22nd November, 2023

Dear Evan, thank you for asking us to provide information on our research into areas relating to the Genetic Technology (Precision Breeding) Bill brought forward by the UK Government.

Background on IBERS

The Institute of Biological, Environmental & Rural Sciences (IBERS) is one of eight strategically supported Biotechnology and Biological Sciences Research Council's (BBSRC) research institutes, and the only one in Wales. IBERS's research vision is to ensure that humanity can sustainably produce the food, feed and plant based industrial resources it needs, at a time of great climate and societal change. To achieve this ambition, IBERS brings together a unique assembly of grassland & plant breeding scientists, state-of-the-art research facilities, stakeholder relationships, and collaborative networks. IBERS provides National Capability in Grassland and Plant Breeding Science through its expertise in crop science and ability to translate research into new plant varieties. Key facilities this ambition and the breeding of future crop varieties that are resilient to, and can help tackle, future climate change include:

- Research farms (Gogerddan, Morfa Mawr, Trawsgoed and Pwllpeiran) ranging from 0-600m above sea level.
- Glasshouses and controlled environment chambers, enabling us to investigate plants under controlled conditions.
- National Plant Phenomics Centre (NPPC). Unique in the UK, the NPPC provides an automated system for non-invasive assessment of longitudinal phenotyping of 1000s of plants in parallel, especially under conditions of stress.
- Seed-Biobank. Comprises over 35,000 accessions of global importance for forage grasses, forage legumes, and energy grasses, which have been collected over the last century. Such a resource is invaluable to our work on the development of more sustainable agricultural systems as well as tackling climate change through more resilient crops and the transition to Net Zero.
- Quarantine glasshouses making us one of few facilities in the UK that can import, multiply and store plant materials, and so represents an important part of our capability to collaborate with the wider global crop science community through the sharing and use of common genetic resources.
- Laboratory facilities provide core capability for molecular, cellular and biochemical studies. Includes confocal and electron microscopy facilities, equipment for metabolomics, genetic transformation laboratories and associated glasshouse facilities that enable the manipulation of model and forage grasses, including through genome editing under controlled conditions.

IBERS has 150 staff, and research income of approximately £10 million per annum, most of which includes collaboration with industry.

Track record of plant breeding in IBERS

IBERS and the institutions that preceded it have a track record spanning over 100 years in plant breeding and commercialisation of varieties across a range of crops including oats (licenced to Senova), forage grasses (Germinal), peas and beans (Wherry & Sons) and Miscanthus (Terravesta). IBERS is the

UK market leader in winter and spring oats, varieties have been marketed by Senova (previously Semundo) since the 1980's. This includes both husked and naked oats. IBERS varieties are estimated to make up 83% of the UK seed area of winter oats. Total UK planted areas for oats were 210,000 ha in 2020, with a market value of £150 million. IBERS forage grass varieties dominate the UK market; estimated to be 39% of the UK market share for grass and herbage, with the next largest being DLF with 14.9%. We are ranked first in the world on Scival (an international research performance assessment tool) for Miscanthus breeding, and have successfully bred the world's first new Miscanthus varieties for the biomass market. Six varieties are registered with the Community Plant Varieties Office (CPVO) and are licenced to Terravesta Ltd for exploitation.

Approaches to plant breeding

The aim of plant breeding is to select plants with desirable characteristics and combine their genetic diversity whilst eliminating unfavourable traits. The characteristics required vary between crops, but typically include increased yield, quality traits, and environmental performance (e.g. resilience to climatic extremes, and to pests/diseases). A breeding cycle typically involves crossing the best available mature plants, testing the resulting progeny in the field, and then selecting the best performers for deployment and use in the next cycle. It is therefore an inherently slow process (e.g. 12-15 years for a new variety), but in mature breeding programmes it is a continuous pipeline, with new varieties becoming available on a regular basis due to ongoing activity.

Conventional breeding typically relies on existing diversity present in the plant that is being bred; for example, a crop plant which shows a particular resistance to drought is crossed with another crop plant that has a high yield in order to produce new varieties carrying both traits. A range of approaches can be used to improve the likelihood of desirable traits being combined in a single plant; in most cases these are variations on the conventional crossing approach, such as crossing an offspring with its parent, or attempting inter-species crosses. Where the desired trait does not exist, mutagenesis can also be used to produce spontaneous genetic variation in the hope of generating new plants with beneficial traits.

Recent innovations in plant breeding

Recent technological advances can potentially accelerate breeding cycles and bring about more accurately targeted genetic improvements in crops, and IBERS is a national leader in developing, assessing or operationally implementing these.

Genomic selection: Advances in approaches to DNA sequencing, and associated high performance computing, have drastically decreased costs and therefore make it possible to generate large amounts of genomic data within plant breeding programmes. Previously selection was only possible from plant phenotypes, which might be influenced by maturity, the environment in which they are grown and the seasonal variation. However, once genomic trait associations have been established, Genomic Selection can be applied, directly from the genomic DNA. The key benefits of this approach are a) that it allows traits of interest to be selected at the seedling stage, thereby reducing time and the costs associated with growing plants to maturity in the field, and b) that the effect of environmental conditions are excluded.

Gene editing: In this technique, DNA is cut at a specific location in the genome. DNA can then be added, removed or replaced at this location. The most commonly used approach (CRISPR-Cas9) is not yet developed for the crops bred in IBERS, but we are actively engaged in the underpinning research that would make this possible in the future. It is certainly the case that significant improvements in the crops we breed in IBERS are achievable without gene editing, but as our understanding of crop genomes improves, there are likely to be specific desirable traits that are much more difficult to breed into crops without gene editing.

IBERS has embraced modern approaches to plant breeding as exemplified by two current projects:

- Miscanspeed – Accelerating Miscanthus Breeding using Genomic Selection (2022-2025, c.a. £2 million, BEIS/DESNZ funded). In this project we are capitalizing on our role in the recent sequencing of the Miscanthus genome, decreases in the cost of DNA sequencing, and our demonstration of the utility of genomic prediction models to predict mature phenotypes based on genetic sequence data. The aim of Miscanspeed is to integrate this knowledge with rapid plant maturation in specialised glasshouses to cut the duration of a breeding cycle from three years to a single year.
- Using AI for plant selection and breeding for Net Zero (2023-2025, c.a. £2 million, UKRI funded). In this project we are using advanced drone-mounted sensing technologies (near-infrared spectroscopy, NIRS and hyperspectral cameras) to detect the chemical composition of plants and indirectly their genetic composition. This data is then being combined with conventional field measurements and incorporated into Artificial Intelligence models. The aim is to transform our ability to analyse complex data sets, recognise data patterns, rapidly incorporate understanding gained from other crops, and generate accurate predictions that will improve selections in our breeding programmes. This should allow us to accelerate breeding gain per cycle.

Financial models of plant breeding

Historically, plant breeding in the UK and other countries was a public endeavour. During the 1980s most of the public breeding programs were sold or arrangements were made for near market costs to be absorbed by commercial companies. Breeding for the commercial market is now generally either undertaken by companies (for crops where the volume of sales generates sufficient income, e.g. maize, sugar beet, cereals), via companies collaborating with each other, or via public sector breeding with sponsorship agreements for variety rights (companies invest in breeding programmes in return for exclusive rights to new varieties). Public sector breeding with open competition for variety rights is also undertaken, but given the lack of finance available via this route is typically a precursor to one of the other financing models.

For the crops we work on in IBERS, the majority of breeding is undertaken via a mixture of sponsorship agreements and public sector support for underpinning technologies and 'pre breeding' (analysing and determining traits that should be brought into commercial breeding programmes, and developing breeding technologies per se).

The Intellectual Property Office estimate that levels of investment to maintain a breeding programme at between £200,000 and £2 million/year. However, the return on investment for breeding is estimated to be 40:1, compared to 5:1 for fundamental research and 15:1 for more applied research. The same report indicates UK royalty income across all crops to be approximately £40m pa.

There are strong reasons for public investment in plant breeding. Market failures in relation to plant breeding are well documented, both in terms of the provision of public goods and the existence of environmental externalities. In the case of public goods (i.e. co-benefits arising from a product that are accrued by someone other than its producer) examples might include flood resilience conferred by a perennial grass, soil carbon sequestration, and the avoided CO_2 emissions that might arise from using bioenergy crops in place of fossil fuel derived energy. Environmental externalities are side effects of the industry concerned that are paid for by society rather than the market. Examples include reliance of particular crops on herbicides, pesticides or fertilisers. Climate change is commonly regarded as the ultimate tragedy of the commons.

The regulatory environment for plant breeding

Our scientists are active in advisory groups (e.g. Professor Huw Jones sits on the UK Food Standard Agency's Advisory Committee on Novel Foods and Processes, and the Defra Advisory Committee on Releases to the Environment). He was also an expert member of the GMO panel of the European Food Safety Authority (2009-2018, including as vice-chair), co-authoring more than 150 scientific risk assessment opinions and technical guidance documents. We are also called upon to provide evidence to governmental and industry bodies more widely in relation to plant science and breeding.

It is our view that regulation in the area of genetic technologies, particularly in relation to gene editing and genetically modified organisms suffers from several key problems. Firstly, it is strongly politicised and inconsistent (e.g. countries not allowing specific modified crops to be grown but being willing to import the same crop as food or feed). Secondly, regulatory mechanisms are not sufficiently agile and future-proof to cope with the relatively rapid advances in the underpinning biotechnology and wider (relatively under-regulated) approaches. As outlined above, there are many ways in which plant breeding is advancing (e.g. by using AI) and it seems unlikely that regulation can keep up with the speed of change. An additional problem is that regulation is not scientifically consistent; instead of risk assessing an end product as would happen in other industries (e.g. the REACH risk assessment approach underpinning EU chemical regulations), the *process* by which a plant is bred is being used to determine the regulations that apply to it, thereby neglecting the fact the results of gene editing are indistinguishable from the types of genetic changes that occur naturally and could be generated by conventional breeding approaches. This lack of regulatory consistency impacts on both the prospects for attracting commercial investment into plant breeding programmes based in Wales and the UK, and also on our ability to maintain our world-leading status as a plant breeding institution.

Final comments

The combination of genomic selection, large scale phenotyping from robots, drones or even satellite based sensors, with AI and other emerging technologies means IBERS is actively contributing to addressing key challenges in commercial and pre-commercial breeding, in addition to undertaking fundamental research on plant science and biotechnology that will underpin future breeding approaches. The most urgent breeding challenges include minimising the nutrient impact of agriculture, improving resilience of crops to future climate challenges, and increasing the food or feed value of our staple crops.

It is our view that there is a particular need to speed up the crop breeding pipeline especially given the impacts of climate change and the frequency of extreme weather events, e.g. droughts followed by flooding events. Many of the crops we work on, compared to cereal crops such as wheat, are early still early in the domestication process. Furthermore, the target traits are not those typically targeted in cereal crops and so are less well characterised. For example, given the increasing dependence of global net zero targets on BECCS (Biomass Energy with Carbon Capture and Storage), new varieties of biomass crops are urgently needed. Having registered the world's first new Miscanthus varieties tailored to the biomass market, IBERS has a unique position both in the UK and globally, and could play a pivotal role in our ability to reach net zero carbon emissions. More broadly we need to find methods that enable an integration of the different technologies, including gene editing, genomic selection, high throughput trait analysis and the use of AI and machine learning, so that we can make new plant varieties more rapidly and with more precision. This will be needed to tackle the local and global challenges ahead as well as provide society, including farmers, industry and consumers, with the food and other land-based products and services it needs.

Dr Judith Thornton, Prof Iain Donnison, Prof Gancho Slavov, Prof John Doonan. 22/11/23.