NEW RESEARCH FROM THE JAMES HUTTON INSTITUTE, SCOTLAND

When you think about potato production, most people will likely think immediately of Ireland. However, if it is seed potatoes that you're after, you are more likely to think Scotland. Scotland has a reputation as being the world's best producer of seed potatoes. So why is that? Is it the pure waters of the highlands, the famously damp weather, the resonance of bagpipes in the air or simply hard graft and science. Dr Jenny Ekman reports

Scots eat a lot of potatoes. Annual consumption of potatoes in the UK is 60 – 70kg per person annually, compared to a mere 17kg/pp in Australia. More than 90% of Scots are said to eat potatoes at least once a day, and chips (or hash browns) are offered with pretty much every meal.

Although a small country, approximately 28,000 ha of Scotland is planted to potatoes[1]. Nearly half of this is high value seed (approx. 12,000 ha). The potato industry not only contributes at least £250 million directly to the Scottish economy, but also supports potato growing in Britain valued at £928 million, with multipliers for processing running into billions[2].

Until Brexit, the Irish and potato industry also largely relied on Scottish seed potatoes. However, EU regulations struck as part of the 'soft border' agreement meant that Scottish seed potatoes were not only prohibited from export to Ireland, but even to Northern Ireland – despite it being still part of the UK. Fortunately, this was recently reversed, and Scottish seed can again be grown in Northern Ireland. Moreover, new export markets were found, with Scottish product now finding its way to a diverse range of countries including Türkiye, Kenya and even Saudi Arabia.

Given the importance of potatoes in Scotland, it is unsurprising that it also hosts major potato research and extension activities.

Research and development is focussed at the James Hutton Institute, Dundee.

THE JAMES HUTTON INSTITUTE (JHI)

JHI is internationally renowned for potato science, with a focus on breeding programs, integrated pest and disease management, sustainability in a changing climate and other applied research. They are also custodians of the Commonwealth Potato Collection, a unique source of potato germplasm.

In July this year I was fortunate to visit JHI and meet some of the potato researchers. The institute is currently expanding; JHI is not only a leader in potato R&D, but also soils, barley, crop development and environmental research. A massive new construction was underway which will house the International Barley Hub as well as an Advanced Plant Growth Centre.

THE NATIONAL POTATO INNOVATION CENTRE - PROFESSOR IAN TOTH

Excitingly for the potato industry, the next proposed development is a National Potato Innovation Centre (NPIC). Based in Dundee but expected to include national and international partners, the NPIC is planned as a state-of-the-art innovation centre. The three pillars of the NPIC are:

1. **Breeding new cultivars** with traits to address climate, disease and quality issues
2. **Sustainable and climate resilient production systems** using precision agriculture, below ground phenotyping, improved disease management and reduced waste
3. **Innovative potato products** such as functional foods, plant based medicines and plastic alternatives

The NPIC will be headed by potato pathologist Professor Ian Toth.

“Although funding for the NPIC has not been confirmed, there is a strong economic case for the project and we have had much positive feedback on the plan. We see the NPIC as a creative cluster for potato research and innovation, building on the existing potato R&D at JHI.”

The Centre would be similar in scale to the International Potato Centre (IPC) in Lima.

“However, whereas the IPC is focussed primarily on potatoes for development, the NPIC would be involved in commercial, applied research,” explains Prof. Toth.

“Examples include application of new technologies for rapid development of improved potato varieties, net zero production strategies to reduce waste, and high value functional foods”.

Plans for new facilities include a greenhouse complex, a pilot processing plant and below ground phenotyping systems.

Future opportunities

With its exit from the EU, the UK Government is looking to partner up in research projects with other countries, especially those that operate similarly.

"There are lots of opportunities, and possibly even Government funding, for collaborative arrangements that would allow UK academia and industry to work with Australian academia and industry on joint projects.”

That would give Australian researchers the opportunity to use and work at the JHI facilities, to the benefit of both. A great adaptation in the current cost-saving climate.

Prof. Ian Toth, Director of the proposed National Potato Innovation Centre, inspects some of the other construction currently occurring at the James Hutton Institute, Dundee.

POTATO GROWTH AND STORAGE - PROFESSOR DEREK STEWART

In the meantime, other new facilities are already going in. Derek Stewart is Director of the Advanced Plant Growth Centre, a £27 million flagship project hosted at JHI. As Derek explains, the project has four pillars:

Postharvest storage

Six sparkling new cold rooms had just been installed at the time of my visit. The rooms have been designed to mimic the conditions inside large potato storage environments, each room being sized to store eight half tonne Standard Potato bins.

They can be used for either seed potato trials, or for extending the storage life of fresh and processing potatoes. Potential projects include testing the effects of different cooling rates, storage times and storage temperatures on seed potato ageing and performance, as well as examining the cold tolerances of different processing varieties. The first planned trial involves a comparison of different anti-sprouting agents (see box out on page 7 for further detail).

Prof. Derek Stewart in the new storage facility.

Controlled environment facility

While the JHI already has some plant growth chambers, this new facility will enable much finer control of environmental conditions, as well as greatly expanding capacity. Everything can be controlled – the atmosphere, light intensity, even rain and wind.

The focus of research here will be adapting to climate change; subjecting plants to heat, drought, flooding and other stresses, then seeing how this affects development.

“The objective is to look at today’s varieties, and how they will cope with tomorrow’s environment. We aim to find plants which can survive difficult conditions and put that information into breeding programs,” explains Derek.

“We can even look at disease problems, as todays’ bugs and microbes might not be the same ones as cause problems in the future”.

Plant phenotyping centre

This centre is also currently under construction. It is designed to allow potatoes grown in the controlled environments to be examined in incredible detail. A whole array of sensors will be integrated to monitor growth and development including infra-red, hyper-spectral, chlorophyll fluorescence, a 3D laser image scanner and possibly others.

"CO_2 and temperature effects on potatoes are really interesting," comments Derek.

"The potato plant likes a bit of warmth, but the tipping point where productivity falls away is sharp. I think that this needs a lot more work. Scientifically, you're juggling all these different effects from temperature and atmosphere, and how plants respond to those".

Vertical farming

Vertical growth towers are indoor ecosystems that allow extremely high plant densities and fast growth rates. They have found commercial application for city production of leafy greens and herbs. They are definitely not normally associated with potatoes.

However, Derek has other ideas.

"The system is fantastic for seed potato production," says Derek.

"Even with the need for energy to power it, the system is so productive that the costs balance out. The sums are even more appealing if renewable energy can be generated onsite. We are not talking microtubers but seed perhaps 30 to 50mm diameter."

When the vertically farmed seed were planted in the field they proved indistinguishable from conventionally produced seed.

"The other thing about vertical farming is plant health," explains Derek.

"You can pretty well eliminate viruses and other diseases from the system. I could imagine a grower group partnering on one of these systems to produce all their own seed".

SUPPRESSING SPROUTS

Up until 2020, 90% of all potato sprout suppression applications used worldwide included CIPC (Chlorpropham). CIPC is cheap and extremely effective. A single application can prevent sprout growth for up to 5 months, with second applications extending this period even longer[3].

However, breakdown products of CIPC have been associated with human and environmental toxicity. Compounds produced during thermal fogging are not only present in fresh potatoes, but are retained after processing and cooking. They are also highly persistent in the environment[4].

In 1996 the USA reduced the amount of CIPC residue allowed on fresh potatoes from 50ppm to 30ppm. The European Union banned use of CIPC outright in 2020, with this same legislation preventing use in the UK. Older storage facilities now cannot be used, due to contamination by this product. While CIPC is still registered for use in Australia, it seems possible that use patterns may be restricted in the future.

In response, a number of new sprout suppressants have become commercially available. These include 1,4-Sight/Dormir (1,4-dimethylnaphtalene), hydrogen peroxide, ethylene and a range of essential oils – clove, spearmint, caraway and orange oil to name a few. While there are individual efficacy trials on each, it is difficult to find data which compares these treatments against each other and for different potato varieties.

With new cold rooms ideal for this purpose, trials at JHI will examine the performance of different sprout suppressants on several of the most important potato varieties.

Prof. Derek Stewart in the vertical farm.

THE MANY FORMS (OR NOT) OF LATE BLIGHT - DR DAVID COOKE

For many people, when you think of potato diseases, you think of *Phytophthora*. Dr David Cooke is a late blight specialist at JHI. He has collaborated extensively in the past with our own Dolf DeBoer, recently retired from the Victorian DPI.

One of his key roles is genotyping samples that come in on FTA cards. These simple cards are used to collect samples of the disease by simply squishing a lesion into the FTA matrix, then sending it through the post. No plant material is included, so there are no issues with import or export.

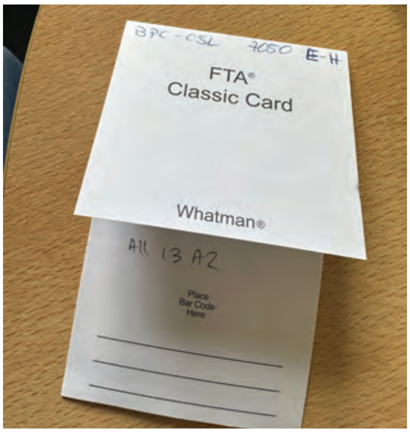
It is through David that we have been able to confirm that Australia still only has the asexual form of late blight.

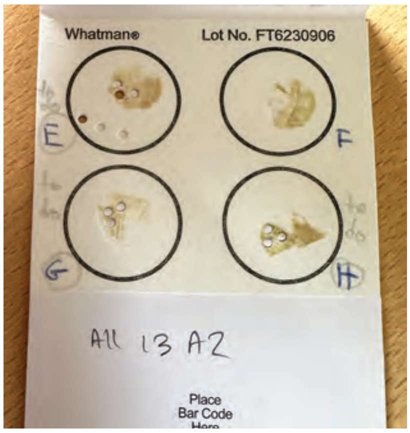
"The last introduction of late blight to Australia was probably before the 1940s," comments David.

"My message to your industry is don't soften the approach, as you're definitely doing a good job of keeping the new strains out".

Dr Cooke suggests every agronomist or agrochemical rep should keep a few FTA cards in their pocket, just in case.

"It's just good to keep checking that the population hasn't changed, and the existing fungicides will still be effective".





FTA cards are used to take and stabilise samples of pathogens. As no plant material is included, they can be readily posted without affecting quarantine.

The cards themselves cost around $2, while the lab testing is about $55 for the four lesions included on each card.

SHEDDING LIGHT ON LATE BLIGHT - DR ELEANOR GILROY

Dr Eleanor Gilroy is a molecular plant biologist with a special interest in how the late blight pathogen infects potato plants. *Phytophthora* is sensitive to UV light, so mainly infects potato plants at night.

Dr Gilroy has discovered that the late blight pathogen is not only affected by UV light, but that infection is reduced by exposure to red light. Her theory is that these wavelengths, which would normally occur at dawn and dusk, trigger plant defence responses.

While using light to control disease in field crops sounds futuristic, this is already a commercial prospect, at least for fruit crops. The company Thorvald provides commercial services in the UK, California and Norway. UV-C emitting robots that look like mobile sun beds are used to control powdery mildew in orchards and polytunnels. In the case of strawberries, a one minute treatment with UV-C light, when followed by a 4 hour dark period, has been demonstrated to almost fully control grey mould in greenhouses[5].

"In the case of *Phytophthora*, UV-C light kills it within a minute. During a blight period, maybe the irrigation boom arm could also carry UV-C lights which would kill the pathogen," suggests Dr Gilroy.

"Alternatively, red light could help prime the plant to fight disease."

Dr Ellie Gilroy is investigating the mechanisms by which late blight infects plants.

SOIL BORNE DISEASES AND THEIR HOSTILE NEIGHBOURS - DR JENNIE BRIERLEY

Dr Jennie Brierley works on soil borne potato diseases, including diagnostics, and has strong links with Australian researchers. Dr Brierley collaborated with the team that developed Predicta PT as part of an international diagnostics project, and has worked a lot on linking detection to disease risk.

"Actually, the South Australian group is ahead of us in some ways now, as they have commercialised the service. Here, commercial adoption is still relatively limited," she explains.

"More recently I've been looking at soil health and how that affects different diseases."

This is part of a major, long term project. The JHI has a site where they are growing potatoes on a six-year rotation. Each field has two halves, one with organic amendments added each year and reduced cultivation (integrated), whereas the other half is normal practice (conventional).

"So far differences have been hard to find, largely because the long rotations are doing a great job at controlling disease".

On the positive side, this suggests that adding organic matter doesn't **increase** disease, as some have thought it might.

Dr Brierley is now taking a different approach, screening soil samples from the different plots against pathogens in pot trials.

"We've found that soil from some of the plots does seem to suppress diseases like *Rhizoctonia* and common scab. So now I'm looking at all the different organisms which are in that soil, and the differences we can find in the soil microbiome".

It's still early days, but the objective is to find new ways to control those most elusive of pathogens – soil borne diseases.

Aerial view of the Centre for Sustainable Cropping site at JHI. Each half field is assigned to either conventional or integrated management.

Pot trials are being used to screen soil from conventional and organically amended plots against soil-borne pathogens such as Rhizoctonia and common scab.

WHERE DO TUBERS COME FROM? - DR ROBERT HANCOCK

It's the sort of question you usually need a child to ask – how does the potato plant decide it's time to make tubers?

Potatoes are perhaps the ultimate preppers of the plant world. From the plant's point of view, tubers are not meant to be eaten, but rather to allow it to survive a hostile winter, re-emerging once warmth returns to the cold soil.

For the original potato plant growing in South America, this was relatively straightforward – they responded to daylength. Shortened days trigger production of a protein signal called SP6A. This travels from leaves to stolons, effectively saying 'winter is coming; time to form tubers'.

However, modern varieties are day neutral, so can be grown at any time of year and any latitude.

"We still don't know exactly how that SP6A signal is integrated in day neutral plants. Presumably it relates to developmental age," explains Robert.

"One thing we do know is that high temperatures stop it in its tracks. As there's no production of SP6A, there are no tubers, no matter how well the plant is growing".

From an evolutionary point of view, flowering is a much better way to reproduce. Forming a tuber is essentially plan B. This may explain why warm, well-nourished, well-watered plants fail to form tubers.

"For example, we found that day/night temperatures of 28°C/18°C almost totally prevented tubers forming for Desiree," states Robert.

"But it's not really heat that's the problem for the plant, as they were still growing well. It seems likely that varieties considered 'heat stress tolerant' actually just have a stronger tuberisation signal."

Dr Rob Hancock at work in the lab, measuring photosynthesis using infrared gas exchange.

"What we're working on is finding the genetic triggers that either increase formation of SP6A or increase sensitivity to low levels of SP6A. Breeding programs can then select plants with genes that will trigger stronger or earlier tuberisation, increase yield, or allow tuberisation at high temperatures."

One of the other promising results Dr Hancock has had is working with Germin-like-proteins (GLPs).

High levels of GLPs make it easier for the plants to shift carbohydrates from the leaves into the tubers. Effectively, they open the gates of tuberisation wider, increasing the rate of tuber bulking.

While this research is still lab based, genes that up-regulate GLPs could be an important part of a future breeding target. They also increase our understanding of how and why potatoes form tubers. Potentially, we can help the 'preppers', but to our own advantage.

REFERENCES

1. Scottish Agricultural Census, June 2020
2. Toth, I. 2022. Delivering a sustainable potato industry for Scotland through management of Potato cyst nematode (PCN) Year one project report. https://www.pcnhub.ac.uk/sites/www.pcnhub.ac.uk/files/2023-05/year_1_summary_report_-_sustainable_potato_industry_for_scotland.pdf
3. Thoma J, Zheljazkov VD. 2022. Sprout suppressants in potato storage: conventional options and promising essential oils – A review. Sustainability 14:6382
4. Boivin M et al. 2020. Sprout suppressive molecules effective on potato (Solanum tuberosum) tubers during storage: A review. Am J. Pot. Res. 97:451-463
5. Janisiewicz WJ et al. 2016. Dark period following UV-C treatment enhances killing of Botrytis cinerea conidia and controls grey mould of strawberries. Postharvest Path. Mycotoxins. https://doi.org/10.1094/PHYTO-09-15-0240-R