POTATO BREEDING AND VARIETY SELECTION

Understanding potato genetics. By Dr Jenny Ekman

Drs Hein, Sharma and Chen work on potato genetics, genomics and breeding. Potatoes are particularly difficult to breed as they have four different copies (alleles) of each gene (tetraploid) instead of the normal two (diploid). This means there are a lot more possible outcomes from crossing varieties, with outcomes frequently unpredictable.

"A really big moment for us was the release of the potato genome in 2011. Sanjeev was an author on this publication, which was a big international effort with many institutes and researchers involved. It's a really big genome. If you were to print it out on paper, you would cover a distance of 2,600 kilometres, nearly the length of the Australian east coast," explains Ingo.

According to Dr Sharma, breeding before the potato genome was known was a bit like going to a library blindfolded and trying to find a book. Now, through genome sequencing, we know which book is where.

One of the puzzles the group has been examining is the genetics behind disease resistance.

"We've examined the genetics of 700 different potato varieties from around the world. We found that only a handful of genes are providing resistance to late blight, nematodes, viruses and other diseases. Most have these have been deployed since the 1960s, which is why resistance is often breaking down."

However, it's not all bad news, as the team has also identified many more genes that could be used. That means there's a huge opportunity to improve resistance by breeding these genes into new varieties.

This process is now easier due to the development of genetic markers for these resistance genes such as Single Nucleotide Polymorphisms (SNPs).

Potato breeders necessarily produce hundreds, if not thousands of new plants a year. Traditional screening by growing the plants, then exposing to disease or stress, requires space, time and lots of work. If we know what gene is wanted, it would be much more efficient to test if the desired gene was present through gene sequencing. This may be quicker, but the data is huge and cost still too high.

"Now we can simply scan for these SNPs," says Dr Chen.

"The markers we have developed are nearly 100% effective at detecting whether the desired gene is present. These are now being used by commercial companies. If the marker is detected, then that gene will certainly be expressed."

The trend now is to try to breed in as many resistance genes as possible. While a single gene may be able to protect the plant from a specific disease, such resistance is fragile. A tiny change in the pathogen may overcome it. Including a range of different resistance mechanisms makes resistance more durable.

According to Dr Sharma, many of the commercial traits of potatoes are controlled by multiple genes.

"Flesh colour, tuber shape, eye depth; these traits are mainly controlled by a single, dominant locus (gene). However, features such as yield and tuber dry matter are more complex, with many genes involved, each contributing a small amount to the trait. This is where machine learning and new genomic prediction models can help direct breeding programs".

Such advances are expected to massively increase the speed of new potato breeding. Such genomic data can be combined with growth information produced through the new JHI Advanced Plant Growth Centre (APGC). As a result, selection processes that used to take more than 10 years could now potentially be completed in two or three.

Dr Sanjeev Sharma (left) with Dr Glenn Bryan, on the sequencing of the potato genome.

COMMONWEALTH POTATO COLLECTION

One advantage specific to the team at JHI is that the institute hosts the Commonwealth Potato Collection (CPC). The collection has at least 1,500 potato accessions, stored as true potato seed. Every year 60 to 80 of these are grown, which means it takes around 20 years to refresh the whole collection.

This process also provides an opportunity to screen each accession against diseases and determine whether resistance is due to a known or novel gene.

Visiting the CPC greenhouse feels a bit like going to a botanic garden, yet all of the plants are *Solanum*. The range is truly extraordinary.

There are long, leggy plants with ridged stems, adapted to climb from the forest floor in their search for light. There are dwarf plants that come from cold, high mountains. Some plants are smudged dark purple, others are pale. Flower colours range from white to pink, purple and almost blue. Many are almost unrecognisable as potato plants, their leaves being anything from pointed daggers to broad ovals to fern like tassels and a wealth of others.

Many of the plants here are diploid, so they only have two copies of each gene. While this makes crosses more predictable, diploid potato flowers are typically not self-compatible. In order to preserve the diversity within accessions, one of the jobs of the staff here is therefore to collect pollen from plants within an accession and use it to pollinate the others. This is labour intensive but necessary.

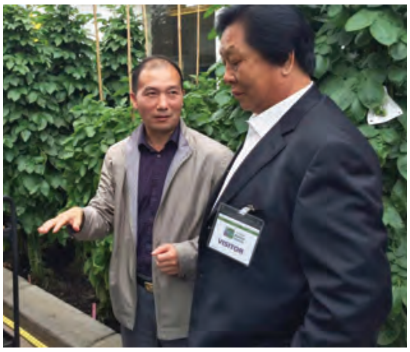
The variability of plants grown from cross pollinated seed within each accession was quite noticeable, with a range of flower colours and leaf shapes.

The only way to ensure a chosen plant propagates true-to-type is to clonally maintain it through cuttings or tissue culture, or re-grow it from tubers. Regrowing from tubers is not realistic, so that leaves tissue culture and cuttings. *More on that later in this issue.*

Staff at work in the Commonwealth Potato Collection (CPC). Each plant is carefully trimmed and staked, and the flowers hand pollinated using pollen collected from a plant within the same accession.

Some of the incredible diversity of potato plants on display at the CPC.

However, there may now be a fourth option. The potato community has found a way to overcome self-incompatibility in diploid plants by taking advantage of the 'SLI gene' used by Dr Chen. Introducing this gene allows a diploid variety to be self-pollinated. After a few generations of selfing, the plant becomes 'homozygous' that is, genetically more pure. When this variety is crossed with another such line the results will be predictable. This contrasts with the 'herding cats' approach in conventional potato breeding. Tomato breeding also uses homozygous lines.



Dr Chin (left) exchanges potato breeding strategies with Mr. Xisen Liang, the Chairman of Xisen Potato Group Ltd.

"Developing such material is very useful, especially adapting the diverse genetic resources that we have here at the CPC so they can be used in hybrid breeding programs, explains Dr Chen."

Of course, the outcome of any breeding program is to produce that's not only productive and easy to grow, but also that consumers want to buy. For example, there are potato varieties available that are highly resistant to potato cyst nematode. Unfortunately, they are not well liked by Scottish consumers so farmers don't grow them.

"I personally think this will change if supermarkets have to put a carbon footprint on products," suggests Ingo.

"If a variety uses less nitrogen, less water, less pesticide, and so has a smaller footprint, then we will see a shift where consumers are more willing to adopt them. At the moment farmers want to grow these new varieties, but they have trouble getting them into the supermarkets."

Dr Ingo Hein in the CPC greenhouse.

THE ROAD TO COMMERCIALISATION - DR JONATHAN SNAPE

James Hutton Ltd is the commercial arm of JHI. This structure has the advantage that it keeps business separate from research, yet lets the two work together.

Director Dr Jonathan Snape explains further: "Our program works closely with the researchers at JHI. So, for example, we can use the genetic markers that Ingo's team has found, taking them from where the science stops to where commercialisation begins."

JH Ltd employs two potato breeders, who work with customers to develop potato varieties with the characteristics they want.

"One thing we do is breed specifically for McCain frozen fries, working with them to determine the characteristics they want." says Dr Snape.

"Once selected, we can send germplasm to McCain trial sites around the world, and they decide which ones suit that environment."

Mayan Gold is one of the varieties developed at the JHI which was – briefly – commercialised in Australia. Unlike most commercial strains, Mayan Gold was a diploid (like the accessions growing in the CPC) and belongs to the cultivated group of Phureja. Phureja potatoes are the direct descendants of potatoes that grew in the Andes Valley, South America, and have little or no tuber dormancy. Compared to commercial tetraploid varieties, Phurejas also generally have lower yield and smaller tubers. However, they also have colour, flavour and texture combinations not found in their tetraploid cousins.

"The feedback we got from our partners in Australia was that Australian consumers aren't that interested in potato flavour, so Mayan Gold couldn't get the premium prices it needed."

"In contrast, one of our other varieties – Nadine – has been very successful in Australia. Nadine is incredibly productive. It wasn't popular here because it didn't have a strong 'potato' flavour. However, if you put tomato sauce on it then it's fine."

I guess Australians just like different kinds of tatties to the Scots!

FROM COMMERCIALISATION BACK TO RESEARCH – GAVIN PRENTICE, AGRICO UK

Just down the road from the JHI are the offices of Agrico UK, one of the many subsidiaries of Agrico BV. Agrico is an interesting company. Formed 50 years ago in the Netherlands, the company remains a co-operative, with more than 1,200 grower members. They now hold the licences of 80 different potato varieties, with a huge range of growing characteristics. One Agrico variety familiar to us is 'Carisma' low GI, otherwise known as Almera.

The company certainly invests strongly in its breeding programme. Agrico Research has its own 4,000m² greenhouse complex in Bant, the Netherlands. Here is where the research produced by Ingo's team really hits the road, as Agrico relies strongly on using DNA markers to test seedling DNA. The ability to test a tiny bit of organic material, instead of growing whole plants through to maturity, is clearly a game changer.

Current breeding programmes are focussed on resistance to PCN, PVY and late blight, as well as producing fast maturing varieties for the "early fries" processing market. There's no point breeding potatoes consumers don't like, so it's not surprising they conduct taste testing too.

In total Agrico BV produces more than 450 kT of seed potatoes annually, contracting an area of over 14,500ha. This sounds impressive, but still represents only 6% of the global market. Nearly all (92%) of this production is exported, and Agrico now has licensed potatoes growing in 80 countries on all continents.

Seed potato production in Scotland has declined slightly in recent times. However, according to Agrico UK's Technical and Procurement manager Gavin Prentice, they still count 60 growers among their members, producing up to 25kT annually of conventional seed, plus a smaller amount (150t) of organic seed.

Research to commercialisation then circling back to research, great to see.

Gavin Prentice, Agrico (right) with Prof. Ian Toth (left) and grower David Pate (centre) in Wester Meathie Farm's current seed storage facility; the company is currently constructing a much larger facility next door.