Reach for the GIN

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Innovation
Pulse genetics

Massive demand for plant-based protein puts the spotlight on peas and beans to deliver for the UK market. *CPM* delves into the research aimed at putting varieties on farm that will meet the challenge.

By Tom Allen-Stevens

A crop that fixes its own nitrogen from the air, is nutrient-rich, with properties that offer a wide range of established health benefits and one that can have a carbon-positive impact in many of its applications: such a crop should surely be heralded and championed?

Pulse crops are widely considered to represent a whole family of this wonder produce, but even the most widely grown — peas and beans — are minor crops in the UK. NFU agrifood policy delivery manager Jack Watts believes it's a missed opportunity that's come about through decades of policy neglect.

"Pulses come with built-in public good, so present a dual purpose for society and farmers alike," he notes.

The EU currently imports around 90% of its protein requirement, with soybean and soya meal imports into the UK alone between 2.5-3M tonnes/yr. "EU policy for the past 40 years has driven quite a significant oversupply of energy-dense grains and that's created a massive deficit of home-grown protein," Jack maintains.

"Soymeal is very competitively priced and it's a good product for monogastric animals. But there is the opportunity in dairy and pigs to substitute around the edges of the market. With changing consumer habits, protein for human consumption is a growing market we risk not capitalising on."

Fundamental problem

Jack would like to see "agile alliances" between arable and livestock producers, underpinned by a "professionalisation" of farm-to-farm trading. But he recognises there's a fundamental problem with pulses that's holding this back. "Beans in particular are stuck between a rock and a hard place — they struggle to compete on the market with soya and in the rotation with wheat. The challenge for the crop is consistency in yields and it's clear UK pulse-breeding and agronomy need fast tracking to offset decades of neglect."

PGRO's Steve Belcher agrees that year-on-year variation in yields is a problem, keeping pulse crops out of the rotation for many. "Particularly in spring-sown crops, there's a perception yields are variable and unreliable, although there's also evidence this is no more the case in pulses than for other spring-sown crops," he notes.

The opportunity for protein substitution is to some extent limited by availability, Steve points out — pulses will at best only ever be included one year in five in the standard UK arable rotation. "This is an area that gets a lot of rhetoric, but not a lot of action, however."

Defra's response is to fund the Pulse Crop Genetic Improvement Network (PCGIN). One of four networks, it's a platform that sets out to serve the process of crop improvement for legumes in the UK. PCGIN is currently running on a five-year programme, with spending channelled into four work packages designed to meet current and future industry requirements.

"We hope the programme produces more resilience in pulse crops to make them more attractive to farmers, and to increase the market value of their product. These two requirements are linked to the major strands of PCGIN activity," explains Steve.

The first is being addressed through improving crop performance and reliability, by establishing the genetic basis for agronomic traits such as standing ability, yield and disease. "Genetic resistance markers have been defined for powdery mildew in pea, for example, but not for downy mildew, an oomycete that has a large impact in diminishing yield of both peas and beans," he continues.

The difficulty here is that downy mildew has many different races, so just one source of genetic resistance would be quickly overcome — three or preferably four genes would be more robust. But there's now a pressing need, he notes. "Most of the seed treatments for this disease have been withdrawn or are restricted temporally in their application, making the discovery of disease

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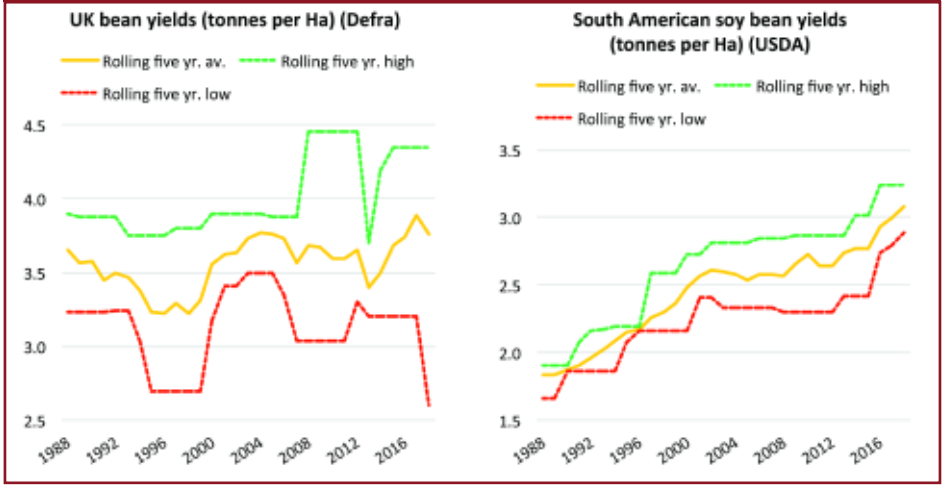
Consistency and performance of bean crops



Beans in the UK struggle to compete with soya — the challenge for the crop is consistency in yields.
Source: Defra and USDA

resistance genes an even more urgent priority."

Standing ability in peas remains one of the biggest reasons why growers tend to avoid the crop, says Steve, although this has improved through recent variety introductions. "In beans, bruchid beetle is the major challenge to overcome as this is the main reason crops fail to meet the spec for the premium human consumption markets."

On the market value side, the focus of PCGIN activity has been to ensure pulse crops are an efficient source of plant-derived protein for both food and animal feed. Driving this is the rapidly growing global demand for pea protein, largely as a meat replacement. There are also calls for food systems to be transformed to protect human health as well as that of the planet — pulse consumption is linked to positive effects on aspects such as the prevention of Type 2 diabetes and obesity.

For the high premium export markets, colour stability is a trait addressed by PCGIN, while for animal feed, improved digestibility of seed components is an important goal.

"PCGIN is one of the feathers in the cap of the support Defra brings to UK Agriculture," says Prof Claire Domoney of John Innes Centre who leads the programme of research. "The aim is that pre-breeding research gets out into the field and doesn't just end up in scientific journals. In that respect it's been ahead of its time and we now get considerably more industry involvement at stakeholder meetings than when PCGIN was first set up."

Steve Belcher hopes that PCGIN will produce more resilience in pulse crops to make them more attractive to farmers, and to increase the market value of their product.

At its heart the research sets out to unravel the pea and bean genomes and understand the genetic components of phenotypic traits seen in the field and in the end products. "Yield is complex and associated with many genes. So we look at the components of yield, such as standing ability and disease resistance. One area where some really exciting progress has recently been made is in downy mildew in peas," she reports.

The work revolves around a diversity panel of 218 lines of pea, that have been drawn from those curated by the Germplasm Resources Unit at JIC. This seed bank of ▸

Genetic improvement comes through a shared approach

The aim for Will Pillinger, pulses breeder for Limagrain UK, is for "farmable" pulse crops. "These are varieties that will take up the slack in stressful years. We currently have LG Raptor, a spring bean new addition to the PGRO Recommended List with a high yield potential to compete with Lynx. There's also LG Aviator, a new large blue pea with powdery mildew resistance topping a good all-round agronomic package."

Coming through candidate trials are LG Viper and Sphinx, spring beans which were highest yielding in National List trials, he says. "We do rely on markers and material that come from PCGIN, especially for blue peas and marrowfats. These have helped improve standing ability in peas, and we're starting to see traits for colour retention coming through into NL trials."

Limagrain is an international company which benefits from a Europe-wide pulse-breeding programme and other global projects and partnerships, Will explains. "But there are challenges and markets that are specific to the UK crop and climate. For our UK breeding programme, the cost of using specialist genomic selection tools to bring new genetics to market, let alone explore new opportunities, is a challenge and has to be very carefully managed."

Will's been involved with PCGIN since it started in 2005 and has helped shape its direction since then. He receives material and genetic markers in a background that's as close as possible to his commercial lines. "In the UK there's a pulse-breeding community that's unique — we work closely with each other, and although we don't share our secrets, we do share knowledge. That's come about through PCGIN, and if key partners weren't involved in it, it wouldn't work," he says.

"The industry has some challenges though — we're working on downy mildew, yield stability and lodging resistance, but other threats include botrytis, fusarium and aphanomyces. With a shrinking chemical armoury, these will only get more acute. Bruchid beetle in beans has also been a massive problem in recent years. We need the investment in research to deliver the genetic solutions we will increasingly rely on."

Will Pillinger needs the investment in research to deliver the genetic solutions the industry increasingly relies on.

PCGIN gets considerable industry involvement at stakeholder meetings, notes Claire Domoney.

▸ over 3500 different accessions has been drawn from all over the world and ranges from wild to cultivated types, with some exotic lines originating from the Himalayas, for example, and also some mutant material. The majority of these lines have been analysed for their genetic relationships and the diversity panel makes up a good representation of the spectrum of pea genes which could be made available to breeders.

"We tested the diversity panel against two different downy mildew pathotypes. The good news is that just over 50 of the accessions showed no infection using one pathotype and most of these also show high resistance to a second pathotype. We're planning to screen against a third shortly."

The aim is to identify the genes responsible and provide to breeders a genetic toolkit that allows them to bring the genes into commercial lines. This includes molecular markers, as well as the germplasm itself, and will complement information already identified on two other genes known to confer resistance. "The beauty of the panel is that it can be made freely available to anyone who wants to dive into the genetics of any trait to improve a pulse variety," she notes.

Significant progress has been made on the genome sequence of pea, with ten lines from the diversity panel sequenced. But there's a problem, says Claire. "A large proportion of the pea genome — over 80% — is repetitive DNA. That makes it very difficult to stitch its genome together from the fragments identified."

The technology used analyses the genome by dividing it up into small sections which are sequenced, she explains. The sequences of the sections are reassembled to build an entire sequenced genome, which can consist of several billion base pairs. "Peas are particularly rich in repetitive elements and it's like trying to build a jigsaw puzzle using identical pieces. It makes it hard not only to identify which genes are linked to a phenotypic trait, but also where they are placed in relation to other genes.

Standing ability

"The Earlham Institute has invested in technology that can analyse much longer strands of DNA, with work to refine our pea sequences due to start shortly," continues Claire. "The work is hugely valuable — there are hormone biosynthetic genes that are linked to height and standing ability, for example. Once we know the physical distance between these genes, we will better understand their impact on traits."

Work has also progressed on colour stability, following the discovery of six new sources of variation in one gene that controls this trait. Initial testing appears to confirm the genetic link and scientists are now working to test these gene variants in near-isogenic lines, which can be compared meaningfully with each other. From there, the best variants can be introgressed into commercial material. "Moving genes from a wild background into cultivars can take a long time, although we're using modern 'speed-breeding' techniques to shorten the time it'll take to bring a pea to market, including those that won't bleach."

Sequencing the pea genome will help identify hormone biosynthetic genes that are linked to height and standing ability.

Initial results of digestion studies on the super-protein pea look very promising.

Perhaps most exciting is progress on the super-protein pea. "We know peas contain proteins responsible for inhibiting digestion, so have looked into what happens if we make genetic changes that have the effect of knocking out these proteins."

What scientists have discovered is that the plant compensates by building other, more nutritious proteins — up to eight classes of protein have been "substituted" in this way. "We've just carried out digestion studies using some of this material and initial results look very promising. This work has great potential to improve the quality and functionality of pea protein for both animals and humans, just as demand for it is going through the roof," notes Claire.

In the future she can see that more focused work on climate change will become a priority, with legumes showing great potential to deliver net zero targets. "We have the R&D resources ready to go, as soon as the funding button is pressed," she says.

And there's real potential for grower involvement. "The introduction of the pea and bean YENs is a big step forward in bringing growers and researchers closer together on the genetic improvement journey. There are also farmers now growing research material, such as a group testing lines known to be rich in dietary-resistant starch. As technology moves forward and we build on these relationships, scientific discovery will accelerate and pulse crops will get the position in the rotation they deserve," concludes Claire. ■

Research roundup

The Pulse Crop Genetic Improvement Network (PCGIN) is one of four projects supported by Defra as part of a long-term research platform for the genetic improvement of arable crops and fresh produce. Awarded £1.3M for the five-year period running from 1 Feb 2018 to 31 March 2023, PCGIN establishes the route by which genetic resources and knowledge are delivered to the UK pulse industry. It develops an understanding of product quality, genomic research and provides links with similar research programmes worldwide. The project started in 2005 and is now in its fifth stage. PCGIN is managed by the John Innes Centre, in collaboration with NIAB, University of Reading, Aberystwyth University, AHDB, PGRO and Defra and with input provided by the commercial sector. *www.pcgin.org*

This article is part of PGRO's delivery of knowledge exchange on its activities to support pulse crops and their cultivation in the UK. *CPM* would like to thank PGRO for its support and in providing privileged access to staff and others involved in helping put these articles together.