Next WGIN Stakeholder meeting – 17 November 2010, RRes, Harpenden

Contents:

Defra Wheat Genetic Improvement Network – Improving the environmental footprint of farming through crop genetics and targeted traits analysis

Background

The UK government is committed to more sustainable agriculture but this vision is facing an ever expanding range of environmental, energy and climate change challenges. Wheat is grown on a larger area and is more valuable than any other arable crop in the UK. Established in 2003, the Wheat Genetic Improvement Network (WGIN) arose directly from a realisation in the early 2000s that over the preceding two decades there had been a widening disconnection between commercial plant breeding activities and publicly funded plant and crop research. The overall aim of WGIN is to generate pre-breeding material carrying novel traits for the UK breeding companies and to deliver accessible technologies, thereby ensuring the means are available to produce new, improved varieties. An integrated scientific 'core' which combines underpinning work on molecular markers, genetic and genomic research, together with novel trait identification, are being pursued to achieve this goal. The programme is managed by a team including representatives of the key UK research groups and breeders. They ensure the programme and its outputs are communicated to the wider scientific and end user communities, via a web site, a stakeholder forum, focused meetings and peer reviewed publications. WGIN liaises with equivalent operations overseas to ensure the programme is internationally competitive.

The initial WGIN project ran for five years (2003-2008) and achieved considerable scientific success. In addition, the sustained networking activities and the availability of datasets generated by the project led to the establishment of many new wheat genetic improvement projects, including some funded jointly by the public sector and industry. Those funded by early 2008 were summarised in the May 2008 Stakeholders Newsletter and since then several additional projects have been agreed. There is no doubt that WGIN has a direct and significant impact on re-establishing the relationship between commercial plant breeding activities and public funded plant and crop research. However significant hurdles remain which currently prevent commercial implementation of much new research which should help to reduce the energy requirement and environmental impact of the UK wheat crop.

This project

The new WGIN Core Project started in 2008 to provide genetic and molecular resources for research in other defra projects and for a wide range of wheat research projects in the UK. The resources under development include wheat genetic stocks, mapping populations, molecular markers and marker technologies, trait identification and evaluation, genomics and bioinformatics. The initially funded partners are the John Innes Centre, Rothamsted Research and The University of Nottingham but support has been allocated for sub-contracted projects which were awarded in open competition during 2009 (see website for details on the funded projects – http://www.wgin.org.uk/information/subcontractorprojects.php).

Objectives 2 to 5:

New Genetic Resources from WGIN

The first WGIN project established key resources to facilitate publicly funded contributions to the genetic improvement of UK bread wheat. The most important of these were:

- The Avalon x Cadenza doubled haploid population - a UK public reference wheat mapping population.
- The AE Watkins landrace collection - a unique snapshot of global germplasm prior to modern selection regimes.
- The Paragon EMS and gamma mutant populations - a platform for the identification of completely novel genetic variation in a UK adapted elite spring wheat.

These resources have had broad impact in academic and commercial research programmes. However, their true potential will now be exploited with the development of new 'derived' resources. This has been the focus of recent WGIN activity in addition to the establishment of some totally new resources.

Why WGIN focuses on NILs

Progress in methodologies for the genetic improvement of wheat varieties fit for more sustainable UK agriculture will include more specific understanding of the biological processes influencing the key traits of grain yield, stress tolerance (abiotic and biotic), and grain quality. A reductionist approach, where the genetic location and specific action of key genes can be defined will allow the predictive deployment of these genes. Figure 1 shows a relatively simple scenario for the WGIN Avalon x Cadenza population in which knowledge of just a few QTL controlling height gives a useful prediction of this trait. This can be achieved for many more traits in wheat breeding programmes if the genes are known and diagnostic molecular markers exist for them.

Examples of the detection of genes influencing ear emergence in Avalon x Cadenza are shown in Figures 2 and 3 overleaf.

NILs have been developed for a large number of QTL controlling crop height, heading date, and grain yield in Avalon x Cadenza. These are summarised in Table 1. In most cases reciprocal NILs have been developed i.e. Avalon allele into a Cadenza background and Cadenza alleles into Avalon. This goes some way to identify interactions of the allele with other genes. The backcrossing strategy means that researchers cannot simply compare pairs of lines. This backcrossing programme was designed so that an experiment comparing two alleles for one QTL involves the study of 32 lines. However, there is potential to reduce this number.

Trait	QTL
Heading date	1B, 1D, 3A, 6B
Crop Height	2A, 2D, 3A, 6A, 6B
Grain Yield	2D, 3B, 5A, 7B, 7D

Table 1: Avalon and Cadenza Near Isogenic Line (NIL) development

Trait	Chromosome location of QTL
Firmness	2B
Loaf volume	2D
L*	4D
Cell number	4D
Cell number	6A
Loaf volume	7A
Loaf volume	7B
Cell number	1B
Lr19 Yield and disease resistance into Paragon	7D

Table 2: Near Isogenic Lines developed by WGIN. All between Malacca and Hereward except for Lr19 which is from three CIMMYT sources (Wheatear, Oasis, and Kamb1) into Paragon.

In addition to Avalon x Cadenza NILs WGIN has undertaken the development of NILs for breadmaking quality (Table 2). The aim of this work is to develop breeding strategies for the maintenance of quality with reduced Nitrogen input. In addition an alien introgression into wheat Lr19, widely used internationally and with potential to increase grain yield without increasing inputs, is being introgressed into UK adapted backgrounds.

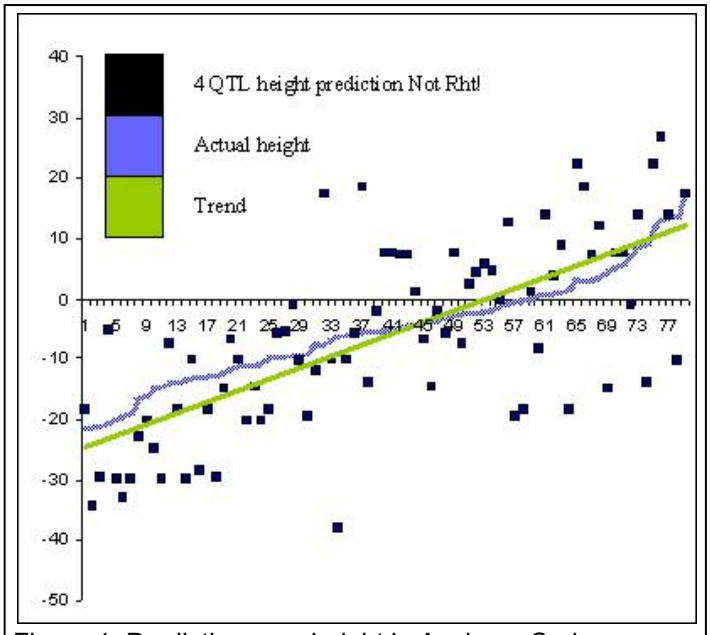

Figure 1: Predicting crop height in Avalon x Cadenza

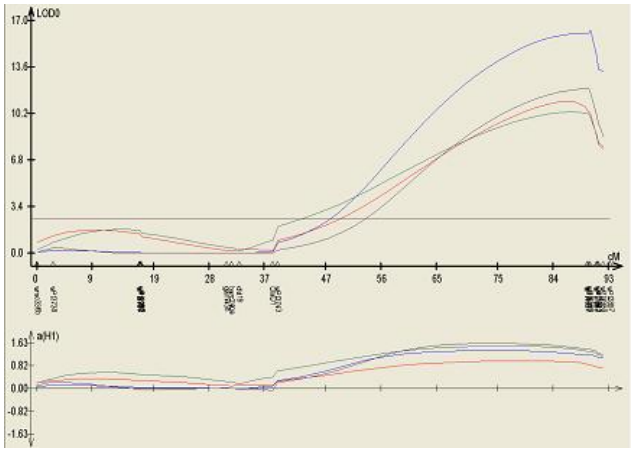

Figure 2: Avalon x Cadenza ear emergence QTL on 1DL

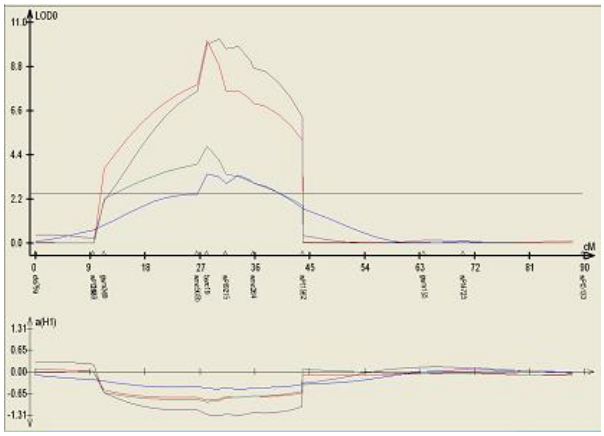

Figure 3: Avalon x Cadenza ear emergence QTL on 3A

New populations and new alleles

The work described so far is designed to better exploit the genetic variation already available to UK breeders. However, as Richard Summers wheat breeding lead for RAGT pointed out while speaking at the UK Monogram Network Meeting (Norwich March 2-4) we need to do more than describe what has already been done! WGIN has moved on from curating and phenotyping germplasm collections to developing resources for their genetic dissection and the extraction of new and useful genes for UK agriculture. These populations are summarised in Table 3. Finally, WGIN has expanded the Paragon gamma irradiated population established by Dr Robert Koebner population now contains over 5000 independent mutagenised lines (Figure 4) and offers the potential for the physical dissection of important genes and the generation of completely new genetic variation, including the abolition of gene functions that were vital to the wild progenitors of wheat but might limit its performance as a crop.

Parents of population	Reason for cross
AEW34 x Paragon	Early maturity
AEW209 x Paragon	Early maturity
AEW468 x Paragon	Early maturity
AEW726 x Paragon	Short
AEW292 x Paragon	Short
AEW736 x Paragon	Short
AEW481 x Paragon	Late maturity
AEW141 x Paragon	Tall
AEW352 x Paragon	Tall
AEW788 x Paragon	Tall
Paragon x Sears Synthetic	Marker mapping and traits
Paragon x Chinese Spring	Marker mapping
Paragon x Drought tolerant ? SSD	Drought
Paragon x Drought tolerant ? phenology selected SSD	Drought
Paragon x Drought tolerant ? BC1-SSD	Drought

Table 3: New populations under development by WGIN.


Figure 4: Gamma irradiated Paragon lines.

All of the material described is available for public and commercial use when its development is complete. Contact Simon Griffiths (simon.griffiths@bbsrc.ac.uk) for further information.

Focus on Objective 3 at RRes: Extending the 'Avalon × Cadenza' mapping population of doubled haploids (DH)

F_1 seeds of the 'Avalon × Cadenza' and reciprocal 'Cadenza × Avalon' crosses were provided to PLANTA (Einbeck, Germany) and in July 2008 > 1000 putative DH plants were returned. All these plants have been vernalised and then grown to maturity under glass at Rothamsted Research. More than 30 grains were recovered from 484 plants, whilst 98 plants produced only 1-10 grains. The former are currently being bulked up in the field on ex-fallow land (two 75-cm rows per line / 15 grains per row) (Figure 5), whereas the latter have already been bulked up under glass (Figure 6) and there are 100-3000 grains available for each DH line. All the 582 new 'Avalon × Cadenza' DH lines will be bulked-up in the field using larger plots for another year (2010/2011) to provide sufficient amount of seed for first field trials. DNA from all the new DH lines is also available at Rothamsted Research for marker analyses.

Figure 6: The Avalon x Cadenza population in the glasshouse.

Objective 8: Improvements of nitrogen use efficiency and quality QTLs linked to NUE: dissecting NUE and quality traits and QTLs

In the present WGIN project, 2 large field multi-year trials are in progress at Rothamsted, which are focussed primarily on nitrogen use efficiency. They are available to the community for phenotyping upon request, and are currently utilised to examine aspects of architecture and take-all biology (within WGIN). The trials comprise a replicated variety/N trial and a replicated trial of a mapping population:

1. The Diversity Trial – this experiment was started in the original WGIN project and typically consists of 20-25 varieties (see Table 4 overleaf) grown at 4 nitrogen levels (0, 100, 200 and 350 kg N/ha) in a triplicated trial. A core set of varieties is retained from year to year (and matches the core in the original WGIN project), however some flexibility exists and suggestions for future inclusion are welcome. In some years specific lines from the mapping population (see below) are being included (currently 6 in each of 2009 and 2010 harvest years). The trial will run for 5 years. Grain and straw harvests and N contents are recorded. Additional phenotyping by the community includes measuring aspects of architecture and canopy longevity. Dried and milled materials have been archived, and fresh grain material stored at -20 °C.

Figure 5: Bulking up the extended Avalon x Cadenza population in the field

2009 harvest	2010 harvest	Notes
1. Avalon	**1. Avalon**	DH parent (Cadenza) for disease escape; WGIN-UQ-NUP
2. Cadenza	**2. Cadenza**	DH parent (Avalon) for disease escape and (Lynx) for disease resistance and NUE; WGIN-UQ-NUP
	3. Chablis NEW	Added because appeared very N-responsive in single previous inclusion (2004)
3. Claire	**4. Claire**	Current RL benchmark Grp 3; Slow developer; DH parent (Lemhi) for disease resistance; WGIN-UQ-Y-NUP-NUTE
4. Cordiale	**5. Cordiale**	Current RL; WGIN-UQ-Y-NUP
	6. Gallant NEW	New high performing Grp 1
5. Hereward	**7. Hereward**	Current RL benchmark bread wheat; WGIN-UQ-NUP
6. Hurley		Low NupE & NutE in 2004 WGIN trial
7. Istabraq	**8. Istabraq**	Current RL; WGIN-UQ-Y-NUTE; WGIN-LQ-%N
8. Malacca	**9. Malacca**	Current RL
9. Marksman NEW 2009	**10. Marksman**	Current RL
10. Maris Widgeon	**11. Maris Widgeon**	WGIN-UQ-%N; WGIN-LQ-Y-NUP-NUTE
11. Mercia	**12. Mercia**	Included because in RHT series
12. Monopol		WGIN-UQ-%N; WGIN-LQ-Y-NUTE
	13. Oakley NEW	High performing group 4, although now removed from RL
13. Paragon	**14. Paragon**	Current RL only Grp 1 spring; WGIN-UQ-%N
14. Riband	**15. Riband**	DH parent (Arina) for disease resistance/escape; WGIN-UQ-NUTE; WGIN-LQ-%N
15. Robigus	**16. Robigus**	Current RL; WGIN-UQ-Y-NUP-NUTE; WGIN-LQ-%N
16. Soissons	**17. Soissons**	Current RL; Early maturing; DH parent (Beaver) for NUE/WUE/Q; WGIN-UQ-%N; WGIN-LQ-NUTE
17. Solstice	**18. Solstice**	Current RL; Most popular Grp 1; WGIN-UQ-NUTE
18. Xi19	**19. Xi19**	Current RL; High yielding Grp 1; WGIN-UQ-Y-NUTE; WGIN-LQ-%N

Table 4: Diversity trial varieties for harvest in 2009 and 2010 at Rothamsted (highlighting newly introduced varieties). (WGIN-RESULTS FROM 2004-2008:UQ-UPPER QUARTILE; LQ-LOWER QUARTILE; Y-YIELD; %N-GRAIN %N; NUP-N UPTAKE; NUTE-GRAIN N UTILIZATION EFFICIENCY).

2. The Avalon x Cadenza doubled haploid population (202 lines) is being grown at 2 N levels over a period of 5 years (see Table 5) in triplicated trials. Yields, N determinations and other basic phenotyping is being performed and will be used to determine reproducible QTL using the available genetic MAP. Selected lines with contrasting phenotypes are being examined in more detail in the Diversity Trial. Dried material and some fresh material have being archived.

Year	Site	N-level (kg/ha)
2007	Rothamsted, Black Horse	200
2008	Rothamsted, Bones Close	100
2008	Woburn	100
2009	Rothamsted, Fosters/Summerdells	100
2010	Rothamsted, Black Horse	200
2011	Rothamsted, tbd	200

Table 5: Avalon x Cadenza trials

Contact: Dr. Malcolm J. Hawkesford, Rothamsted Research.

Objective 10: Take-All disease

The diversity trial, within the WGIN 1 programme, was designed to investigate the nitrogen use efficiency (NUE) of different NW European commercial winter wheat cultivars. This trial which tested 22 cultivars grown as a first wheat proved an invaluable resource in advancing the hypothesis that cultivars can differ in their ability to build-up the take-all fungus (see newsletter October 2009). The findings from these trials have now been accepted by Plant Pathology in the form of a written refereed paper (McMillan et al (2010)). The results from all five trial years will be available on the WGIN website shortly.

Data from the trials have been put to practical use by selecting cultivars which have consistently shown differences in take-all inoculum build-up to create different disease pressure in the field. Large plots of Hereward (high building variety) and Cadenza (low building variety, 4 replicates of each), were sown in autumn 2008. After harvest, each large plot was sub-divided to contain eight 10 x 3m plots and soil cores were taken from each individual plot to measure the take-all infectivity of the soil. Each sub-plot within the large plot was sown with a different commercially grown wheat variety to study the resistance/tolerance to take-all at different disease pressures.

Publicity:

BBC countryfile:

BBC countryfile was at RRes in the end of April interviewing Malcolm Hawkesford on food security and filming the WGIN diversity trials (Figure 7). The report focussing on food security is scheduled to be shown on countryfile in May.

Cereals 2010:

Both JIC and RRes will be represented at Cereals 2010 (Royston, Cambs, June 9-10). JIC is sharing a stand with NIAB and TAG and will have the Watkins collection on display. At the RRes stand WGIN will exhibit the diversity trial, a *T. monococcum*/Septoria display and plants with high and low take all inoculum.

Figure 7: John Craven from BBC countryfile interviewing Malcolm Hawkesford. Background: WGIN field trials at RRes

Subcontractor Projects:

The selection process for the subcontractor projects was completed in January 2010. The approved projects are ' Non-destructive screening of WGIN Paragon mutants for grain NUE traits' led by Richard Weightman (ADAS) and 'Exploring the use of $\Delta^{18}0$ and total mineral ash content in wheat as a new tool for phenotyping wheat with respect to water inputs' led by John Foulkes (University of Nottingham). An outline of the project plans can be viewed at the WGIN website.

Publications:

McMillan, V. E., Hammond-Kosack, K.E. and Gutteridge, R. J. (2010) Evidence that wheat varieties differ in their ability to build-up inoculum of the take-all fungus, *Gaeumannomyces graminis* var. *tritici*, under a first wheat crop. Plant Pathology (accepted).

Vasilis C. Gegas, Aida Nazari, Simon Griffiths, James Simmonds, Lesley Fish, Simon Orford, Liz Sayers, John H. Doonan, and John W. Snape A Genetic Framework for Grain Size and Shape Variation in Wheat. Plant Cell First published on April 2, 2010; 10.1105/tpc.110.074153

Barraclough, P. B., Howarth, J. R., Jones, J., Lopez-Bellido, R., Parmar, S., Shepherd, C. E. & Hawkesford, M. J. (2010) Nitrogen efficiency of wheat: genotypic and environmental variation and prospects for improvement. European Journal of Agronomy. doi:10.1016/j.eja.2010.01.005

Forthcoming events:

Wheat workshop in Novi Sad, Serbia (15-16 June): UK wheat scientist and breeders will meet up with wheat workers from Serbia, Croatia, Hungary, Romania, Bulgaria and the Czech Republic to exchange information on wheat genetics, physiology, pathology and breeding to increase opportunities for cooperation with that region.

For further information on the WGIN project please see www.wgin.org.uk or contact us at wgin.defra@bbsrc.ac.uk.

The contributors to this newsletter were: At Rothamsted Research: Kim Hammond-Kosack, Malcolm Hawkesford, Richard Gutteridge, Kostya Kanyuka and Elke Anzinger. At the John Innes Centre: Simon Griffith and John Snape.