Development of (ICIS) for Australian wheat breeding programs

Summary

The project has achieved significant advances in relation to the development of the International Crop Information System (ICIS) to allow implementation by Australian wheat breeding programs. These include:

1. Changes to ICIS to meet requirements of Australian programs for storage and retrieval of phenotype, genotype, and pedigree information.
2. Establishment of a help facility (telephone, email, web) to assist breeders implement and manage ICIS.

The project has achieved its aim of increasing the efficiency of, and interaction among, Australian and International Maize and Wheat Improvement Center (CIMMYT) wheat breeding programs. Furthermore, significant contributions have been made to the international development of ICIS software.

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Conclusions

This project has made significant contributions to the development of ICIS and its implementation in Australian plant breeding programs, as outlined above. ICIS now has the functionality to provide a fully integrated data management system that can be implemented by any of the GRDC-funded programs. Furthermore, ICIS is an open-source and supported by the International Rice Research Institute (IRRI) and, more recently, CIMMYT.

Adoption of ICIS has been relatively slow for a number of reasons. These include a) perceived lack of functionality and difficulty of use; b) perceived conflict between IRRI and CIMMYT on database development; c) development of ‘in-house’ software by many breeding programs; and d) limited support for implementation of ICIS. The false perceptions of ICIS are being addressed slowly, and it is expected that the implementation of ICIS as part of the new CIMMYT suite of projects will provide breeders with a positive experience of the functionality and power of ICIS, thereby assisting adoption by wheat breeding programs throughout Australia. Recently, CIMMYT has decided to implement ICIS (rather than the International Wheat Information System (IWIS)), and the management of database development at IRRI and CIMMYT is now being coordinated by Graham McLaren. The adoption of ICIS by CIMMYT will make the process of exchanging data between the Global Wheat Information System (GWIS) and CIMMYT much simpler and error free. As CIMMYT data will become directly transportable between ICIS databases, this will provide further incentive to Australian wheat breeding programs to adopt ICIS. The availability of fully-functional, open-source, and fully-supported database software provides a major incentive to breeding programs - it is expected that these advantages, once fully appreciated, will also assist future adoption rates. Finally, on-site support and training will have assisted adoption - this is being addressed as part of the new project (UQ00040).

Recommendations

It is recommended that GRDC:

1. Actively promotes the functionality and advantages of ICIS as a data management system for its founded plant breeding programs.
2. Adopts ICIS as the mechanism for exchange of information (pedigrees, trial data, phenotype information, genetic maps, quantitative trait loci (QTL), etc.) between GRDC-funded projects and the users of this information (i.e. plant breeders and researchers).

The implementation of a single, unified data management system will greatly facilitate the mining and utilisation of information and germplasm for the enhancement of plant breeding programs throughout Australia, and ultimately for Australian farming enterprises through the deployment of better adapted, higher yielding, high quality, more robust varieties.

Outcomes
One of the key benefits expected from project UQ158 was an increased efficiency of and interaction between Australian and CIMMYT wheat breeding programs. Increased efficiency and cooperation between CIMMYT and Australian wheat breeding programs has obvious benefits to the Australian grains industry.

This key outcome has been achieved through the implementation of a web version of ICIS (GWIS). The web version now contains all Australian and CIMMYT pedigrees, which are updated regularly as new information becomes available, providing a comprehensive resource for both Australian and CIMMYT breeders, and researchers interested in bread wheat. Furthermore, the project has demonstrated the capacity of ICIS to provide a mechanism for sharing of data and results (nationally and internationally) - GWIS also includes field data from the international wheat adaptation trial, as well as field trials established as part of project UQ157 and its predecessors.

The recent decision by CIMMYT to adopt ICIS as its data management system will enhance future capacity to share and integrate data from CIMMYT- and GRDC-sponsored programs (e.g. the new CIMMYT suite of projects).

Achievements/Benefits
There have been successful implementations of ICIS in Australian grains research programs.

The Genealogy Management System (GMS) in ICIS is being used extensively by Dr Howard Eagles for both wheat and barley pedigrees. Dr Eagles finds that ICIS has facilities which other software does not offer, such as the ability to enter confidential pedigrees and calculate coefficients of parentage (COP) from vast data sets which include the confidential pedigrees. His most extensive use of ICIS has been with barley, where Dr Eagles has entered more than 2,000 pedigrees, often tracing back to landraces. This has allowed the origins of important alleles in modern varieties and breeding lines to be identified. He has also used these pedigrees to determine relationship matrices, some including more than one million COP values. This enables correction for biases in the calculation of gene effects from plant breeding data. Dr Eagles has had assistance from Ms Sandra Micalef from The University of Queensland (UQ) and Dr Graham McLaren from IRRI in providing modifications to the software so that old varieties and breeding lines (which for barley and wheat have a COP with themselves of 1.0) can be correctly distinguished from crosses (which have COP with themselves between 0.5 and 1.0). This was essential for the correct calculation of relationship matrices.

The Winter Pulse Germplasm Bank at the Victorian Institute for Dryland Agriculture (VIDA) has adopted ICIS as its main software for data management. Ms Micalef visited VIDA (August 2002 and March 2003) to introduce and install ICIS and also to train the personnel working on the project. Dr Bob Redden and Mr Ranjan Balachandra are in the process of loading evaluation data from field trials for lentils and chickpeas. They have found some of the advantages that ICIS can contribute to their project include the:

1. Ability to store data from different sources - i.e. the International Center for Agricultural Research in the Dry Areas (ICARDA), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the United States Department of Agriculture (USDA) and Australia in a single database.
2. Ability to store and search using synonyms because of the unique identification of germplasm.
3. Ability to search using passport and/or evaluation information.
4. Flexibility in storage of data using multiple scales for traits (i.e. 1–9 or absolute values).

In the near future, Dr Redden and Mr Balachandra are looking to link this information with a barcode seed tracking system they are developing. The flexibility of the ICIS software and database will allow them to bring in other types of data, such as molecular and fingerprinting data. They have also reported that the ICIS programmers at IRRI have been very supportive in developing their requirements for the web search engine and also responsive to their queries. Mr Balachandra is working solely on the ICIS software and is also collaborating with IRRI for further development on the ICIS web search engine using Java programming language.

There have been multiple requests from researchers and breeders to send them more information about ICIS and also the ICIS software. The project team has assisted Angela Juhasz at CSIRO in Canberra, Ky Mathews at UQ/CSIRO in Brisbane, Tobias Schoep at Murdoch University (MU), and Daniel McDonald at the University of Sydney (US) to install the wheat database with the ICIS software.

There have been successful implementations of ICIS in Australian grain breeding programs.
In July 2003, Hayden Kuchel visited UQ and was given training on how to use ICIS. As part of the GRDC-funded Association Mapping and Whole Genome Projects at the Molecular Plant Breeding Cooperative Research Centre (MPBCRC), Mr Kuchel is using large pedigrees to analyse historical genomic manipulation through breeding. This work aims to integrate both genotypic and phenotypic data, but in such a complex population this requires some innovative approaches. Mr Kuchel finds that ICIS has been critical to the development of this process: "Firstly, ICIS provides an up-to-date reference for determining the pedigree of our research germplasm. Secondly, and most importantly, the coefficient of parentage function within ICIS, is allowing the University of Sydney to more accurately analyse our data sets. By including the pedigree based relationships between lines in trait analysis, underlying breeding values can be determined and later used for genotype-phenotype investigations."

Dr Robyn McLean from the Department of Agriculture and Food Western Australia (DAFWA) visited UQ in August 2002 to be introduced to ICIS. She has implemented a grain management system (GMS) as the pedigree management tool for PBS Genesis, the database facility used by the WA grain breeding programs.

ICIS has been fully implemented by the wheat breeding program of Grain Biotech in WA. It was fully implemented by the Germplasm Enhancement Program (CEP), which was part of the wheat breeding program at the Leslie Research Centre in Toowoomba, but has not been adopted by the main breeding program there.

Dr Reg Lance at DAFWA has installed the barley version of ICIS - the International Barley Improvement System (IBIS). Both the wheat and barley breeding programs at Horsham use GMS to manage their pedigrees with the help of Dr Eagles.

ICIS databases

Currently, UQ is the curator of GWIS and IBIS. The wheat database contains over 4.5 million pedigrees and over five million names.

An update of the wheat pedigrees has been received recently from CIMMYT and has been to GWIS, and is now available on the GWIS website. The updated databases are distributed to various GWIS users in the Australian wheat breeding and research programs.

Web development

The web version of ICIS for wheat, GWIS, is now operating successfully on a UQ based server. The GWIS website can be found at http://gwis.lafs.uq.edu.au

It contains information on Australian wheat pedigrees, pedigrees from CIMMYT, and field evaluation data collected on imported CIMMYT germplasm. In the near future, GWIS will contain information about Canadian pedigrees. It can also be used to make accessible any data that wheat scientists and researchers would like to make public. A mailing list, to which anyone can subscribe, has been set up to keep all participants informed of progress and news on GWIS.

To subscribe to the list, users can send an email to majordomo@lists.uq.edu.au with the following text in the BODY of the message: subscribe icis-info-end.

ICIS workshops

ICIS2002, the 7th International ICIS workshop, was held at UQ from 9–12 April 2002. It was a great success with 56 participants from around the world. An ICIS developers’ workshop was held from 24–26 June 2003 at UQ. Dr Bob Redden and Mr Balachandra from VIDA also attended this workshop.

Dr Ian Delacy and Ms Micallef attended an ICIS training workshop held at ICARDA in Aleppo (Syria) in September 2003. ICARDA has adopted ICIS for its plant breeding information management system. This workshop was aimed at introducing and training the ICARDA breeders on how to use ICIS and facilitate information management of their breeding programs. Breeders from CIMMYT in Turkey also attended this workshop. A presentation over the internet from NUNZA, a large international vegetable breeding company based in the Netherlands, was given to show how ICIS has been successfully implemented for 25 different crops in their organisation.

Dr DeLacy attended a developers' workshop at IRRI from 14–23 January 2004. This workshop was held to plan further developments of ICIS, including the Inventory Management System (the Seed Management Module is an application written
on top of this), the Gene Expression Management System (GEMS), and development of improved applications for uploading and correcting historical genealogies.

**Development contributions**

There has been a large contribution by the group to develop a Seed Management System (SMS) for ICIS, in conjunction with IRRI and NUNZA. This system will be used to manage all seed stocks for breeding programs or germplasm banks. The germplasm bank at IRRI requires this system to be developed to replace the legacy system. The application will be able to trace the seed history of all germplasm. Ms Micallef visited NUNZA in September 2002 to discuss the seed management system requirements with breeders. Dr DeLacy visited NUNZA twice to help plan the SMS. Dr DeLacy and Ms Micallef also visited IRRI in March 2003 to develop the SMS together with IRRI breeders and program developers. ICIS 2005 was held at Nunhems (Netherlands) during the last week of February (21–25). Dr Delacy and Ms Micallef attended the workshop and presented talks on UQ’s involvement with ICIS development, wheat database management difficulties, and future project plans with ICIS.

Ms Micallef has developed the technical requirements document for the SMS detailing all use case functions, table structures and DLL programming syntax. This document has now been incorporated into the ICIS technical manual which is included with each ICIS installation.

The project team has participated in the design of the GEMS which will be able to store all information on genes and QTL.

During March 2005, Dr Richard Trethowan from CIMMYT visited UQ to observe how ICIS has been implemented. Dr Tom Payne from CIMMYT has also contacted US on synchronising the wheat databases (IWIS and GWIS), in view that CIMMYT will migrate to ICIS.

**Other research**

Funding for continuation of support for use of ICIS by GRDC-sponsored breeding programs has been negotiated as part of a new project -UQ00040. Although the main focus of this new project will be the implementation of ICIS for the storage and retrieval of data generated in the new CIMMYT suite of projects, the project staff will continue to be involved in the future development and enhancement of ICIS in collaboration with IRRI and CIMMYT.

**Intellectual property summary**

ICIS is an open-source system.