GRDC Grains Research Update Focus Session

"New breeding directions and technologies"
Convenors: Drs Greg Rebetzke and Mike Ewing
Attendance approximately 60

Introduction and session chairman – Greg Rebetzke

This Crop Research Update Forum provided an opportunity for research leaders to explain improved methods used in the evolving breeding industry. In turn, non-specialists could engage more effectively with breeders and researchers alike, and ask probing questions in developing understanding and a more realistic appreciation in expectations around new breeding developments and what they might deliver as new crop varieties.

Yield increases along with maintained or improved tolerance to biotic stresses and product quality remain the main drivers for investment in crop breeding. However, the ways in which breeding is conducted and the technologies available to breeders is changing rapidly. Making sense of these new opportunities and their effective integration is a serious challenge to commercial breeders. In the session we learned and were updated from experts separately contributing to the breeder's 'tool box'. We obtained some sense as to how the new technologies might be integrated along with conventional breeding methods to more rapidly and efficiently deliver new genetics into our major crop improvement programs.

Breeding technologies are growing in scope to include high-throughput phenotyping, new statistical genetics and bioinformatics, germplasm acquisition and characterisation, and molecular genetic tools. Understanding each specific breeding technology and the potential for industry impact is a major challenge for the non-specialist and we often latch onto the catchy words used by breeders and researchers without really understanding what is behind conventional and molecular technologies.

Key presentations and content

There were six technology-based short presentations with each presentation downloaded to allow fuller access to the content. Each presenter used their current research to expand an understanding of the applications of the technologies. A practicing plant breeder (barley breeder Dave Moody) then presented a clear account of how a typical crop breeding program was structured and how the different technologies could be effectively integrated to provide realized benefit to the breeder particularly given real world constraints such as resource limitation. The presentation were:

Overview – *Greg Rebetzke, Francis Obgannaya, Juan Juttner*

Breeding technologies are dynamic in their development and in delivering improved genetic gain. The GRDC invests across a broad range of new and existing technologies that aim to improve genetic gain through greater genetic diversity, greater accuracy in selection, improved confidence in gene identification, and reduced time between successive varietal releases. The target for breeders is in delivering more robust crop varieties that contain genetics with improved performance (e.g. water productivity), improved tolerance to disease, and greater marketability through improved quality.

Molecular markers – *Chengdao Li*
Molecular markers are simple biochemical identifiers of genes located in the different chromosomes. They are inexpensive and reliable in allowing a breeder to identify and then select if a breeding line contains a desired gene. Multiple markers can allow the identification of breeding lines containing many desirable genes including those related to improved disease resistance or grain quality, characteristics considered expensive to assess in glasshouse or field testing. Differences in the frequency of molecular markers between introductions allows identification of new genetic diversity for use in breeding, and the reducing cost of markers is becoming key in the developing area of genomic selection.

Transgenic breeding or GMOs - *Geronimo Watson*
Genetically-modified organisms (GMOs) are widely grown overseas and especially in the maize and soybean industry. Here novel genes not native to the crop have been transferred from other species to improve resistance to herbicides (e.g. RoundupReady®) and insects (e.g. BT). The opportunity then is to identify other non-native genes for improved performance into wheat. For example, a novel 'transcription factor' gene 'HAHB4' has been transferred from sunflower into wheat using transgenic breeding approaches. This drought tolerance gene 'turns on' a large number of other genes to improve performance of sunflower under drought. Preliminary research in Argentina indicated the HAHB4 gene increases water productivity in droughted wheat experiments whereas the gene has little to no benefit where conditions are favourable and water was not limiting. The benefit with GM-based breeding is that novel genes can be readily transferred across different plant and animal species, and the transfer is done with minimal disruption to the recipient crop. The disadvantage of GM is the high cost of regulation and strict control of new GM events particularly when targeting commercial release in a new variety.

CRISPR/gene editing - *Yong Han*
Clustered regularly interspaced short palindromic repeats (CRISPR) together with the cas9 enzyme permits the editing of genomic DNA. The technology allows for specific chromosomal regions to be targeted in manipulating. Resulting mutations can then be used to change plant characteristics important in plant defense to disease, improved nutritional quality and/or other aspects of crop adaptation. While the technology is in its infancy successful changes have been developed in crops overseas. There is still uncertainty in regulation of this technology as to whether it will be treated as GM or conventional technology.

Genomic selection and novel statistical approaches - *Dini Ganesalingam*
Population breeding permits the selection of complex traits representing many small genetic effects throughout the genome using breeding models combining genome-wide molecular markers and robust phenotyping. The breeding models allow the prediction of potential for a breeding line not yet tested thereby reducing the cost and

time between breeding cycles. Further, the larger populations possible should allow for the selection of many more favourable genes before moving to the expensive stages of field-testing. Complementing the promise of this exciting technology is the improvement in statistical modelling used to assess breeding lines across multiple locations and years. The power in these models has significantly increased breeder's confidence in selecting for improved broadly - and/or regionally adapted lines for commercial release. These models also guide the statistical analysis and variety rankings delivered from the GRDC's NVT trialing system.

Novel germplasm and FIGS – *Ken Street*

A systematic rather than random approach to the accumulation of genetic material to search for special crop traits can be highly effective. There is a relationship to the selection pressures that have been imposed at the site of plant collection and the genetic make up of those plants. By identifying the characteristics of the target environment and matching them to soils, climate etc. of collection environments, genetic material of high potential value can be identified. This involves a formal process of layered information mapping called FIGS (Focused Identification of Germplasm Strategy). A recent application of this approach has been the identification and collection of wheat germplasm with the potential to tolerate frost when grown across the Australian wheatbelt.

High-throughput phenotyping of breeding populations - *Greg Rebetzke*

Phenotyping represents the visual characterization of those attributes important in selection. Traditional phenotyping has resulted in today's modern varieties but can be slow and expensive. Molecular markers are quick, reliable and inexpensive but the genetic complexity of many economically important traits will limit the use of molecular markers to all but genetically simple characters. High-throughput phenotyping (HTP) uses modern technologies to capture digital and reflectance information on individual plants or plots. Resulting information is then returned to the breeder as data from which selection for ground cover, biomass, canopy temperature and potentially yield can be made. All data is collected non-destructively and using reduced labour and time. In turn, costs are low and large populations phenotyped at all stages of a breeding program from early generations to advanced yield trial. While not displacing yield collected from a plot header, the information from HTP can be used to select indirectly for yield early in the breeding process, and used later in combination with field-based header yield to develop indices aimed at increasing breeder confidence in selection between advanced breeding lines.

How can breeders make better varieties? *- David Moody*

Breeders aim to deliver new crop varieties that are competitive owing to improved productivity and reliability, and profitability to growers. The breeder's tool-box has access to many tools to 'speed-the-breeding' and reduce the cost in delivering a new variety to market. Many of the tools described earlier have the potential to significantly impact breeding progress. New diversity with FIGS and CRISPR, improved molecular markers for difficult-to-measure traits, and advanced statistical methods are all key to successful long-term breeding. Molecular markers and CRISPR/GM focus on single genes as these are simpler to manage using these technologies. Genetically complex characters including yield and some disease and quality traits, contain many hundreds of genes and so are slow and expensive to manipulate across many 1000's of breeding lines. To this end, considerable promise has been demonstrated with genomic selection and high-throughput phenotyping where many genes can be assessed and selected for simultaneously. Furthermore the cost in selection using these tools is reducing almost daily so that potentially entire breeding programs could be managed through integrating across these technologies, and in combination with improved molecular markers, statistics and new genetic diversity, deliver improved robust varieties with traits not yet present in current crops (e.g. frost and heat tolerance, improved nutrient-use efficiency, weed competitiveness).