Final Project Summary

Project title	PhD: Understanding the genetics of wheat yield to deploy high and stable yielding wheat varieties across UK environments		
Project number	211130023	**Final Project Report**	SR45
Start date	Oct 2014	**End date**	Sep 2017
AHDB Cereals & Oilseeds funding	**£54,000**	**Total cost**	**£108,000**

What was the challenge/demand for the work?

The overall aim of the studentship was to generate the knowledge to help develop new wheat varieties with high and stable yield across environments. To address this the challenge was to understand specific quantitative trait loci (QTL) on wheat chromosome 5A and 6A which we had shown to affect grain size and yield. The work was done in close coordination with the major breeding companies RAGT, KWS and Limagrain who were working closely with the student to translate her discoveries into commercial breeding programmes.

How did the project address this?

The student used a combination of genetic, physiological and molecular approaches to address the question. The main summary of the work was:

- Using near isogenic lines (NILs) we found that the 5A and 6A QTL act through different mechanisms to increase grain weight. The 5A QTL acts post fertilisation, primarily to increase grain length (4.0%) through increased pericarp cell size. The 5A QTL also has a pleiotropic effect on grain width (1.5%) during late grain development. The 6A QTL acts during very early grain development, perhaps pre-fertilisation, and specifically increases final grain width (2.3%).
- Fine-mapping reduced the QTL mapping intervals and revealed complex underlying genetic architectures. The 6A QTL mapped to a large linkage block in the centromeric region of chromosome 6A containing the known grain size gene, *TaGW2-A*, although we provide evidence to suggest that this is not the causal gene underlying the 6A QTL. Fine-mapping of the 5A QTL suggests that two tightly linked genes with an additive effect on grain length underlie the locus. A haplotype analysis suggests that the 5A QTL is not fixed in UK germplasm.
- The corresponding physical intervals for both the 6A and 5A QTL remain large and contain several hundred genes, making speculation on candidates for the causal genes difficult. A transcriptomics study with the 5A NILs provided insight into the genes and pathways that are differentially regulated and hence may play a role in controlling the differences in grain weight.

What outputs has the project delivered?

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Germplasm and markers:

- The studentship generated new genetic markers which more closely tag the QTL affecting grain size. These have been transferred to breeding companies to help in their marker-assisted selection programmes.
- We have generated new combinations for the 5A and 6A regions and these have been shared with UK breeders within the DFW programme to test how combining both gene can improve yield stability. Our early results suggest that combining both genes leads to more stable yield than either one on its own.
- We have developed advanced germplasm with different mutant alleles of *TaGW2*. These are being tested at the moment and again, we have transferred mutant alleles in the A, B and D genome to UK breeders alongside the associated genetic marker. These are currently being introduced into UK lines by the companies.

Publications:

1) Simmonds J, Scott P, Leverington-Waite M, Turner AS, Brinton J, Korzun V, Snape J, Uauy C. 2014. Identification and independent validation of a stable yield and thousand grain weight QTL on chromosome 6A of hexaploid wheat (*Triticum aestivum* L.) BMC Plant Biology 14:191
2) Simmonds J, Scott P, Brinton J, Mestre TC, Bush M, Del Blanco A, Dubcovsky J, Uauy C. 2016. A splice acceptor site mutation in *TaGW2-A1* increases thousand grain weight in tetraploid and hexaploid wheat through wider and longer grains. Theoretical and Applied Genetics 129:1099-1112
3) Brinton J, Simmonds J, Minter F, Leverington-Waite M, Snape J, Uauy C. 2017. Increased pericarp cell length underlies a major QTL for grain weight in hexaploid wheat. New Phytologist. 215:1026
4) Brinton J, Simmonds J, Uauy C. 2017. Ubiquitin-related genes are differentially expressed in isogenic lines contrasting for pericarp cell size and grain weight in hexaploid wheat. *bioRxiv* doi.org/10.1101/175471

Science communication to general public:

1) NFU Annual General Meeting. Building bigger grains of wheat. Halesworth UK, 2017 (student)
2) ‘Pint of Science’. Norwich UK, 2017 (student)
3) JIC Breeders day. Norwich UK, 2017 (student)
4) Gatbsy Plant Science. Can wheat genomics help alleviate food insecurity? Cambridge, UK 2017
5) Science Meets Faith. Is it ethical to oppose modern plant breeding technologies? Cambridge, UK 2017
6) Women of the Future conference; poster presentation. Norwich, UK (student)

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7) Agricultural Industries Confederation Agribusiness Meeting: A step change in plant breeding to achieve a UK competitive advantage. Peterborough, UK 2016
8) Norwich Science Festival: Pint of Science. Norwich UK, 2016
9) JIC Research Support Staff Science Accessible Meeting: Wheat hidden's potential. Norwich, UK 2016
10) Fascination of plants day. Norwich UK, 2015
11) CropTec: Emerging trends and technologies in crop science. Peterborough, UK 2014
12) Technical Seminar at Cereals: 20:20 Wheat - a reality or a pipe dream? Boothby Graffoe, UK 2014
13) NRP event at Cereals: Collaborating to revolutionise UK wheat. Boothby Graffoe, UK 2014
14) Farming Futures: Emerging trends and technologies in crop science. Meriden, UK 2014

Scientific conference presentations:

1) Italian Society of Genetics (SIGA) and Plant Biology (SIBV) Joint meeting. Pisa, Italy 2017
2) Monogram Meeting, Bristol, UK 2017 (student)
3) University of Aarhus, Denmark 2017
4) Plant and Animal Genome Conference. San Diego, USA 2017 (student)
5) GarNet Natural Variation Meeting, Cambridge, 2016
6) University of Bologna, Bologna, Italy 2016
7) University of Potsdam, Potsdam, Germany 2016
8) University of Nottingham, Nottingham, UK, 2016
9) University of Liverpool, Liverpool, UK 2016.
10) GarNet Annual meeting, Cardiff, UK 2016
11) Gatbsy Summer School, York, UK. 2016
12) Association of Applied Biologists. Harpenden, UK 2016
13) Plant and Animal Genome Conference. San Diego, USA 2016
14) Cold Spring Harbor Laboratory. Cold Spring Harbor, US 2015
15) International Wheat Conference. Sydney, Australia 2015
16) Monogram meeting, Rothamstead Research, UK 2015 (student)
17) Australian Center for Plants and Functional Genomics. Adelaide, Australia 2015
18) EPSO-EC Conference at EXPO Milano. Milan, Italy 2015
19) Leeds University (Centre for Plant Sciences). Leeds, UK. 2015
20) University of Lund. Lund, Sweden 2015
21) Rank Prize Meeting. Grasmere, UK 2015
22) University of Exeter. Exeter, UK 2015

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23) Limagrain/Biogemma. Clermont-Ferrand, France 2015
24) Instituto de Biología Molecular y Celular de Plantas (CSIC-UPV). Valencia, Spain 2015
25) University College Dublin. Dublin, Ireland 2015
26) Norwich-Cambridge Student Symposium, Cambridge, UK, 2014 (student)
27) Max Planck Institute of Plant Breeding (NIBB-TLL-MPIPZ meeting). Cologne, Germany 2014
28) Institute of Experimental Botany. Olomouc, Czech Republic 2014
29) Society of Experimental Biology. Manchester, UK 2014
30) CNRGV-Genomes Day. Toulouse, France 2014
31) 2nd Plant Genomics Congress. London, UK 2014

Who will benefit from this project and why?

- **Crop geneticists**: fellow academics working on yield and the genetics of grain size and shape have benefitted from the germplasm developed in the project and from the outcomes of the research which have been all published in open access journals.
- **Breeders**: the ability to have genetic markers to select for larger grains and improved yield is of importance to breeders and to the overall wheat farming industry. Being able to select at early stages for enhanced grain size and shape will allow more efficient selection in the breeding process and we hope this will lead to increased yield gains in time. The interaction of the two genes provides a route for yield stability with genetics and this is now being investigated in more detail. The breeders have had access to all the germplasm, markers and information along the PhD so they have started breeding and benefiting from this information from day 1 of the PhD.
- **Farmers**: the ability of farmers to access and grow improved varieties with stable and enhanced on farm yield will boost their competitiveness and should translate into improved farmer income. They will be able to access these benefits in the form of improved varieties which will be bred more efficiently by breeders as outlined above. The enhanced grain size genes improve the complete distribution of grain sizes. This upward shift in the proportion of small grains will benefit farmers by avoiding “back of combine” grain loss due to small grains.
- **Millers**: the regions result in wider and slightly longer grains which translate into higher TKW. We are currently examining their effects on specific weights and flour extraction rates to inform millers of potential benefits associated with these regions.
- **General Public**: having access to home-grown wheat is a perceived benefit for many consumers. Improved varieties that can maintain and enhance yield under changing climatic conditions will secure UK-sourced wheat for millers and consumers. The training of the PhD

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student in crop genetics is also a benefit to society at large. The exact means by which the student will benefit society could be varied, but it will be up to the student to decide how they will make an impact and contribution to wider society. • **Environment**: higher yielding varieties without necessarily higher inputs (all our trials to date are done in randomized fields with conventional fertilization regimes) will benefit the environment by allowing for higher on farm yields and reducing pressure to expand cultivated surface.

If the challenge has not been specifically met, state why and how this could be overcome

How have you benefited from this studentship?
This studentship has allowed me to learn and develop essential scientific skills in genetics and molecular biology, bioinformatics and field trials. In addition, I have had the opportunity to present my research internationally and to discuss my work with a wide range of people including researchers, breeders, farmers, other industry representatives and the general public. The annual AHDB student symposiums and industry visits have provided invaluable insights into the potential applications of research. In the future, I plan to pursue a career in scientific research, ideally focussing on understanding the mechanisms controlling final yield in wheat. Currently, I am undertaking a postdoctoral position that will build on outcomes of this PhD research project.

Lead partner	Cristobal Uauy, John Innes Centre
Scientific partners	
Industry partners	
Government sponsor	

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