the new cultivars. These crosses may be between existing elite cultivars or between an existing cultivar and other germplasm that has been chosen as a source of a new trait such as disease resistance or seasonal growth.

Important traits in this program include seasonal and total herbage production, forage quality for grazing animals, resistance to diseases such as crown rust, seed yield and relatively broad adaptation to target environments in which the new cultivars are to be grown and grazed.

Stage 2. (Years 3 to 5 in Figure 3) Most grass crops in Australia and New Zealand are sown as grazed pastures, and they need to be able to withstand uneven grazing pressure. This is in contrast to crops that are sown for use as hay crops, which are subject to much more uniform herbage removal by mechanical harvesting. Accordingly, this program puts a strong emphasis on selection under grazing by animals, in order to be able to select for traits such as good root growth to confer resistance to animals pulling whole plants from the ground during grazing and good palatability for grazing animals.

Stage 3. (Years 5 to 11 in Figure 3) Potential synthetic cultivars are formed through polycrossing among selections from Stage 2 of the program. Seed is produced to enable the testing of numerous potential varieties in small plot trials. As in any plant breeding program the best results may be achieved when evaluation is performed in situations as close to commercial reality as possible. For this reason the potential varieties are sown as swards in multiple environments and they are subjected to grazing by animals. The size of the swards and the number of sites is limited by the availability of seed in early years so the program has a concurrent effort to increase the amount of seed for those varieties showing promise. In later years, the number of potential varieties is reduced and the size of the plots is increased.

Breeding Programme Outline
Perennial Ryegrass

Year 1	X F_1 Seed	50 crosses
Year 2	F_2 Seed production	50 lines
Year 3/4	Selection under grazing	120,000 plants
Year 5	Clonal rows	2000 rows
Year 6	Seed production	50 varieties
Year 7-9	Multi location small plot trials	50 varieties
Year 9-11	Large plot trials	6 varieties
Year 12	Potential Variety Release Farmer Demonstration Trials	1? variety

Figure 3. Typical grass breeding program as undertaken by NZ Agriseeds.

Future advances in grass breeding

One of the disadvantages of current breeding methods is that selection does not effectively use all of the additive genetic variation in populations. In future, there may be greater use of molecular markers to assess relatedness among progeny and to help estimate breeding values. This could provide a way of improving genetic gain without radically altering the basic structure of the breeding programs which are based on logistical considerations such as seed availability and the need for grazing. Research is currently underway to address these issues.

References

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