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SID 5 Research Project Final Report

- **Note**
  In line with the Freedom of Information Act 2000, Defra aims to place the results of its completed research projects in the public domain wherever possible. The SID 5 (Research Project Final Report) is designed to capture the information on the results and outputs of Defra-funded research in a format that is easily publishable through the Defra website. A SID 5 must be completed for all projects.
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Project identification

1. Defra Project code: AR0709
2. Project title: Defra - Wheat Genetic Improvement Network - WGIN
3. Contractor organisation(s): Rothamsted Research, Harpenden, Herts, AL5 2JQ
4. Total Defra project costs (agreed fixed price): £ 1,850,539
5. Project: start date ..... 01 July 2003
   end date ..... 01 November 2008

6. It is Defra's intention to publish this form.
Please confirm your agreement to do so.....**YES** ☒ **NO** ☐

(a) When preparing SID 5s contractors should bear in mind that Defra intends that they be made public. They should be written in a clear and concise manner and represent a full account of the research project which someone not closely associated with the project can follow.

Defra recognises that in a small minority of cases there may be information, such as intellectual property or commercially confidential data, used in or generated by the research project, which should not be disclosed. In these cases, such information should be detailed in a separate annex (not to be published) so that the SID 5 can be placed in the public domain. Where it is impossible to complete the Final Report without including references to any sensitive or confidential data, the information should be included and section (b) completed. NB: only in exceptional circumstances will Defra expect contractors to give a "No" answer.

In all cases, reasons for withholding information must be fully in line with exemptions under the Environmental Information Regulations or the Freedom of Information Act 2000.

(b) If you have answered NO, please explain why the Final report should not be released into public domain

Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

Defra is facing an ever expanding range of environmental, energy and climate change challenges. The wheat genetic improvement project (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 public funded plant and crop research. There was also general acknowledgement that the LINK funding mechanism was failing to connect the two because only limited funds were available from the commercial sector. The Caligari report in 2002 (ST0158) (2002) highlighted both these concerns and prompted a call by Defra in July 2002 for the creation of a series of genetic improvement networks to be established for each of the key UK field crops.

Since the WGIN project started in 2003, both the Stern report and a recent Defra-commissioned review (IF0101) highlighted in a costs-benefit comparison that in terms of input investment *vs* output, plant genetic research which targeted the development of new varieties with public good outcomes significantly outperform other research activities. An acknowledged major advantage of this research approach compared to others was that the benefits of genetic improvement are permanent and cumulative. Accrued public good benefits from crop breeding and the use of new, improved varieties by farmers would include a reduction in greenhouse gases and in energy use (climate change mitigation), improved water quality in nitrogen vulnerable zones and improved biodiversity within the cropping landscape. Wheat is the UK's No1 crop and about 1.8m ha of land is required to be used to generate a total annual production of about 15.5m tonnes. Therefore improvements to the wheat crop are likely to be particularly advantageous.

The WGIN project had two funded research partners, the John Innes Centre and Rothamsted Research. There were two overall project aims. The scientific aim was to generate pre-breeding material carrying novel traits to the UK breeding companies and to deliver accessible technologies thereby ensuring the means are available to produce new, improved varieties. Therefore an integrated scientific 'core' evolved which combines underpinning molecular markers, genetic and genomic research, together with novel trait identification. These genetic and molecular resources and new trait information were made freely available and could therefore be used in a wide range of additional wheat research projects in the UK. The second

and equally important WGIN project aim was to reactive a thriving UK wheat network which encompassed all the key UK research groups in both the public and private sectors and to facilitate the connection of this UK network to the international wheat community.

Over the 5 years a robust network was established and maintained. The eighteen Management meetings held over the project duration at rotating locations have brought together wheat scientists and breeders. Their style was somewhat different from the management meeting of the other GINs because they focused not only on presenting and discussing the WGIN project research results but also invited presentations by others on relevant wheat projects, emerging technologies, newly funded wheat projects and those wishing to raise awareness of new research topics. The six annual Stakeholder meetings (held each November) were also well attended (75-100 participants). These often had specific themes like energy production, food and feed quality traits, efficient utilisation of inputs and in last two years a section focussing on the economic value of the wheat crop and future predictions on global outputs. All the presentations given at both the Management and Stakeholders meetings are freely available via the WGIN website (http://www.WGIN.org.uk). Over the project duration, the stakeholder membership has increased steadily from about 60 and is currently 131. Members include wheat breeders, farmers, agronomists, food and feed processors, members of HGCA and defra and researchers in the UK and overseas. Nine WGIN newsletters have been produced and distributed to the stakeholder membership as well as posted on the WGIN website. There have been three farm tours, two at JIC and one at RRes, providing opportunities to view WGIN field trials. These trials have also featured in the annual Rothamsted Research Association and John Innes Friends research day visits. International links have been strengthened as a result of joint workshops with CIMMYT (Dec 2004 and June 2007), INRA France (April 2005), and CAAS China (Dec 2007). Several WGIN research demonstration plots were presented at Cereals 2006, Cereals 2007 and Cereals 2008. These illustrated the genetic diversity in key new traits either identified or generated within the project. They also demonstrated their value to modern agriculture, in terms of environment protection, reduction of energy costs and improving crop resilience to the potential effects of climate change.

As a result of the sustained networking activities as well as WGIN datasets available ahead of publication via the WGIN website, numerous new wheat genetic improvement projects have been funded which involve either joint public-industry funding or public only funded projects. Those funded by early 2008 were summarised in the May 2008 Stakeholders Newsletter and since then two additional projects have been funded.

There have been several key research highlights from the core WGIN project

1. The mutagenesis of two different hexaploid wheat genotypes has lead to the identification of useful variation in key traits of interest to the breeders including stay green and white grain..
2. The Avalon x Cadenza DH mapping populations is now well covered with various types of molecular markers and is used in numerous publically funded trait projects.
3. The development of a core set of conserved orthologous set (COS) markers. Maintenance of key germplasm collections, The AE Watkins Collection, Gediflux collection, precise genetic stocks, and new resources such as Paragon deletion lines generated by gamma ray mutagenesis.
4. Variation for nitrogen use efficiency parameters (typically > 10-20%) has been identified amongst modern commercial wheats, although these have been bred to perform under high N inputs. Season to season stability for yield and NUE parameters has been assessed in the commercial wheat varieties.
5. In total, 39 wheat varieties have been ranked for yield, grain N, N-uptake ability and N-utilization efficiency, in 5 years of trials.
6. The establishment of a TILLING platform based on Cel1 digestion of DNA heteroduplexes has allowed us to generate novel alleles for a number of candidate genes that underpin key traits such as plant height, grain quality and starch biosynthesis. These new alleles are being assessed within research programmes in the UK and Europe. A novel mutation detection strategy based on high resolution melt analysis was also conceived, and a number of individuals were trained in one or more detection methods.

7. The diploid einkorn wheat *T. monococcum* has proven to be an excellent source of novel resistance to three key UK fungal disease, namely Septoria tritici leaf blotch, take-all on the roots and eyespot on the stem base. Through WGIN breeding methods to introgress traits from distantly related wheat species have been successfully re-established in the UK.
8. Taking advantage of the 5 years of diversity trials used for the nitrogen use efficiency project, several modern wheats have been identifies which consistently lower take-all inoculum build up in a 1st wheat situation. This should provide a new control strategy to be devised based on variety rotation which will help to minimise the risk of severe take-all occurring in the following 2nd wheat crop.

So far five publications have appeared in international peer reviewed publications, a further three have been submitted for publication and several others are at the late stage of preparation or are at the planning stage. For many of the traits, between 3 and 5 years of data were required to establish that either genotype differences really did exist and then to explore the genetic basis of this variation. There have been 24 significant invited oral presentations of WGIN research results in the UK and elsewhere.

During the 21st century we will enter, what may become known as the 'post-fossil-fuel' era. The WGIN core projects, many of which will continue within the project's renewal, should help to alleviate the energy thirstiness and environmental impact of the UK wheat crop. However, key hurdles remain which currently prevent commercial implementation of much of this new research. For example, the existing national and recommended trials are only done under high input regimes. For Defra to achieve its key environmental, energy and climate change targets whilst maintaining food security, a new way forward to evaluate and secure tested elite germplasm fit for these public good purposes must be sort.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:
   - the scientific objectives as set out in the contract;
   - the extent to which the objectives set out in the contract have been met;
   - details of methods used and the results obtained, including statistical analysis (if appropriate);
   - a discussion of the results and their reliability;
   - the main implications of the findings;
   - possible future work; and
   - any action resulting from the research (e.g. IP, Knowledge Transfer).

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

Peer Reviewed:
Kanyuka, K., Lovell, D., Mitrofanova, O., **Hammond-Kosack, K.E.** and M. J. Adams, M.J. (2004) A controlled environment test for resistance to soil-borne cereal mosaic virus (SBCMV) and its use to determine the mode of inheritance of resistance in wheat cv. Cadenza and screening *Triticum monococcum* genotypes for sources of SBCMV resistance. Plant Pathology **53**, 154-160.
Weblink: http://www.ingentaconnect.com/content/bsc/ppath/2004/00000053/00000002/art00005?crawler=true

Hayden M J, Stephenson P, Logojan A M, Khatkar D, Rogers C, Elsden J, **Koebner R M D**, **Snape J W** and Sharp P J (2006). Development and genetic mapping of sequence tagged microsatellites (STMs) in bread wheat (Triticum aestivum L). Theoretical and Applied Genetics
Weblink: http://www.ingentaconnect.com/content/klu/122/2006/00000113/00000007/00000381

Hai-Chun Jing, Dimitry Kornyukhin, Kostya Kanyuka, Simon Orford, Anastasiya Zlatska, Olga P. Mitrofanova, Robert Koebner, Kim Hammond-Kosack. Identification of variation in adaptively important traits and genome-wide analysis of trait-marker associations in Triticum monococcum. Journal of Experimental Botany 58 (2007), pp. 3749-3764.
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Nadia Al-Kaff, Emilie Knight, Isabelle Bertin, Tracie Foote, Nicola Hart, Simon Griffiths and Graham Moore. Detailed dissection of the chromosomal region containing the Ph1 locus in wheat Triticum aestivum: with deletion mutants and expression profiling, Annals of Botany 2008 101(6):863-872
Weblink: http://aob.oxfordjournals.org/cgi/content/abstract/101/6/863

Jing HC, Lovell D, Gutteridge R, Jenk D., Kornyukhin D, Mitrofanova OP, Kema G, Hammond-Kosack KE (2008) Phenotypic and genetic analysis of the *Triticum monococcum - Mycosphaerella graminicola* interaction. New Phytologist 179, 1121-1132
Weblink: http://www3.interscience.wiley.com/journal/119880304/abstract?CRETRY=1&SRETRY=0

Submitted to peer review awaiting comments:

Simon Griffiths, James Simmonds, **Michelle Leverington**,Yingkun Wang, Lesley Fish, Liz Sayers, **Leodie Alibert, Simon Orford**, Laurence Herry, Sebastien Faure, David Laurie, Lorelei Bilham, **John Snape**. Meta-QTL analysis of the genetic control of ear emergence inelite European winter wheat germplasm. Theoretical and Applied Genetics. Accepted subject to corrections.

Parry MAJ, Madgwick PJ, **Bayon C, Tearall K**, Hernandez-Lopez A, Baudo M, Rakszegi M, Hamada W, Al-Yassin A, Ouabbou H, Labihili M and **Phillips AL**. Mutation discovery for crop improvement. Submitted to J. Exp. Bot.
Hai-Chun Jing, Carlos Bayon, Kostya Kanyuka, Simon Berry, Peter Wenzl, Eric Hunter, Andrzej Kilian, **Kim Hammond-Kosack** (2009) DArT markers: diversity analyses, genomes comparison, mapping and integration with SSR markers in *Triticum monococcum*. (submitted to *BMC Genomics*)

Bernhard J. Hofinger**, Hai-Chun Jing**, **Kim E. Hammond-Kosack**, Kostya Kanyuka High-resolution melting analysis of cDNA-derived PCR amplicons for rapid and cost-effective identification of novel alleles of eukaryotic translation initiation factor 4E (eIF4E) gene in barley. (Submitted to *TAG).*

Hai-Chun Jing, Jason J Rudd, and **Kim Hammond-Kosack (**2009) Genetic and biochemical evidence from *Triticum monococcum* reveals that HR-independent isolate-specific resistance to *Mycosphaerella graminicola* in wheat is an ancient conserved mechanism. (To be submitted)

Non-Peer reviewed:

Jing, H.C., Lovell, D., Kornyukhin, D., Kanyuka, **K., Tearall, K., Phillips, A., Orford, S., Koebner, R**., Mitrofanova, O.P. and **Hammond-Kosack, K.E.** (2005). New approaches for durable disease resistance in wheat. BCPC International Congress & Exhibition–Crop Science & Technology, 963-970

Popular press articles:

Anon (2005) Wheat Improvement at Rothamsted pp4. Occasional article

BBSRC business news article Spring 2005 - **John Snape**

Take-all and the Wheat Genetic Improvement Network (WGIN), RRA newsletter, issue 27, June 2008

Triticum monococcum, an ancient relative of wheat, is a rich source of resistance to Septoria tritici blotch disease by **Hai-chun Jing, Richard Gutteridge** and **Kim Hammond-Kosack**, RRA newsletter, issue 27, June 2008

Article on **Malcolm Hawkesford's** NUE research in Farmers Weekly, 20 June 2008: Scientists seeking to reduce crops' reliance on nitrogen inputs by 20%

Reinventing Wheat, The Furrow, Spring 2008: paragraph on **Malcolm Hawkesford's** NUE research

Threat might rise with more second wheats, Farmers Weekly, 21st March 2008. Article on **Richard Gutteridge's** work on Take All.

Take-All poses significant threat to second wheats, Farmers Guardian, 21st March 2008.
This article mentions WGIN take-all research.