MOLECULAR PLANT BREEDING CRC

2008/2009 ANNUAL REPORT

Leading the conversion of genetic and molecular discoveries into innovative solutions that deliver benefit to Australia's grain and pasture industries.

Established and supported under the Australian Government's Cooperative Research Centres Program

Associated organisations

A cooperative venture between:
Department of Primary Industries, Victoria (DPI Vic)
The University of Adelaide
South Australian Research and Development Institute (SARDI)
Department of Agriculture and Food, Western Australia (DAFWA)
Murdoch University
International Maize and Wheat Improvement Centre, Mexico (CIMMYT)

Supporting participants:
International Centre for Agricultural Research in the Dry Areas, Syria (ICARDA)
Australian Grain Technologies (AGT)
ABB Grain Ltd
BASF Plant Science
Grains Research and Development Corporation (GRDC)
Dairy Australia (DA)
South Australian Grains Industry Trust (SAGIT)
Integrain Pty Ltd
Longreach Plant Breeders Pty Ltd
Meat and Livestock Australia (MLA)
Geoffrey Gardiner Dairy Foundation (GGDF)
Heritage Seeds Pty Ltd

Joint venture partner:
PGG Wrightson Limited

Contents

From the Chairman

This is the penultimate Annual Report from the Molecular Plant Breeding Cooperative Research Centre (MPBCRC). For those of you who are new to the CRC, let me quickly run through our history for you. We began in 1996 as the CRC for Molecular Plant Breeding (CRCMPB) and brought together some of the leading researchers in the fields of cereals and pastures prebreeding. Back then our focus was on the discovery of new genes and genetic markers, and also platform technologies that could help Australian farmers build sustainable and profitable businesses. In 2003, we were successful in securing an extension of funding from the Federal Government and MPBCRC was born. You may be excused for thinking that our chosen name for the new CRC was remarkably unimaginative and that this reflects the nature of the people working within the CRC. Happily, this is not the case. We consulted widely and found that "Molecular Plant Breeding" had built a strong brand among its peers and endusers and the CRC partners deliberately chose to maintain this brand in their new venture. MPBCRC has worked hard to further strengthen this brand, making sure that the Australian farmer recognises the value of innovation and supports it wholeheartedly.

While continuing to invest in R&D, the new CRC also substantially increased its investment and focus on commercialisation, the process of bringing our technologies onto the market where endusers can extract the maximum benefit. MPBCRC, as you will see in the CEO's report, has achieved some significant outcomes. In the last six years, it has been very pleasing to observe that MPBCRC has successfully moved its technologies closer to the market. As a grain grower, I am acutely aware that my entire livelihood depends critically on continuing research and development into frontier technologies and this is why I have continued to strongly support the activities of the CRC. How else would I, as an Australian farmer, be able to address environmental risks such as drought, salinity and frost? How else would I be able to address the major challenge of increasing productivity to feed a rapidly growing population with the same amount of arable land? The technologies that MPBCRC are developing will not provide all the answers but they will play an integral role in an armoury of tools that Australian farmers will use to face up to the big challenges.

› As a grain grower, I am acutely aware that my entire livelihood depends critically on continuing research and development into frontier technologies.

It is with a degree of sadness that the Governing Board has decided that MPBCRC would not seek to extend its funding from the Federal Government and will cease activities around June 2010.

I am very glad that much of MPBCRC's research into pastures will be integrated into the new Dairy Futures CRC which was successful in securing funding from DIISR in Round 11 of the CRC Selection Round and is expected to begin operations around January 2010. The combination of skills, expertise and enthusiasm of those involved, lead me to be confident that the Dairy Futures CRC will have a positive impact on the dairy industry.

While it is sad that MPBCRC will finish in 2010, it has been a wonderful fourteen year journey and our Board and participants are absolutely delighted about its achievements to date. The Board would like to offer our thanks and congratulations to the CRC's staff, researchers and partners for a job well done.

Dr. Tony Gregson AM, FTSE

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research projects during 2008/09

From the CEO

During the reporting period, I had the pleasure of addressing over 800 Australian farmers at various conferences and the recurring theme has been: "How do we help farmers address risks that they regularly face?" An example that I have often employed is growing wheat. If you grow wheat in Australia, your crop is likely to experience water stress from below average rainfall about 50 % of the time. It then comes as no surprise that every time I speak about MPBCRC's drought tolerant GM wheat program, there is intense interest among grain growers and indeed strong support from them. Rather than harbouring suspicions about the new technology, farmers more often than not, ask me "When will the new variety of GM drought tolerant wheat be on the market?". I always answer honestly: 'It's at least seven to eight years away". However, it will take a lot longer if we don't have the support of farmers and the general public.

As reported in 2007/08, Australia's first field trial for GM wheats expressing different candidate genes for drought tolerance received regulatory approval during 2008 and commenced ahead of schedule. The second year of these trials took place during the reporting period, with identification of lead events and selection of candidate genes undertaken for the production of 'market-ready' transformation events. The third field trial is scheduled for the next reporting period. With the recent renewed interest in GM wheat from multinational agribusinesses and grain grower groups around the globe, it is pleasing to note that MPBCRC, in partnership with BASF Plant Science (Limburgerhof, Germany) is conducting one of the most advanced programs in the development of drought-tolerant GM wheat in the world.

Two highlights from MPBCRC's pasture improvement program during the reporting period were the commencement of Australia's first, and the world's largest, field trials for GM perennial ryegrass and tall fescue plants with enhanced fructan metabolism and modified lignification respectively. So what does this mean in English? All of the pastoral industries, including the dairy and livestock industries, are based on the conversion of feed into metabolisable energy which in turn drives the production of milk, meat and wool. In this program, we aim to increase the productivity of dairy cows and beef cattle by developing GM pasture varieties that are easier to digest and contain more water-soluble carbohydrates (molecules which produce energy). The desired end result is grass that livestock can convert into more metabolisable energy, which then drives the production of higher quantities and quality of milk and meat. This work is expected to make a substantial contribution to increasing the productivity of the pastoral industries and is undertaken through Gramina Pty Ltd, the CRC's joint venture with PGG Wrightson Genomics (Christchurch, New Zealand) – the program is on track for a product launch around 2013.

MPBCRC has continued our strong record for developing technologies for high throughput genotyping and genetic marker development. During the reporting period, MPBCRC researchers identified novel SNPs and SNP haplotypes for genes associated with herbage quality in perennial ryegrass, as well as novel SNP markers for disease, biotic and abiotic stress tolerance in barley. New genetic variation was also identified for salt tolerance via sodium exclusion in barley and wheat. This information provides a solid platform for researchers to continue investigating salt and drought tolerance in cereals.

› We aim to increase the productivity of dairy cows and beef cattle by developing GM pasture varieties that are easier to digest and contain more energy molecules.

Since MPBCRC's inception, considerable effort has been applied to securing collaborative agreements with major Australian wheat breeders as a means of securing a route to market for our technologies in Australia. During 2008/09, MPBCRC was successful in attracting two new Supporting Participants, Intergrain Pty Ltd and Longreach Pty Ltd. Engagement with these two new participants, together with an existing Supporting Participant, AGT Pty Ltd, means that MPBCRC has established strategic partnerships with wheat breeding companies that capture well over 80% of the Australian market. The involvement of these companies will further enhance our ability to bring our technologies to the market and deliver benefits to endusers.

The Education and Training program continues to rapidly expand, with the joint initiative project Get into Genes (delivered in partnership with the Australian Centre for Plant Functional Genomics) attracting over 2000 students and teachers during 2008/09. To date, Get into Genes has engaged with over 10,000 Australian students. The continued success of Get into Genes has been aided by La Trobe University joining as a delivery partner.

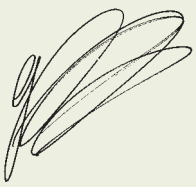
MPBCRC had 27 students working towards their PhDs during 2008/09, with five conferred in that period. A review of recent graduate employment destinations showed all stayed within the plant science industry.

Our outreach and communication activities will be expanded in 2009/10, with funding secured during the reporting period from the Department of Agriculture, Fisheries and Forestry's Recognising Women Farmers initiative to run a series of workshops on "Understanding Biotechnology." This program will use some of the resources and learnings from our other outreach activities to engage with rural women and promote understanding and use of plant biotechnology in farming communities. MPBCRC will be running this program in partnership with Partners in Grain South Australia, the Victorian Farmers' Federation and the Birchip Cropping Group. Funding was also secured from National Science Week for additional activities.

MPBCRC's media profile remains significant, with over 160 media appearances in print, on radio and on television during 2008/09. Compared to 2003/04 (MPBCRC's first reporting period), there has been a 7,522% increase in the number of visits to our web site and a 742% increase in the level of media exposure. We believe in engaging with endusers and the general public in order to pave the way for the use of our frontier technologies and there is some evidence that our efforts have been productive.

The CRC has worked assiduously to gain maximum leverage from funds provided by the commonwealth and its participants. External revenues (cash sourced from organisations other than DIISR or core participants) have increased by 84% compared to 2003/04.

It has been a very productive year for MPB CRC and I would like to thank the CRC's researchers, its head office staff, the Board of Directors and our research and commercial partners for their contributions.



Dr. Glenn Tong FAICD

About MPBCRC

Vision

Australia's crop and pasture industries underpinned by innovation in molecular plant breeding.

Mission

Leading the conversion of genetic and molecular discoveries into innovative solutions that result in varieties to benefit Australia's crop and pasture industries.

Objectives

Enhance collaboration among researchers and industry, and use intellectual property and other resources more effectively.

Establish, develop and undertake world class, high quality, industry focused collaborative research programs in molecular breeding for cereals and pastures.

Commercialise products of CRC research for the benefit of Australia and beyond, providing return on investment, where appropriate.

Entice and train excellent plant breeders and researchers.

Promote MPB's profile as a globally reputable organisation and foster ownership by the Participants.

Governance and management

Board

Dr Tony Gregson, Chair (independent)
Dr Glenn Tong, CEO
Jeff Arney (independent)
Gary Cornelius (independent)
Rob Lewis (SARDI)
Rob Loughman (DAFWA)
Dr Thomas Lumpkin (CIMMYT)
Dr Clive Noble (DPI Vic)
Philip Weickhardt (independent)

CEO
Dr Glenn Tong

Research Director
(Non-transgenic Technologies)
Dr Michael Francki

Research Director
(Transgenic Technologies)
Prof German Spangenberg

Management team

Ian Christensen, Chief Operating Officer
William Lancaster, IP & Contracts Manager
Melanie Carew, Communications Manager
Dr Heather Bray, Education Manager
Vicki Kokolakis, Accountant
Nora Veljanovski, Executive Assistant

Program Management Committee
Dr Glenn Tong, Chair

Program 1: Transgenic technologies
Prof German Spangenberg

Program 2: Non-transgenic technologies
Dr Michael Francki

Program 3: Education Program
Dr Heather Bray

The Board


Dr Tony Gregson


Dr Glenn Tong


Mr Jeff Arney


Dr Rob Loughman


Affiliate Professor Rob Lewis


Dr Thomas Lumpkin


Dr Clive Noble


Mr Philip Weickhardt

The MPBCRC Board aims to provide strategic direction to ensure the CRC can achieve its research and commercialisation goals. In pursuing this objective, the Board has committed to the highest standards of corporate governance. This commitment is reflected in the Board's high proportion of independent members.

The Board maintains a standing Audit Committee for the purposes of overseeing the financial reporting process and establishing accounting policies for the CRC. The Audit Committee is made up of independent Board members Gary Cornelius, Jeff Arney and Philip Weickhardt as well as Chief Operating Officer Ian Christensen. The Board meets four times a year.

Mr Rob Delane, an Executive Director of DAFWA, resigned from DAFWA and has been replaced on the Board by Mr Rob Loughman. There have been no changes to Participants in the CRC during 2008/09.

Dr Tony Gregson Chairman (independent)

Tony Gregson is a grain grower from Victoria's Wimmera region. He has an extensive science and corporate research management background. He has PhD and DSc degrees from the University of Melbourne and has held academic positions at the University of New England, the University of North Carolina at Chapel Hill and at Oxford.

Tony is a Fellow of the Royal Australian Chemical Institute and the Australian Academy of Technological Sciences and Engineering. He is Chairman of Bioversity International based in Rome, and a member of the CGIAR Alliance Board and of the CGIAR Genetic Resources Policy Committee. He is also Chairman of Plant Health Australia, Chairman of the University of Ballarat Water In Drylands Collaborative Research Program, a member of the Crawford Fund Board of Governors and Chairman of the Victorian Crawford Fund Committee. He was an inaugural Board member of CSIRO and the GRDC, and a Board member of the Rural Finance Corporation of Victoria, the Australian Nuclear Science and Technology Organisation and of CIMMYT in Mexico.

Dr Glenn Tong Chief Executive Officer

Glenn Tong graduated from the University of Melbourne with a Bachelor of Science (Hons) and a PhD (specialising in the chemical synthesis of modified DNA). Since transitioning from research to biotechnology commercialisation in the mid 90s, Glenn has established a successful track record in the negotiation and execution of commercial transactions, including collaborative R&D agreements, joint ventures, in-and out-licensing agreements and capital raisings. Glenn is presently Chief Executive Officer and a director of the Molecular Plant Breeding Cooperative Research Centre, Managing Director of Molecular Plant Breeding Pty Ltd and a director of Gramina Pty Ltd (a joint venture between Molecular Plant Breeding Pty Ltd and PGG Wrightson Genomics Ltd). Previously, Glenn was Managing Director and CEO of Pacific Oligos Pty Ltd (an incorporated joint venture between the University of Queensland and a private company), Managing Director and CEO of Genset Pacific Pty Ltd (a subsidiary of Genset SA), Managing Director (Commercial) of AgGenomics Pty Ltd (an incorporated joint venture between Genetic Technologies Limited and the Victorian Government) and Director and Principal of BiotechSmarts Consulting. Glenn was a member of the AusBiotech Ltd Agricultural Biotechnology Advisory Committee from 2003 to 2008, and a Graduate and Fellow of the Australian Institute of Company Directors.

Mr Jeff Arney (independent)

Jeff Arney is a commercial grain and seed producer with broad experience in industry policy development and R&D, including experience in varietal testing and evaluation. Jeff has a mixed farming property near Bordertown, South Australia, where he grows wheat, barley, pulses, oilseeds, irrigated lucerne and other seed crops. He is highly regarded across the state as a progressive farmer, and has an extensive knowledge of the Field Crops Industries, through his involvement with many State and National industry organisations. Jeff has held numerous leadership roles in the grains industry. He has served as president of Grains Council of Australia and Chairman of SA Farmers' Federation Grains Council. Jeff was a panel member of Grains Research and Development Corporation for the Southern Region (SA, Victoria and southern NSW) from 2005 to 2008 and is a past member of the Plant Breeders Rights Advisory Committee (PBRAC). Jeff is currently a member of the Ministerial Advisory Committee for Branched Broomrape Quarantine Area in South Australia.

Mr Gary Cornelius is a Senior Adviser and Director of Leadenhall VRG – corporate advisers a specialising in mergers and acquisitions and of the valuation of companies, businesses and Intellectual Property. He is a Fellow of the Finance and Treasury Association and of the Australian Institute of Company Directors. His background includes over thirty years in corporate consulting, banking, finance and international trade in Australia and overseas. He undertook a part-time secondment to the South Australian Department of Premier and Cabinet as an adviser on economic and financial issues to the Micro-Economic Reform Unit from 1994 to 1998 and regularly consults to Governments at a high level. He is also a director of a number of private companies. Gary is a non-executive director of MPBCRC and Chairman of the Audit Committee.

Dr Rob Loughman

Rob Loughman is Manager, Cereal Breeding and Research with the Department of Agriculture and Food Western Australia. He is an agricultural science graduate from the University of Sydney where he also undertook his PhD in plant pathology. His research areas include genetic improvement in grain crops, particularly wheat and barley, and the application of integrated crop disease management principles for profitable and sustainable production. He currently manages a research portfolio area of the Western Australian Department of Agriculture's Grains Program covering cereal pre-breeding, physiology, quality, pathology, crop evaluation research and related biometrics. He has extensive experience in research strategy and research communication.

Affiliate Professor Rob Lewis

Rob Lewis is currently the Executive Director of the South Australian Research and Development Institute (SARDI). Rob has an extensive research and research management background, in marine sciences. He then became SA's Director of Fisheries prior before being appointed to SARDI in 1992. SARD is the South Australian Government's principal research organisation related to the life sciences. He has a Bachelor of science (Hons) from Adelaide University, an honorary Doctor of Science from Flinders University and an Affiliate Professorship with Adelaide University.

Rob holds directorships and memberships with a number of research and commercial companies and committees including the Australian Genome Research Facility Pty Ltd, Australian Grain Technology Pty Ltd, Airborne Research Australia, CRC Molecular Plant Breeding, MPB Pty Ltd, AW Howard Memorial Trust Inc, NCRIS Integrated Marine Observing System (IMOS), National Advisory Board, the University of Adelaide School of Molecular and Biomedical Science Advisory Board, the University of South Australia Institute for Sustainable Systems and Technologies Advisory Board, the University of South Australia Centre for Nutritional Physiology Advisory Board, South Australian Advisory Board of Agriculture, KJT Lewis Trust and KJT Lewis Pty Ltd. Rob is a Fellow of the Australian Academy.

Dr Thomas Lumpkin

Thomas Lumpkin is Director General of the International Maize and Wheat Improvement Centre based in Mexico. He holds a Bachelor degree in agronomy from Washington State University and Masters and PhD degrees from the University of Hawaii. Thomas grew up on a farm in eastern Washington State and as a young man served in the USA Peace Corps in India. Subsequently he carried out his doctoral research in mainland China and then served for more than 20 years on the faculty at Washington State University. Prior to joining CIMMYT, Thomas was Director General of the Asian Vegetable Research and Development Centre in Taiwan. He is widely known among the agriculture and development communities for his books and publications on azolla, azuki, edamame, wasabi, marketing, bio-confinement of GMOs, global horticultural needs and approaches to poverty alleviation in the developing world.

Dr Clive Noble

Clive Noble is the Chief of Science and Technology – Agriculture Research and Development at the Department of Primary Industries Victoria (DPI Vic).

In his present role, Clive oversees DPI's investment, evaluation and reporting framework for DPI's research, practice change and compliance activities for the agriculture and fisheries sectors. Clive also manages the technology commercialisation activities of DPI arising from its research and development programs. Clive is also the Chairman of Agriculture Victoria Services Pty Ltd – the commercial arm of DPI that deals with research and development.

Clive has extensive experience in rural Victoria and in science leadership, having been a Regional Manager for DPI and the Institute Director of the Tatura/Kyabram/Cobram based Institute. He has had extensive roles with industry and the community through representing government on Catchment Management Boards, industry associations and Commonwealth committees.

His research background is in plant breeding and plant physiology, particularly for irrigation agriculture.

Mr Philip Weickhardt

Philip Weickhardt has been a Commissioner with the Productivity Commission since 2004, having previously served as an Associate Commissioner (2002–03). Prior to this, Philip was CEO of Orica (previously ICI Australia), a Director of ICI Australia and Chairman of Incitec and ICI NZ. This experience with ICI Australia and Orica gave him extensive experience relevant to leading a large international group with a significant R&D program and in the international commercialisation of new technology. Philip is a visiting lecturer in the Executive Education area for Melbourne Business School and is Chairman of the not-for-profit organisation, the Earthwatch Institute. Philip is also a Fellow of the Royal Australian Chemical Institute, and of the Australian Academy of Technological Sciences and Engineering and a foundation Fellow of the Australian Institute of Company Directors. He sits on an Advisory Board for the Anglo American Group in Australia and chairs a CEO Roundtable for CEDA. He has a Master of Science from Melbourne University and has completed the Advanced Management Programme at Harvard Business School.

Commercialisation and utilisation

The MPBCRC was established to develop and contribute to improvements in the cereal and forage breeding industries. In particular, MPBCRC set out to apply new techniques in genetics and genomics to crop and forage breeding and, through the application of this new technology, to increase the rate and extent to which desirable traits could be found and bred into commercial varieties of wheat, barley and forage grasses.

Humans have been breeding plants for thousands of years so the basic techniques of identifying and evaluating superior plants to serve as 'parents' is well known. Also well known is that development of a new cultivar takes many years, with twelve to fifteen years from first cross to released variety being not uncommon.

Breeders search widely, often in wild places, for individual plants (donors) that display a desirable characteristic. From collected seed, a breeding 'parent' is grown and this is crossed with existing lines in the hope that some of the offspring will inherit the desirable characteristics of both parents. However, most offspring comprise about 50% from each parent and so finally obtaining progeny with only a small component from one original parent and a very large component from the other parent requires many generations of 'back crossing' or mating of offspring of the first cross with parents from an existing developed line.

MPBCRC attempts to expedite and accelerate this process in several ways:

- We find 'genetic fingerprints' for desired traits so that breeders can tell which progeny have the trait, even when the plants are immature. In this way, breeders can eliminate 'poor' progeny earlier.
- We find genetic fingerprints for traits that are desirable but difficult or expensive to measure. This speeds up the process, reduces cost and enables more complex traits to be optimised.
- We have simplified the testing process for identifying genetic fingerprints so that breeders can simultaneously evaluate dozens of traits in a single experiment. This provides breeders with more breeding power at a lower cost.
- We have developed 'cut and paste' technologies that allow transfer of a gene or a trait from one plant into another, thereby largely circumventing the breeding process. This accelerates cultivar development enormously, but it requires a very large amount of testing to confirm that the cut and paste process delivers the intended result and does not produce unintended side effects. The process is extremely useful in situations where the desired trait exists in another plant that cannot be 'crossed' with the target crop.

Notwithstanding the efforts of MPBCRC, the product development cycle for the plant breeders is still substantially longer than the seven years for which CRCs are funded. Given then that there is no possibility within the life of the CRC to generate specific cultivars, MPB has adopted some alternative approaches to commercialisation.

First, instead of developing products or cultivars and only then trying to commercialise them, MPB tries wherever possible to attract commercial funding into the research program at an early stage. This makes for a riskier investment by the commercial partner as the research may not be successful, but has enabled the CRC to attract many millions of dollars of additional

funding that has, in turn, facilitated the development of substantially more robust and ambitious development projects than would otherwise have been possible. Three examples of this are:

- A $28 M collaborative R&D program with BASF Plant Science to develop GM wheats that are drought tolerant and fungal resistant.
- A $28 M incorporated joint venture, Gramina Pty Ltd, with PGG Wrightson Ltd (New Zealand) to develop GM forage grasses with improved nutrition and digestibility.
- Renewed three year funding for a $6M project to develop genetic markers for desirable forage traits, from industry representatives: Dairy Australia, Meat and Livestock Australia and Geoffrey Gardiner Dairy Foundation.

A second major strategy of the CRC has been to co-locate technical staff from Australia's largest cereal breeding entities in the same laboratories as CRC researchers to ensure that the detailed technical outputs of CRC research, especially the genetic fingerprints for desirable traits, are immediately available for adoption by our industry partners. The CRC identifies and validates genetic fingerprints that are associated with desirable traits and breeding staff from our industry partners then use the same equipment and test methods in the same laboratories to look for these fingerprints in their own plants. In this manner the wheat and barley breeding programs associated with MPBCRC (i.e. University of Adelaide and DAFWA components of Barley Breeding Australia, AGT and Intergrain wheat breeding programs) now conduct over 100,000 marker tests per year in their breeding programs.

› $1,639,060 – total value of commercial projects

A third strategy has been to licence out some of the technologies that the CRC has developed that have relevance to other participants in the crop breeding industry who are not members of the CRC.

And a final approach to commercialisation has been to put some technologies, particularly research tools, into the public domain for all to use.

Commercialisation of some of our forage improvement technologies is being conducted by Gramina Pty Ltd, a joint venture between MPB and PGG Wrightson Ltd (a leading New Zealand based forage seed company). This joint venture was established to develop new high performance cultivars of commonly used forage grasses by the application of modern molecular technologies.

In 2008–09 Gramina made further progress and is now conducting its second year of field trials of both its tall fescue and perennial ryegrass prototypes. Initial breeding crosses between field trial candidates with other elite breeding stock are under way and the project remains on track to deliver commercial cultivars.

Overall, MPBCRC has a large number of commercialisation processes and projects underway. Highlights for 2008/09 includes the:

- Extension of the original agreement with Agriseeds Pty Ltd (New Zealand) for a project on ryegrass endophytes with additional funding.
- Licensing of project germplasm to Australia's three main wheat breeding companies.
- Filing of four patent applications (including one divisional) over new technologies.

Patents maintained by MPBCRC during the reporting period

Single Sequence Repeats (SSR)	Molecular markers in ryegrass and fescues	Australia: 77197 New Zealand: 509193	Granted and sealed
Lignin genes	Modification of lignin biosynthesis	Australia: 2001265670 New Zealand: 523033 New Zealand: 532000 New Zealand: 532001 New Zealand: 542667 USA: 7429649	Granted and sealed
		Europe: 01942874.7	Under examination
	Sense Suppression	PCT/AU08/001034 Argentina: P080103127 Uruguay: 31.242	Filed
Fructan genes	Fructosyl transferase homologues from ryegrass and fescue species	Australia: 2001265676 New Zealand: 523032 Europe: 01942880.4 USA: 10/311193	Granted and sealed
Disease resistance	Modification of plant resistance to diseases and/or pests	New Zealand: 523538 Australia: 2001 276169 USA: 7122718	Granted and sealed
Lifecycle genes	Manipulation of plant life-cycles and/or growth phases	New Zealand: 525585 Australia: 2002 213672	Granted and sealed
Gene promoters	Use of bi-functional alpha amylase-subtilisin inhibitor promoter to direct expression in pericarp of plants	Australia: 2003 271420	Granted and sealed
	Pollen-specific promoter	Australia: 2004 249788 USA: 20060282919 New Zealand: 544217	Granted and sealed
		Europe: 04737025.9	Under examination
	Endosperm specific promoter	USA: 61/170171	Provisional filing
	Basal endosperm transfer layer specific promoter	USA: 61/177898	Provisional filing
Wheat transformation	Method for wheat transformation using Agrobacterium	Australia: 2007204597 Argentina: P-070 100125 Chile: 76-2007 China: 101421402A India: 2007/079538 Europe: 1979483 USA: 12/087634	Under Examination
Plant Technology		PCT/AU2009/001211	Filed
Temperature Switch PCR	Method of amplifying nucleic acid	PCT/AU2008/001396 Argentina: 080104100	Filed
ddSNP	Improved mapping method for polyploid subjects	PCT/AU2008/001397 Argentina: 080104101	Filed

End-user involvement and CRC impact on end-users

Delivery of outcomes from MPBCRC's research and development activities depends heavily on the close involvement of end-user organisations. This is partly due to the nature of our R&D, in that the development and implementation of new technologies for improving crop breeding necessarily involves crop breeding organisations. The technologies being developed by the CRC are particularly relevant to the early stages of new product development by crop breeding organisations. The value of these technologies comes from their early and broad application to the selection of improved, genetically enhanced breeding lines for new variety development.

Some of the relevant organisations are themselves either Core or Supporting Participants in the CRC; others are not, and are therefore engaged by alternative contractual means.

During 2008/09, MPBCRC was pleased to add Longreach Plant Breeders Pty Ltd and Integrain Pty Ltd as Supporting Participants. The agreements with these organisations will further enhance our ability to secure a pathway to market for our technologies.

Major end-users of our research outputs, and the benefits arising from their involvement with MPBCRC, are identified in the following table.

End-user Involvement in CRC Activities

DAFWA	Core participant	Wheat and barley breeding (WA)	Access to latest markers and assay technologies for molecular breeding	Shorter development times, decreased costs, novel traits, broad screening
CIMMYT	Core participant	Wheat breeding (Mexico)	As above	As above
UA (BBA)	Core participant	Barley breeding (SA)	As above	As above
Australian Grain Technologies Pty Ltd	Supporting Participant	Wheat breeding	As above	As above
ABB Grain Ltd	Supporting Participant	Grain distribution and marketing	Access to new/improved germplasm	Returns from distribution and marketing of new improved varieties
GRDC	Supporting participant Investor on behalf of industry	Investment in molecular research on cereals on behalf of grains industries (ACT)	Improved/continued world competitiveness of the industries they represent	Increased productivity and access to novel products for the cereals industry
Geoffrey Gardiner Dairy Foundation, Dairy Australia, Meat and Livestock Australia	Investor on behalf of industry	Investment in molecular research on pasture grasses on behalf of the dairy and livestock industries	Improved/continued world competitiveness of the industries they represent	Increased productivity and access to enhanced forage products for the pastoral industries
BASF Plant Science	Supporting participant and licensee of MPBCRC IP	Development of transgenic wheats	Access to jointly-developed novel technology for use in generating novel wheat varieties for global markets	Returns from sales of novel wheat varieties in global markets
PGG Wrightson	Licensee	Multiplication, marketing, sales and distribution of transgenic pasture seeds (New Zealand – with licensees in many overseas markets)	Access to new pasture grass varieties, comprising combination of desired traits not presently available in the market, for distribution and marketing worldwide)	Returns from sales of novel pasture grass varieties in global markets
ACPFG	Research collaborator	Researcher in plant functional genomics (SA)	Access to complementary skills and technology, for development and delivery of new generation products	
Numerous research organisations (26)	Licensees	Users of MPBCRC's SSR and MRT marker technologies	Access to technology not otherwise readily available, for use in R&D	
Intergrain Pty Ltd	Supporting participant	Wheat and barley breeding (headquartered in WA)	Access to germplasm developed by MPBCRC	
Longreach Plant Breeders Pty Ltd	Supporting participant	Wheat breeding (headquartered in SA)	Access to germplasm eveloped by MPBCRC	

Program 1: Transgenics technologies

Program Leader Prof German Spandenberg

Program overview

Program 1 aims to increase the rate of genetic gain in cereal and forage plant improvement through the development of novel transformation methodologies and gene systems and their delivery in transgenic breeding. Transformation events with improved tolerances to environmental stresses such as drought, improved disease resistances, and new quality attributes will be developed in wheat, perennial ryegrass, tall fescue and white clover and delivered to breeding programs.

Program 1 focuses on developing and deploying GMO techniques to enhance cereal and forage molecular breeding. MPBCRC is working to develop new and improved methods for the production of genetically modified (GM) wheat, perennial ryegrass, tall fescue and white clover. Candidate genes for important traits such as drought tolerance and fungal disease resistance are being identified and assessed in GM wheat. Genes involved in key metabolic pathways and developmental processes are being identified and evaluated in GM perennial ryegrass, tall fescue and white clover to develop forages with enhanced herbage and environmental quality.

Novel tools for transgenics

The production of genetically modified (GM or transgenic) plants represents a powerful tool for the analysis of plant gene function as well as for the development of novel transformation events for incorporation in transgenic breeding programs. MPBCRC is undertaking projects which aim to develop novel tools for transgenic breeding in cereals and forages. These include the development of a toolbox of promoters (regulatory gene sequences) required to target the expression of transgenes (transferred genes) to specific organs, tissues and cells and to regulate transgene expression in a developmental- and environmental-controlled manner.

A set of promoters for organ-specific, tissue-specific and cell-specific expression has been identified, isolated and evaluated in transgenic wheat plants. In addition, following microarray-based expression profiling in wheat which led to the identification of novel candidate genes with a diversity of expression patterns, novel wheat promoter sequences were isolated and corresponding transgenic wheat plants have been produced. Expression patterns of reporter genes under the control of these regulatory gene sequences were assessed in planta.

A major requirement for the production of 'market-ready' transformation events is to reduce the complexity of transgene integration patterns; with preferably single transgene copy, selectable marker-free transformation events being required. Genetic transformation using the soil bacterium, *Agrobacterium tumefaciens*, has been demonstrated to result in a higher frequency of single/low copy transgene insertions. Research undertaken has developed a robust and efficient *Agrobacterium*-mediated transformation system for wheat enabling the production of 'market-ready' transformation events.

Novel genes for transgenics

MPBCRC is also focusing on developing novel gene systems for transgenic breeding in cereals – primarily wheat – and forages; as well as on isolating and characterising novel genes of significant potential benefit to breeding programs, such as genes controlling chromosome pairing and recombination or genes involved in the regulation of resistance to plant pathogens.

Research within this area has two aims; to identify and characterise genes located not only in the Ph (pairing homoeologous) region of bread wheat but also outside of this region, and to identify the genes controlling chromosome pairing and recombination. Chromosome pairing and recombination are essential processes during early meiosis in sexually reproducing organisms. Allohexaploid wheat represents an ideal crop plant for studying the genetic control of chromosome pairing during early

› Program 1 focuses on developing and deploying GMO techniques to enhance cereal and forage molecular breeding

meiosis. During meiosis, pairing is restricted to homologous chromosomes, despite it containing three closely related genomes: A, B and D. Wheat mutants in the *Ph* region exhibit an altered chromosome pairing phenotype and elevated recombination rates between homoeologous chromosomes. Isolation of genes derived from within the Ph2 region could be of significant benefit to breeding programs as tools for accelerated alien gene introgression. Comprehensive microarray-based transcriptome analysis has led to the identification of over 1300 transcripts that are developmentally regulated during meiosis in wheat. Candidate genes involved in meiotic processes have been identified in wheat; selected candidates have been isolated and comprehensive functional analysis of TaASY1 and TaMSH7 has been undertaken through the production of transgenic barley or wheat plants with modulated expression of these genes.

Further research has also identified novel candidate genes for both drought tolerance and non-host fungal disease resistance. A set of these identified and isolated genes has been transferred to wheat to assess their performance in conferring tolerance to abiotic and biotic stresses, respectively. Australia's first field trial of GM wheat plants expressing different candidate genes for drought tolerance was undertaken following regulatory approval received from the Office of the Gene Technology Regulator (OGTR). Field trials with GM wheat plants for enhanced drought tolerance over two years allowed the preliminary identification of lead candidate genes that conferred significant grain yield advantage in selected transformation events under drought stress conditions with no yield penalty under irrigated conditions.

In the move towards more sustainable production systems in the 21st century, increased productivity and profitability of pasture based dairy systems is required. These increases will be best achieved by focussing molecular plant breeding efforts into increasing nutritive value and biomass production of forage grasses (such as perennial ryegrass and tall fescue) for enhancing animal production and mitigating methanogenesis from enteric fermentation in ruminants, and into improving quality for enhanced animal welfare, and increasing abiotic stress tolerance and nutrient efficiency of forage legumes (such as white clover).

Consequently, research within Program 1 has already identified and isolated novel genes involved in lignin biosynthesis and fructan metabolism for their deployment in molecular breeding of GM forage grasses with enhanced nutritive value. Furthermore, genes involved in the biosynthesis of organic acids and proanthocyanidins in white clover have been isolated and characterised for their deployment in molecular breeding of GM forage legumes with aluminium tolerance and bloat safety. GM white clover plants expressing organic acid biosynthesis genes under control of root-tip prevalent promoters were generated and transformation events showing enhanced performance when grown under aluminium stress were identified.

Perennial ryegrass and tall fescue frequently contain endophytic fungi (*Neotyphodium lolii* in ryegrass and *N. coenophialum* in fescue) which result in both beneficial and

detrimental properties. The presence of the endophyte has been shown to improve seedling vigour, persistence and drought tolerance in marginal environments as well as provide protection against some insect pests. However, endophyte-infected grasses may be toxic to livestock because the fungus produces a wide range of chemicals, many of which have a high degree of biological activity against mammalian systems.

A systems biology approach to study the endophyte/grass symbiotic association has been enabled through the development of world's first genomic resources in Neotyphodium endophytes, including a comprehensive collection of expressed sequence tags, genome survey sequences, oligonucleotide microarrays interrogating over 5,000 endophyte genes, reporter endophytes as well as other underpinning tools and methodologies for genome, transcriptome and metabolome analyses. Furthermore, genome survey sequences based on Australia's first massively parallel sequencing Roche 454 GS FLX technology platform have been generated from *N. lolii*, including six *N. lolii* genotypes from each of the major groups of genetic diversity. The genome size of *N.* lolii is c. 30 Mb, and each genotype has been estimated to be sampled at c. 80% coverage for a typical 100 Mb sequencing run, leading to an over 95% genome coverage in the *N. lolii* composite genome sequence assembly. It is expected that knowledge arising from this research will lead to designer endophyte-grass combinations for enhanced pasture quality, safer and improved pasture production.

Novel transformation events for breeding

Building on novel tools and novel genes for transgenesis applications arising from other research activities described above, 'market-ready' transformation events will be generated in wheat, perennial ryegrass, tall fescue and white clover. These novel transformation events will incorporate transgenic technologies following a sensible choice of targets for molecular breeding. After thorough analyses under containment laboratory and glasshouse conditions, selected transformation events are evaluated in small-scale planned field releases.

Transformation events in perennial ryegrass for modified lignin biosynthesis and fructan metabolism were produced as a first step towards the development of high-energy ryegrass. Similarly, transformation events in tall fescue for modified lignin biosynthesis were generated towards the development of high digestibility forage grasses. Australia's first and the world's largest field trial with transgenic perennial ryegrass for modified fructan metabolism and transgenic tall fescue for modified lignin biosynthesis to enhance herbage quality and nutritive value were established.

Transformation events in white clover for modified organic acid biosynthesis were produced as a first step towards the development of aluminium tolerant, nutrient efficient clover. Furthermore, gene flow studies in white clover were undertaken to support the eventual release of the world's first GM white clover with virus resistance. Transformation events in white clover stacking GM traits for alfalfa mosaic virus resistance and aluminium tolerance traits were generated.

Highlights

- GM wheat plants for assessment of novel candidate genes for drought tolerance were produced and offspring was recovered for the identification of transformation events for field evaluation.
- Australia's first field trial of GM wheat plants expressing different candidate genes for drought tolerance was undertaken upon regulatory approval from the Office of the Gene Technology Regulator. Individual transformation events with enhanced yields outperforming negative controls under drought stress were identified in this first field trial. Identification of lead events and selection of candidate genes for the production of 'market-ready' transformation events was enabled through further evaluation in a second year field trial undertaken.
- GM wheat plants for assessment of novel candidate genes for fungal disease resistance were produced, offspring was recovered and subjected to disease screening leading to the preliminary identification of candidate genes for non-host fungal resistance.
- A robust pipeline for the generation of 'market-ready' transformation events in wheat based on *Agrobacterium*-mediated transformation was established enabling the production.
- Novel candidate genes for fungal disease resistance in barley were isolated and functional analysis was initiated.
- Novel candidate genes developmentally regulated during meiosis in wheat were identified through microarray-based transcriptome analysis and corresponding GM wheat plants were produced for their functional analysis.
- Novel gene promoters with a range of specificities were identified in wheat through microarray-based transcriptome analysis and corresponding GM wheat plants were produced for the functional analysis of the isolated gene regulatory sequences.
- GM perennial ryegrass plants with modified lignin biosynthesis and fructan metabolism for enhanced nutritive value were produced, subjected to functional analysis and selected for field evaluation.
- Australia's first, and world's largest, field trial of GM perennial ryegrass plants expressing different candidate genes for enhanced fructan metabolism was undertaken upon regulatory approval from the Office of the Gene Technology Regulator.
- GM tall fescue plants with modified lignin biosynthesis for enhanced herbage quality were produced, subjected to functional analysis and selected for field evaluation.
- Australia's first and world's largest field trial of GM tall fescue plants expressing different candidate genes for modified lignification was undertaken upon regulatory approval from the Office of the Gene Technology Regulator.
- GM white clover plants with modified organic acid biosynthesis in roots for enhanced aluminium tolerance and nutrient acquisition efficiency were produced and subjected to functional analysis.
- Comprehensive functional genomics tools and methodologies were established to study temporal and spatial changes in transcriptome and metabolome in the grass-endophyte association including the world's first perennial ryegrass-*N. lolii* oligonucleotide microarray.
- Genome survey sequencing of the perennial ryegrass endophyte was undertaken for wild type endophytes and novel endophytes with different toxin profiles leading to the establishment of a significant genomic resource for *N. lolii.*

PROGRAM 1: Featured project

Deployment of transgenic technologies in designer white clover

Key Researchers: Prof German Spangenberg Dr Aidyn Mouradov, Dr Stephen Panter, Fernando Rossello and Dr Kevin Smith

White clover is an important component of temperate pastures, worldwide. Clover, as a legume, fixes nitrogen in the soil and provides dairy cattle with a high quality protein source. However, clover is sensitive to aluminium toxicity in acidic soils, which are common in Australia. Its high protein content can also contribute to bloating in ruminant animals, with implications for animal welfare and farm budgets. The productivity of white clover is also limited by a number of viruses – chiefly alfalfa mosaic virus, clover yellow vein virus and white clover mosaic virus.

This project aims to improve the aluminium tolerance of white clover by increasing the production of organic acids and their secretion into the soil, and to improve the bloat-safety of white clover by increasing the level of condensed tannins in leaves. These traits can be pyramided with the established traits of transgenic virus resistance and delayed leaf senescence.

Candidate genes related to organic acid production have been identified in white clover. Three white clover genes involved in organic acid metabolism correspond to citrate synthase, nodule-enhanced malate dehydrogenase and phosphoenolpyruvate carboxylase. Full length cDNAs corresponding to each of these candidate genes have been isolated and sequenced, and corresponding transformation vectors for their targeted overexpression in plants have been produced. Transgenic white clover plants expressing a chimeric nodule-enhanced malate dehydrogenase under control of a root-tip prevalent promoter have been generated and analysed. This transgenic strategy, which aims to increase the production and release of organic acids from roots, led to the identification of transgenic white clover plants that show improved performance under aluminium stress. These plants form the basis for the development of white clover germplasm and cultivars with stacked traits including alfalfa mosaic virus resistance, aluminium tolerance and bloat safety.

Program 2: Non-transgenic technologies

Program Leader Dr Michael Francki

Program overview

The rate of genetic gain in crop and pasture breeding programs relies on the ability to detect and deploy pre-existing natural genetic variation that will assist in improving commercial cultivars. The use of DNA-based genetic marker systems provides the opportunity to track genes controlling genetic variation, select and predict progeny with desirable traits in commercial breeding prior to phenotypic evaluation.

The non-transgenic technologies program is focused on developing the most efficient DNA-based genetic marker systems for traits important to the cereals and pasture industries – technology transfer platforms, combining and tracking genes in relevant genetic backgrounds for adoption by commercial breeding.

Program objectives

- **Developing molecular markers for tracking variation of high value agronomic traits during germplasm development and commercial breeding.**
- **Conducting genetic analysis and chromosomal map location of genes controlling natural variation relevant to pasture and cereal breeding programs.**
- **Building bioinformatics platforms to enhance effective technology transfer between users.**
- **Developing new and improved germplasm for a range of traits important for cereal breeding.**

Overview of results to date

A significant number of projects were completed during 2008/09, with a number of outcomes that could be adopted by breeding programs, and applied in cultivar development. Transfer of project outputs for adoption and utilisation by breeding programs have either been achieved during the course of the project or are in the process of developing an appropriate strategy for uptake and/or commercialisation.

We have delivered effective techniques and strategies for deployment of molecular genetic marker technologies for the breeding of perennial ryegrass and white clover, the key species for temperate pasture plant agriculture. This information allows breeders to breed novel, high-performing perennial ryegrass and white clover varieties suitable for temperate Australian grazing conditions, supporting effective and profitable grassland agricultural production. New marker technologies continue to be developed for wheat and barley, including the development and application of single nucleotide polymorphism (SNP) markers for biotic, abiotic and grain quality as well as the application of Multiplex Ready Technology™ (MRT™) for durum wheat in collaboration with breeding programs. These technologies are being made available to plant breeders, achieving our aims of adoption and utilisation.

Significant progress has been made in gene discovery projects with a number of genes identified which are involved in the defence response in barley when infected with necrotrophic fungal pathogens. The biological function of these genes has been determined in transgenic analysis conferring levels of disease resistance when transgenic plants were infected with fungal pathogens.

The outcomes in gene discovery provide the opportunity to identify natural variants of these genes in adapted and unadapted germplasm and develop suitable diagnostic DNA markers for selecting for disease resistance in breeding programs. Moreover, the development of transgenic lines provides exciting prospects for combining non-transgenic and transgenic approaches to develop barley varieties with suitable levels of resistance against necrotrophic pathogens.

The projects have delivered significant progress in understanding the genetic control of abiotic stress tolerance in cereals and in developing tools and strategies to track genetic diversity for germplasm development. Evaluation of wheat and barley has identified germplasm with suitable Na^+ exclusion, a major physiological component for developing salt tolerant cereal varieties. Interestingly, quantitative trait loci for Na^+ exclusion on chromosome 2H in barley coincides with a similar region for Na^+ exclusion in wheat homoeologous group 2 chromosomes, indicating that similar genes in wheat and barley may be involved in controlling uptake of Na^+.

Research has led to the identification of genetic variation in barley which can be used for variety development for improving salt tolerance. Chromosomal regions controlling phenotypic variation for yield under drought stress in multiple environments have been identified in wheat and corresponding DNA based markers have been developed. Elite wheat germplasm with improved yield under drought stress has been delivered for evaluation and use in Australian breeding programs.

Progress is being made in understanding allelic combinations in wheat which control flowering time and adaptation to specific grain production environments in Australia. This progress includes identifying known alleles as well as discovering new alleles of vernalisation and photoperiod response genes in selected Australian wheat breeding material. The information and new tools will not only allow breeding programs to develop highly adapted varieties for yield gains in Australian grain production environments but will also provide valuable knowledge on the pleiotropic effects of phenology on other agronomic characteristics.

Bioinformatic interfaces fill critical gaps in the informatics supply chain for molecular plant breeding and DNA marker-related work. Ongoing activities include genetic map curation as well as maintenance and minor enhancements of systems to support technology and data transfer through the MPB-GENica website. The integrated systems enable molecular researchers and breeders to efficiently share, select and integrate enormous amounts of data as part of the workflows. It is envisaged that these developed systems will also have commercial potential as stand alone tools or packaged integrated systems.

Highlights

- Identification of novel SNPs and SNP haplotypes for genes associated with herbage quality traits in perennial ryegrass.
- Identification of novel SNP markers for disease, biotic and abiotic stress tolerance in barley and development of Multiplex Ready Technology™ for SSR marker screening in durum wheat.
- Identification of defence response and reactive-oxygen species associated genes implicated in controlling disease caused by the fungal pathogens *Pyrenophora teres f.sp. teres* and *Rynchosporium secalis* in barley.
- Identification of chromosomal regions and associated markers for yield under drought stress on chromosomes 4A, 5A, 6A and 6B in multiple environments.
- New genetic variation identified for a major physiological trait (Na^+ exclusion) that contributes to salt tolerance in barley and wheat.

› The projects have delivered significant progress in understanding the genetic control of abiotic stress tolerance in cereals and developing tools and strategies to track genetic diversity for germplasm development.

PROGRAM 2: Featured project

Analysis of defence response genes in barley

Key researchers: Dr Paul Bogacki and Dr Klaus Oldach

DNA-based genetic markers provide a means of identifying pre-existing genetic variation in natural populations and of tracking gene combinations for expression of desirable traits in breeding. Although random DNA markers linked to genes controlling variation for a large number of traits are available, their usefulness in selecting progeny in breeding and accurately predicting trait expression depends on close linkage between the DNA marker and the gene. Ideal DNA markers are those that represent the gene that controls trait expression. These diagnostic or 'perfect' DNA markers provide the capability to select progeny in breeding programs and accurately predict desirable trait variation prior to phenotypic evaluation. In order to develop 'perfect' DNA markers, there is a need for discovery and for determining the biological function of genes responsible for trait variation.

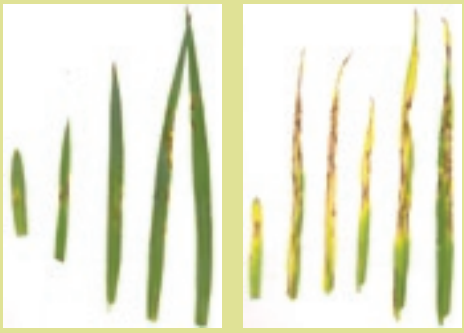
Barley net- and spot-form of net blotch, caused by the fungus *Pyrenophora teres,* are two of the major diseases affecting barley crops in Australia. Improved knowledge on the genes that control resistance can lead to the development of diagnostic DNA markers to track resistance in variety development during breeding. MPBCRC researchers Dr Paul Bogacki and Dr Klaus Oldach at SARDI, with co-funding from the South Australian Grains Industry Trust (SAGIT) have identified a suite of barley genes related to components of plant defence mechanisms that respond to pathogen infection to identify likely candidates controlling disease resistance.

The study identified 21 defence response genes that showed an increase or decrease in expression levels between resistant and susceptible barley varieties when infected with the fungus; these genes may play a role in controlling disease. Genetic mapping has shown that these genes are distributed across all seven barley chromosomes and some co-localised with regions controlling net blotch resistance on chromosomes 6H and 7H, as well as chromosomal regions associated with resistance to other barley diseases. Differential expression profile and map location both indicated that some genes may have a distinct biological function in controlling net blotch resistance.

The functional role of defence response genes on chromosomes 6H and 7H was further analysed by transforming individual genes into the highly susceptible barley variety "Golden Promise" and monitoring disease resistance. A total of seven genes were transformed into barley lines. One transgenic line over-expressing a gene, *HvPtr28*, with similarity to an ethylene-forming enzyme (*HvPtr28*) involved in the synthesis of ethylene, a key signalling molecule for initiation of plant defence response, was shown to have improved resistance to net form of net blotch (Figure 1). Improved resistance was quantified both by visual symptom assessment and PCR quantification of fungal DNA on infected seedling leaves. The remaining six genes did not have a significant effect in improving disease resistance. It appears, therefore, that at least the *HvPtr28* gene has a biological role in controlling resistance during the initial stages of plant defence response to net form of net blotch.

HvPtr28 is a target gene for screening transcript variations in barley germplasm to develop a diagnostic marker for improved net blotch resistance. Furthermore, current work focuses on the characterisation of potential genes controlled by *HvPtr28* to establish its role in the ethylene pathway.

Figure 1: Leaves from transgenic barley plants over-expressing *HvPtr28* (ethylene-forming enzyme like protein gene) and infected with *Pyrenophora teres f.sp. teres* compared with a non-transformed susceptible barley variety "Golden Promise" (control).



Education and Training

In the past year the Education and Training program team has continued to develop and deliver targeted education and training products that engage the community, excite young people about plant science, support the teaching of science in schools and add value to research training.

Education in schools and in the community is a major focus for MPBCRC's Education and Training program and our achievements in this area are assisted by our significant collaboration with the Australian Centre for Plant Functional Genomics (ACPFG).

MPBCRC and ACPFG's joint initiative secondary schools program, Get into Genes continues to grow with La Trobe University joining as a delivery partner. In the 2008/09 financial year, 1548 students and teachers have attended sessions in Victoria, with an additional 983 attending workshops in South Australia.

La Trobe University's support of the program was strengthened with the Faculty of Science, Technology and Engineering providing dedicated laboratory space which was officially opened by Professor Roger Parish in September 2008. Get into Genes was also showcased at the La Trobe University open day in August 2008. Get into Genes also expanded its regional outreach running sessions in Cooryong (Victoria) in August 2008 with support from Biotechnology Australia, as well as running sessions in South Australia.

In August–September 2008, in conjunction with ACPFG, we participated in Science Alive!, the showcase activity and for National Science Week in Adelaide, and the Royal Adelaide Show, engaging over 3000 people. Our Gene Juice Bar display was also showcased at the University of Adelaide open day in August 2008, the Victorian DPI Knoxfield open day in November 2008, the Wimmera Farm Machinery field days in March 2009 and the Amazing World of Science in Canberra in May 2009.

Other community events that MPBCRC participated in included:

- Open Access College "GM Foods Online Forum" (August 2008).
- Barham High School agriculture open day in collaboration with the Gene and Nano Technology Information Service. A presentation of Get into Genes and MPBCRC research presentation given by PhD student Yi Tu (September 2008).
- Get into Genes presentations at teacher conferences in CONASTA (July 2008), STAVCON (November 2008), STAV VCE Biology (February 2009), Victorian Agriculture and Horticulture Educators (December 2008), STAV VCE Biology (February 2009), SASTA (April 2009) and ATASA (May 2009).
- International Wheat Genetics Symposium: Get into Genes stand with ACPFG (August 2008)
- The "Spotty Barley Mystery" for GrowSmart student camps and teacher professional development (December 2008). These workshops were developed in conjunction with ACPFG, the CSIRO Science Education Centre and SARDI.
- National Farmers Federation Conference (June 2009).

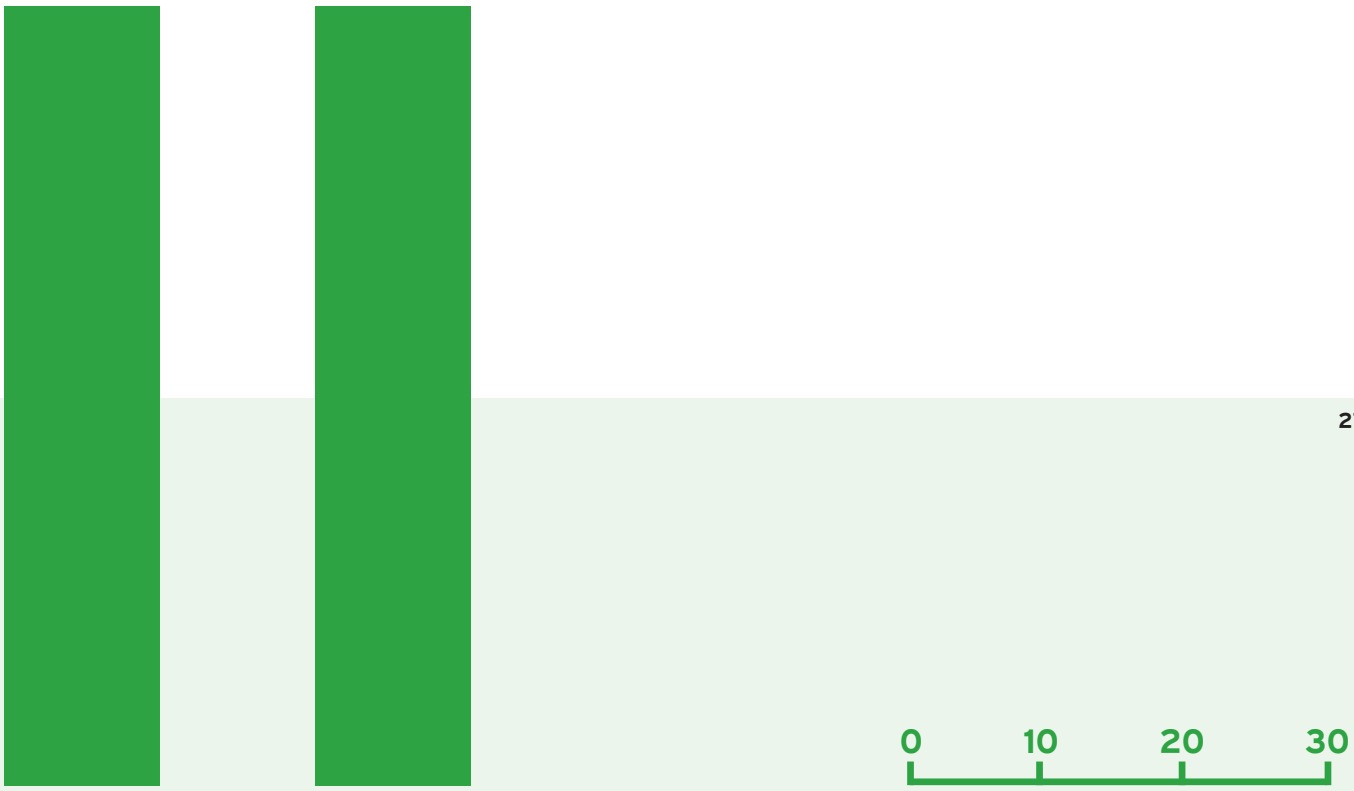
During the reporting period eight student submitted their PhD theses, with five conferred by 30 June 2009. The total number of completed students for both MPBCRC and its precursor CRCMPB is 47, with 11 starting with MPBCRC after July 2003. A total of 27 students were working towards their PhDs within MPBCRC for 2008-09, with the majority (66%) having non-university supervisors (primarily from DPI Victoria and SARDI). During 2008/09, MPBCRC also had one honours student Karleen Shaw at Murdoch University, supervised by Dr Mike Francki and Dr Allison Crawford.

MPBCRC's students continued to find employment within the plant science industry. Employment destinations for recent PhD graduates included Hexima Ltd (Dr Peter Dracatos), The Australian Centre for Plant Functional Genomics (Dr Bao Lam Huynh) and the French National Institute for Agricultural Research (INRA) in Versailles, France (Dr Wayne Crismani).

Our annual Student Retreat was held in July 2008 in conjunction with the Annual Research Conference at Creswick, Victoria. This training opportunity for postgraduate students included workshops on obtaining funding for research ideas and giving compelling presentations.

MPBCRC Training for plant breeders has also been active with the Systems Biology workshop delivered through DPI Victoria in May 2009 attracting over 100 attendees.

In the coming year, the Education and Training program will focus on finalising and delivering resources currently in development and on a review of program components.



PhD students completed

Students at MPBCRC in 2008/2009

Name	Title	Institute	Supervisor	Funding
PhD Students completed				
Lam Huynh	Genetic characterisation and QTL mapping for grain inulin in wheat	UA	Dr J Stangoulis, Prof R Graham, Prof D Mather, Dr H Wallwork, Dr K Williams	IPRS / MPBCRC
Jingjuan Zhang	Abiotic stress in wheat with a special reference to terminal drought	Murdoch	Dr T Setter, Prof R Appels, Dr M Cakir	Murdoch / MPBCRC
Peter Dracatos	Development and implementation of candidate gene-based molecular markers in out-crossing forage species	DPI Vic / La Trobe	Prof J Forster, Dr A Gendall	GGDF
Wayne Crismani	Microarray expression analysis of candidate meiotic genes in bread wheat	UA	Dr J Able, Dr U Baumann, Dr T Sutton, Prof P Langridge	MPBCRC
Yi Tu	Functional analysis of gene families involved in lignin biosynthesis in perennial ryegrass	DPI Vic / La Trobe	Prof G Spangenberg, Dr A Mouradov	MPBCRC
Yingying Cao	Fructan metabolism in perennial ryegrass	DPI Vic / La Trobe	Prof G Spangenberg, Prof R Parish	MPBCRC
Shamila Abeynayake	Analysis of clover genes related to condensed tannin synthesis in white clover	DPI Vic / La Trobe	Prof G Spangenberg, Dr A Gendall, Prof R Parish	MPBCRC
Reetinder Gill	Male sterile facilitated recurrent selection in barley breeding	Murdoch	Dr R Lance, Prof R Appels	Murdoch / MPBCRC
PhD Students enrolled				
Allen Tarr	Protein profiling for predicting barley malting quality traits	Murdoch/ DAFWA	Prof R Appels, Dr R Lance, Prof M Jones	MPBCRC
Ryan Walker	Regulation of blackpoint formation in barley	UA	Dr A Able, Dr J Able, Prof D Mather	UA / MPBCRC
Dean Diepeveen	Investigation into decision support systems with application to grain quality improvement	Murdoch	Prof R Appels, Prof M Bellgard, Mr H H Liang	MPBCRC
Stephen Talbot	A study of the introgression of genetic material from synthetic hexaploids in Australian bread wheats	UA	Prof A Barr, Prof K Chalmers, Dr F Ogbonnaya	SAGIT
Maia Rabinovich	Genome analysis of the fungal endophyte *Neotyphodium lolii*	La Trobe	Dr T Gendall, Prof R Parish, Prof G Spangenberg	MPBCRC
Arturo de Lucas Arbiza	Risk assessment for the release of transgenic white clover and perennial ryegrass	La Trobe	Dr T Gendall, Prof R Parish, Prof G Spangenberg	MPBCRC
Bakhyt Nurzanhuly	Genetic analysis of drought tolerance traits in a cross between two broadly adapted bread wheat genotypes	UA	Prof D Mather, Dr M Reynolds, Prof G McDonald, Dr R Trethowan	MPBCRC
Elysia Vassos	Conversion of feed barley to malting types	UA	Dr J Eglinton, Prof D Mather, Prof A Barr	ABB

Name	Title	Institute	Supervisor	Funding
James Breen	Host-pathogen Interaction between hexaploid wheat (*Triticum aestivum*) and the pathogenic fungus *Stagonospora nodorum* using bioinformatics and comparative genomics analysis	Murdoch	Prof M Bellgard, Prof R Appels	MPBCRC
Fernando Rosello	Production and characterization of transgenic white clover for multiple virus resistance, increased aluminium tolerance and improved nutrient efficiency	La Trobe	Prof G Spangenberg, Prof R Parish	MPBCRC
Hiroshi Shinozuka	Comparative genomics and physical mapping of the self-incompatibility genes of perennial ryegrass	La Trobe	Dr T Gendall, Prof J Forster, Prof G Spangenberg	MPBCRC
Hayley Jolly	Functional characterisation of novel candidate genes with roles in chromosome pairing in bread wheat	UA	Dr J Able, Dr A Milligan	APA / MPBCRC
Allison Hogg	Development and implementation of candidate gene-based markers	La Trobe	Dr T Gendall, Prof J Forster, Prof G Spangenberg	MPBCRC
Pei Tian	Designer novel endophytes associations	La Trobe	Dr K Smith	
Tejaswini Dhavale	Functional genomics of fructan biosynthesis in perennial ryegrass	La Trobe	Prof G Spangenberg, Prof T Gendall	MPBCRC
Bhuwaneshwari Vala	Designer clover – development of white clover germplasm with multiple virus resistance and delayed leaf senescene	La Trobe	Prof G Spangenberg	MPBCRC
Shan Shan Liang	Study of wheat transformed for fungal resistance for response to selected fungi	La Trobe	Prof G Spangenberg	MPBCRC
Katherine Linsell	Fungal gene expression in the *Rhynchosporium secalis*/barley interation	UA / SARDI	Dr K Oldach, Dr F Keiper	GRDC
Piyume Ekanayake		La Trobe	Prof G Spangenberg	
Julie George	Candidate-gene based marker development and validation in white clover	DPI / La Trobe	Dr J Foster, Prof R Parish	GGDF
Pei Tian	Grass endophyte functional genomics	Vic / La Trobe	Prof G Spangenberg, Prof C Pallaghy	MPBCRC
Joanne Elsden	Map-based cloning of a quantitative trait locus in barley	UA / ACPFG	Prof K Chalmers, Dr N Collins, Dr J Eglinton, Prof P Langridge	GRDC

Honours

Tamara Huber	Genetic variation in wheat gluten proteins implicated in coeliac disease	UA / SARDI	Dr D Mather, Dr M Appelbee	UA
Karleen Shaw	Candidate genes controlling variation in xanthophyll content in wheat	Murdoch	Dr A Crawford Dr M Francki	MPBCRC

Communication Strategy

MPBCRC's communication strategy aims to engage key stakeholders, encourage uptake of research findings by end users and communicate research progress and outcomes. Our key stakeholders include:

- Internal: MPB researchers, students and commercial partners
- External: general public, schools and media
- Research: other researchers and potential collaborators.

Engagement with MPB researchers, students and commercial partners continues through regular face to face contact as well as through the use of communication tools such as our websites and the newsletter 'On the Mark'. Via these forums, as well as email circulations, we continue to highlight the events, research development and community outreach activities of the CRC.

The Annual Research Conference is another opportunity for researchers and stakeholders to be updated on the activities of the other CRC participants. This year the meeting was held in Creswick, Victoria and was attended by around 100 delegates who were inspired by addresses from eminent scientists and business people such as Sir Gustav Nossel AO and Dr. Ganesh Kishore (Burrill & Co, US). Feedback indicates that researchers value the conference as a means of interacting both professionally and socially with staff who are located in other nodes. This strengthens existing collaborations and fosters new linkages.

A major aim of MPBCRC's communication strategy is to engage with the community to promote awareness and support of our technologies. One of the most effective means of engaging with external stakeholders such as the general public is through the mainstream media. MPBCRC continued to increase its media profile during 2008/09, appearing in print, on radio and on television over 160 times. The focus on both metropolitan and rural media across Australia has led to other benefits and opportunities such as increased interest in our research and opportunities to communicate directly with local farming and community groups.

› Engagement with MPB researchers, students and commercial partners continues through regular face to face contact as well as the use of communication tools such as our websites and the newsletter 'On the Mark'.

MPBCRC has continued to engage with the general public through the activities outlined in the Education and Training section. In addition to this, we have been successful in winning a number of grants to increase our community engagement programs. Commencing in July 2009, we will be undertaking a series of workshops on "Understanding Biotechnology" for rural women, as part of the Department of Agriculture, Fisheries and Forestry's Recognising Women Farmers initiative. We have also received federal funding from National Science Week to support our activities during August 2009.

MPBCRC has a multi-faceted commercialisation strategy. In part this strategy involves fostering very close relationships with cereal breeding organisations, all of which are SMEs. Through frequent interactions from the project level upwards, the CRC aims to ensure that its outputs are readily available to be taken up by breeding programs.

Another facet involves a targeted approach to the formation of new commercial partnerships. Potential collaborators are often identified by the researchers themselves and partnerships are built from existing relationships. The CRC also actively communicates its interest in potential areas of collaboration with the wider industry in a strategy that aims to establish programs in particular areas of MPBCRC research.

MPBCRC will be hosting the international GMCC '09 conference: 'Coexistence between genetically modified (GM) and non-GM based agricultural supply chains'. Our involvement in this will strengthen linkages with leading researchers in the field as well as government policy makers and regulators. The conference will provide opportunities for collaboration as well as identifying and discussing coexistence across the entire agricultural supply chain.

Publications

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Referred journal publications

Specified personnel

The administration of the Molecular Plant Breeding CRC is conducted by a small team spread across two locations:

- Victorian AgriBiosciences Centre, Bundoora, VIC
- University of Adelaide, Waite Campus, Urrbrae, SA

Dr Glenn Tong
Chief Executive Officer

Mr Ian Christensen
Chief Operating Officer

Mr William Lancaster
IP & Contracts Manager

Ms Melanie Carew
Communications Manager

Dr Heather Bray
Education Manager

Ms Vicki Kokolakis
Accountant

Mrs Nora Veljanovski
Executive Assistant

Ms Belinda Griffiths
Education Officer

Performance measures

Performance Measure	03/04	04/05	05/06	06/07	07/08	08/09
1. Collaborative arrangements						
Objective: Enhance collaboration among researchers and industry, and use IP and other resources more effectively.						
Extent of collaboration of participants within MPBCRC programs						
Number of projects with more than one participant (%)	72	77	62	51	70	23
Extent of national and international collaboration with non-participant organisations						
Agreements	1	0	2	2	1	0
National collaborations	7	18	25	29	24	15
International collaborations	17	24	27	37	16	29
Interactions with R&D corporations and other funding bodies						
Number of projects with funding from R&D corporations	15	25	19	22	22	11
Interactions and involvement of industry						
Number of projects with industry funding	3	9	9	7	8	7
Number of projects with industry involvement	9	9	10	7	8	7
Attendance at Annual Research Meetings						
Number attending	104	118	115	138	92	98
2. Research and development						
Objective: Establish, develop and undertake world-class, high-quality, industry-focused collaborative research programs in molecular breeding for cereals and pastures.						
Effective research portfolio that is output-focused and relevant to industry needs						
Number of refereed journal publications	88*	26	52	40	78	43
Number of conference papers	85	57	106	39	74	34
Number of book chapters	13	16	13	20	17	6
Number of books	0	0	1	0	0	2
Effective procedures to assess research portfolio						
Progress reports submitted (%)	100	100	100	100	100	100
Reviews conducted	1	1	0	2	0	0
New projects developed	10	6	5	3	0	0
Achievement of research outputs according to target milestones for current year						
Output milestones met (%)	90	95	95	95	85	97

Performance Measure	03/04	04/05	05/06	06/07	07/08	08/09
Number of events demonstrating national and international recognition of Centre staff						
Invited lectures and conference participations	38	78	49	70	89	62
Involvement in advisory roles	10	14	11	16	12	12
Success in attracting research and commercial funding from external bodies						
Number of new external grants	3	12	6	3	0	4
Value of additional external grants	$1,110,000	$2,051,837	$1,830,772	$3,122,323	0	$2,644,904
Total value of external grants	$3,942,000	$4,378,307	$4,791,183	$4,430,566	$3,426,617	$3,191,585
Total value of commercial projects	–	$1,248,600	$847,200	$1,608,400	$1,798,721	$1,639,060

3. Technology transfer

Objective: Commercialise products of CRC research for the benefit of Australia and beyond, providing return on investment, where appropriate.

Capture of IP using legal means						
Internal disclosures for patentability/protection assessment	2	2	3	3	2	3
New provisional patent filings	0	1	1	0	4	4
Complete applications filed	1	1	1	1	7	8
Patent applications in prosecution/being maintained	22	23	29	17	36	37
Patents accepted/allowed	0	4	9	13	14	21
Commercialisation: technology development and licensing						
Research licences for MPB technology entered into	4	0	10	13	7	5
Confidentiality agreements executed for the purposes of confidential negotiations regarding business development	5	5	3	8	14	6
Collaborative R&D agreements entered into	1	10	9	8	6	3
Licensing agreements entered into	1	6	5	0	2	4
Agreements with end-users vis-à-vis technology development and commercialisation	2	4	1	1	1	1

4. Education and training

Objective: Entice and train excellent plant breeders and researchers.

Post graduate students						
Postgraduates enrolled	41	39	25	29	32	18.5
Total postgraduates completed (CRCMPB/MPBCRC)	25	27	36	39	43	48

Performance Measure	03/04	04/05	05/06	06/07	07/08	08/09
Additional training opportunities provided	1	1	1	1	1	1
Students with non-university co-supervisor (%)	83	59	52	62	64	66
Training for people already working in plant breeding						
Training opportunities provided	2	2	2	2	3	1
School activities						
School education activities	7	32	57	120	112	113
Teacher training activities	9	3	5	5	11	7
Community awareness activities						
Community education activities	4	4	14	7	5	12
Overseas experience						
Number of overseas visits for staff or students supported	3	3	5	10	9	10

5. Communications

Objective: Promote MPBCRC's profile as a globally reputable organisation and foster ownership by the Participants.

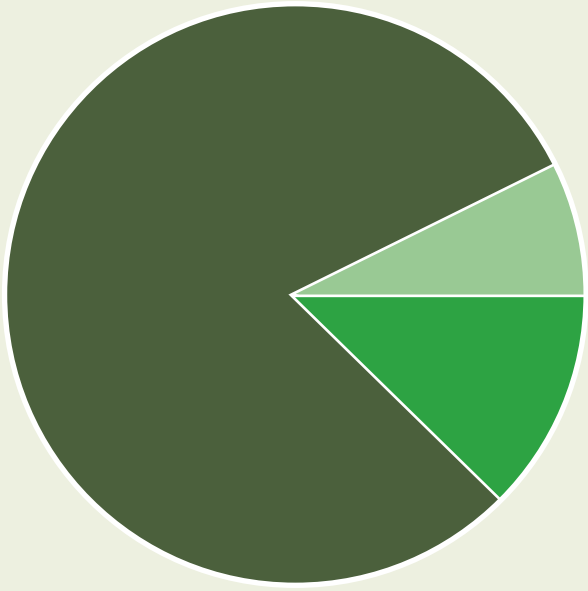
Internal communication activities						
Newsletters issued	0	3	4	4	4	2
Staff surveys/formal feedback forums	0	2	2	2	2	1
External communication activities						
MPB publications	1	7	8	6	7	2
Sponsorship of MPB-related activities	3	4	4	2	9	5
Visits to Centre website (page views)	1,731	46,347	31,445	95,939	102,756**	131,937
Activities of Centre staff in media, field days and other communication activities						
Media appearances (print, radio and TV)	19	27	76	95	111	160
Attendance at field days and industry forums	8	21	16	14	10	23

* 03/04 column includes refereed journal articles that had been submitted for publication, but not yet published by 30 June 2004. Subsequent years include only published articles.

** Estimated based on figures from March–June 2008.

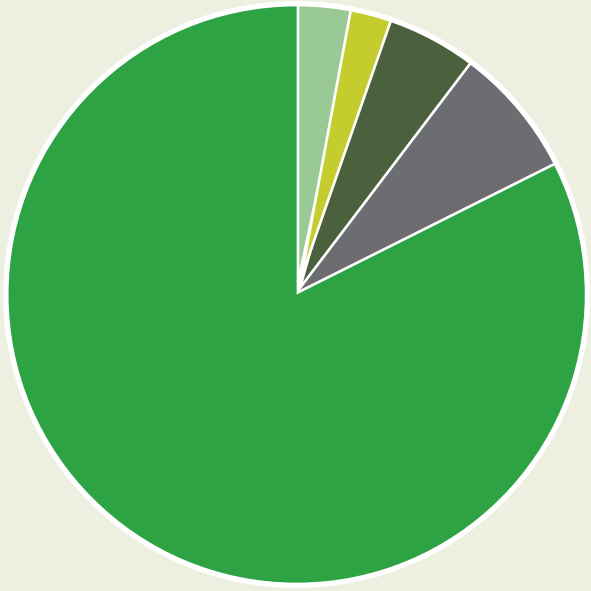
Summary of resources

Funding sources



Cash from grants	$5,020,000
Cash from participants	$4,483,000
In-kind from participants	$17,121,000

Expenses



Research projects	$23,877,000
Education	$376,000
Communications	$255,000
Commercialisation	$441,000
Administration	$597,000

Financial information: A full account of MPBCRC's in-kind contributions, cash contributions and resources has been prepared in accordance with DIISR guidelines and is available upon request.

Glossary of terms

MPBCRC	Molecular Plant Breeding Cooperative Research Centre
ACPFG	Australian Centre for Plant Functional Genomics
AGT	Australian Grain Technologies
CIMMYT	International Maize and Improvement Centre
CRCMPB	Cooperative Research Centre for Molecular Plant Breeding (precursor to MPBCRC)
CRCNPB	Cooperative Research Centre for National Plant Biosecurity
DA	Dairy Australia
DAFWA	Department of Agriculture and Food, Western Australia
DPI Vic	Department of Primary Industries Victoria
EST	Expressed sequence tags
FTO	Freedom to operate
GGDF	Geoffrey Gardiner Dairy Foundation
GM	Genetically modified / genetic modification
GMCC	Genetically modified coexistence conference
GMO	Genetically modified organism
GRDC	Grains Research and Development Corporation
ICARDA	International Centre for Agricultural Research in the Dry Areas
IP	Intellectual property
MLA	Meat and Livestock Australia
OGTR	Office of the Gene Technology Regulator
PCR	Polymerase chain reaction
Ph	Pairing homoeologous
PPO	Polyphenol oxidase
QTL	Quantitative trait locus
SAGIT	South Australian Grains Industry Trust
SARDI	South Australian Research and Development Institute
SNP	Single nucleotide polymorphism
SSR	Simple sequence repeat