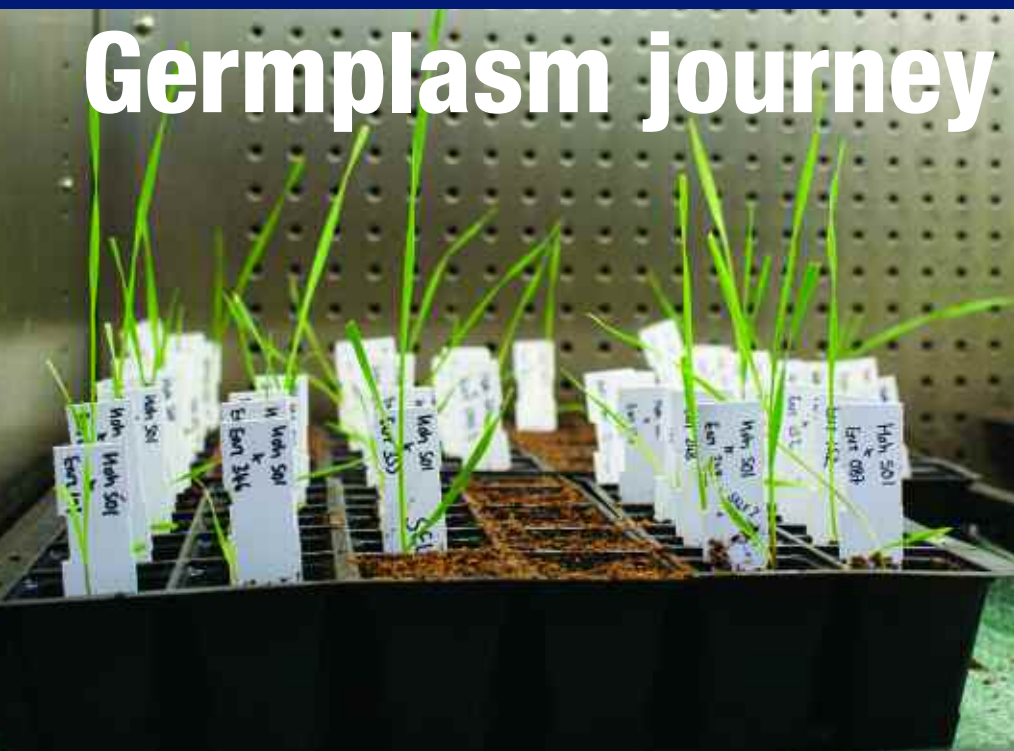


Germplasm journey



It must have been an odd sight when Dr Francis Lupton arrived for work each morning at the Plant Breeding Institute (PBI) at Trumpington, Cambs: despite standing well over six feet tall, he insisted on driving a Mini.

But it was his work with John Bingham in reducing the height of UK wheat that may have been one of the biggest breeding breakthroughs in its history. "The semi-dwarf varieties were a real quantum step in terms of plant breeding," notes Dr Penny Maplestone of the British Society of Plant Breeders (BSPB).

"By changing the distribution of plant material from the straw and leaf to the grain, they brought about a 20% yield increase for growers, so the work really established the PBI as a centre of excellence for UK breeding. The great attribute the institute had was that it spanned the wheat research spectrum from fundamental science through to finished varieties."

Independent wheat breeding consultant Bill Angus worked in John Bingham's team at PBI. "John Bingham led the market-driven wheat-breeding programme while Francis Lupton worked more in the background developing the material. Together they changed the model of wheat-breeding and brought about a new era of 10t/ha yields," he says.

“The main goal isn't to gain intellectual property but to address the science towards pre-competitive industry challenges.”

Semi-dwarfs were far from new, however. The material originated in Japan, was brought over to America in the 1950s and was developed at the International Maize and Wheat Improvement Center (CIMMYT) by Norman Borlaug in Mexico — the start of the 'Green Revolution'. "The PBI didn't get its hands on semi-dwarfs until the early 1960s, but they had to be adapted to the UK climate," explains Bill Angus.

"Some breeders said it was a waste of time, but Francis Lupton soldiered on and developed the genetics, and eventually Hobbit, the first true semi-dwarf, arrived on the scene in 1973."

John Bingham's skill was in spotting the opportunity and he developed the trait into a series of varieties that enjoyed remarkable commercial success. Virtue, Longbow, Galahad and Norman, for example, which appeared in 1981, were the first semi-dwarf varieties to be widely grown across the UK.

Capable talent

Public funds supported the PBI and it grew in size and prominence, spear-heading both pre-breeding research and commercial development of lines across a range of crops. By the mid-1980s there were over 200 staff and it drew in the most capable UK breeding and scientific talent as well as visiting research students. Of 14 wheat varieties on the 1989 Recommended List, 11 were bred by the PBI.

But it was privatised in 1987 and its influence declined. "It had effectively been a government monopoly," notes Bill Angus. "The work on semi-dwarfs and milling wheats was brilliant as was the supporting departmental work on crop physiology and pathology. But there was fairly modest innovation in terms of introgressing new traits — too much of the research was on supporting the breeding rather than taking it a step further."

For Penny Maplestone, however, a chasm then opened up in breeding research. "After the demise of the PBI there was a rather dark period. Varieties progressed in

While the Recommended Lists represent the most significant part of AHDB Cereals and Oilseeds activity on varieties, the lifeblood of new lines lies in breeding and pre-breeding research. CPM tracks its history and prospects.

By Tom Allen-Stevens

commercial lines and fundamental research continued, but something had to be done to link the two."

The commercial return for breeders was secured when the Plant Royalty Bureau, the pre-cursor to BSPB, was set up in 1966 to gather royalties from the industry. It was further strengthened when royalties on farm-saved seed were introduced in 1996 and today these provide £10M of the £35M total royalties collected by BSPB for breeders.

"It's a level of funding that secures the development of new varieties and ensures the AHDB Cereals and Oilseeds Recommended List average wheat yield progresses at a rate of around 0.5% per year, for example. But it's not enough to fund more strategic research, and breeders must work in partnership with academics through private/public partnership to achieve this."

The LINK programme of agricultural research started in the mid 1990s and as its name suggests, restored this. Commercial interests, including breeders and AHDB, would contribute towards large, government-funded projects and help steer their direction. The development of orange wheat-blossom midge (OWBM) resistance, through a project that ended in 2001, was a particular milestone, recalls Penny Maplestone.

"It meant an insecticide spray could be replaced by good plant genetics, and this benefitted the industry as a whole, rather than one particular breeder. The resistance gene was identified through the collaboration and the commercial partners in the project introduced it to the market through their varieties, making it available to all breeders.

"It was a club arrangement that worked well, securing a commercial outlet for worthy public-funded research but with breeders working together for relatively little cost in a pre-competitive research arena."

The model has continued through various iterations, and today a key pre-breeding research programme is the BBSRC Crop Improvement Research Club (CIRC)."

"It's a relatively small investment for us of just £10,000/year," notes Dr Ellie Marshall of AHDB — one of the club members. "But it gives us access to a programme with total funding of over £7M across 15 projects.

"It also gives CIRC members the opportunity to influence the selection and progress of those projects to ensure some really useful outcomes for growers and processors."

BBSRC is the primary source of funding, with £500,000 provided by The Scottish Government and industry contributing a further £560,000 to the club. End



Work carried out at PBI changed the model of wheat-breeding, says Bill Angus.

users are represented by the likes of the Scotch Whisky Research Institute and nabim, who sit alongside the main UK breeders and AHDB. They steer the projects conducted across 13 research institutions.

"The projects will always have an emphasis on delivering yield, but there are issues of quality, pest and disease resistance, and agronomy they also address. So there's a balance of trying to overcome environmental challenges as well as maintaining crop performance," she continues.

Work developing resistance to turnip yellows virus (TuYV) is a prime example. "The loss of neonicotinoids has brought TuYV forward as a key priority in oilseed rape. The project is now close to delivering a genetic toolkit all breeders will be able to use so the industry no longer has to rely on crop protection products," she points out.

Co-ordinating the projects is Dr Simon Bright. "They're now at an exciting point," he enthuses. "The main goal isn't to gain intellectual property but to address the science towards pre-competitive industry challenges."

The model for all the projects is that they must be high quality inventive science, pointed at a specific problem, he explains. "I have to admit that some of the projects we're supporting I thought at first were a long shot, but they're delivering results."

One example is a project between Essex University and Rothamsted Research, led by Prof Martin Parry, manipulating the photosynthetic carbon metabolism in

wheat. "The perception has been that yield is sink-limited, so a whole generation of crop science has largely ignored photosynthesis. This project has looked again at the biochemistry turning carbon dioxide into yield," explains Simon Bright.

What the research team did was to use GM techniques to increase a key enzyme in wheat to get a step-up in photosynthetic ability. "The first plants in the greenhouse look bigger and work harder to produce yield," he continues.

"It's a GM technique, so can't be used in the field at the moment, but it looks like we're fishing in the right pool to increase biomass, whereas before this was just academic speculation. The project finishes in early 2016, but has attracted fresh international funding so it will continue.

"There's also a whole suite of projects around roots which may have a big impact on varieties — this science is really pushing the boundaries."

Work at the University of Nottingham, led by Dr Martin Broadley, for example, has developed rapid root-phenotyping screens for arable crops. "Just as breeders look for traits in the plant above ground, this screening methodology identifies what's going on beneath the soil surface," says Simon Bright.



After the demise of PBI, there was a perception the link between breeding and pre-breeding research had been cut.



The research team used GM techniques to increase a key enzyme in wheat to get a step-up in photosynthetic ability.

"Lab results have now been confirmed in the field, so it's opened a whole new area of breeding for root architecture."

Ten of the projects have associated PhD studentships, he points out. "The great thing about the club is the close involvement with industry — these students get to know people in leading commercial companies, which builds lasting relationships. For BBSRC it's getting cutting-edge science out into the field."

Breeders agree it's a formula that's working. "Breeding research is in a much better place now," comments Bill Angus. "There's a very positive relationship between the private and public sectors, so there's every reason to be upbeat about the varieties we'll see appearing in UK fields in years to come." ■

Web window

www.plantbreedingmatters.com — more on how plant breeding has shaped cropping, food and the environment.

www.bbsrc.ac.uk/circ — full details of CIRC and its projects.

Iconic wheats — milestone varieties of the past 50 years

- **1973 — Maris Huntsman** — changed the model of higher-yielding wheats, and finally replaced Cappelle Desprez that had been on the RL since 1953.
- **1977 — Hobbit** — the first true semi-dwarf which heralded the start of a new era of high yielding varieties from PBI.
- **1980 — Avalon** — the first of the semi-dwarf good bread-makers, allowing less reliance on Canadian imported wheat.
- **1983 — Galahad** — one of the first modern biscuit wheats and, with Norman and Longbow, opened up the soft milling and valuable export markets.
- **1986 — Slejpner** — set new standards in high-yielding, short-strawed hard feed wheat, with a good specific weight, and also a private-sector challenge to PBI's market dominance.
- **1988 — Mercia** — took over from Avalon and at one time had 26% of the UK wheat-growing area.

- **1989 — Riband** — forged a new strategy for high input, high output wheats — with a stiffness score of 9, it responded well to high N and fungicide inputs.
- **1991 — Hereward** — quickly became a miller's favourite and stayed on the RL until 2011.
- **1993 — Brigadier** — eclipsed Riband and took 25% of the wheat area, with an initially robust disease profile, before changes in yellow rust populations.
- **1999 — Claire** — became a firm favourite with farmers, along with Consort. Good for biscuits and sowing early, it extended the drilling window as farms got bigger. Still on the RL, no other UK wheat variety has earned more in royalties.
- **2003 — Robigus** — the first popular variety with OWBM resistance, combined with a good agronomic package and high yield potential.
- **2011 — KWS Santiago** — set new standards for yield potential of a high input, high output feed wheat.



KWS Santiago set new standards for yield potential of a high input, high output feed wheat.

- **2014 — Skyfall** — a milling wheat with feed wheat yield potential, it captured growers' interest with its good agronomy, as well as OWBM and eyespot resistance.

Note: views on varieties expressed by Bill Angus

Variety development timeline

1960s

- Plant Royalty Bureau formed, after UK enacts the Plant Varieties & Seeds Act 1964, establishing a legal framework for the collection of royalties on protected crop varieties (1966)

1970s

- Norman Borlaug wins Nobel Prize for breeding high yielding wheat for Mexico (1970)
- Winter wheat variety Maris Huntsman offers 20% yield advantage over previous market leader Cappelle Desprez (1972)
- Golden Promise, bred in the early 1960s using gamma ray mutation, is the leading spring malting barley variety. Maris Otter dominates the winter barley market (1976)
- Establishment of single-low oilseed rape varieties supports major UK expansion of the crop in response to CAP support incentives

1980s

- Virus-resistant tobacco becomes the first GM crop approved for field release in the USA (1983)
- Double-low oilseed rape varieties deliver improved end-use quality for food and animal feed (1989)

1990s

- Domestic forage maize area exceeds 100,000ha, thanks to breeding success in adapting the crop to UK growing conditions (1994)

2000s

- Introduction of semi-dwarf type oilseed rape varieties

Did you know?

Every £1 invested in plant breeding generates at least £40 in added value within the wider UK economy

**Selected developments shown.
For the full animated timeline,
visit cereals.ahdb.org.uk/genetics**