Non-Forage Crops

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The aim of the programme is to create new sustainable options by exploiting genetic variation in non-forage crops. In terms of the IGER mission statement, we concentrate on the development of crops for food, animal feed and energy within grassland-dominated landscapes and systems.

New varieties are an important output of the programme upon which the effectiveness of our work is judged. As a result of working closely with industry to deliver radical improvements in sustainable production and end-use, oat genetic improvement is regarded as a successful model for breeding for the public good.

**Oats**

IGER has been responsible for major improvements to the oat crop in the last 10 years. New varieties have made oats both easier to grow and more profitable, and are a major factor for the average national yield of oats now being greater than that of barley. The release of the variety ‘Gerald’ in the 1990s has made oats more economic and acceptable to farmers, largely due to its short straw and reduced risk of lodging (Figure 3.1). This has reinforced oats as a valuable and profitable break crop, conferring yield advantage to following wheat crops. Oats are also good for the environment as they require less pesticide than other cereals and have a higher nitrogen use efficiency.

Fig 3.1 The oat variety ‘Gerald’ won the NIAB Cereal Cup in 2003 – the first time the cup has been awarded for an oat for 27 years.
Before 2004, the genetic improvement of oats was carried out through projects funded by Defra, the Home-Grown Cereals Authority, the British Oat and Barley Millers Association and SW Seed Ltd, with underpinning research from BBSRC. The Defra Report on 'The Role of Future Public Research Investment in the Genetic Improvement of UK Grown Crops', published in September 2002, concluded that this partnership between public and private research, constituting a continuous pipeline of research, had been very successful in delivering a stream of outcomes.

For milling, we have identified genetic advances to combine dwarfness and good kernel content, and to incorporate new sources of resistance to mildew and crown rust. In naked oats used for poultry feed, we have identified a number of lines that appear to combine very high oil content (13-15%) with much better yield and agronomic characters. For feeding to ruminants, we are combining more digestible husks with high oil groats. The resultant grain will be extremely valuable for feeding on-farm and in compounds. In all cases we are incorporating new sources of resistance to mildew and crown rust.

Since April 2004, public and industrial research and development have been brought even closer together in a Sustainable Arable LINK project sponsored by Defra and the Scottish Executive Environment and Rural Affairs Department and entitled ‘The incorporation of important traits underlying sustainable development of the oat crop through combining ‘conventional’ phenotypic with molecular marker technologies’ (OatLink). This is aimed at developing oats to meet the new needs of millers and poultry producers in order to capitalise on the value of oats to sustainable agriculture. It seeks to combine molecular marker and conventional selection for economic competitiveness and well-defined end-user traits. Apart from IGER, other participants of OatLink include SW Seed, BOBMA, HGCA, Bernard Matthews Foods Ltd, British United Turkeys, British Poultry Council, Svalof-Weibull AB, the Roslin Institute, ADAS Rosemaund, Elm Farm Research Centre, GB Seeds Ltd and Oat Services.

In order to overcome the problems of selecting for complex characters such as yield, and of measuring quality characters, we have developed over 200 molecular markers. These reflect differences in the underlying genetic code governing the inheritance of characters. They will be used to identify and then tag the genes involved in complex traits.

The project aims to improve the sustainability of oats through identifying and then selecting for the attributes of oats for organic production. Thus we will, for the first time, be selecting varieties for organic systems under organic conditions. In addition, we are initiating research to improve sustainability further, in terms of more efficient energy and resource use and less risk of pollution. This would set the benchmark for other cereals.

**Durable resistance in oats and related species**

Disease attack reduces yield and quality, and much past effort has concentrated on single gene-controlled resistance that is easily manipulated by plant breeders. Certain pathogens such as the powdery mildews, however, combine massive spore production with high mutation rates and, under selection pressure, they adapt quickly to overcome this form of resistance. Thus, in this war between fungus and plant, victory in battle has often proved ephemeral. Currently, therefore, farmers rely on chemical controls to back up this unreliable resistance.

Our objectives, therefore, are to characterise and exploit the mechanisms of durable resistance to powdery mildew in oats and barley (Figure 3.2). The oat variety ‘Maldwyn’ has durable resistance that limits both pre- and post-infection fungal development. The independence of contributory mechanisms is being examined in populations derived from hybrids between Maldwyn and mildew-susceptible oat lines. Descendants of these hybrids will be analysed histologically and
molecular markers associated with individual resistance mechanisms sought. The ultimate aim is to identify the genetic basis of this durable resistance in order to facilitate its incorporation into modern oat varieties and support the search for similar mechanisms in other cereal and grass species.

**Energy crops**

Since 2004, we have extended the remit of the NFC research programme to include biomass crops for energy; the giant grass *Miscanthus* and short rotation coppice willow. Through the process of photosynthesis, energy crops are a cheap means of converting solar energy to biomass which can then be converted to electricity and heat. Biomass can play an important role in meeting UK targets for the reduction of CO\(_2\) emissions within a mix of renewable technologies. Energy crops also offer new and significant opportunities for novel farm enterprises and can act as bio-filters of wastes.

**Miscanthus**

Genetic improvement of *Miscanthus* is needed to raise yield and, to a lesser extent, combustion quality, and to increase the number of clones, currently three, to lessen genetic vulnerability (Figure 3.3). The first step is to assemble and assess genetic resources from worldwide genetic collections. Clones with valuable and complementary characteristics are being hybridised to produce new diploid and triploid hybrids from which the best genotypes will be selected.

Marker-assisted selection will ultimately aid rapid and precise selection, particularly for traits such as height, time of flowering, senescence and combustion quality. Knowledge of the maize (*Zea mays*) genome is seen as particularly valuable as, like *Miscanthus*, it is a grass exploiting the C4 pathway successfully in temperate climates. From recent work, it is clear that *Miscanthus* research could receive a boost from the wealth of molecular markers available from maize research.

This work links to the involvement of IGER and Rothamsted Research in the SuperGen Biomass and Bioenergy Consortium, relevant objectives of which are to establish how biomass chemical composition affects thermal conversion properties and emissions and to identify quality traits in grasses for improved bio-fuel processing.
Willows
Our work on willow consists of a large demonstration project known as Helyg i Gymru – Willow for Wales. We have established 35 ha of short-rotation coppice willow on different farm types at different altitudes (Figure 3.4). The objectives are to evaluate the economics of production and energy flows, the effects of willow plantations on the whole farm enterprise (including environmental impacts - by Cardiff University), the best genotypes and management practices, and the quality and steady supply needs of end-users (in conjunction with EGN1, Mid-Wales Energy Agency, RWE npower and others as appropriate). The information will be disseminated to farmers and other stakeholders.

Work so far has shown the importance of having varieties that are able to compete with weeds. There appear to be wide differences between varieties. We are testing the adaptation to different altitudes of advanced varieties from the Rothamsted willow breeding programme and Agrobransle (a project partner). In this way we are able to select potential varieties that otherwise would not get tested under the special conditions of Wales. If specific adaptation to western Britain in native willows is identified, we would seek to involve Rothamsted in using the material in their breeding programmes and in identifying molecular markers linked to the specific traits.

We are currently discussing mechanisms of support of biomass crops with the Welsh Assembly Government.

Future opportunities
In order to continue the delivery of new sustainable options by exploiting genetic variation in our portfolio of crops, it is essential that we continue to invest in research which will increase our generic understanding of underlying genetic and physiological mechanisms but also take into account the uniqueness of our crops (‘science push’). We must at the same time meet the needs of diverse stakeholders (‘market pull’). In oats, new opportunities include developing varieties with drought resistance, and pest and disease resistance in order to respond to climate change, breeding naked oats suitable for feeding to pigs, and high antioxidant/beta-glucan/oil lines for functional food (delivering health and other benefits) and/or non-food uses. In energy crops, where there has been under-investment in research, there is considerable scope for research using physiological and genetic approaches developed in model species to better understand vital processes such as flowering and nutrient recycling.

In the future, there is likely to be much greater diversity of crops for food, feed and energy. Non-food crops for industrial use present new opportunities for exploiting genetic variation. We consider that adding value will be more important in crops in the future. Miscanthus, for instance, could be used to produce renewable feedstock chemicals substituting those from oil, with the residues being used for biomass.

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