

Media Briefing

Crop science – exploiting genetics for better crops

The UK is a world leader in plant science research, but the challenge is to apply this knowledge to the benefit of industry and society. The strategic importance of crop science was highlighted in a 2003 BBSRC review, which emphasised how the advances in UK crop research needed to be applied to a greater extent in plant breeding and agriculture. As a result of this review, BBSRC has now funded 18 projects through a £13.3M crop science initiative to turn ideas from basic plant research into practical applications for crop breeders.

The aim of the initiative is to apply principles of sustainable development to future crop production, using the potential of biotechnology to sustain crop yields, and extend the range of products while reducing negative environmental impacts of agriculture.

Potential benefits for farmers, growers and breeders include:

Improved shelf life for broccoli. A Warwick HRI project, receiving almost half a million pounds, aims to identify genes involved in broccoli quality to enable production of broccoli varieties with improved shelf life.

More starch variety for improved bread and beer. Scientists at the John Innes Centre and NIAB will collect and assess wheat and barley varieties from around the world, developing a greater variety of starch for the improvement of a range of products. The project has received over £1.3M of funding.

Enhancing wheat resistance to insect pest. Researchers at the Universities of Durham and Newcastle and the Central Science Laboratory have received almost £750,000 to investigate wheat plants' genes for self defence against wheat bulb fly and cereal aphids. They will study how the insects tolerate defence strategies, and develop new strategies for environmentally-friendly insecticide.



Improving willow biomass yields for bioenergy. The project will investigate the regulation of coppicing in willow to improve the biomass yield from willows. The research at the University of York and Rothamsted Research has received almost £1M of funding.

Identifying genes for predictable seedling growth. Researchers at the Warwick HRI aim to identify genes which influence seed vigour and how they regulate germination.

Controlling wheat's defence against aphids. The aim of this Rothamsted Research project is to develop means to switch on the production of wheat plants' natural defence compounds against aphids only when necessary, conserving the plant's energy and reducing the development of pest resistance.

MAPPING AND ANALYSIS OF BROCCOLI GENES

Broccoli is a popular vegetable, widely consumed for its perceived health benefits. Rapid yellowing and loss of nutrients and flavour in broccoli and other green leafy vegetables after harvesting causes problems to suppliers and consumers.

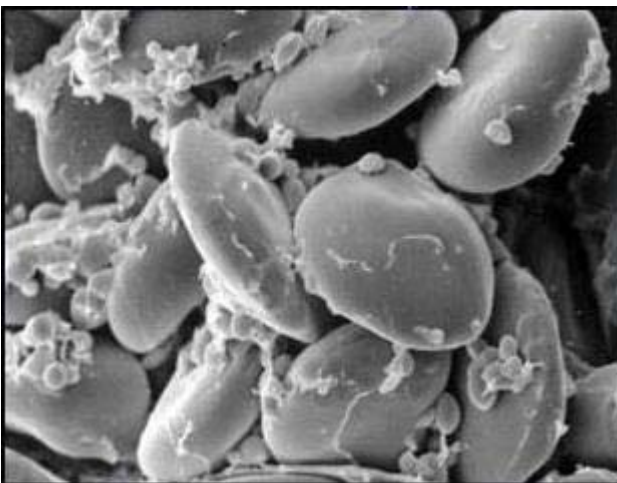
This project will exploit a unique broccoli mapping population that shows a wide variation in several quality traits to identify genetic markers linked to beneficial traits. These findings will be utilised by Syngenta plant breeders who are partners in the project. The molecular component of the genetic variation in shelf life will be characterised by gene expression and metabolome analysis. In addition, levels of key nutrients such as vitamins, flavonoids and glucosinolates will be assessed both at harvest and following storage. Identification of genes involved in quality and their positions in the chromosome will enable production of broccoli varieties with improved shelf and fridge life.

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NEW VARIETIES OF WHEAT AND BARLEY FOR BETTER BREAD, BEER AND BIODEGRADABLE BAGS



Barley

The Smart Carbohydrate Centre will produce varieties of wheat and barley that contain new, improved types of starch. Starch is the main component of flour and malt. The type of starch in these products affects the quality of bread and beer and the cost of bioethanol production. Pure starch from flour is used in

processed foods, paint, glue, paper, cosmetics, and biodegradable packing and plastic. Each of these uses ideally needs a different type of starch.

At present, UK varieties of wheat and barley all have rather similar types of starch. The researchers will collect and study varieties from around the world that have different types of starch, then consult a panel of experts – including breeders, millers, bakers and nutritionists – to decide which of these will be useful. With this information, we can start to breed new varieties that will benefit industries using flour, malt and starch, and also farmers, crop breeders and consumers.

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ENHANCING RESISTANCE TO WHEAT INSECT PESTS

Two of the major insect pests of wheat in the UK are wheat bulb fly and cereal aphids. Spraying with pesticides is inefficient, costly, and environmentally undesirable, and damage by bulb fly larvae is often done before the farmer has realised the problem. In addition, climate change is extending the range and severity of attacks by these insect pests in the UK.

The research programme will investigate three areas: first, how wheat plants defend themselves, to identify defence genes for wheat breeding programmes; secondly, how wheat bulb fly and cereal aphids overcome plant defence strategies, to find ways of countering this adaptation; and thirdly, developing novel strategies for producing environmentally-friendly insecticides, based on blocking the uptake of sugars or amino acids from the insect gut, or using orally-delivered fusion proteins containing insect-specific toxins and a binding/transport domain.

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BRANCHING OUT TO HELP OUR FUEL SUPPLY

Over three-quarters of UK energy is derived from fossil fuels. However, the associated emission of greenhouse gases is causing global warming and fossil fuel supplies are reducing. Renewable sources of energy which are associated with minimal net release of greenhouse gases are urgently needed. Biomass crops are perennial, fast growing species that rapidly accumulate combustible material (e.g. stems) which can be burnt for heat or electricity or converted to liquid transport fuels. Greenhouse gas

emissions are minimal and few chemical inputs are required for growth. Willows are among the main UK biomass crops and are harvested every three years in coppicing cycles.

The researchers will take advantage of the advanced knowledge on branching control in the model plant *Arabidopsis* to investigate the regulation of coppicing in willow. The project is linked to a willow breeding programme and the overall goal is to facilitate the selection of improved biomass willows in breeding.



(A) *Arabidopsis* wild type (left) and max mutant (right) with increased branching. This collaborative project will investigate the role of MAX genes in willow (B-C) to understand the control of shoot number, which is related to shoot thickness and biomass yield. Examples show: (B) willow with few thick stems and (C) more, thinner stems.

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FINDING GENES FOR VIGOROUS SEEDS

Predictable seedling establishment is essential for crop production to be resource efficient and cost effective, and therefore critically important for farmers. Successful seedling establishment is dependent on high seed 'vigour', but despite improvements by seed producers over the years this aspect of seed quality remains elusive.

Earlier research with Brassica crops at Warwick HRI has shown that there is an important genetic basis to seed vigour. In this new project, the researchers will examine these genetic differences and aim to identify genes which influence seed vigour. The research will provide insight into how these genes regulate germination, and through partnership with the major seed producer Syngenta exploit the findings in commercial breeding programmes.

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USING WHEAT'S CHEMICAL DEFENCE AGAINST APHIDS

Wheat is an important agricultural crop in the UK. Aphids can reduce grain quality and wheat yield by direct feeding and transmission of diseases. The project will exploit plants' chemical defence against pests to develop alternative, more environmentally friendly pest resistance strategies for cereal crop plants.

The researchers will study hydroxamic acids, a family of compounds produced in wheat and some other cereals that defend plants against pests, and exploit ways of increasing production in the wheat by investigating the action of other natural plant chemicals, called plant activators. The aim is to develop means to switch on the production of the plant's natural defence compounds only when necessary, thereby conserving the plant's energy and reducing the development of pest resistance.

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SUSTAINABLE METHODS TO CONTROL DEVASTATING PARASITIC NEMATODES

Plant parasitic nematodes cause estimated annual losses to global agriculture of \$125bn. Potato cyst nematode costs the UK potato industry an estimated £50M per year. Control often depends on nematicides that are both harmful to the environment and possibly human health. They are often essential for economic potato cropping in the UK.

The new technology to be used in this work can control plant parasitic nematodes without harming the environment. The technology overcomes many concerns associated with producing novel proteins in the plant for protection. The technology will express a small number of dsRNA molecules in the potato plant to silence particular genes of the parasitising

nematodes. This will prevent the establishment of the pathogenic interaction with the plant.

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GENETIC RESISTANCE TO STRAWBERRY WILT DISEASE



Fragaria vesca, wild woodland strawberry

Strawberry wilt is a serious fungal disease that is widespread in the UK. In the past it has been controlled by soil sterilisation using methyl bromide, but this is an ozone depleter which was banned in 2006.

In this project the native British wild strawberry will be used as a model to study the genetics of resistance to wilt at the DNA level. Work on the model species will lead to the identification of genes that are responsible for resistance in the cultivated strawberry. DNA markers for resistance will then be developed that can be used by strawberry breeders to produce new varieties that have strong and stable resistance to wilt. This will greatly assist the long term sustainability of strawberry production in the UK, and consumers will benefit from improved availability of fresh, locally produced strawberries.

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NON-CODING SHORT RNAs AND THEIR EFFECT ON AGRONOMIC CHARACTERISTICS OF TOMATO VARIETIES

The project aims to develop a tool using non-coding short RNA molecules in cells (sRNA) as molecular markers of valuable characteristics in tomato plants. A recently discovered class of sRNA regulate the level of protein production and chromosome structure by targeting specific mRNA and DNA sequences. The consequence of the targeting event is reduced mRNA accumulation and suppression of DNA transcription. Preliminary experiments with tomato and Arabidopsis have identified loci in the genome responsible for production of sRNA and that these loci are differentially expressed in different plant varieties.

In the first phase of the project a comprehensive catalogue of sRNA loci in the tomato plant will be identified. Correlation between plant phenotypes and production of specific sRNAs will then be established through statistical analysis. The project will also evaluate whether agronomic traits can be modified when selected sRNAs are overexpressed or suppressed.

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HARNESSING THE GENES OF WILD WHEAT RELATIVES

Wild relatives of wheat have useful characteristics such as increased tolerance to drought, salt and cold and disease resistance. To meet the requirements of growing wheat under climate change and poor soil conditions, it will become increasingly important to be able to exploit such characteristics by transferring the genes responsible for such traits to wheat. However this transfer into wheat by conventional breeding is very difficult. Wheat has three sets of genetic information, or genomes, which inherently should make wheat genetically unstable. Stability is conferred by a gene complex, known as *Ph1*, which effectively prevents recombination of genes across the different genomes - genes in genome A can only recombine with genes from A, B with B, etc. However this makes it very hard to get desirable genes from wild species into modern wheat varieties.

Following extensive research into the *Ph1* mechanism, the scientists are investigating how to temporarily switch off the *Ph1* gene complex using drugs, allowing breeders to transfer in useful "wild" genes without upsetting the genetic stability in the field. This method could greatly increase the pool of

genetic material breeders can use to improve varieties.

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ADVANCED PRECISION CROP BREEDING

New crop varieties are still routinely produced by crossing together existing strains and selecting among the progeny. Nowadays, “crossing the best, picking the best and hoping for the best” can be enhanced by information available in the genetic fingerprint of varieties. However, this first requires that accurate associations are identified between genetic fingerprint and target traits.

MAGIC is an experimental method to increase precision. It requires two simple extensions to the more traditional method of analysing genetic fingerprints in which two parents are crossed and associations are searched for among the segregating progeny. Firstly, rather than simply crossing two lines, a population is established by crossing together multiple founder lines with more genetic diversity, yielding more associations. Secondly, rather than searching for associations immediately after crossing, the population is first cycled through several additional generations of crossing. As a result, associations are located with greater accuracy. We are setting up MAGIC populations in UK’s most important crop, winter wheat.

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DEFEATING £3BN POTATO BLIGHT

The potato disease, late blight, caused by the water mold *Phytophthora infestans*, is considered a threat to global food security with estimated costs of more than £3 billion annually worldwide. Recently it was discovered that the pathogen transfers proteins into potato cells where they may play a major role in the disease process. Conserved DNA sequences within these pathogenic proteins make it possible to identify them.

Knowledge of how pathogenic proteins work to establish infection, how they are delivered inside host cells, and how they may be recognized by host defence surveillance systems will provide new opportunities to combat this disease. The aims of this

project at the Scottish Crop Research Institute and the University of Aberdeen are to identify *P. infestans* proteins that trigger durable disease resistance that may be utilised in breeding programmes, and to seek inhibitors that will interfere with the transfer process of these proteins.

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GETTING PRACTICAL OUTCOME FROM BRASSICA RESEARCH



Brassica crops are major components of the UK’s arable agriculture and horticulture. Oilseed rape, the primary source of vegetable oil in Northern Europe, is high in polyunsaturates with huge potential to provide new nutritional and renewable non-food products. Brassica vegetables contain beneficial nutrients, with elevated amounts of anti-oxidants, vitamins and anti-carcinogenic compounds, as well as uptake of minerals such as zinc and iron.

The AdVaB consortium will enable research findings relating to *Brassica* genetics and genomics to be translated more rapidly into practical outcomes, particularly through genetic crop improvement. Researchers and plant breeders will be provided with tools and information for better understanding of crop traits in terms of the function of underlying genes. This will capitalise on the recently announced BBSRC-funded UK contribution to sequencing the

complete *Brassica* 'A' genome, and previous investment in the related reference plant species *Arabidopsis*.

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OPTIMISING WHEAT GRAIN SHAPE AND SIZE



Beaver



Soissons



Rialto



Spark

The size and shape of the cereal grain affects how it behaves during processing, particularly in the yield and quality of the flour produced during milling.

The aim of this project is to understand the mechanisms that control the size and shape of wheat and barley grain. The project intends to use information from previous studies on endosperm development in *Arabidopsis* and maize and combines a range of approaches from classical genetics to molecular and cellular biology. In addition, experimental milling studies will be used to relate grain behaviour during processing to changes in architecture. This interdisciplinary approach is bringing together a new team of scientists with complementary skills from six academic institutions. The outcome of the research will lead to the breeding of new varieties of wheat and barley with improved milling and malting efficiency and flours with enhanced nutritional quality.

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PRE-BREEDING WHEAT FOR BETTER SUSTAINABILITY

This project will support crop pre-breeding in two areas that have the potential to improve the sustainability of wheat in the UK. Firstly, teams from NIAB and the John Innes Centre (JIC) will apply a research breakthrough from JIC scientists on the major photoperiod response gene (*Ppd*). The teams will provide molecular markers, novel alleles, and key information on *Ppd* effects on ear development and other loci affecting flowering time. Secondly, the researchers will commence a pre-breeding activity that exploits a collection of synthetic hexaploid wheat (SHW) lines and varieties with SHW pedigrees developed at CIMMYT in Mexico. These will provide sources of novel genetic variation for improvement of agronomic performance and yield potential in UK and European wheat.

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IDENTIFYING PLANTS' GENES CONTROLLING VIRUS-RESISTANCE



Virus-resistant brassicas

Viral infections cause significant damage to plants reducing the yield and quality of crops. Although growers can spray insecticides to try to minimise the spread of insect-borne viruses, such treatments are relatively ineffectual. Scientists from the University of Warwick and Rothamsted Research are planning to harness plants' natural resistance against viruses to try to develop a broader range of resistance.

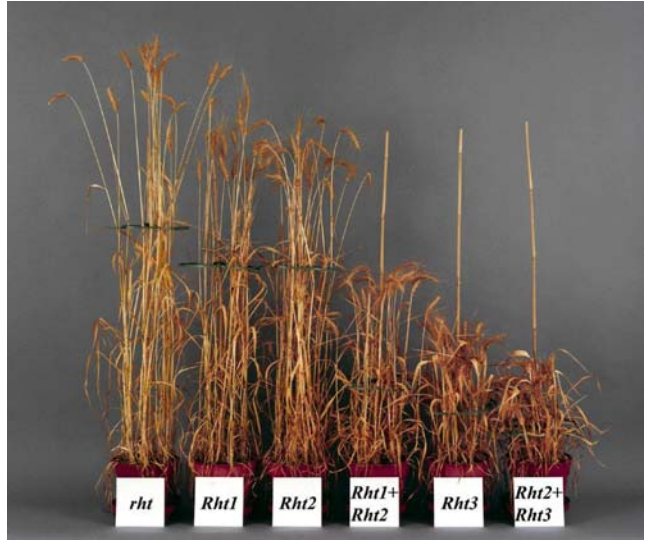
The new project aims to identify the plant genes controlling broad-spectrum resistance to a virus and develop markers that can be used to incorporate the resistance in commercial crops. Identifying the resistance genes could make it possible to create

broad-spectrum resistance in a range of important UK crop types including barley and brassicas.

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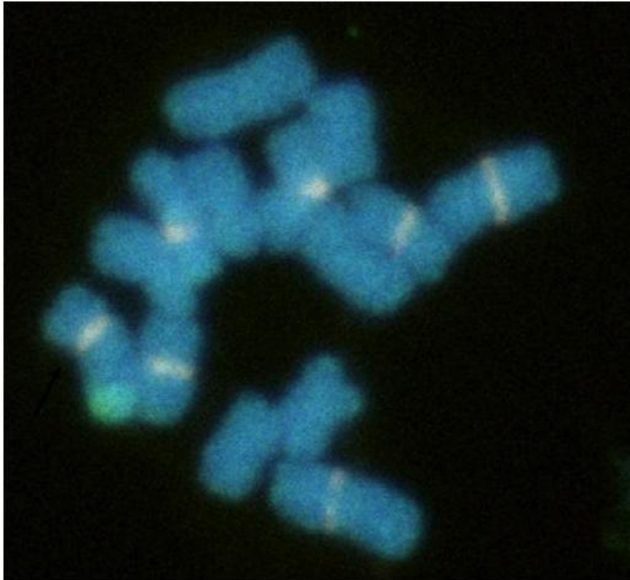
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A SECOND GREEN REVOLUTION FOR A CHANGING CLIMATE



The 'Green Revolution' increased wheat yields worldwide partly through the introduction of shorter varieties where less of the plants' energy was wasted producing straw. These plants were also stronger and more capable of bearing the increased yields. The new dwarf varieties carried a gene that made them unresponsive to the plant's own growth hormone.

UNDERSTANDING AND EXPLOITING THE GENETIC SIMILARITIES OF GRASS, WHEAT AND BARLEY



This project plans to harness genetic knowledge of grass, wheat and barley to develop improved breeding strategies and varieties for a group of crops worth over £8bn a year to UK agriculture.

The researchers will undertake high resolution comparison of the similarity of gene order between grass, wheat and barley by using the rice genome sequence and the *Lolium/Festuca* grass hybrids and their derivatives. The work will be exploited to establish a resource that will enable the transfer of information on the genetic control of target traits, such as drought tolerance, between the species which will be utilised for the development of superior varieties that are able to meet the challenge of increasing demand and the need to adapt crop plants to the changing environment and sustainable agricultural practises. The research will also help to develop modern and more effective breeding strategies.

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Changes in climate, agricultural practice and possible future restrictions in the use of fertilisers and growth-regulating chemicals mean that current varieties may no longer be as effective. Part of this collaboration between Rothamsted Research and John Innes Centre is aimed at identifying additional sources of dwarfing genes in wheat. A second aim is to test dwarfing genes for their effectiveness in protecting plants from drought and other stresses. The researchers plan to introduce these novel genes into modern varieties that commercial breeders can develop into the next generation of bread wheats.

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