National Potato Innovation Centre (NPIC)

Strategy for Potato Research in the UK

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Summary

In February 2024, three workshops took place in Dundee, York and Cambridge to identify the main strengths of the UK potato industry but also the challenges that it faces both now and in the future. The workshops also identified how scientific research can help to address some of these challenges, beginning a new chapter of engagement between the potato industry and science, both in the UK and internationally. **The workshops are seen as an important first step in tackling the most pressing challenges in the industry through a commitment to disruptive science across potato and other areas of research in close collaboration between science, industry and government**.

These workshops were hosted by the **National Potato Innovation Centre (NPIC)** through the James Hutton Institute and James Hutton Scientific Services, together with ADAS, Agrico UK Ltd., Agri-Tech Centre, British Potato Trade Association, Fera, GB Potatoes, Harper Adams University, Produce Solutions, NIAB, SRUC and Teagasc. Delegates from 70 organisations from across the UK (and including Teagasc from the Republic of Ireland) participated in the workshops, spending over 18 hours together in discussion. Represented within these organisations were some of the UK's leading potato researchers who worked together with industry to collect the important findings of this report.

The workshops identified many **strengths** within the UK potato industry, including a strong reputation, a world-renowned seed certification scheme, high health status, long rotations, high soil quality, sustainable and cost-effective production, the Safe Haven Scheme as well as good industry, science and government interactions. However, as with all businesses globally, several **challenges** were identified both now and in the longer term, including profitability and economic stability, lack of skills and labour, lack of investment, pests and diseases, loss of plant protection products (and other crop protection products, e.g. sprout suppressants), regulatory constraints, climate change, lack of research funding and reduced knowledge exchange. While all the above challenges were seen as important in the longer-term, impacts from climate change and, to a lesser extent, sustainable production were seen as increasing in priority.

Although science may not be able to address all challenges identified, a coordinated effort to increase collaboration with the science community is seen as an important step towards addressing a wide range of these challenges. To that end, priorities for **scientific opportunities and solutions** were identified as including new improved varieties with resilience against pests and diseases (P&D) and climate change, other P&D monitoring and control options through improved integrated pest management (IPM), improved decision support tools, improved soil health, water use efficiency and low carbon growing methods, novel products for new markets, as well as knowledge exchange, training and education. As with the above challenges, the importance of identifying solutions related to climate change and soil health, through improved low carbon growing methods, improved water use efficiency etc. increased in priority in the longer-term.

Publication of the outcomes of the workshops will now become a platform for further engagement with the industry, government and scientific communities (both in the UK and internationally) as well as assisting NPIC in the development of its strategic objectives.

Introduction

Potato is the third main food crop globally, and the second in the UK (after wheat), and is key in government strategies worldwide (including in Europe, China, India and Sub-Saharan Africa) to attain food security by ensuring a reliable and sustainable supply of healthy food. However, a range of factors continue to challenge and limit potato production. By employing modern scientific methods and closer collaboration between industry, government and science, many of these challenges can be met. To achieve this, the James Hutton Institute has established and manages a state-of-the-art science innovation centre (National Potato Innovation Centre [NPIC]) that will work in partnership with all stakeholders, both nationally and internationally, as part of a creative cluster to generate new findings, innovative products and high skilled jobs in new industries.

Scan here
to find out more about NPIC

The NPIC has conducted stakeholder consultation and engagement throughout 2023/24 to shape and develop the initiative, particularly in considering a UK-wide scope and agenda.

As part of this engagement, three one-day workshops were held in February 2024 in Dundee (James Hutton Institute), York (Sandburn Hall) and Cambridge (NIAB) hosted by the James Hutton Institute and James Hutton Scientific Services, together with ADAS, Agrico UK Ltd., Agri-Tech Centre, British Potato Trade Association, Fera, GB Potatoes, Harper Adams University, Produce Solutions, NIAB, SRUC and Teagasc. The aim of the workshops was to better understand the industry's strengths but also their challenges, and the need and demand for scientific solutions to overcome these challenges. These potential solutions will help to form the priorities for research within the NPIC. There was a total of 118 participants, including 80 from industry, which included most segments of the supply chain, except retailers. In addition, 32 academics attended from 12 UK potato research organisations (James Hutton Institute, NIAB, SRUC, Sainsbury Lab, JIC, ADAS, Fera and the Universities of Dundee, Glasgow, Harper Adams, Greenwich and Lincoln) and one from the Republic of Ireland (Teagasc), together with 6 government attendees making 70 organisations in total (Appendix I).

A senior figure from either an academic organisation or industry welcomed participants to each workshop (Supplementary information Table S1). The workshops then proceeded with a series of presentations, firstly on 'The National Potato Innovation Centre (NPIC)' presented by its Director Ian Toth, followed by 'An industry perspective on the UK potato industry: strengths and challenges' by leading figures from the potato industry (Supplementary information Table S1). Following these presentations, there was a 45 min breakout session split into four groups at each venue, making 12 breakout groups across the three workshops. In the breakout groups, delegates were asked what they considered to be the UK potato industry's greatest strengths but also its main challenges. Each breakout group included a rapporteur from one of eight potato research organisations who fed responses back to the participants (Table S1). Following feedback, a series of questions on industry strengths and challenges were asked via a questionnaire (slido.com), allowing delegates to respond to questions in real time on their smart phones. A presentation then took place on 'How can science help to futureproof the UK potato industry (a science perspective)'. This was followed by more breakout and feedback sessions (another 12 across the three workshops) on 'Futureproofing – potential science solutions to industry challenges' accompanied by another Slido questionnaire before concluding the day with a roundup session.

Industry strengths

Questionnaire and breakout sessions

Potato production in the UK is seen as one of the most resilient in Europe. When asked to rank a list of nine UK potato industry strengths (developed with industry stakeholders prior to the event and using Slido), results from the three workshops combined ranked strengths in the following order (strongest at the top) (Supplementary information Table S2):

1. Strong reputation
2. Seed certificate scheme
3. High health
4. Good industry, science, government interactions
5. Long rotations
6. Sustainable production
7. Safe Haven Scheme
8. Cost effective production
9. Soil quality

Strengths by location

While rankings between the three workshops were similar, some differences showed that:

- Dundee ranked *high health* (rank 1) and *soil quality* higher than both York and Cambridge.
- Cambridge ranked *good industry, science, government interactions* and *sustainable production* more highly than Dundee and York.
- York ranked *long rotations* higher than Dundee, who in turn ranked them higher than Cambridge.

When asked to comment on other strengths, both in the questionnaire and during breakout sessions, the following were also identified:

- Cross industry collaboration
- Progressive growers
- Resilient farm businesses - ability to rise to the challenge
- Ability to change
- Good body of historical R&D
- Knowledgeable growers
- Skilled and professional workforce
- Big corporate partnerships funding research
- Full traceability from farm to retail/processor
- People who are dedicated and passionate about the industry
- Flexibility
- Innovative
- Professional and well-trained farming community
- Adaptable
- Suitable climate, favourable growing conditions
- Sufficient water
- Good products and consumer support
- Access to strong (world-leading) potato science community
- Good quality agronomy advice
- Innovative individuals
- Well defined industry roles – research / KE, processor/packer, breeders, agronomists
- Strong supply chain relations
- Island status helping to control the movement of pests and diseases
- A good product

Industry challenges
Questionnaire feedback

From a list of ten options (developed with industry stakeholders prior to the event) attendees at the three workshops were asked to rank their top five challenges in the following categories: Own business(s) and UK potato industry, last 5 years, next 5 years and longer-term (next 10-15 years) (Supplementary information Tables S3-8). By combining results from the three workshops, three sets of data were produced to show how people ranked challenges based on i) their own business(es) compared to the UK industry; ii) their own business(es) over time; and iii) the UK industry over time.

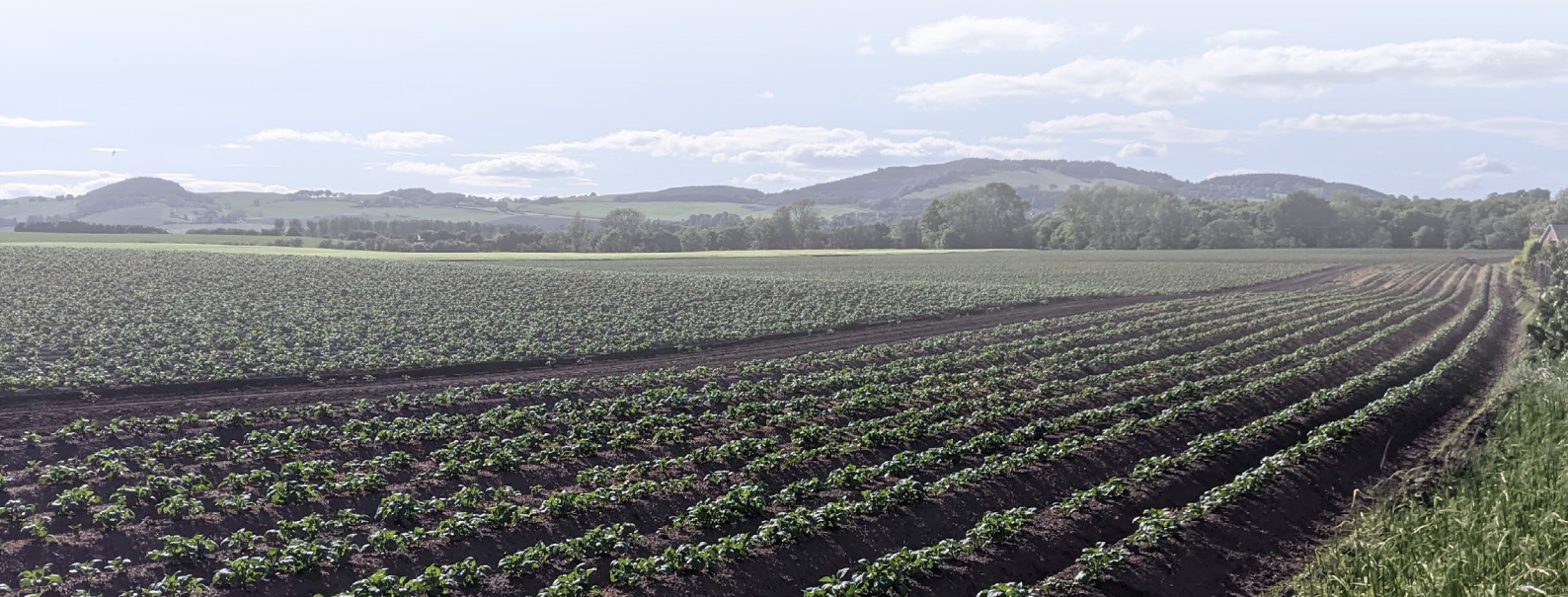
In all cases, the challenges that consistently featured most highly included:

- Pests and diseases
- Loss of plant protection products
- Regulatory constraints
- Profitability / economic stability
- Climate change

There was generally little variation between rankings across categories, typically with no more than two places between them. However, on occasion some differences were observed. These included:

Challenges - your business vs UK industry

- When considering challenges in the last 5 years, *profitability / economic stability* was seen as the most pressing issue compared with individual businesses (rank 4). This trend was also seen when considering the next 5 years, although to a lesser extent.
- *R&D spending* was seen as being a greater issue for individual businesses than for the UK industry both in the last and in the next 5 years, with this trend continuing in the longer-term.
- Particularly over the last 5 years, *Land availability* was seen as a greater issue for the UK industry than for individual businesses, with the trend continuing in the longer-term.



Challenges over time

Your business(es) over time

- There was little change in priorities when considering the last and the next 5 years, but in the longer-term *climate change* clearly became more important, ranking as the top challenge compared with the last and next 5 years (rank 6).

UK industry over time

- While there were no major differences in rankings between the last and next 5 years for any of the challenges, *climate change* (as with 'your own business(es)'), ranked first in the longer-term compared to the last and next 5 years (rank 4).
- Demand for *sustainable production* increased in the longer-term compared to the last 5 years but remained relatively low on the list of challenges overall.

Challenges by location

Dundee, York and Cambridge variation

When considering responses from the three workshops independently (Dundee, York and Cambridge), again there was good agreement in terms of the top 5 challenges (see above). However, some differences were observed, most notably:

- *Climate change* was seen as more of a challenge for individual businesses over the last 5 years for York and Cambridge than Dundee. However, in the longer-term all groups saw this as the number 1 priority.

Of those challenges below the top 5, other notable differences included:

- *Land availability* was seen as a bigger challenge for both individual businesses and the UK industry in York and Dundee than in Cambridge over the last 5 years. This was also reflected to some extent in the next 5 years and in the longer-term.
- *Lack of R&D* spend for individual businesses was a more important issue in the last and next 5 years in both Dundee and Cambridge than in York.
- In the longer-term, York saw *Regulation*, both for individual businesses and the UK industry, as more of an issue than Dundee and Cambridge.

Industry challenges
Breakout sessions feedback

Although the challenges outlined in the questionnaire were predetermined following limited industry consultation, to allow rankings to be made during the workshops, opportunities were also given to highlight further challenges both within the questionnaire and in the breakout sessions. The outcomes of those discussions are summarised below.

Profitability

Profitability and economic stability are seen as an important factor for the potato industry to ensure its long-term future. The combination of pest and disease threats, fertilizer availability and cost, climate change and reduction of inputs is severely threatening profitability, and therefore the future sustainability of the industry.

Beneath the overarching requirement for profitability, the following areas are seen as vital to the future of the potato industry.

Skills and labour

The potato industry is an aging sector with a lack of succession planning and fewer younger people wanting to enter the industry, not least because of long hours, low pay and changes in lifestyle choices. This is leading to a loss of knowledge and experience but also a lack of skilled labour to assist with new technologies such as drones, AI, breeding etc. as they are being introduced. Retention is seen as a bigger issue than recruitment so adequate training is an important way to ensure people already in the industry are upskilled and motivated, so that they have the skills to deal with new challenges. Brexit has exacerbated labour issues with fewer European staff to help with jobs, e.g., grading. With fewer new people joining the industry, current staff are having to work longer hours raising safety concerns. **More incentives are needed to help recruit and retain staff, with a more concerted effort to increase the visibility of the potato industry as a career choice, bringing in and training more tech-savvy individuals, e.g. PhD placements and apprenticeships.** People at all levels are required by the industry, including graders, technicians, agronomists and researchers.

Uncertainty and lack of investment

A short-term focus by the potato industry is a growing challenge, with aging infrastructure and a lack of capital investment in new equipment and machinery, e.g., some storage facilities have not been upgraded since the 70s and 80s. Much of this lack of investment is due to the uncertainty around future economic stability, with costs of production increasing sharply and a lack of clarity over policies surrounding the on-going loss of plant protection products (PPPs) to control weeds, pests and diseases but also those involved in other aspects of crop protection, e.g., sprout suppression (included in this report with PPPs). This includes through the Chemicals Regulation Directorate (CRD) but also through the Sustainable Farming Incentive [SFI], which offers rewards to growers to motivate them towards such schemes. New storage methods and facilities would provide a major boost to overcome the loss of storage chemicals, e.g., CIPC.

Volatility and business challenges with uncertainty over future returns are affecting the whole supply chain, with increasing and uncertain energy costs, security around water and fertilizer, loss of PPPs, the global political situation affecting imports and exports, and a constant downward pressure on product prices leading to reduced margins. It is felt that policy makers have concentrated on funding priorities elsewhere, e.g., health and, where decisions are made, they are done so in isolation rather than taking a more holistic approach for the industry, e.g. a better government-industry engagement is needed through a clear food strategy, particularly regarding food security. Consumer demand is also changing, with the fresh market dropping and processed potatoes increasing by 10% per year (the majority through imports). It is felt that the fresh market is not being given the

same attention as other fresh produce and there has been a slow and disjointed response to this changing market demand.

This overall lack of uncertainty is leading to a loss in efficiency and constant firefighting, with more growers leaving the industry than joining, culminating in a smaller number of businesses and a few larger ones dominating. A less reactive approach is needed, together with **a more positive industry that has a 'road map' to follow, where emerging challenges are identified, and different parts of the industry are working together to oversee the bigger picture through a foresight group to help bring different interests together.** This is particularly important in maintaining industry resilience following the demise of AHDB potatoes, where an advocacy role and the ability to respond to emerging challenges are required.

It is considered essential to work with retailers, who are sometimes considered disconnected from the rest of the industry. This would ensure that they have a more informed choice of varieties through a closer partnership with scientists and breeders who, in turn, could steer their priorities towards better variety choices whilst still meeting market requirements. This is especially important in relation to the sustainability agenda, where choice of variety could enhance positive consumer attitudes towards the fresh potato market.

A decline in new potato-based food products coming through requires a concerted effort to develop new products and to seek new markets. This might include the development of new varieties to meet such demands, together with education on the benefits of these products to add value to the industry. Valorisation of green waste is also seen as a potential way forward, with by-products including biodegradable plastics and other non-food uses.

Pests, diseases and weeds - Loss of Plant Protection Products

Loss of PPPs is seen as a growing threat to the potato industry for the control of pests, diseases and weeds (including groundkeepers, which harbour and increase P&D populations). New P&D threats are also increasing through increased trade and climate change. Help with key PPPs is needed from CRD to ensure that optimal products can continue to be used. As these products become fewer, a transition period is required to allow new methods of IPM to be developed. Such methods will become essential and include varietal resistance, biologicals, decision support tools, sampling and diagnostics and longer rotations (if the latter can be done while still meeting demand, especially considering reduced land availability). However, it is felt that innovation in this area could be slowed by risk aversion and lack of uptake.

Biological solutions also need the engagement of CRD. While resistant varieties are seen as a major tool for IPM, the gene pool in breeding programmes is currently small and therefore limits varietal effectiveness against P&D. The use of untapped genetic resources in breeding programmes and the acceptance of precision breeding, e.g., improvements in plant defence through RNA / gene editing techniques, are needed (together with advocacy roles to help with public, supermarket and government acceptance of precision breeding).

As more land is rented for potato production, care of that land is becoming more of a challenge, e.g., the presence of groundkeepers. Also, viruses are one of the main threats currently, potentially brought about by loss of PPPs and storage products, climate change and dual-purpose cropping, meaning that industry may well not be managing viruses as well as it did in the past. This could lead to a reduction in seed production and the provision of virus-free seed. In addition, over the next 30 years, land availability could become a major threat, e.g. due to increase in PCN leading to exclusion of growing areas and a decline in production.

Regulations

It is deemed essential that there remains a close association between the potato industry and the CRD to ensure that there is continued dialogue over the use and regulation of PPPs, especially those that are under threat. Some important PPPs are being or have recently been removed, e.g., Mancozeb for controlling late blight, putting pressure on remaining chemistry. The removal of such PPPs before alternative solutions are available will continue to negatively impact the industry and a risk versus benefit culture should prevail. All available tools that could benefit production in the absence of chemistry, e.g.,

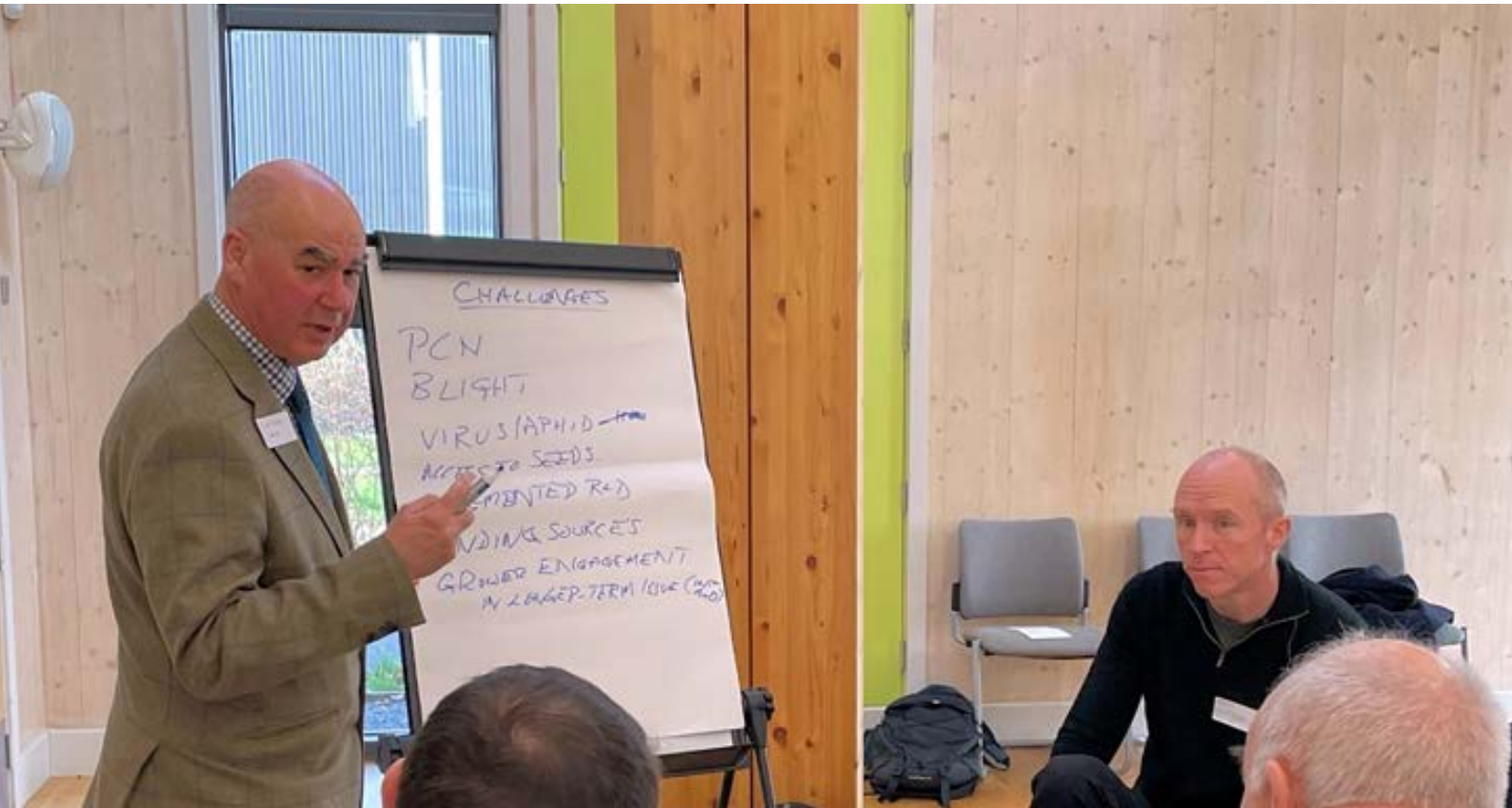
precision breeding (including gene editing), should be considered for adoption. There is also a feeling that regulatory authorities move too slowly for technological advances or are constrained, e.g. Artificial Intelligence (AI) and Genetically-modified organism (GMO)-free Scotland, and an advocacy role is needed to demonstrate the value of such technologies to all relevant groups.

There has been a substantial impact for import and export following Brexit and, in some cases, regulation implementation is now done twice: both by the UK and by the EU. There has been a complete loss of export opportunity of seed potatoes to the EU, which puts more emphasis on North Africa but, with ongoing political instability, such markets cannot be fully relied upon, and new export opportunities are needed. In terms of imports, it is difficult to get seed into the UK (not possible for Scottish growers) unless it is a direct purchase by the grower, whereby more paperwork is needed and costs incurred to register as an importer. It also limits access to new varieties and new genetics. Free trade is therefore required with the EU. Overall, issues around import/export continue to affect the UK's self-sufficiency, which has fallen to just over 60% in 2024 from 100% back in the 1970s.

Sustainability / Regenerative Agriculture

More could and should be done to improve the sustainable production of potatoes and ensure that industry marketing highlights these sustainability credentials with consumers. However, **there is a need to be clearer about how 'sustainable' or 'regenerative' production is defined, especially when associated with government incentives. This will allow growers to assess the risk of applying such methods versus the profit that may come from the use of less 'sustainable' criteria.** Whatever the definition, there are positive steps that can be taken, for example:

- Protecting soil health and maintaining soil carbon
- Maintaining buffer strips and field margins
- Using leguminous cover crops to fix nitrogen
- Reducing energy requirements
- Reducing waste
- Replacing fertilizers with manure (although the increased use of manure may not balance with the long-term aim of reducing meat intake)
- Improving use of PPPs and finding IPM-based replacements
- Improving water use efficiency and better use of irrigation
- Producing and using varieties with resilience trains (e.g., against drought / heat stress and resistance to pests and diseases)
- Changing the length of rotations and embracing new technologies including AI, robotics, automation etc., all while overcoming the current yield plateau.



To meet sustainability objectives, there is a need to better understand these areas through research, e.g., to avoid soil damage and maintain soil health a clearer understanding of organic matter, nutrition and microbiomes is required. This research should go hand in hand with practical considerations, since protecting soil depends on farmer practices that come with knowledge over the generations, and which is made more difficult through the increasing use of rented / temporary land.

Climate change

Unpredictable and extreme weather is seen as a major challenge to production, with water use and storage being a major limiting factor. Understanding the impacts of extreme weather and the longer-term impacts of climate change, including through the modelling of extremes, require action now to better understand and act up on them. Volatility of weather, with droughts and floods, is seen as a major challenge, along with security of water supply, water use efficiency and irrigation requirements, heat stress, physiological issues and increases in endemic and novel pests and diseases, e.g., viruses. An important solution to these issues is through the development of new resilient drought tolerant, pest and diseases resistant, early maturing varieties using novel methods such as speed breeding that will help to get them quickly to market.

Research and Funding

Research outcomes were seen as vital by the potato industry but there was a concern, especially with the demise of AHDB Potatoes, that end user-relevant research has reduced and become more fragmented with less funding for this area, leaving a gap between research and application. This may be due to a lack of strategy in setting research priorities, focussing too much on reactive rather than proactive research. A clear research strategy is needed that will make a difference to production and the current challenges faced by the industry. This would begin by better understanding what new information is needed and then identifying who might fund this. However, this does not distract from the need for some 'blue sky' research, which is important for horizon scanning. It was also felt that social science research is lacking and would help to better understand consumer attitudes, e.g., perceptions of waste on consumption. A need for independent variety trials was seen as something to complement research, e.g., for bio-stimulants, novel products, biological pesticides etc.

Knowledge Exchange

Industry greatly values communication of research outputs to their members and appreciates the KE activities that currently take place between researchers and industry. However, especially since the demise of AHDB Potatoes, this is often not enough and could be improved. Opportunities / venues for KE have also been lost in recent years. It is important to get research outcomes into practice and ensure that translation of research outputs is a major part of the work. There is an awareness that there are past research outputs that are often forgotten about in favour of communicating the latest data. Combining the latest data with that of the past would help to fill gaps and ensure that current and previous research funding is used to its maximum benefit. Much of the past research funded by AHDB is available on a database, although the longevity of the database is in question, but it is also seen as being difficult to access. An improved database of knowledge is required to improve access to this and other past research outputs, e.g., how to find concise information on the outcomes of current and previous climate change research.

More interaction with the media is needed to engage with the public on the importance of food production, the challenges that exist in agriculture and to get positive messages across on healthy food choices, e.g., potato is a nutritious product that can be eaten in place of fast food, helping to improve people's diets (especially children). These messages on both food production and healthy eating could be on the school curriculum. It is also important to combine this with better engagement of retailers. Examples include early engagement in new varieties coming through and how they meet market requirements, or retail constraints on PPPs. An important suggestion to improve engagement between science and industry is to work collaboratively as much as possible and include government as well as international partners where relevant.

Opportunities and solutions
Questionnaire feedback

Delegates were asked to rank a list of twelve options (developed with industry stakeholders prior to the event) relating to opportunities for science to help deal with challenges in the following categories: i) over the last 5 years, ii) over the next 5 years and iii) over the longer-term (10-15 years) (Supplementary information Tables S10-S12). Opportunities and solutions were ranked in each of these categories, with scores from the three workshops combined (the top ranking appearing at the top of the list), together with a comparison between rankings across categories.

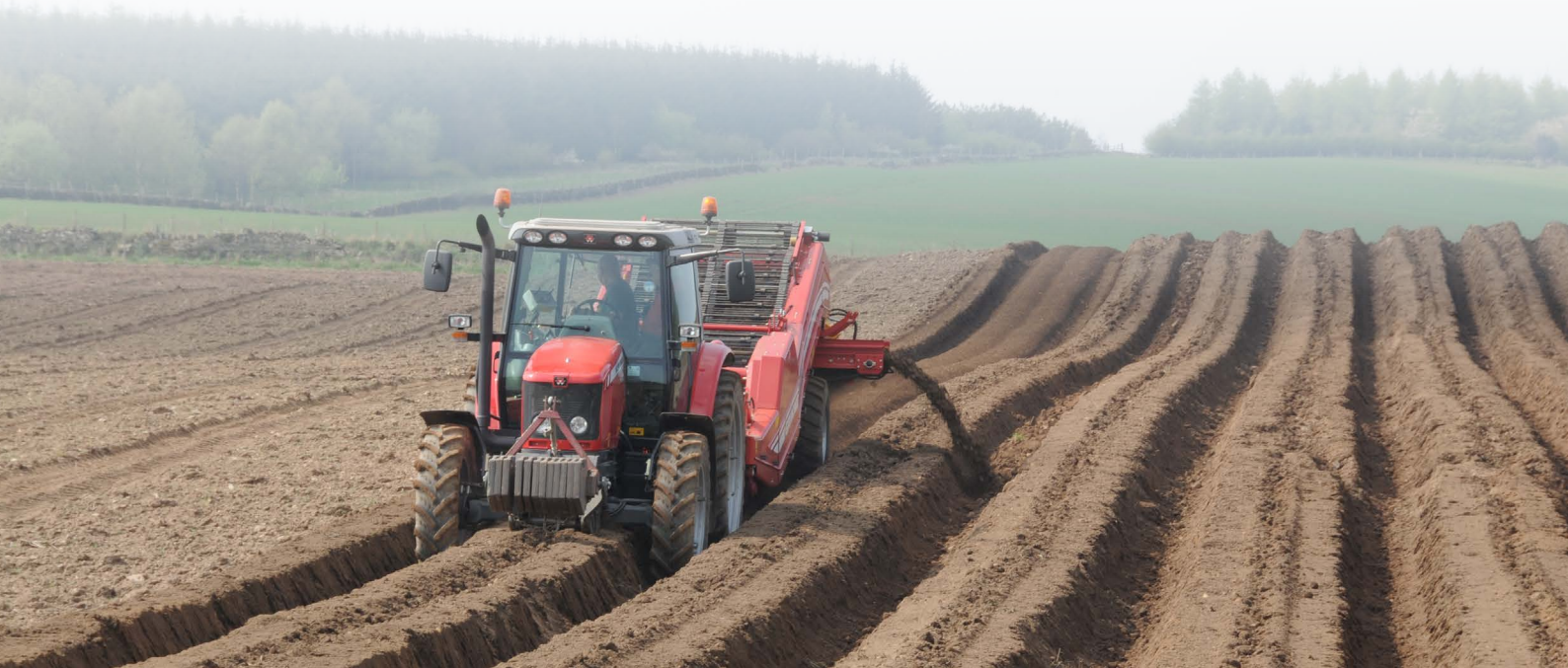
Opportunities and solutions that consistently featured in the top 6 included:

- New improved varieties – pests and diseases
- New pest and disease control options
- Pest and disease monitoring
- New improved varieties – climate change
- Soil health
- Decision support tools
- Improved water use efficiency
- Low carbon growing methods

Challenges over time

There was generally little variation between priorities across the 4 categories, typically with no more than 2 places between them. However, on occasion some differences were observed, particularly when comparing rankings from now and the longer-term. These includ:

- *Low carbon growing methods* were considered more important in the next 5 years than in the last 5 years.
- *Improved water use efficiency* was seen as being more important in the longer term than in the next 5 years
- The biggest changes were observed for *improved water use efficiency* and *low carbon growing methods*, which increased in importance from the last 5 years to the longer-term'



Opportunities and solutions over time - by location

When considering responses from the three workshops independently (Dundee, York and Cambridge), again there was good corelation in terms of the top 5 challenges (as above). However, some differences were observed, most notably:

- Dundee and York *saw improved water use efficiency* as less of an issue than Cambridge in the last and next 5 years, respectively, but its importance increased for all groups when considering the longer-term.
- *Improved application technologies* was more highly ranked by Dundee than by York and Cambridge in the last 5 years, but this ranking fell to match York and Cambridge in the longer-term.
- *Low carbon growing methods* was more highly ranked by Cambridge than by York and Dundee in the last 5 years, but this ranking increased to match Cambridge in the longer-term.
- *Soil health* was seen as being more important by York than by Dundee and Cambridge in the next 5 years, but this importance increased for all groups in the longer-term.
- Cambridge ranked *decision support tools* as more important than York and Dundee in the next 5 years, but all groups saw this as being less important in the longer-term.
- *Storage and transport* was seen as more important for York and Cambridge than for Dundee in the longer-term.

Opportunities and solutions
Breakout sessions feedback

Although the opportunities and solutions outlined in the questionnaire were predetermined following limited industry and science consultation to allow rankings to be made during the workshops, options were also given to highlight further opportunities and solutions both within the questionnaire (Supplementary Table S4) and in breakout sessions. The outcomes of those discussions are summarised below.

Improved varieties

The continued development of improved varieties is seen as a major advance for the industry on many levels. Using new and enhanced breeding technologies and exploiting the genetic diversity available in potato germplasm collections, e.g., Commonwealth Potato Collection (CPC), multiple improvements are envisaged. For example, while most commercial potato varieties belong to a single species (*Solanum tuberosum*), the CPC has over 80 different species that are largely untapped in the exploitation of their genetics. Since many of these species are diploid (two sets of chromosomes as opposed to four in *S. tuberosum*), new diploid breeding technologies, e.g., Breeding 2.0 – using diploid inbred lines of potato to speed up the breeding process for quicker outcomes, will revolutionise how varieties are bred and shared. Using these new technologies, together with other precision breeding techniques, durable resistance to P&D, climate and other traits are envisaged through novel combinations of genes. *Could the equivalent of golden rice for potato be produced?*

It is expected that, in time, variety profiling and management will take place, matching varieties with factors such as soil type and/or different genotypes of P&Ds encountered. This will be achieved by combining genetic improvement with agronomic optimisation to ensure optimal growth and less waste under different circumstances. Understanding the genetics of potato and the molecular information contained within it, will allow the development of improved markers that are able to assess a wide range of new and existing varieties. This will lead to a better understanding of the myriad of genes underlying different traits, and so help to select suitable parental breeding material and undertake variety profiling.

New improved varieties, and improvements to existing ones, would add economic value to the industry, with breeders working alongside and regularly visiting scientists who undertake these new technologies to tie outputs to industry need. The development and use of true seed and reducing the cost of mini tuber production are seen as potential ways to improve the profitability of industry and help to reduce the number of field generations. Other areas include the use of independent field trials for new varieties, including those produced through precision breeding, and the use of AI for rapid phenotyping and design of such varieties.

Traits mentioned include:

- Higher yielding crops
- Early maturity
- Drought tolerant
- Pest and disease resistance and tolerance (e.g. late blight, PCN, viruses)
- Dormancy
- Starch
- Nutrition
- Photosynthesis
- Skin set
- Tuber number
- Frost tolerance
- Size uniformity
- Water use efficiency
- Shelf life
- Non-greening
- Low PPP input
- Nitrogen-use efficiency
- Brusing (e.g. through a better understanding of enzymic oxidation [PPO])
- Cold-induced sweetening
- Nitrogen fixation

New pest and disease control options - Integrated Pest Management (IPM)

In the questionnaire, crop protection was deemed to be the number one priority for the industry against a range of P&Ds, including but not exclusively late blight, blackleg, PCN, aphids and viruses (incl. PVY, PLRV), which lead to crop losses, less land availability and lower profitability. As increasing numbers of PPPs continue to be removed from the market, improved control options are needed. Some of these options were highlighted and include:

- Improved varieties (which was seen as a major solution), including the use of precision breeding where appropriate
- Understanding pest biology and modelling, considering factors such as weather but also how forecasting relates to different plant and pest genotypes
- Improved prediction and forecasting through modelling and decision support tools (DSTs)
- Alternative chemistry and biologicals (with consideration for regulatory approval)
- Natural predators (revisit 'muck and magic')
- Microbiomes, suppressive soils and soil health
- Understanding the interactions between pests, potato crops and biocontrol agents
- Inhibitors
- Cover / Trap crops (including those bred and engineered to be more effective)
- Improved / alternative sampling and early detection with options for integrating engineering, robots and AI
- Precision agriculture, e.g., use of drones, spot spraying etc.
- Predictive sampling and better monitoring tools for rapid decision making, e.g., for aphids, viruses
- Soil amendments, e.g., Chitin to assist with PCN suppression
- RNAi
- Elicitors
- Straw
- Buffer strips
- Improved storage
- Electronic noses, e.g., in store

The effectiveness of landscape-level monitoring, e.g., UK / Europe-wide support systems, such as Fight Against Blight, is seen as important, combined with more efficient application of diagnostics and forecasting to identify hot-spots earlier and with a faster turn-around time. A better understanding of an integrated approach to P&D control is also seen as important, with IPM consisting of multiple complementary control options. As this would make management more complex, forums for the communication of best practice are seen as important to success. Further development of hand-held devices for rapid in-field decision-making is seen as an important step forward.

Environmental impacts / Regenerative Agriculture

Potato uses 20% less water than cereals with 4 times the yield. Even so, it is imperative that every effort is made in the future to ensure that the environmental impacts of potato production are reduced as much as possible, while protecting both yield and quality. This may be achieved using more and improved integrated management tools, including improved IPM methods and precision tools such as underground tuber size diagnostics, image-based rogueing, field detection sensors, drones and robotics, software, multi-spectral imaging and more hand-held devices to help decision making. While improved sustainability is being achieved, partly through a reduction in the use of certain PPPs, alternative methods that fit within an IPM system require considerable improvement if potato yields are to be maintained. Some of this work should look to develop novel varieties but may also include the use of RNAi, soil amendments such as chitin-based, and other biological solutions, i.e., novel biocontrol agents, improved action and availability of local beneficials and more suppressive soils, all developed through a better understanding of soil health and how that relates to soil microbial populations (microbiomes). The use of eDNA and a better understanding of microbiomes will help to relate the microbial constituents (including P&Ds) of soil to better management practices and their impacts, including plant growth enhancement.

Soil health remains a major component of regenerative agriculture, including the maintenance of soil carbon and protection and restoration of soil biodiversity. Understanding the impacts of nutrition, phosphate availability, compaction,

water availability and drainage, erosion and tillage will all be crucial for maintaining our soils into the future. Efforts to tackle fertilizer overuse through eco-friendly alternatives such as the use of applied foliar biostimulants (e.g., BlueN), green nitrogen (from renewable energy sources), mixed cropping (including nitrogen-fixing legumes) and self-fixing crops will also impact regenerative agriculture. A major component of this will be our response to current extreme weather events and the future climate. As the methods available for modelling increase, i.e., through machine learning and AI, this will become a major component of climate change prediction and help to manage reductions in inputs, weather and P&D forecasting, irrigation and plant growth.

Storage is an important area for research as tubers spend a long time in storage, yet tools to manage them are disappearing, e.g., CIPC. To prevent sprouting and to better understand the triggers for this, longer storage, skin finish and storage disease control are all seen as important through improvements in storage efficiency, dehydration monitoring, temperature monitoring, CO2, infrared disease control and volatile detection in store, e.g., electronic noses. Finally, modelling, data sharing, data management and connectivity will assist in identifying trends, e.g., the consequences of climate on fresh vs processed markets.

Novel products and new markets

The idea of identifying novel high value products for potato is an interesting concept, allowing industry to add value to waste by identifying new revenue streams for improved profitability, efficiency and sustainability. This would include both tuber and haulm (whole crop) to produce non-food commodities such as fibres for clothing, pharmaceuticals, nutraceuticals, vaccines, novel food commodities starches (for plastics), proteins and other nutrients, adding value to waste while supporting the circular economy. This might use existing varieties but could also take advantage of the pool of untapped genetics and chemistry that could be mined in the development of new varieties bred specifically for alternative markets, with genetic improvement being combined with agronomic optimisation. There may also be a need to develop or improve methods for product processing, e.g., development of a haulm harvester and the need for pilot plants, all working across the different sectors within the potato supply chain.

Knowledge exchange, training and education

A continued emphasis on translation and education is seen as essential in rebuilding the reputation of potato as a nutritional product. This should include outreach and engagement to influence governments, policy, retailers, industry and the public. For government engagement, it is particularly important for science to inform regulations on topics such as precision breeding, loss of PPPs, soil carbon etc. Existing guidance should be reviewed and updated where necessary.

Focus groups between growers and scientists are encouraged and specific efforts to undergo KE with agronomists will ensure that science innovations make it through to practice. The use of field trials and demonstrations, perhaps based on the Strategic Potato (SPoT) Farms model of AHDB, is seen as important to help translate science and show it in action, particularly through individual case studies. More social science input is envisaged to examine behavioural change, potato's nutritional qualities, waste perception on consumers, consumer attitudes and choice, non-greening lighting in shops or non-greening potatoes, decision models to engage with farmers and how to better use potato as a food source. This will help to break down science outcomes and translate them to farmers. Building potato KE networks around specific topics would help to foster greater links between science and industry but also between scientists in relevant potato-oriented research areas, thus also helping to bring the science community together.

Consolidating data and outcomes of previous research projects should be a focus area, e.g., gathered through AHDB and other funders. *Are the answers already out there and, if so, how do we get access to them in a simple and digestible way?* Getting growers involved in the National Potato Innovation Centre (NPIC) to allow them to have their say in future research is one way to ensure KE occurs across the whole potato supply chain.

Training is necessary to bring new, skilled people into the industry, especially as things such as technology and regulation are becoming an ever more important part of potato businesses, yet expertise in these areas is often lacking. Developing courses to provide the relevant skills would help the industry to maintain and attract new entrants.

Conclusions

Workshops hosted by the National Potato Innovation Centre (NPIC) at the James Hutton Institute and James Hutton Scientific Services, together with ADAS, Agrico UK Ltd., Agri-Tech Centre, Fera, GB Potatoes, Harper Adams University, Produce Solutions, NIAB, SRUC and Teagasc, held in Dundee, York and Cambridge in February 2024, are the beginning of a process to improve the coordinated engagement of science, industry and government in the UK and beyond in terms of potato production. They will help to bring together potato scientists with those from other science disciplines in a disruptive approach to meeting industry-led challenges.

The workshop outcomes presented here demonstrate the range of issues affecting the UK potato industry and the need for further engagement between the industry, government and scientific communities. This information will be used to develop the strategic objectives of the NPIC, to ensure it engages, supports and improves the UK potato industry.

Glossary

AI – Artificial Intelligence
CPC – Commonwealth Potato Collection
CRD – Chemicals Regulation Directive
GMO – Genetically-modified Organism
IPM – Integrated Pest Management
KE - Knowledge Exchange
NPIC – National Potato Innovation Centre
P&D – pests and diseases (including weeds)
PPP – Plant Protection Products
R&D – Research and Development
SFI – Sustainable Farming Directorate

Appendix I

List of organisations taking part in the workshops

ADAS	McCain Potatoes
Agrico UK Ltd	Meijer Seed Potato Ltd.
Agrii	Mertoun Estate Farms
Agri-Link Produce	NFU
Agri-Tech Centre	NFUS
Albert Bartlett	NIAB
B&C Farming	National Potato Innovation Centre (NPIC)
BASF plc	Pan European Potato Enterprise Ltd
Bayer Crop Science UK	Pepsico
Blackthorne Arable	Potato Processors Association (PAA) Ltd
British Potato Trade Association (BPTA)	Potato Solutions Ltd.
Caledonia Potatoes Ltd	Produce Solutions (Greenvale AP)
Central Plains Group	Robert Lindley Ltd.
Certis Belchim UK	RS Cockerill Ltd.
Coldstream Farm Seed	SA Consulting
Craignathro Farm	SAC Consulting
Crop4Sight	Sainsbury Laboratory
Cygnet Potato Breeders Ltd.	SAOS
DormFresh	SASA
East of Scotland Growers	Seed Potato Organisation (SPO)
Fera Science	Soil Essentials
Frontier Agriculture	SRUC
GB Potatoes	Stark Potatoes Ltd.
Harper Adams University	STET
HSE Gov	Taygrow Ltd.
Hutchinsons	Teagasc
HZPC UK	The Humble Potato Co. Ld.
Ibbotsons Produce Ltd	Thistle Agronomy
James Hutton Institute	University of Dundee
James Hutton Limited	University of Glasgow
James Reid and Partners	University of Greenwich
John Innes Centre	University of Lincoln
KFF Potatoes	UPL Potato
KWS UK	VCS Potatoes Ltd.
McCain Foods	Whole Crop Marketing Ltd.