Final Project Summary

Project title	Adaptive winter wheat populations: development, genetic characterisation and application		
Project number	RD-2007-3378	**Final Project Report**	PR558
Start date	April 2008	**End date**	September 2012
AHDB Cereals & Oilseeds funding	£11,468 (in-kind)	**Total cost**	£1,420,962

What was the challenge/demand for the work?

Conventional UK wheat crops are composed of monocultures of individual varieties selected for production under high inputs. Consequently, when grown under low input conditions such varieties have considerable yield and quality shortfalls (4 to 5 t/ha modal range). This reduced productivity is the result of the interaction between varieties that have not been selected for production under low-input conditions, and the field environments that are often highly variable in the absence of a range of inputs, especially under rapidly changing climatic conditions. New research was required to use genetic variability of the wheat crop to help buffer such environmental variation.

How did the project address this?

Genetic variability could be achieved by a massive increase in the number of varieties grown in monoculture. However, this would require a major investment by breeders with no equivalent return, the material would be unable to adapt to future change, and there would be no interaction among the varieties. The alternative is to grow plant genotypes together so that they can complement and compensate for each other under different environments. The simplest approach is to use mixtures of varieties but the potential for genotypic interactions is limited because of the relatively small number of mixture components. A more complex, but potentially more robust and resilient solution is to use CCP (Composite Cross Population) as in the 'evolutionary breeding'.

Evolutionary breeding using CCP involves inter-crossing appropriate parents in many different bi-parental and higher order combinations. The segregating progenies from the crosses are bulked and then exposed to natural selection in the localities in which they are to be grown. Large amounts of genetic variation are exposed to different localities over several years of natural selection and seed multiplication, thus expanding the genetic variation while limiting the effect of the environmental variation. Some degree of mass selection, positive or negative, can be applied to guide the natural selection, but the end result should be populations that adapt to localities while retaining genetic variation and hence adaptability for further change.

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This is a potential approach for generating wheat crops which perform stably under a wider range of climatic conditions, not only in terms of their yield but also in terms of their quality, while allowing a major reduction in synthetic inputs. Because of the buffering and compensation effects within a CCP, they are predicted to show increased stability in comparison to genetically uniform monocultures. The agronomic capabilities of the three CCP which are the focus of this current study, have previously been established and they have been shown in field trials to perform better than the means of their individual parent varieties for a range of characters including grain yield.

What outputs has the project delivered?

A number of conclusions on CCP have emerged from this research project:

1) Replicated field trials showed that the CCP had a reduced grain yield in comparison to currently used pure lines under conditions of high input, while yield differences were not significant under organic cropping conditions. This means that CCP are potentially more suitable to low-input and organic than to conventional systems.

2) The three different populations were tested to investigate their potential end uses: A high yield population (YCCP), a high baking quality population (QCCP) and an all-rounder population (YQCCP). On the basis of various agronomic and quality performance indicators, as well as marketability to end-users, the QCCP is seen as the most promising population among the three tested populations.

3) The CCP showed increased yield stability in comparison to pure lines in replicated field trials, but on-farm participatory trials across the UK could not confirm this result.

4) The CCP did not adapt to the cropping conditions under which they were grown; this was evident both from molecular data and from comprehensive field trials. Yearly fluctuations in weather conditions are likely to have counteracted any adaptation to the site-specific factor associated with cropping management and soil conditions.

5) Field trials showed that both CCP and (complex) variety mixtures are more or less equivalent with regard to their agronomic performance. Preference for either CCP or mixtures is therefore likely to follow other criteria than those based purely on agronomic performance.

Who will benefit from this project and why?

Beneficial for the industry: The indication from the narrative comments received from the bakers involved in the project was that the CCP are capable of producing bread-making flours of a commercially acceptable standard, and that in unblended flours, site effects were particularly strong on various quality parameters. The bakers found that the CCP flours produced loaves with a range of

colour and texture characteristics, with site-related environmental, crop management and storage factors, including grain moisture, Hagberg falling number (HFN) and protein content being identified as more important for quality than the within-crop genetic diversity. There is a strong indication from the results of this study are that the populations can produce dough with gluten properties that meet industry standards and produce loaves which rise as well as those from commercial flours. Overall, flours from the CCP were not consistently worse than commercial alternatives as bread making material.

In distilling tests the alcohol yield of the grain tested was not significantly affected by crop management system or growing site. In fact, the only factor that had an impact on the alcohol yield was the population type, with the YCCP giving a higher yield than the YQCCP, which may be due to the higher nitrogen levels in the YQCCP.

Uses in animal feed: In tests of the CCP's suitability as animal feed, the frequency of the 1R chromosome decreased in advanced generations of both the YCCP and YQCCP compared to the starting frequencies, and this could be observed as continuing in the majority of the populations from the F_7 to F_8. This suggested strong selection against this chromosome segment. In the YQCCP samples, the frequency of the 1R arm was usually less than 10% of the seed. At this frequency, the arm is unlikely to impart any significant detrimental effect on quality due to the dilution effect of the 1BS arm. Therefore, these results suggest that the use of the seed of the YQCCP for bread making and the YCCP for animal feed will not be impaired by the low frequency of the rye genes.

If the challenge has not been specifically met, state why and how this could be overcome
Wheat varieties are needed that can cope with multiple, and (increasingly) variable stresses. While evolutionary plant breeding offers a potential solution, as genetic diversity within the crop populations buffers against such stresses, it is currently unknown how much, at what spatial level, and what kind of diversity is needed in relation to specialist approaches (such as varietal drought resistance), for building resilient cropping systems that can withstand multiple and variable stresses. One approach is the use of evolutionary plant breeding to increase the tolerance of variability through exposure of genetically diverse populations to highly variable conditions.

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