Plant Breeding Matters
The business and science of crop improvement
Access to improved crop varieties – delivered to market by the commercial plant breeding and seeds sector – is the foundation for successful, productive agriculture. Over the past 30 years more than 90% of the yield gains in our major crops are due to plant breeding innovation.

Faced with the global challenges of food security, climate change and pressure on the world’s finite natural resources, reports from Foresight (Future of Food and Farming) and the Royal Society (Reaping the Benefits) have highlighted the need for continued progress in plant breeding as the single most important factor in meeting the food, feed and fuel needs of a world population set to reach 9.6 billion by 2050.

Plant Breeding Matters is a unique source of information about the business and science of plant breeding, produced by the British Society of Plant Breeders (BSPB).

With a focus on key themes such as food, health, economy and the environment, this booklet explains how plant breeders develop, test and bring new crop varieties to market, and how innovation in plant breeding contributes to improving the quality, performance and productivity of our agricultural and horticultural crops.

For more information about the BSPB and the latest plant breeding news go to www.bspb.co.uk

Richard Summers
Richard Summers, BSPB Chairman
May 2014

PLANT BREEDING - THE ESSENTIAL PLATFORM FOR SUSTAINABLE AGRICULTURE
Plant Breeding Matters

Plant breeding is the business and science of crop improvement. It is an innovation-based sector, focused on developing plants better adapted to human needs.

The demand for new varieties of agricultural and horticultural crops, adapted to our unique growing conditions, is never ending, driven by the challenges of new pest and disease pressures, weather patterns and changing market requirements.

The development of crop varieties with improved yields, end-use quality and environmental performance provides the essential foundation for sustainable, efficient agriculture, and the starting point for the UK’s £90bn food supply chain.

As the world faces up to the major challenges of population growth, climate change and pressure on natural resources, the contribution of plant breeding is increasingly recognised as a key factor in addressing global concerns over food security and sustainable development and in stimulating a vibrant economy.

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The origins of plant breeding stretch back thousands of years to the first primitive farmers who selected the best plants in one year to provide seed for their next crop. More recent scientific and technological developments have allowed a much greater rate of improvement. Until the early 1960s, plant breeding in Britain was largely confined to publicly funded research. This situation changed dramatically in the mid-1960s, with the passing into law of the 1964 Plant Varieties & Seeds Act. This legislation introduced a system of royalty payments on individual plant varieties, known as Plant Variety Rights, and triggered a rapid expansion of plant breeding as a commercial enterprise in its own right.

**Gregor Mendel**

Gregor Mendel first provided a scientific explanation of genetic inheritance in the mid-19th century. In his experiments with peas, Mendel crossed plants with different characteristics such as whether the seed is round or wrinkled. He found that the offspring had either round or wrinkled seed, the same as the parents with no intermediate types, and that when these offspring were crossed with each other, the round and wrinkled seed types were inherited in a stable 3:1 ratio. Mendel's work went largely unrecognised in his own lifetime and it was not until the early 20th century that it was rediscovered to form the explanation of heredity and pave the way for modern plant breeding.

**Norman Borlaug**

Norman Borlaug and his colleagues working in Mexico made a major breakthrough in scientific plant breeding when they were able to introduce dwarfing genes into wheat to produce new varieties with much higher yield potential and greater response to fertiliser than traditional varieties. This started the Green Revolution, a step change in the development of higher yielding varieties for the developing world and the foundation of much of today’s crop breeding.
None of the major food crops grown in Britain are native to this country. The cereals, root crops, pulses and oilseeds which make up the familiar patchwork of our farmed landscape have their origins in many different parts of the world. They have all been adapted, through plant breeding, to thrive under UK growing conditions.

Plant breeding today

Modern plant breeding is a sophisticated, high investment business. Much of the basic underpinning crop genetic research is still conducted in the public sector, but commercial plant breeders provide the only route to market for improved crop varieties.

More than 60 plant breeding companies, based in the UK, are active across the entire spectrum of plant species used for food, feed and energy.

Plant breeding makes a significant contribution to the nation’s gross domestic product and to the growth and competitiveness of the UK’s food economy.

An independent study concluded that every £1 invested in plant breeding generates at least £40 in added value within the wider UK economy, from higher yields and input savings at the farm level through to import substitution, export earnings and enhanced processing efficiency within the food and drink manufacturing sector.

Download a copy of the independent study at www.plantbreedingmatters.com/history.php

Every £1 invested in plant breeding generates at least £40 in added value within the wider UK economy
The basic aim of all plant breeding techniques is to generate new genetic diversity and then select plants with the desired improved characteristics.

The creation of each new variety is a complex, costly and skilled operation. It is also time-consuming – early-stage varieties in today’s breeding programmes must anticipate the needs of farmers, consumers and the environment in ten years’ time and beyond!

Breeding techniques vary between crop species, but the scientific principles of plant breeding remain true to Mendel’s first discovery that selected parent plants can be cross-pollinated to combine desired characteristics in a single variety.

These characteristics are determined by genes – units of hereditary material that are transferred from one generation to the next.

Since each plant contains many thousands of genes, and the breeder is seeking to combine a range of traits in one plant (such as high yield, quality and resistance to disease), developing a successful variety has been compared to playing a fruit machine – not with three reels but several hundred. The skill of the plant breeder lies in improving the chances of hitting the jackpot by combining all the desired characteristics in the same variety.

“Future food-production increases will have to come from higher yields. Unless progress with agricultural yields remains very strong, the next century will experience sheer human misery that, on a numerical scale, will exceed the worst of everything that has come before...”
Norman E. Borlaug, 1970

Creating new varieties

Plant breeding in practice

1 The female parent is emasculated so that it cannot self-pollinate and pollen is transferred from the male parent with a paint brush to make the cross

2 Pollinated plants are bagged to ensure that the female parent receives pollen only from the chosen male parent

3 Seed from the F1 plants is collected and sown out to produce an F2 population in which all the plants are uniform; this is oilseed rape

4 Seed is collected from the pollinated plants and sown out to produce an F1 population in which the plants, in this case wheat, are genetically very diverse
Pedigree plant breeding involves crossing carefully chosen parent plants then selecting the best plants from the resulting offspring to be grown on for further selection.

For cereal crops, hundreds of individual crosses are carried out to create seed for the first filial (or F1) generation. The resulting F1 plants are uniform, but the following (F2) generation segregates out into many thousands of different plants. It is this enormous diversity of new gene combinations which may hold the key to a successful new variety.

Seed from the best of these F2 plants is grown on in small rows or plots and the best plants again selected. As promising new lines emerge, tests are conducted to assess factors such as yield, disease resistance and end-use quality. This process is repeated year after year until pure lines of only the very best plants remain, ready for seed multiplication and entry into official trials.

Hybrid breeding exploits the performance boost derived in a single season from the first cross between two carefully selected parent lines. This breeding method is widely used to produce commercial varieties of field vegetables, sugar beet, maize and oilseed rape.

F1 hybrid varieties are unique in expressing heterosis, or ‘hybrid vigour’ in the growing crops for a single year. This may result in higher yields, greater uniformity, or improvements in quality.

While inbred lines breed true year after year, the performance gains of F1 hybrids are not maintained as subsequent generations segregate to produce highly variable offspring.

See how plant breeders start the process by cross pollinating selected parents in peas in the ‘Guide to how to cross peas’ video clip at www.plantbreedingmatters.com/innovation.php

Download the BSPB hybrids Factsheet at www.plantbreedingmatters.com/innovation.php
Enhanced breeding

With increased genetic knowledge and improved technology, plant breeders have developed ways to enhance the speed, accuracy and scope of the breeding process.

The lengthy interval from initial cross to commercial variety can be reduced in a number of ways:

- **maintaining parallel selection programmes** in northern and southern hemispheres allows two generations to be produced each year;

- **single seed descent** enables large numbers of small plants to be cultivated in artificial growth rooms, with two or more generations produced per year;

- **doubled haploid breeding** allows breeders to produce true breeding seed of a variety within a single generation;

- **mini-tuber breeding** in potatoes speeds up the slow multiplication process by producing miniature plants under greenhouse conditions.
Modern scientific techniques also enable plant breeders to introduce new sources of genetic diversity and to establish whether desired characteristics are present at an early stage in the breeding programme:

- **embryo rescue and assisted pollination** allow breeders to expand the range of available characters by making crosses between plants which would not normally produce viable offspring;

- **advances in genomic science** have transformed breeders’ understanding of the function and location of individual genes or combinations of genes, and the speed with which genetic variation can be analysed;

- **marker-assisted selection** uses high-throughput DNA screening technology to determine at an early stage whether desired traits are present in a new variety;

- **transformation** (often used synonymously with GM) allows desired traits to be added, modified or deleted in a plant variety without reshuffling entire genomes. This extends the range of characters available, and allows specific genes to be expressed without introducing unwanted characteristics.

Other novel breeding techniques such as oligonucleotide-mediated site-specific mutagenesis or cis-genesis expand the range of possibilities for plant breeders to transfer genetic characteristics between plants and alter genetic function within plants in a highly targeted and efficient way and are the subject of much exciting plant science R&D. Cereal yields are currently increasing through breeding at 0.5% per annum but the UN FAO says that global food production needs to increase by 70% in the next 40 years. Plant breeders need to be able to use all the scientific tools potentially at their disposal if this is to be achieved.
Before a new crop variety can be placed on the market, it must undergo a statutory testing process. Successful varieties are placed on a National List, or register of approved varieties.

National Listing rules are determined at EU level, and apply to all the major agricultural and horticultural crop species. Official trials are conducted, in most cases for a minimum of two years, to test each candidate variety for a range of characteristics which together determine its distinctness from other varieties, as well as its value to growers and end-users.

National Listing is rigorous and ensures that only varieties which are novel and distinct and which are a clear improvement over existing varieties may be added to the List and marketed.

**National Listing – DUS**

All varieties submitted for National Listing are assessed for Distinctness, Uniformity and Stability (DUS). In the case of cereals, some 30 individual characteristics of the plant are inspected to verify that it is distinct (i.e. clearly distinguishable from other varieties), that its characteristics are uniform from one plant to another, and that the variety is stable from one generation to the next.

DUS tests are carried out to highly detailed official protocols which are published by Fera at [www.fera.defra.gov.uk/plants](http://www.fera.defra.gov.uk/plants).

**National Listing – VCU**

For agricultural crops, National Listing also involves trials to establish a candidate variety’s Value for Cultivation and Use (VCU). This provides an independent assurance that only varieties with improved performance or end-use quality can be approved for marketing.

In the UK, BSPB is authorised by the government to organise VCU testing for most crops. Read more about BSPB’s role at [www.bspb.co.uk](http://www.bspb.co.uk). Protocols for VCU trials published by Fera can be found at [www.fera.defra.gov.uk/plants](http://www.fera.defra.gov.uk/plants).
Recommended and Descriptive Lists

National Listing is no guarantee of success in the market place. Further non-statutory trials are conducted each year to compare the agronomic performance and end-use quality of the best varieties. These independent trials provide the basis for detailed variety information and advice to growers and their customers.
As well as developing new varieties, plant breeders maintain the genetic purity of pre-commercial seed supplies year by year. This process is costly and time-consuming, but essential to ensure the quality and performance of each variety.

For cereals, variety maintenance begins after a few years of selection trials, when the promise of a variety is just emerging as a single row containing around 100 plants.

The breeder bulks up supplies of purified Breeder’s seed into Pre-basic and then Basic seed. Each year, specialist seed producers grow Basic seed for the first generation of Certified seed, called C1 seed. After one more year this becomes C2 seed, the main source of Certified seed used by farmers in the UK.

The plant breeder continuously maintains Breeder’s seed for the process of multiplication through Pre-basic, Basic, C1 and C2 seed to ensure the variety’s performance and quality year after year.

Greater emphasis is now being placed on preserving the identity of individual varieties after harvest, both to conserve quality characteristics and to meet consumer demands for assurances about the integrity and traceability of their food.

Seed certification

Seed of an approved variety can only be offered for sale if it meets strict quality criteria laid down in UK and EU law.

The UK’s official seed certification system offers an independent assurance of quality to growers. Minimum standards apply for varietal identity, purity and germination capacity. In addition, strict limits apply to seed-borne diseases and the presence of physical impurities such as weed seeds.

Around 9% of the UK arable area is used to multiply the pure lines of seed from the plant breeder into Certified seed. This involves several thousand individual crops, each grown under specific management regimes to ensure that the purity and integrity of the resulting seed is maintained. To gain certification, every seed crop must undergo crop inspection and seed testing.

Seed certification underpins the health and purity status of the major agricultural crops in the UK. It offers an independent benchmark of quality on which buyers of seed and their customers depend.

Vegetable seed is marketed as Standard seed, which also has to meet prescribed standards for identity and quality and be officially labelled.
Farm-saved seed

For certain combinable crops and potatoes, growers can opt to save their own seed for sowing the following year (farm-saved seed) provided care is taken to ensure that the crop remains healthy and free from impurities, that the resulting seed is carefully conditioned and cleaned and that a farm-saved seed payment is made to the breeder. F1 hybrid varieties may not be farm-saved unless the breeder has given explicit permission.

Quality seed production - a farmer’s view

Philip Gorringe has been producing Certified seed of winter wheat, winter barley, peas and grasses on 900 acres in Herefordshire for the last 40 years.

The system begins with assessing the suitability of a field, he explains. “Previous cropping is an important consideration. With cereals, for example, you can’t have grown the same species the year before and preferably not for two years. Where this isn’t possible, a seed grower has to be willing to hand rogue the field and spray the stubbles with glyphosate in the autumn, to eliminate any volunteers.”

Seed growers can be producing Pre-basic, Basic or C1 seed, or a combination of all three, he points out. “In some instances, you may have the first ever field of a given variety.”

Once cereal crops come into ear, they are inspected to determine whether standards have been met. Where Pre-basic or Basic seed is grown, an independent PHSI officer from Fera will perform the inspection. “There are a number of things they test for at this stage, including varietal purity and in the case of barley, pigment changes.” Contamination with other species, particularly wild oats, also has to be avoided.

Lower grades can be inspected by the seed company with check inspections done by Fera.

Once harvest is underway, cleanliness is everything. “Our grain stores are all segregated and cleaned, so that each seed batch can be stored separately. They also have separate access points, so that they can be opened from the outside.”

All harvesting equipment is cleaned thoroughly and hoovered out with industrial equipment and compressed air. “The combine will be cleaned down twenty times during harvest. It takes two men approximately three hours to complete.”

All crops are labelled in store and have to be dried using an on-floor ambient system. Once they reach 16% moisture, they are sampled for purity, germination and moisture.

Philip Gorringe enjoys the close relationship he has with the five plant breeding companies he works with to produce seed. “With seed production, the whole supply chain, from breeder to merchant to grower, has to work together. It’s good business for everyone.”
Funding plant breeding

Plant breeding involves a major investment in people, technology and facilities. Research and development takes place over many years, with no guarantee of success.

Developing an individual variety is expensive. The cost of maintaining a competitive UK wheat breeding programme, for example, is estimated at £1.5 to £2 million per year.

The breeder’s principal return to fund the ongoing process of crop improvement is a royalty on seed used. Only varieties which succeed in the market place are rewarded.

Plant Variety Rights

Plant Variety Rights (PVR), also known as Plant Breeders’ Rights, provide the mechanism for the breeder to obtain a royalty. PVR is a unique, internationally recognised form of intellectual property applied to each new plant variety. It is similar in principle to the intellectual property protection offered via copyright on books and CDs and provides the breeder with a time-limited monopoly over production and sale of propagating material of a protected variety. To be granted PVR, a variety must be Distinct, Uniform, Stable (DUS). It must also be novel and have an approved name.

In Europe plant breeders may protect their varieties with Community Plant Variety Rights, awarded by the CPVO, or with UK Plant Variety Rights awarded by Fera.

The PVR campaign aims to raise awareness and understanding of how intellectual property protection within the plant breeding industry is delivered through Plant Variety Rights.

www.plantvarietyrights.org

Farm-saved seed payments

The need to maintain investment in increasingly costly plant breeding programmes led, in 1991, to international agreement that the concept of Plant Variety Rights should be extended to cover farm-saved as well as certified seed.

Farmers have a long tradition of saving seed of improved varieties for replanting from one season to the next. This agreement recognised the breeder’s contribution to the progressive genetic improvements enjoyed by growers saving their own seed. It was incorporated into European law in 1994.

Since 1996, an industry-wide system for collecting payments on farm-saved seed has operated for certain crop species in the UK. Payment levels are lower than royalty rates on certified seed, and apply only to newer varieties. The system is supported across the farming industry as a means to safeguard future investment in crop improvement.

Royalty collection

In the UK BSPB is the plant breeders’ licensing and royalty collection agency. The Society licences the production and sale of Certified seed of protected varieties on its members’ behalf and collects their royalties. BSPB also collects farm-saved seed payments under the terms of an agreement between the BSPB and the National Farming Unions.

www.cpvo.europa.eu

www.fera.defra.gov.uk

Through the FAIR PLAY campaign, plant breeders and the farming unions are working together to safeguard future innovation in plant breeding.
Economy – Why plant breeding matters

A constant flow of new crop varieties with improved yields, performance and end-use quality provides the essential foundation for a competitive farming industry and a dynamic food chain.

Independent economic research has demonstrated that every £1 invested in plant breeding generates at least £40 within the wider food economy.

The economic benefits of improved varieties range from increased yields and input savings at the farm level through to import substitution, export earnings and enhanced processing efficiency with the food and drink manufacturing sector.

The forty-fold return on investment associated with plant breeding significantly outperforms other research-based sectors.

By improving the productivity and output value of our major crops, plant breeding provides the starting point for our £90bn food and drink industry, the UK’s biggest manufacturing sector, which sources more than two-thirds of its raw materials from Britain’s farms.

Yield increase

Although total UK barley production declined by 44% between 1982 and 2008, average yields increased by 1 tonne per hectare over the same period, of which 90% is attributed by NIAB to the contribution of new varieties (see page 21).

Based on an average barley price for 2010 of £79.70 per tonne, the gross value of the barley yield increase due to plant breeders is £75.6 million per annum.

Brewing and distilling

The additional alcohol extracted from each tonne of malting barley as a result of varietal improvements has increased UK whisky distillers’ annual production potential by up to 66.8 million bottles, with a retail value on the export market of £483 million per year.

Improved barley varieties have also delivered processing benefits by reducing beta glucan content, allowing significant gains in productivity worth £105 million per year in reduced staff costs to the UK brewing industry.

UK malting sector

By delivering continual improvements in the malting quality of home-grown barley varieties, plant breeders have helped ensure the viability of the UK malting industry – worth £511 million per year and employing 2,000 people – in a highly competitive international market.

"The competitiveness of the British malting industry depends on a thriving plant breeding sector to deliver improvements in quality, performance and yield of home-grown malting barley varieties."

Colin West, Executive Director, Maltsters’ Association of Great Britain
CASE STUDY 2: Wheat

Yield increase
Between 1982 and 2008, the wheat yield increase attributed to plant breeding is valued at between £373 million and £445 million per year at 2010 prices.

This takes into account a 33% increase in national average wheat yields, from 6.2 t/ha in 1982 to 8.3 t/ha in 2008, around 90% of which is due to the contribution of plant breeding (see page 21).

Import substitution
The development of high protein, hard-milling UK wheat varieties suitable for breadmaking enabled home-grown wheat used for flour milling to increase by 57%, or 1.7 million tonnes, between 1982 and 2009.

This has helped safeguard up to 750 jobs and £300 million of annual turnover in the UK flour milling industry.

UK branded bread market
The development of improved breadmaking varieties is supporting a trend to use 100% home-grown wheat in the £2.9 billion UK branded bread market. Market share growth for companies based on meeting targets for the use of home-grown wheat will depend on strong promotion, product innovation and UK provenance claims which would not be possible without the efforts of plant breeders.

“Advances in wheat breeding and breadmaking technology have enabled flour millers to use an increasing proportion of home-grown wheat in the grist, reversing the UK's historical dependence on imported breadwheat.”
Alex Waugh, Director General, National Association of British and Irish Millers
Suitability for UK cultivation
By shortening the growth period in forage maize, plant breeders have adapted this sub-tropical crop to thrive under our growing conditions, providing an important home-grown forage option for UK farmers.

Farmers have rapidly recognised and adopted the benefits of early maturing, higher yielding varieties, and between 1989 and 2008 the UK forage maize area increased six-fold from 26,000 ha to 150,000 ha.

Milk production benefits
Adding maize to grass silage helps improve the gross margin per dairy cow. Research comparing diets of grass silage alone with maize silage fed in combination with grass silage has identified the following advantages:

Higher ration intake – the addition of maize silage improves dry matter intake by 3.8 kg per day to 13.6 kg relative to grass silage alone.

Lower production costs – maize silage typically costs £73 per tonne of dry matter versus grass silage at £85 per tonne. The cost differential reflects the higher dry matter content of forage maize.

Higher milk yield – forage maize has been found to deliver an increase in milk yield of 2.4 kg per day, as well as increased protein and fat.

Based on the area of forage maize grown in 2008, plant breeders have supported the provision of improved dairy rations worth £66 million per year in reduced feed costs and increased productivity.
The combined challenges of population growth, climate change and increasing pressure on the world’s natural resources of land, water and energy have prompted calls for the ‘sustainable intensification’ of global agriculture.

At its most basic level, this means increasing productivity while consuming fewer resources and with reduced impact on the environment.

Plant breeding will be at the forefront of the genetic innovation needed to deliver the required gains in sustainable, efficient production, for example by developing higher-yielding, more climate-resilient crop varieties better adapted to cope with extreme weather conditions and by improving the resource-use efficiency of our major crop plants.

The development of improved crop varieties can also help protect our countryside and farmland biodiversity. Increasing productivity on land that is already farmed, for example through the adoption of higher-yielding varieties and farming systems, reduces pressure on uncultivated land and natural habitats.

CASE STUDY 1:
Plant breeding for climate change

The effects of climate change are predicted to have a major impact on prospects for global food production. At the same time, agriculture itself is a major contributor to greenhouse gas emissions.

Plant breeders can help tackle the causes and effects of climate change in a number of ways.

Resistance to new pests and disease
The need for new varieties adapted to the UK’s unique growing conditions will continue to be driven by the challenge of evolving disease and pest pressures. Climate change may lead to the more rapid development of entirely new strains of disease, changes in disease resistance levels, or the arrival of new pests.

Drought and stress tolerant varieties
Resource conservation will become increasingly significant in the UK if, as predicted, climate change leads to warmer, drier summers. Developing crops with improved tolerance to drought and heat stress is a global priority among researchers and plant breeders.

Varieties suited to reduced inputs and cultivations
Like all other industrial sectors, agriculture is under increasing pressure to cut carbon emissions. Plant breeders are already selecting for varieties which have greater nutrient use efficiency, pest and disease resistance and higher harvest index, and can therefore help reduce sprays and fuel consumption. Similarly, selection of varieties which perform well under minimal- or no-tillage regimes can reduce the need for ploughing which contributes to greenhouse gas build up by releasing soil carbon and consuming fuel.

Adapting new crops to UK conditions
By shortening its growth period, plant breeders have adapted forage maize to thrive under UK growing conditions, allowing a six-fold increase in plantings since the late 1980s. Warmer, drier conditions may also open up possibilities to increase production of grain maize in the UK, or to establish new crop species – such as soya or durum wheat – on a commercial scale. Again, plant breeding will be needed to adapt such crops to UK growing conditions.

Improved seasonality of produce
Wherever possible, UK food retailers are keen to increase their sourcing of local products in an effort to reduce food miles. Many farmers are already responding to these opportunities, and plant breeders can help by further extending the availability of seasonal vegetables and fresh produce.
CASE STUDY 2: Plant breeding and biodiversity

It is a frequent misconception that the success of modern plant breeding has led to an erosion of natural biodiversity. In fact quite the opposite is true.

Maintaining genetic diversity is central to the process of crop improvement. It is in every breeder’s interest to ensure that the gene pool from which new traits are selected remains as extensive as possible.

Plant breeders are actively engaged in a range of national and international programmes to identify, classify and conserve the valuable genetic biodiversity within cultivated crop varieties, landraces and wild plant species.

Indeed plant breeders were among the first to raise concerns about the need to maintain plant genetic resources for food and agriculture, and created the first gene banks during the 1930s.

On a global basis, plant breeding companies commit an average of 5% of their research budget to conserving biodiversity in the form of wild and adapted genetic resources.

Plant breeders collaborate with genetic resource collections to search for sources of variation to introduce new traits such as disease resistance, drought or salt tolerance and yield increase. New and powerful genomics tools, high throughput sequencing technology and molecular markers are opening up radical new opportunities to understand, unlock and exploit the diversity in the collections to improve the crops of tomorrow. Plant breeders also help ensure that the collections include the latest commercial varieties, as breeders developing varieties for the UK market routinely deposit samples of their UK National List entries into a special BSPB collection held at the John Innes Centre.

Watch the video clip ‘Variety is Life’ at www.plantbreedingmatters.com
The combined pressures of population growth, climate change and declining natural reserves of land, energy and water are driving global concern about the security and sustainability of our future food supply.

The world’s population is set to exceed 9 billion by 2050, and the UN Food and Agriculture Organisation (FAO) predicts that food production must increase by at least 70% over the next 40 years to keep pace.

But with limited land available to bring into production, the only realistic prospect of delivering sustainable food security is through increased productivity and improved efficiency on land that is already farmed.

Increasing pressure on the use of pesticide and fertiliser inputs – through tighter environmental controls and spiralling costs – means that crop genetic improvement, delivered to the market through locally-based plant breeding programmes, will underpin this second Green Revolution.

By delivering higher-yielding, more climate resilient crop varieties, resistant to the emergence of new and more virulent pests and diseases, advances in plant breeding will underpin the ‘sustainable intensification’ of agriculture required to secure our future food supplies.

At the same time, plant breeders must respond to the changing demands and expectations of consumers, and meet the exacting quality specifications of the food chain with improved varieties, tailored to the needs of specific end-markets.

Innovation in plant breeding is the single most important factor in delivering continued improvements in the quality, availability and affordability of our food.
Recent research has shown that innovation in plant breeding is now the single most important factor contributing to growth in UK cereal yields.

Statistical analysis of trials yield data over the past 60 years by researchers at the National Institute of Agricultural Botany (NIAB)* found that while cereal yield increases prior to the early 1980s were due to a combination of factors, including increased mechanisation and more widespread use of fertilisers and pesticides, yield gains in the UK wheat and barley crop over the past 25 years have been almost exclusively due to the genetic improvements delivered by plant breeders.

The study showed that winter wheat yields have more than trebled over the past 60 years from around 2.5 tonnes/ha in the mid-1940s to around 8 tonnes/ha today.

Non-varietal factors such as improved crop nutrition, crop protection, machinery and agronomy remain an essential component of modern crop production to help realise the genetic potential of new varieties.

But the NIAB study confirmed that the yield-boosting contribution of these non-genetic factors has remained broadly neutral over the past 25 years, highlighting the essential role of varietal improvement as the platform for future yield growth.

Richard Summers, BSPB Chairman, demonstrates how breeders have reduced the height of the wheat plant from Little Jos, a variety from around 80 years ago, to Moulin, from the 1980s.

Plant breeding contributes to increased crop productivity in many different ways:

**Physical yield**
Breeding improved crop varieties which convert more of their biomass into productive yield is the single biggest contributor to improved crop output. The development of shorter-strawed cereal varieties is a striking example of how this has been achieved. By transforming more of the crop’s productive energy into valuable grain, the introduction of these ‘semi-dwarf’ varieties marked a 20% step change in UK cereal yields.

**Disease resistance**
Progress in plant breeding has significantly improved the genetic resistance of modern crop varieties against the threat of viral and fungal infection, reducing harvest losses and enabling crops to realise their yield potential. Key examples include resistance to rust and mildew in cereals, rhizomania in sugar beet and late blight in potatoes.

**Physical characteristics**
Changing a crop’s physical structure can also boost yields. The development of semi-leafless field peas, for example, helped to boost intrinsic yield while improving the crop’s standing ability and the efficiency of harvesting.
Tim e of m aturity

Plant breeding technology has brought major improvements in the uniformity with which crops ripen ready for harvest. This not only reduces potential crop losses at harvest (as in the case of pod shatter in oilseed rape), but has also transformed growers’ ability to mechanise harvesting operations in the field vegetable sector.

Other agronomic factors

By improving crops’ ability to cope with a range of other agronomic pressures, advances in plant breeding continue to underpin progress in agricultural productivity. They include:

- genetic resistance to pests, such as nematode resistance in potatoes;
- shortening the crop life cycle, to expand a crop’s geographical growing area, e.g. forage maize;
- stress tolerance, such as frost resistance in field vegetables, to extend the seasonal availability of home-grown produce.
Food safety and nutrition are key priorities for today’s health-conscious consumers. Progress in plant breeding can deliver health-related benefits in a number of ways.

**Expanding choice in fresh produce**

By providing continuous improvements in the quality, taste, convenience and seasonality of our fresh fruit and vegetables, innovation in plant breeding is increasing choice, diversity and excitement for consumers, contributing positively to the nation’s five-a-day healthy eating targets.

**Delivering health benefits**

Plant breeders are developing a range of new crop varieties with specific health advantages, from oilseed crops with healthier oil profiles to brassica crops with increased levels of beneficial nutrients and oats with enhanced levels of antioxidants and beta-glucan.

**Improving food safety**

Progress in plant breeding is also addressing key food safety concerns. Improvements in disease resistance, for example, can help reduce levels of harmful mycotoxins caused by fungal infections, while quality improvements can help reduce or eliminate anti-nutritional factors such as erucic acid in oilseed rape.
Healthier vegetable oils

A ten-fold expansion in the UK oilseed rape crop from the mid-1970s to today’s 700,000 hectares can be directly linked to two major plant breeding breakthroughs. Varieties were first developed in the 1970s with reduced erucic acid levels to make the oil more suitable for human food use. This was followed in the late-1980s by ‘double-low’ varieties, with reduced glucosinolate levels to improve the quality and nutritional value of the resulting meal for animal feed.

More recently, plant breeders have developed oilseed varieties with modified oil content to help reduce dietary consumption of trans fatty acids, which have been linked to increased risk of heart disease and stroke. Trans fats are the result of partial hydrogenation of vegetable oils, a process used in the food industry to prevent rancidity and extend product shelf life.

Plant breeders have responded with a range of new oilseed rape varieties whose oil profile is high in oleic acid and low in linolenic acid. This offers food processors improved stability in storage and use without hydrogenation, reduced saturated fats and negligible levels of trans fatty acids when used for frying.

Progress is also taking place to develop oilseed crops enriched with omega-3 fatty acids similar to those found in oily fish. This will provide a renewable, plant-based source of these essential, health-giving oils while helping to alleviate pressure on endangered fish stocks.

High oleic, low linolenic (HOLL) oilseed rape varieties have been bred to produce healthy low saturated fat vegetable oil that is stable at high temperatures.

CASE STUDY 1: Healthier vegetable oils
The UK distilling market seeks malting barley varieties with low levels of a compound called glycosidic nitrile (low-GN varieties). This is in response to concerns that, under certain conditions, a breakdown product of glycosidic nitrile can react with ethanol, catalysed by copper in the stills used for whisky distilling, to produce traces of a potentially harmful substance known as ethyl carbamate.

Thanks to the development of improved malting barley varieties, the distilling industry is now able to reduce GN levels even further to meet the stringent quality demands of the major Scotch whisky export markets such as the USA.

Malting barley varieties are already available showing a five-fold reduction on previous GN levels, and breeding efforts continue to focus on the development of high-yielding varieties with non-producing levels of glycosidic nitrile.

By developing low GN varieties, plant breeders have helped to safeguard one of the UK’s largest whisky export markets – USA and Canada – from future regulatory change. These markets were worth £466 million in 2009.

Once again, UK plant breeders are responding to the demands of an increasingly health-conscious market place, safeguarding export markets worth £ billions to the UK economy.

CASE STUDY 2:
Low-GN barley varieties

By developing low GN varieties, plant breeders have helped to safeguard one of the UK’s largest whisky export markets – USA and Canada – from future regulatory change. These markets were worth £466 million in 2009.
By improving the on-farm performance and end-use quality of our major food crops, plant breeding makes a significant contribution to our quality of life by providing the essential starting point for a secure and affordable food supply.

But plant breeding also contributes to a better quality of life in many other ways:

- by supporting improvements in crop productivity, the development of higher-yielding new varieties helps protect marginal habitats and landscapes for wildlife and recreation;

- gardeners enjoy the benefit of improved varieties of shrubs, ornamentals, fruit and vegetables, and a choice of grass seed adapted to a range of uses, from low-maintenance landscaping to hard-wearing lawns;

- plant breeders have also developed grass varieties to suit many different sporting uses, from compact, fast-repairing turf for football and rugby pitches to a dense, close-knit surface for golf greens;

- innovation in vegetable breeding has broadened choice, diversity and convenience in the fresh produce market, helping the nation meet its ‘five-a-day’ target for healthy eating.
To meet today’s fast-paced lifestyle many consumers want convenient, meal-sized portions of their favourite vegetables, throughout the year and with minimum need for preparation.

Cauliflowers are one example: whole cauliflowers just take up too much space!

That’s why there has been a steady rise in sales of fresh cauliflower florets sold both on their own and in mixed vegetable packs. To satisfy the demands of this growing market sector, UK vegetable breeders have introduced cauliflower varieties that have been selected to produce a very dense white curd and high numbers of florets per head, just the right size for pre-packs.

This characteristic enables growers to produce high yields of fresh florets, and helps meet the demand for convenient, healthy food at a reasonable price for consumers.

Plant breeders have developed a whole range of new varieties to bring convenience to retailers and consumers, for example seedless peppers, non-bleeding red cabbage, ‘burpless’ cucumber, cabbages with even-sized, dark green leaves for retailing in packs of shredded spring greens, potatoes for every culinary purpose, and varieties with extended growing seasons to provide in some instances a year-round supply of home grown produce.

Innovation in vegetable breeding has broadened choice, diversity and convenience in the fresh produce market, helping the nation meet its ‘five-a-day’ target for healthy eating.
Innovation in grass breeding has delivered year-on-year improvements in the performance of perennial ryegrass – the main grass type used in sports and amenity applications – as breeders strive to develop the ideal playing surface.

Here are just a few of the major breakthroughs in grass breeding made in recent years:

- **Advances in wear tolerance** delivered through improved varieties allow today’s sports pitches to withstand an extra 30% playing time compared with 30 years ago;

- Breeding has extended the **growing season** for grass varieties, aiding repairs and regeneration all year round, regardless of conditions. The result is a stronger performance right through winter, as well as an improved winter colour;

- The development of **fast-establishing** annual ryegrass varieties capable of germinating in temperatures as low as 3°C means establishment and growth can be achieved quickly and all year round – even in the cooler autumn and winter months;

- The introduction of **shade-tolerant** species and varieties has helped address the issue of shade – a real problem for sports turf development and maintenance in some of our top stadia.

CASE STUDY 2:

**Breeding the perfect sports turf**

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BSPB publishes annually the Turfgrass Seed Booklet, listing the best amenity grass varieties and their characteristics as determined from independent variety trials conducted by STRI. (Visit www.stri.co.uk for more information)

These publications are available to download at www.plantbreedingmatters.com/lifestyle.php
### Glossary

**Breeder’s seed**  
The first stock seed produced by a breeder of a new variety at the start of the multiplication process.

**BSPB**  
The British Society of Plant Breeders, the association representing plant breeders in the UK. [www.bspb.co.uk](http://www.bspb.co.uk)

**Certified seed**  
Seed which is produced within an official certification system, which has passed field inspection for varietal purity and seed testing for purity and germination; seed of agricultural crops in Europe may not be marketed unless certified.

**Cis-genesis**  
A technique involving the transfer of genes, similar to transformation but used to insert genes from the same or a related species.

**CPVO**  
The Community Plant Variety Rights Office is the office that handles applications for and awards European PVR. [www.cpvo.europa.eu](http://www.cpvo.europa.eu)

**Doubled haploid breeding**  
A laboratory technique for producing true breeding seed of a variety within a single generation by creating a haploid plant with half the usual number of chromosomes and then doubling them to produce a homozygous or pure line of the plant variety. Used to accelerate the progress of a promising variety through the breeding programme.

**DUS**  
Distinctness, Uniformity and Stability; a new crop variety must pass a growing test for DUS to be authorised for marketing and/or to be granted Plant Variety Rights.

**Embryo rescue (and assisted pollination)**  
A breeding technique used to make crosses between plants where the cross would normally produce offspring that are not viable. A way to expand the range of genetic diversity by combining genes from plants that could not normally be crossed by mechanical transfer of pollen outside the lab.

**F1**  
The first generation of plants that results from a cross between two parents; F1 plants are uniform.

**F2**  
The generation that results from sowing seed from F1 plants; these plants are all genetically different. Sowing seed from an F2 plant leads to the F3 generation and so on.

**Farm-saved seed**  
Seed of certain species of agricultural crop that is the product of a farmer’s own harvest and which he retains for sowing on his own holding. [www.fairplay.org.uk](http://www.fairplay.org.uk)

**Fera**  
The Food and Environment Research Agency. [www.fera.defra.gov.uk](http://www.fera.defra.gov.uk)

**Genome**  
The complete set of genes of a plant as contained in a reproductive cell.

**Genomics**  
The study of genes, their functions, their interactions and how they control the growth and development of organisms.

**Green Revolution**  
A period of rapid scientific progress in the development and introduction of new crop varieties and other agricultural technologies in the 1960s, that led to significant increases in crop yields, especially in developing countries.

**Hagberg Falling Number**  
A standard predictive measurement to assess the quality of wheat grain for milling and baking purposes.

**Heterosis**  
Also known as hybrid vigour, the improved performance shown by a hybrid variety over that of its parents.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Hybrid</td>
<td>A plant which is the offspring of a cross between two or more genetically different parents</td>
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<tr>
<td>Inbred line</td>
<td>A genetically pure variety produced by repeated self-pollination that breeds true and is stable over generations</td>
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<tr>
<td>Landrace</td>
<td>A locally adapted, non-uniform population of a crop species, grown by farmers in a specific area over a long time period</td>
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<tr>
<td>MAGB</td>
<td>Maltsters Association of Great Britain, the representative body for malting companies, which operates a testing and approval system for malting barley varieties in collaboration with plant breeders. <a href="http://www.ukmalt.com">www.ukmalt.com</a></td>
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<tr>
<td>Marker assisted selection</td>
<td>Using markers in the plant genome that are linked to specific desirable traits such as disease resistance to be able to identify quickly and easily whether the characteristic of interest is in a seed or plant</td>
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<td>Nabim</td>
<td>National Association of British and Irish Millers, the representative body for flour millers, which tests and approves new wheat varieties for their milling potential in collaboration with plant breeders. <a href="http://www.nabim.org.uk">www.nabim.org.uk</a></td>
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<tr>
<td>National List</td>
<td>In Europe, a register of varieties in a Member State that are legally approved to be marketed</td>
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<td>NIAB</td>
<td>National Institute for Agricultural Botany, research institution that carries out much of the DUS testing for the UK, seed certification for England &amp; Wales and VCU trials and quality tests for new varieties. <a href="http://www.niab.com">www.niab.com</a></td>
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<tr>
<td>Oligo-nucleotide-mediated site-specific mutagenesis</td>
<td>A laboratory method to alter the function of a specific gene in a plant to change a characteristic of the plant in a highly targeted way</td>
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<td>Pedigree breeding</td>
<td>Crossing and repeated selection of plants having desired characteristics</td>
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<tr>
<td>PHSI</td>
<td>Plant Health and Seeds Inspectorate, official Government inspection body for seeds, plant health and compliance with the relevant regulations</td>
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<tr>
<td>Plant Breeders’ Rights (PBR)</td>
<td>The most used <em>sui generis</em> system of IP protection for plant varieties, synonymous with Plant Variety Rights</td>
</tr>
<tr>
<td>Plant Variety Rights (PVR)</td>
<td>See Plant Breeders’ Rights</td>
</tr>
<tr>
<td>Pre-basic and Basic seed</td>
<td>After Breeder’s seed, the next two generations in seed multiplication, usually produced under the breeder’s control, the first two generations of seed within the official seed certification system</td>
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<tr>
<td>Seed certification</td>
<td>The official scheme for the certification of seed in Europe</td>
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<tr>
<td>Single seed descent</td>
<td>A method to speed up the genetic purification of a new variety by producing each new generation from a single seed of a plant of the previous generation</td>
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<tr>
<td>Standard seed</td>
<td>The legal marketing standard for most vegetable seed sold in Europe; standard seed must meet defined standards for identify, quality and be properly labelled</td>
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<tr>
<td>Transformation</td>
<td>Altering a plant’s genetic make-up by inserting genes from unrelated plants or other organisms to introduce new attributes</td>
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<td>UN FAO</td>
<td>United Nations Food and Agriculture Organisation. <a href="http://www.fao.org">www.fao.org</a></td>
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<tr>
<td>VCU</td>
<td>Value for Cultivation and Use; new agricultural crop varieties must pass growing tests for VCU to be approved for marketing in Europe</td>
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