

Developing technologies to underpin a productive farming future



MOLECULAR PLANT BREEDING CRC



The challenges we face

The challenge is real...

- World population will rise to 10 billion people by 2050 (UN).
- Global agricultural production must grow 70% by 2050 (FAO).
- Global food reserves are low and are not meeting consumption levels (USDA).

Australia is a major contributor to the international traded food industry.

Increasing global challenges provide Australia with a strong opportunity to deliver real world benefits and positive outcomes for farmers, the economy, environment and society as a whole.

There are mounting issues to face...

Our changing environment with unpredictable weather patterns and less agricultural land sees farming face additional pressures. Up to 400 global disasters a year, such as floods and drought, are now impacting on the production of food (UN).

Australia's production of wheat, beef, dairy and sugar could decline by as much as 19% by 2050 under these changes in climate (ABARE).

This wave of change leads to serious pressures on agriculture. Quite simply, we need to grow more food on less available land.

MPBCRC developed innovative technologies for the improvement of cereals and pastures to address these issues, providing tangible benefits and solutions for farmers. The CRC also invested substantial resources into training the next generation of researchers and breeders to ensure that the Australian farming industries will be supported by innovation.



Biotechnology provides a useful tool...

Biotechnology and the application of modern genetics (such as DNA fingerprinting) can greatly speed up crop breeding.

In particular, genetic modification has the potential to deliver outcomes not available to conventional breeding. It enables the incorporation of traits into plants that would be very difficult or impossible to do using conventional breeding. This can result in higher yields per land area, as well as preventing and minimising the impact of disease and inclement weather.

MPBCRC used innovative science to help the cereals and pasture industries remain competitive, viable and sustainable in a fiercely competitive international market and through inclement climatic conditions.

A long commitment – the MPBCRC

The Molecular Plant Breeding CRC (MPBCRC) was successful in achieving a second round of CRC funding in 2003 to continue to build upon the advances of the CRC for Molecular Plant Breeding. This enabled strong industry linkages to focus on the commercialisation and delivery of applications for farmers. From start to finish, these two CRC's have made a 14 year investment to secure a future for Australian farmers. MPBCRC and partners invested \$160M over 7 years. Through a limited selection of projects (in which \$83 M was invested) that formed the basis of a detailed economic impact analysis, the CRC's technologies could potentially deliver \$439 M in economic improvement to Australian agriculture.

CRC Molecular Plant Breeding (1996 - 2003)

The CRC provided:
the discovery of genes and genetic markers and
the development of platform technologies for cereals and pastures.

Molecular Plant Breeding CRC (2003 – 2010)

The MPBCRC, with over 200 scientists and more than 20 supporting participants across industry, academia, government and breeders in Australia and internationally, delivered benefits to the Australian grain and pasture industries by developing and implementing:

- DNA markers, genotyping technologies and predictive tools that fast-track commercial wheat breeding programs
- Genetic modified (GM) wheat with increased yields under environmental stresses
- GM pasture grasses with improved herbage quality and nutritive value for more productive livestock.
- Education and training of a new generation of researchers and molecular plant breeders to support the grain and pasture industries.

Addressing the Challenges by Producing real world impacts...

CEREALS

Tolerance to environmental stresses

Drought tolerant wheat

The opportunity: Every time a farmer plants a crop of wheat in Australia, there is a 50% chance that the crop will be subjected to water stress. This results in annual losses of over \$200 million. This program focused on increasing wheat productivity by improving tolerance to water stress. Australian research is paramount in this area as international programs are more focused on other crops.

MPBCRC outcomes: Three successful 'proof of concept' field trials showed yield improvements under drought conditions of 10-20%. Twenty-eight experimental wheat lines containing genes for drought tolerance were developed. Due to the prevalence of drought, modest average yield improvements would still potentially deliver a substantial return on investment (\$5.40 for every \$1 invested) and a net present value of \$36 M.



Tolerance to salinity

The opportunity: Over 83% of Australia's cropping land is at risk of salinity. This lost production opportunity is estimated at \$1.3 billion per annum.

MPBCRC outcomes: The identification of salt tolerant traits and markers in wheat and barley genomes is an important step. These markers were published and germplasm made available to breeders. The salt tolerant germplasm appears to increase biomass of the plants under saline conditions by 10%. These newly identified salt tolerant varieties could be worth \$130 million per year to Australian grain growers and generate a return on investment of \$2.30 for every \$1 invested with a net present value of \$9 M. If ongoing trials show yield benefit in lightly saline areas, the economic value of the varieties could increase substantially.

Grain characteristics

Increasing quality

The opportunity: Cereal crops provide around 70% of the world's food supply. Understanding the characteristics that can improve quality of barley and wheat can potentially boost Australia's billion dollar exports by up to a third.

MPBCRC outcomes: The behaviour of tens of thousands of genes and their control mechanisms were assessed. The program identified the genes that contribute to malting quality in barley, as well as those behind bread quality for wheat.

PASTURES

Improving grass quality and nutritive value

High energy perennial ryegrass

The opportunity: Production of higher energy pastures, which produce more biomass and higher sugar content, enables farmers to achieve higher livestock productivity and better returns. This improves volume, quality and continuity of milk and meat supply.

MPBCRC outcomes: MPBCRC conducted Australia's first, and the world's largest, field trials for GM perennial ryegrass and tall fescue. The trials achieved higher energy (fructan) levels than commercial cultivars and growth was faster and more water efficient. The technology opens up significant opportunities for harvestable carbon yields. This product is due for commercialisation in 2016. Higher nutritive quality leading to increased productivity is anticipated to provide 10-20% higher farm gate gross value. High fructan perennial ryegrass is expected to deliver \$4.50 of benefit for every \$1 invested with a net present value of \$41 M.

High digestibility forages

The opportunity: Easily digestible forages will potentially improve livestock productivity. Fescue, paspalum and brachiaria forages are used extensively in beef and sheep production. The production of high digestibility (low lignin) forages is applicable to a wide range of plant species and regions. The forages will be easier for animals to digest and convert into metabolisable energy which in turn drives more efficient meat and wool production.

MPBCRC outcomes: Low lignin forages create better quality pasture that is expected to produce faster weight gain and lower animal methane emissions. This enables increases in meat and wool production through the additional numbers of stock that farmers can run per given area of land. This product can be applied to a range of forage species and climatic regions. It is likely to have strong offshore interest, with a beneficial return on investment of \$1.20 for every \$1 invested and a net present value of \$2 M (accounting for domestic returns only).

Small changes to improve nutrition can greatly increase animal performance. A 6% unit increase in digestibility can result in a 27% increase in summer milk production. This could translate to millions of dollars in benefits to the dairy industry.

RESEARCH AND TECHNOLOGY TOOLS

The opportunity: The CRC has developed technological tools that allow breeders to make important selection decisions quickly to accelerate genetic gain, boost productivity and improve the quality of their cultivars. This enables cost reductions through optimising important and complex traits. The tools offer farmers the ability to predict, understand and learn about biotechnology and genetic information and how this can provide real on-farm benefits. The tools provide knowledge on plant responses to pests, pathogens, salinity and drought, as well as quality traits that impact the market value of the harvested crop.

High-throughput genotyping and testing methods

MPBCRC outcomes: The CRC developed high-throughput genotyping systems to use in marker assisted breeding resulting in significant cost and time reductions. A patent application on a new genotyping technology (Temperature Switch PCR, TSP) was filed. TSP delivers an accurate, rapid and economical genotyping method offering simple and reliable detection of DNA sequence differences, especially for genetically complex species such as wheat. The CRC has also developed another genotyping tool, multiplex-ready technology (MRT), which fast-tracks genetic mapping and increases the efficiency of genetic discovery in wheat and barley. TSP and MRT are currently used in CRC partner organisations such as Australian wheat breeding companies.

Cross prediction technology software

MPBCRC outcomes: The CRC, in collaboration with Australian wheat breeding companies, developed the concept, design and successful implementation of a new wheat breeding approach. This technology is estimated to reduce the cost of wheat breeding by 2.5% and enables quick assessment of the success of crossing different varieties of wheat. The technology is particularly applicable to improving wheat for bread-making as the behaviour of tens of thousands of genes and mechanisms controlling bread quality can be quickly assessed.



Molecular marker discovery

MPBCRC outcomes: The use of DNA markers can greatly accelerate breeding, as well as aid in addressing disease resistance in cereal crops. Over 30 markers discovered by MPBCRC are now being used by cereal breeders. This includes markers for traits in wheat that are particularly difficult to characterise as well as markers for frost tolerance in barley. MPBCRC was the first to publish markers for resistance to crown rot and root lesion nematode in wheat. Gene marker tools will also be used to produce new varieties of clovers within the next few years.

Examples of research and technology applications:

- Developed high yielding wheats with increased grain protein, which are being evaluated in further trials this year.
- Established waxy durums as fat replacements for baking products. Bulk grain has been produced and baking tests confirm a strong potential for commercial use.
- Developed a unique set of barley leaf scald isolates which are routinely used to identify the presence of resistance genes in breeding germplasm. This enables identification at the seedling stage instead of having to wait for later growth stages in field trials.
- Malting barley is easily stressed. Markers were identified to help alter hardy, feed barleys into elite malt performers.

Education and Training

The outreach community education and training programs were highly successful in reaching students, teachers, farmers and the broader community.

- Approximately **42,000 people** have become aware of MPBCRC research and applications
- MPBCRC attended over 40 community events and 25 grower events
- Over 50,000 DNA extraction demonstrations were performed
- **Over 10,500 students** and teachers have attended *Get into Genes*
- Over 30 professional development events were held for school teachers

Community engagement

The engagement products and programs covered:

- Educational roadshows (eg. In2Science)
- National Science Week events (eg. Gene Juice bar)
- Workshops (eg. Recognising Rural Women workshops)
- Online resources and training activities (eg. 'Molecular Training Techniques DVD')
- Student retreats
- Laboratory research tours
- Field days, Agricultural shows (eg. Royal Adelaide show exhibition and presentations)
- Community panels, discussions and online forums (eg. at Rotary clubs)
- 'Get into Genes' educational workshops for students/teachers (eg. 'Get into Genes' workshops for Malaysian teachers)
- Career expos (eg. Wimmera careers fair)
- Professional development days for teachers
- Crop and research updates (eg. GRDC crop updates)



Training of researchers and breeders

The number and age of skilled researchers in plant breeding requires attention. The majority of biologists and breeders are over 50 years of age. Scientists in the training program experienced 'basic' and 'strategic applied' research in plant sciences and the use of molecular techniques.



- MPBCRC has produced **43 graduates** – 9 of which are working in plant science internationally.
- There were 18 honours student completions.
- The MPBCRC will provide 4 plant breeders and 20 plant scientists by 2015.

The MPBCRCs training program will supply two-thirds of the industry demand for scientists and a third of the demand for breeders between 2010 and 2015.

The Future

The following programs will be continued after the wind up of MPBCRC:

- Development of MPB germplasm – InterGrain Pty. Ltd., AGT Pty. Ltd., LongReach Plant Breeders Pty. Ltd., University of Adelaide, CIMMYT
- Development of novel endophytes – Royal Barenbrug Group (Netherlands and US), New Zealand Agriseeds Ltd., Heritage Seeds Pty. Ltd. (Australia), DPI Vic and Dairy Futures CRC
- Get into Genes education and outreach program – Dairy Futures CRC, Australian Centre for Plant Functional Genomics
- GM pastures program – Gramina Pty. Ltd., PGG Wrightson Seeds Ltd. (New Zealand), DPI Vic and Dairy Futures CRC
- Salt tolerant wheat program – SARDI and the University of Adelaide
- Timing of plant flowering – Western Australian Agriculture Authority (formerly Department of Agriculture and Food Western Australia, DAFWA)
- GM Wheat program – BASF Plant Science (Germany) and DPI Vic



MPBCRC Core Participants and Supporting Participants

Core Participants

Department of Primary Industries, Victoria (DPI Vic)
The University of Adelaide
South Australian Research and Development Institute (SARDI)
Western Australian Agriculture Authority [formerly Department of
Agriculture and Food Western Australia (DAFWA)]
Murdoch University
International Maize and Wheat Improvement Centre, Mexico (CIMMYT)

Supporting participants

AGT Pty. Ltd.
BASF Plant Science (Germany)
Dairy Australia Ltd.
Geoffrey Gardiner Dairy Foundation
Grains Research and Development Corporation (GRDC)
Heritage Seeds Pty Ltd
International Center for Agricultural Research in the Dry Areas (ICARDA)
InterGrain Pty. Ltd.
LongReach Plant Breeders Pty. Ltd.
Meat and Livestock Australia Ltd.
New Zealand Agriseeds Ltd.
Royal Barenbrug Group (Netherlands and US)
Southern Cross University

A detailed Economic Impact Analysis is available to download from the
MPBCRC web site: www.molecularplantbreeding.com



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