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Adaptive winter wheat populations: development, genetic characterisation and application

The aim of this project is firstly to determine the yield, quality, and stability of wheat Composite Cross Populations (CCPs) under high and low input management over a wide range of environmental conditions through phenotypic monitoring and analyses; secondly, to analyse genotypic changes using molecular markers which will help to determine the relative importance of different genotypes, gene complexes and genes for phenotypic performance and adaptation; and thirdly to develop the application, processing and marketing capabilities of the CCPs for a range of end users.

Project code: Wheat Breeding LINK

Project leader: The Organic Research Centre – Elm Farm

Project partners:

Research
The Organic Research Centre - Elm Farm (ORC)
John Innes Centre (JIC).

Industry
Bread Matters Ltd,
CPB Twyford Ltd,
Crisp Malting Group Ltd,
Dove Farm Foods Ltd,
East Haydon Farm,

Farmeco Ltd,
HGCA Ltd,
LEAF Ltd,
Letheringsett Watermill,
New Houses Farm,
Nickerson-Advanta (UK) Ltd,
Norton Organic Grain Ltd.,
North Elmham Bakery,
Organic Arable Marketing Company Ltd,
Organic Farmers & Growers Ltd,
Progressive Farming Trust Ltd,
RAGT Seeds Ltd,
Rushall Farms,
Shipton Mill Ltd,
Soil Association Certification Ltd,
Soil Association Ltd,
The Arable Group,
W & H Marriage & Sons Ltd,
Wakelyns Agroforestry

Start date: April 2008

End date: October 2012

Funder: Sustainable arable LINK project (Defra)

EFRC Programme: Cereals

Project aim:
The overall aim of the project is to improve the performance and stability of performance of winter wheat under environmental conditions that are forecast to become more unpredictable and more costly to ameliorate through inputs. This will be achieved by determining the performance and stability of performance of wheat Composite Cross Populations (CCPs) over a wide range of environmental conditions and relating this to phenotypic and genotypic analyses. This aim includes determination of the application, processing and marketing capabilities of the CCPs for end users.

Abstract of research:
The major advantage of using wheat CCPs or mixtures is to buffer crop production against increasing environmental variation while allowing a major reduction in synthetic inputs. Initial indications are encouraging in these directions, but the number of environments to which the material has been exposed is limited. More field trials and observations are needed to:

i) increase the range of environmental exposure in space, time and management system;
ii) increase the numbers of generations of selection across all environments; and
iii) expand farmer experience of using CCPs and mixtures.

Although it is expected that CCPs will be more effective than mixtures as the range of environments is increased, because of the greater diversity of plant phenotypes, we

have not yet found an obvious difference. A supplementary question is whether increased diversity can lead to local site adaptation.

This initiation of the use of evolutionary breeding in wheat in the UK includes selection for improved performance in low-input conditions which is not practised in current breeding programmes. Apart from the absolute numbers of components or parents, it is likely that some individual varieties may contribute more, or less, than others to the performance of CCPs or of mixtures. We therefore need more information on the contributions of different genotypes, and indeed specific major genes and chromosomes, to overall performance over time. The performance of the CCPs in a range of different environments will provide insights into the evolution of the genomes in wheat and the relationship with phenotypic expression.

If CCPs or mixtures are to be used in practice, then we also need more information on the value of the crop for different end-uses.

Finally, use of CCPs in practice would require the development and institution of an appropriate legislative system together with systems for seed production, distribution and storage. Variety mixtures and out-crossing crops are already catered for in existing EU legislation; the model for rye and rye-grass could be a suitable model for further development of the CCP legislative system. Alternatively, closed loop systems could be developed which would avoid this need and lead to new market opportunities for local food systems.

Objectives:

1. Quantify the yield, quality and stability of performance of CCPs over the four project years at four main trial sites.

2. Determine the types and extent of genotypic evolution in the adaptation of CCPs to region, management and year.

3. Estimate the relationship between genetic and phenotypic contributions of individual parent varieties to YQ CCPs selected under different regional and management conditions.

4. Estimate the extent to which disease restriction in mixtures and CCPs differ from each other and contribute to yield stability.

5. Determine the performance and stability of performance of CCPs among 24 farms across a range of climatic conditions relative to the variety Claire and the standard farm variety, in all project years.

6. Compare the performance of the CCPs with or without either Pegassos or Xi 19 as extra parents, at four main sites, in project year 4.

7. Determine the effect of mass selection on CCPs.

8. Determine the bread-making quality of flour from the CCPs.

9. Determine the acceptability of CCPs for use in malting, distilling and animal feed.

Expected benefits:

Industry

- Increased economic returns from high and stable yield and quality over diverse environments.
- Decreased cereal production costs from reduced agrochemical inputs (whilst maintaining yield and quality).
- Potential reduction of greenhouse gas emissions, e.g. by reducing inputs and by improved fermentation efficiency of grain production to be used for biofuels.
- Marketing 'edge' for small scale producers, organic, low input or non-organic from locally adapted CCPs.
- Unique products will support local food supply networks.

Science

- Evaluation of the scale and direction of genetic changes in CCPs in response to natural selection under different farming practices and at different locations.
- Improved understanding of the relationship between genotype and phenotype in evolutionary breeding.
- Demonstration and comparison of the level and stability of performance of CCPs compared with varieties and evolving variety mixtures across different systems and locations.
- An understanding of the value of CCPs for industrial and small-scale baking, malting, distilling and feed use.
- A source of novel genetic material for pure line breeding development.

Environment

- Potential improvement in nutrient scavenging ability, leading to a reduction in nitrate leaching (Water Framework Directive).
- Increased biomass from improved crop performance, which has benefits for soil fertility, and reduced erosion (Soils Framework Directive).
- Reduced biocide use through increased crop resistance against pests, diseases and weeds which has consequent benefits for farmland biodiversity.
- Potential reduction of greenhouse gas emissions through improved fermentation efficiency of grain production to be used for biofuels and reduced use of oil (inputs and vehicle use).

Outputs:

Throughout the project duration, the farming industry will receive research outputs at regional meetings, in articles from collaborative partners, and at open days held by ORC, and other partners. Output from the bakeries will enable informal taste-tests to be carried out with the general public, to further disseminate project results.