POWERING PEA PRODUCTIVITY

John Innes Centre

PGRO

Agri-Tech East

BBSRC

CONTENTS

1.0 EXECUTIVE SUMMARY

Peas are high in protein, gluten-free and can contain a starch that has the potential to reverse diabetes when consumed within a prescriptive diet. These elements make the crop highly desirable as a functional food ingredient, both for its nutritional benefits and also as an alternative to other sources of protein such as meat or soy.

Peas also improve soil health, by fixing nitrogen to make it more bioavailable and provide a useful break crop within a rotation. Traditional markets for peas include frozen, canning and animal feed.

However, the crop is challenging to grow and, despite best efforts by the industry, yields have been falling over recent years. Lack of consistency – both in quantity and quality – mean that peas are perceived as risky by growers, and this has restricted investment in this crop.

To better understand the UK market opportunity for peas and to create a roadmap for increasing the quality and quantity of the crop, individuals from across the value-chain were brought together within the workshop 'Powering Pea Productivity', co-ordinated by the John Innes Centre with support from PGRO and Agri-Tech East and sponsored by the BBSRC.

63 delegates attended the workshop including representatives from across the value-chain: growers and grower groups, processors, food brands (such as Birds Eye and Princes), food retailers, breeders, technologists, agronomists, researchers and advisors.

Scene-setting talks outlined: the new market opportunities for pea protein, fibre and starch as nutritional and functional food ingredients, the constraints on cultivation and the external impacts on value of the crop.

The delegates were asked to discuss the challenges and identify the priorities.

Seven key themes emerged:

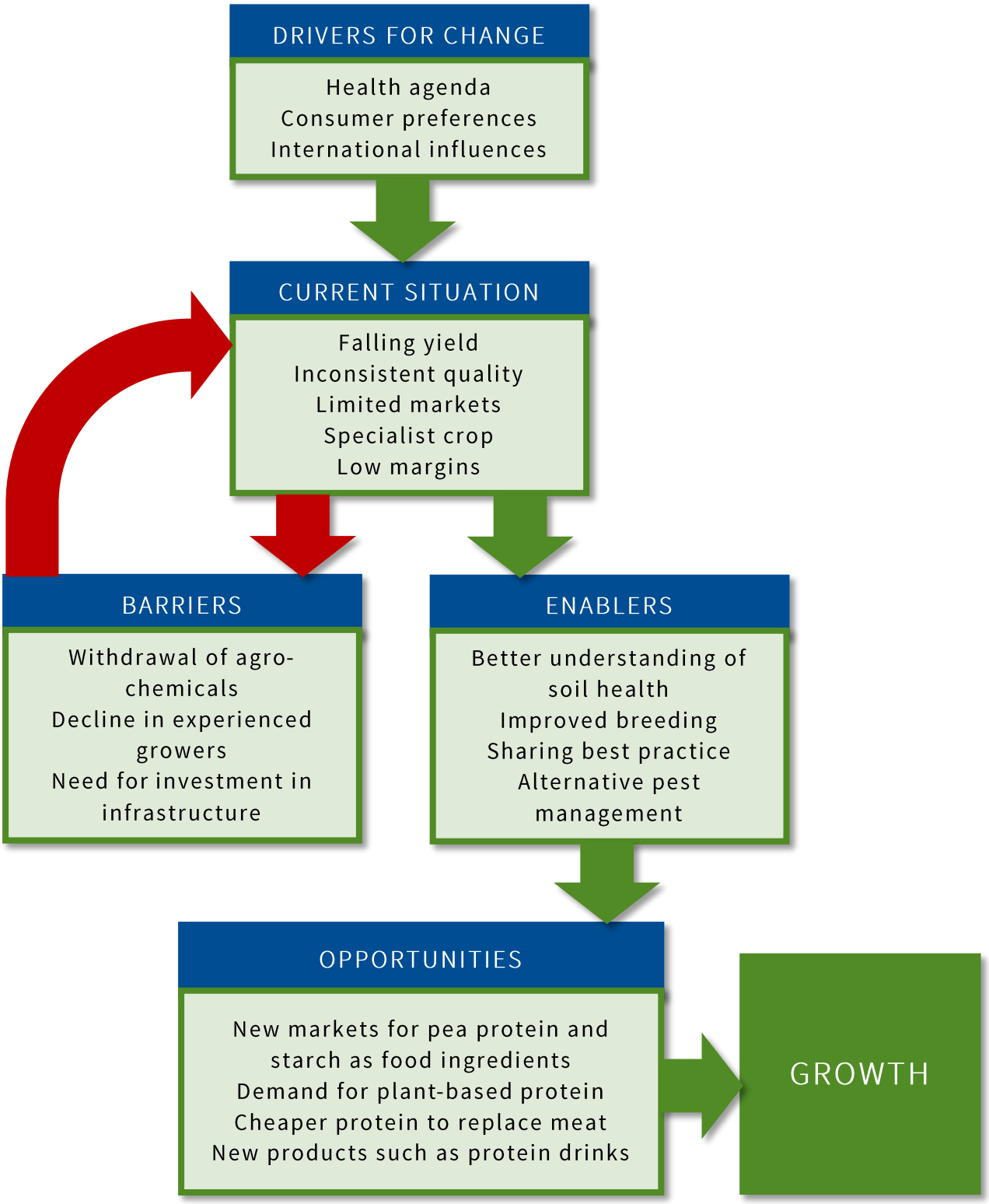
1. Soil health and improved rhizobia performance
2. Crop nutrition
3. Good farm practice and evidence-based technology
4. Alternative pest control
5. Alternative disease control
6. Breeding for improved plant physiology and growth
7. Development of new food markets

The outcomes include:

- A roadmap for the next 1-3 years, 3-5 years and 5+ years
- Identification of areas where further knowledge is required
- Outline of a number of action topics for development.

These topics will require a multidisciplinary approach, of which industrial innovation, knowledge exchange, best practice and academic research will be important components.

SUMMARY OF THE ROADMAP



2.0 CURRENT MARKETS

There are two different types of pea, which support different markets and have different functional properties that can be exploited in processed food production.

Vining peas are a premium crop, high in sugar and resistant starch which are picked fresh for freezing or canning. These peas are characteristically wrinkled in appearance when dried.

Combining peas are harvested dry for human consumption as canned (whole or 'mushy') or dried peas, micronised for pet foods, flour or for animal feed. These are lower in sugar and resistant starch. These peas are characteristically smooth in appearance when dried.

Constraints for growing peas

- **Used as a break crop to build fertility and control weeds** – In England peas are typically sown from late February and harvested from June to August. This allows time to clear the land of weeds, such as blackgrass, before sowing and to harvest before the main crop wheat. Use of peas within a rotation has been shown to increase soil fertility through various interactions but most notably from nitrogen fixation by nodules on the roots. However, it requires attention to produce a high quality crop and is often sacrificed if a more valuable crop competes with time.
- **Restricted by soil type** – The area available for pea production is determined by geography. Peas need a free draining soil. The majority of peas in the UK are grown to the east of the A1 from Lincolnshire to Essex over an area of 33 – 34,000 hectares. Vining peas are grown from East Anglia to Dumfries in Scotland.
- **Timing critical** – The timing of harvest influences the sugar and moisture content of the pea crop, which affects the value of the crop. For combining peas farmers wait for the crop to dry off, which can make the crop vulnerable to bleaching if it rains. Rainfall can also flatten the crop, making it difficult to combine.
- **Variable yields** – The yield can vary significantly between farms. The Pea YEN report[1] 2018 reported yields varying between 4.66 tonnes a hectare to 2.6 tonnes, and this was for a group of committed farmers with similar soils and conditions. Average yields are considerably less than at a peak in 1999 when the national average was 4 tonnes per ha.
- **Specialist crop** – The UK is the largest producer of peas for freezing in Europe. Vining peas are grown by specialist farmer groups, for example the Anglia Pea Growers. Vining peas require a specialist type of harvesting equipment with a high capital investment. Combinable peas can be grown by a broader range of farmers but are often considered risky, with very variable returns year on year.
- **Distance to processor** – Timing is critical in pea harvesting: top quality peas for freezing are grown within 2.5 hours of a factory, such as the Birds Eye factory in Hull, and those for canning peas within 3 hours of the Princes factory at Long Sutton, Lincolnshire.

3.0 SCENE SETTING – SIGNIFICANT NEW MARKET OPPORTUNITIES

The workshop looked at the opportunities for peas beyond freezing, canning and animal feed and called upon a number of experts to provide input:

Dr Paul Sheldrake of the Healy Group, Dr Katerina Petropoulou of Imperial College London, and Justin Barrett of Askew and Barrett.

3.1 OPPORTUNITY FOR USE OF PEA PROTEIN, FIBRE AND STARCH BY PROCESSORS

Paul Sheldrake commented that at a recent event discussing the potential for textured pea protein and flour as a plant-based replacement for meat and eggs, there was a *"massive [positive] response from food manufacturers*".

A Summary of the Opportunities

- **Plant-based protein** – there is increasing demand from consumers for plant-based proteins for both health and ethical reasons – 16% of all new food product developments are vegan (source: Healy Group)
- **Good source of natural food ingredients** – there is always demand from food manufacturers for functional food ingredients, in particular protein isolates but also sources of fibre and starch
- **Protein is valued for its nutritional benefits** – essential for the growth and repair of the body – and also for its technical properties as a flour, binder, gel or emulsifier, as well as a textured protein for meat substitution or as a crispy coating. See diagram: ***Driving Innovation***
- **New markets** – there is a growing opportunity in micronized protein for sports nutrition and baby foods
- **Investment by industry** – there is considerable innovation in the market by companies such as Novo Farina
- **Sustainable source of protein** – peas are a more sustainable protein option when compared to meat. 2050 is predicted as a time of 'peak meat', after which more plant-based protein will be needed to take up the shortfall. Additionally, concerns over sustainability of soy may also create an alternative market for peas
- **Vegan alternative** – pea protein can also be used as an egg substitute for gelling
- **UK competitive advantage** – UK produced peas are desirable for use by Japanese food processors for snacks such as wasabi as they are traceable and GM free
- **Gluten-free** – peas are also gluten-free and are not known to trigger an allergic response

Challenges

- **Bitterness** – pea protein isolates are bitter and breeding is required to remove or reduce this
- **Supply** – guarantee of quality and quantity of supply is vital for manufacturers; if this is not available procurement will move to Canada or other overseas locations
- **Infrastructure** – Considerable investment is required by the industry in processing infrastructure, for example to micronize protein or create textured protein, and there is concern over the scalability of these processes

Driving Innovation

3.2 OPPORTUNITY TO USE PEA STARCH TO IMPROVE HEALTH

Dr Katerina Petropoulou of Imperial College London described new research findings on the *"potential of resistant starch to reverse diabetes".*

- The type 2 diabetes endemic affected 3.7m people in the UK in 2018; this is set to cost £10bn and consume 10% of the NHS budget by 2025.
- Type 2 diabetes is preventable and reversible – it is caused by poor diet and a sedentary lifestyle
- Pea starch, particularly for vining (wrinkled) peas, is high in amylose, which is resistant to digestion. This means it promotes beneficial fermentation in the colon, which causes sugars to be released into the blood over a longer period, reducing spikes in blood sugar levels, which in turn improves control of body sugars by insulin.
- Use of resistant starch from peas in snacks, fast food and processed foods could help to tackle type 2 diabetes
- Pea starch has been shown to be beneficial in aiding recovery from malnutrition
- A 'prescription diet' incorporating pea starch has the potential to provide a treatment for diabetes, and long-term use of pea-substitutes could help maintain health – reducing the burden on the NHS and improving the quality of life for millions of people[1]
- The development of new combinable pea varieties containing resistant starch will create opportunities for growers to access new markets

Conclusions:

Wrinkled Peas

- Unique food structure **>** Lower digestion rates **>** Lower blood glucose
- Higher Fermentation rates **>** Higher Secretion of beneficial metabolites
- Unique Food Structure **>** Applied to other legumes
- Awaiting Long term study **>** Role of gut bacteria in blood glucose control

Pea flour

Flour processing **>** increases absorption rate BUT lower glucose and insulin with wrinkled pea flour

[1] Identifying crop variants with high resistant starch content to maintain healthy glucose homeostasis – K Petrolpolou et al. Nutritional Bulletin https://doi.org/10.1111/nbu.12240

3.3 CHALLENGE OF INCONSISTENT YIELDS AND QUALITY

Peas are a speciality crop and farmers who choose to grow peas do so for a variety of reasons. Experts **Matt Smith** of F Smith & Son and **David Robinson** of Frontier Agriculture provided input to the workshop.

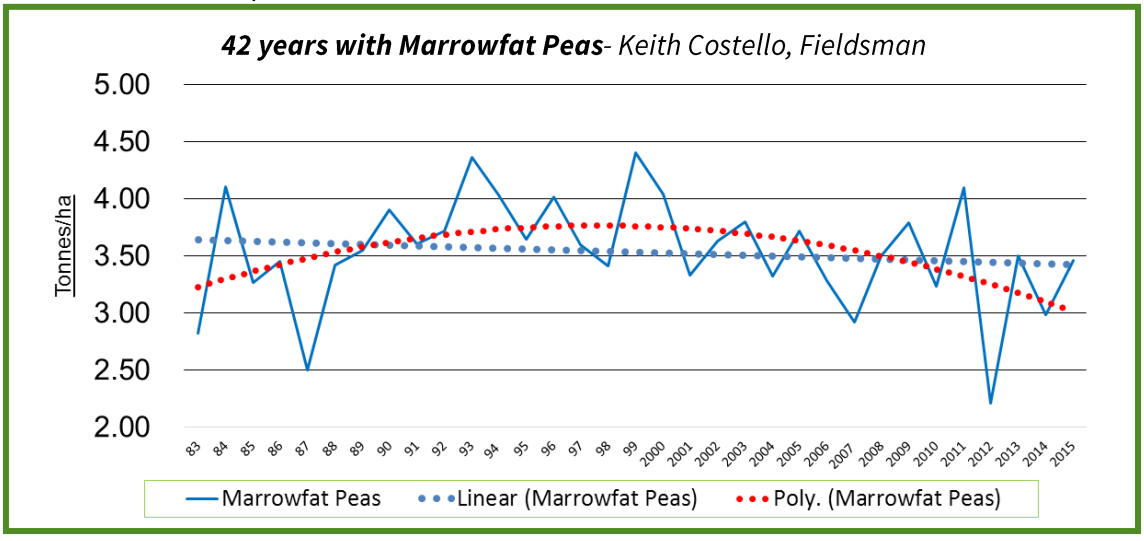
Matt Smith's comment "I like peas" was a telling statement. Peas are challenging to grow and profit can be lost in a shower of rain.

Opportunities

- **The value of peas is greater than monetary** – peas fit within the rotation, offer disease control, reduce irrigation for future crops of potatoes, improve soil health, and offer uplift in yield of following crops such as wheat. However, measuring this value is difficult

Challenges

- **Knowledge transfer** – traditionally much of the knowledge has been gained through experience 'on-farm' or through participation in growers' groups. Reduction in the numbers of growers and changes in management practice risks the loss of this knowledge
- **Reduction in labour** – farmers have to prioritise tasks, so timely operations for niche crops may have to be sacrificed. Timing is vital for peas: the seed bed needs to be well prepared and dry; establishment needs to be vigorous, the window for harvesting is tight, the moisture level is critical, weather must be dry and warm, and heavy rain can cause lodging
- **More profitable alternatives to peas** – maize and beet for AD plants are a significant land use alternative and oats are growing in popularity. Additionally, markets for spring barley and soy are getting bigger, and Countryside Stewardship Schemes are becoming more valuable, making non-food alternatives for the land more attractive
- **Pests are an increasing challenge** – pigeon damage has increased, with few effective control methods, and pesticides are being withdrawn; in addition, peas are vulnerable to adverse weather
- **Withdrawal of agrochemicals will have an impact on peas** – potentially this will have a greater impact on other break crops such as oil seed rape, and the falling value of sugar beet may make peas more attractive in comparison
- **Pea yields are static –** there are a number of factors involved and research is needed to evaluate and help overcome them



3.4 INFLUENCE OF GLOBAL MARKETS AND POLICY DECISIONS

Through the questions and answer sessions a number of other influencers and drivers were mentioned.

As in all areas of the agri-food value-chain, local and global markets and policy decisions influence pea production.

- The industry is concerned about the number of pesticides that are being withdrawn from use and there is a lack of knowledge of how to farm without them. Uncertainties over regulatory frameworks and the cost of registration may deter new alternatives entering the market
- Although welcomed by the industry, the 'greening' policy designed to encourage the use of peas within a rotation was introduced rapidly. This caused an increase in surplus tonnage of low-quality product. This resulted in a loss of confidence and lower market values
- The UK's soil and climate provide natural benefits for growing peas, there is significant expertise and the UK has a strong reputation for quality and traceability. However other countries such as Canada see the potential of this market and overseas competition was an area of concern. The industry needs to find a reason for value in local production. Currently this lies largely in improving consistency of quality, reliability of continuous availability and flexibility of delivery
- Pricing and contracts are key. Where farmers are working closely with food manufacturers – Birds Eye, Princes Limited – the crop is profitable, however the demand for canned and fresh peas is static so this does not offer an opportunity for others to enter the market

4.0 KEY THEMES DISCUSSED IN THE ROUNDTABLE SESSION

4.1 Soil health

The decline in pea performance may be an early indicator of poor soil health.

Anecdotal evidence suggests that peas are more sensitive to a reduction in micronutrients and organic content in the soil than cereals, which, are more resilient to adverse conditions.

This suggests that improving soil health for peas might also prevent future loss of yield in cereals.

Many participants mentioned that a major limiting factor is that the 'ideal' soil for peas is not known.

The AHDB-funded work on soil health was mentioned by Fen Peas and it was thought this would be of interest to pea growers. More work is needed into understanding the impact of compaction, contribution of organic matter, and the availability of micronutrients.

Other alternatives to field cultivation were also discussed such as continuous cropping in controlled environments and using hydroponics instead of soil. Some of the larger food processors had considered these options but concluded that the investment currently required would be prohibitive.

4.2 Improving rhizobia performance

All plant roots exert an influence on the soil immediately around them. This region, known as the Rhizosphere, supports a rich diversity of microorganisms. These have a symbiotic relationship with the plant, feeding off sugars extruded by its roots and in return making micronutrients more readily available.

Legumes have an additional functionality; they develop root nodules, which are induced by nitrogen fixing bacteria. These bacteria, in exchange for carbohydrates supplied by the plant, fix nitrogen from the air within the soil, making it available to the plant. However, residual soil nitrogen fertilizer can inhibit early nodulation. Understanding this mechanism is important for genetic improvement.

The benefit of nitrogen fixation and the effect of fungal associations on soil structure, soil crumb and the release of other mineral nutrients is also seen by improved yields of following crops, such as wheat, and this may result in lower levels of inorganic fertiliser being required as a result.

There was discussion on ways to improve conditions for the microorganisms in the soil.

Increasing knowledge of biostimulants is creating the potential for use of naturally occurring (organic) mechanisms to boost plant health and resilience.

A number of participants in the workshop – Itaka Crop Solution, Biotechnica – provided input during discussions on the opportunities for using improved seed treatments and seaweed preparations to improve plant performance.

It was considered that more evidence is required to prove the efficacy of these approaches and thought is required to how regulation can be used to ensure quality assurance while not creating barriers to innovation.

4.3 Good farm practice

Pea performance is highly volatile, the crop is susceptible to weather and operations require careful timing. The expertise of the grower is an important factor in success.

Matt Smith reported participating in trials with Dalton Seeds to improve the seed crop. He also conducted his own trials into different methods of cultivation such as minimum tillage, use of cover crops, and the impact on cropping after peas (where potatoes seem to have more benefit than wheat).

If this is representative of other dedicated pea growers then it suggests there is considerable scope for increasing farm-based trials and pooling this knowledge. However, there was debate on the competitiveness of the industry and the need to provide incentives to encourage sharing of information, for example contracts that reward best practice.

Roger Vickers, CEO of PGRO, observes: "Best practices are generally built into contracts as minimum standards, with the standard of quality being the grower's contractual reward for a commodity."

One approach to sharing best practice that is well regarded by growers is the Pea YEN. The Pea YEN team is supporting a small core of growers to establish a good understanding of the issues behind the falling yields. The Pea YEN has already revealed some interesting findings, such as that some micronutrients in the soil are may not be sufficiently bioavailable, as leaf samples from peas showed a potential deficiency in manganese. The YEN is creating a baseline for the data and it plans to expand this activity working closely with growers and end customers.

4.4 Evidence based technology

A number of the participants were from technology-based companies and they shared their perspectives.

For other crops such as potatoes, there are sophisticated yield models that indicate the impact of different factors and suggest potential interventions. There is an opportunity to develop improved models for peas. However, this would require better forms of data collection, and a number of participants in the workshop – Hutchinsons, Hummingbird Technologies – suggested ways this could be achieved.

Additionally, as peas require ideal conditions for sowing and harvesting, more localised predictive weather forecasts would help inform decision-making. If this data was made available it could feed into yield models, allowing the financial impact of various options to be considered.

4.5 Alternative pest and disease control

With the withdrawal of core agrochemicals there is an urgent need for an alternative approach to pest and disease control based on prediction, prevention and mitigation.

The cost of inputs was considered small compared to the risk of losing the crop.

Loss of a crop was also considered a risk to organisations further up the chain, as they would then have to import more expensive produce to cover the shortfall. This creates instability in the value chain. Initiatives to share risk and improve consistency of quality and quantity would benefit all in the value chain.

Emerging technologies such as sensors to detect disease threat, imaging to provide early warning of crop damage and mechanisms to collect and count bugs were all discussed and considered as ways to make pest control more strategic.

Initiatives to improve conditions for threatened field birds have inadvertently created ideal conditions for woodpigeon to become a major agricultural pest. Most will attempt to raise several broods each year, potentially as many as four or five broods with two eggs in each.

Technology for protecting crops from pigeons, seed treatments that make seed unpalatable (within EU directives) or improved forms of bird scarer would provide an immediate benefit to yields.

Discussion also included the potential benefits of intercropping – growing different varieties or crops within the field. This is being made possible with precision seed drilling. Trials by PGRO have indicated that this may have benefits in terms of reducing the spread of disease and reducing the risk of losing a whole crop.

Consideration would be needed of the additional technologies that may be required to differentially harvest sections of the field or methods of segregating the pulses once harvested, ie separating beans and peas.

4.6 Breeding for improved plant physiology and growth

There are opportunities to breed for more than yield, for example resilience to adverse weather, and for nutritional and functional value and for taste. These would improve the value of the crop to farmers and processors and create a competitive advantage for UK produce.

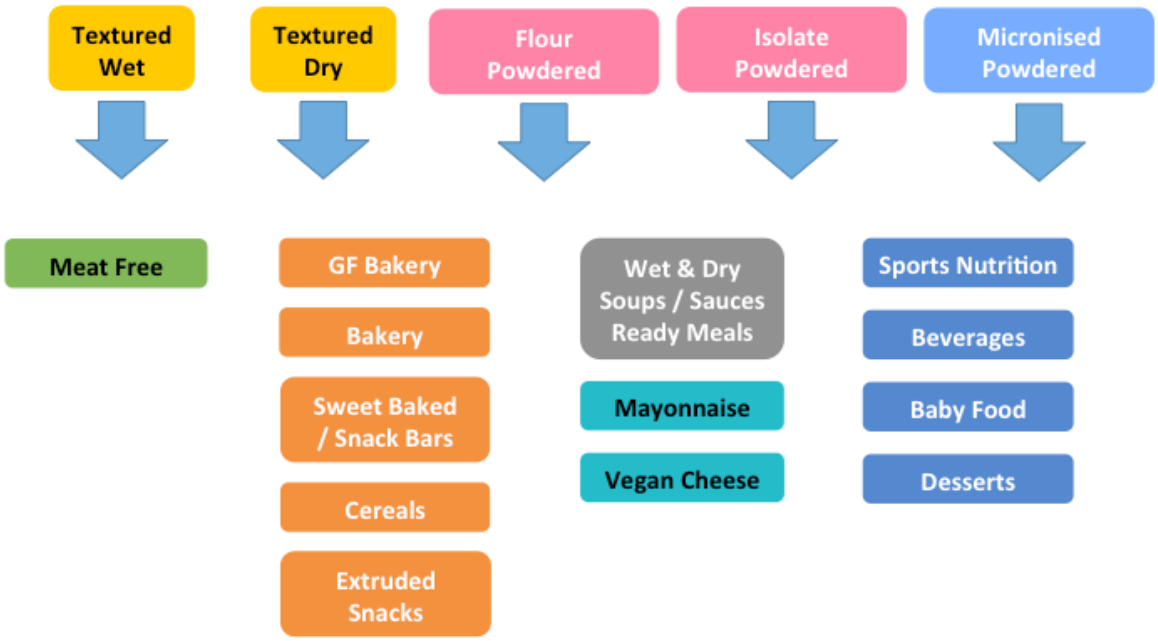
The two crops – vining and combining - have been bred to have different agronomic characteristics (flowering habit, and other traits related to harvestability), so to introduce a trait from one to the other requires extensive breeding.

Breeding could also be used to improve land use efficiency, for example, peas that can be harvested earlier would reduce the pressure on farmers at peak times. Breeding to change maturity dates would potentially enable the farmer to drill seed for different varieties at the same time but harvest at staggered times, reducing the pressure on resources and spreading the risk of loss.

4.7 Development of new food markets

A number of companies, PeaWise and Novofarina for example, are already using pea seeds/pea flour in innovative ways and this is highly promising.

Transforming the pea powder



Paul Sheldrake, the Healy Group

An additional benefit is that it might create new markets for peas that have been damaged by bleaching and staining; this is currently a major issue for the farmer and results in loss of value.

Although colour is perceived to be important, it is not known to be associated with adverse functional properties. An adjustment in the processing industry over perception of quality and the new opportunities emerging that use flour or processed protein may overcome this issue.

For example, a yellow pea is already being used for pea flour/crumbs etc, so a bit of staining should not impact this market.

However, processes which might have already been developed to deal with pea flour may need to be changed again to take account of the properties of 'resistant starch' flour types as these will behave quite differently. This will require some development work.

Where green peas are used for extruded snacks etc. the development of improved natural colourings may mask staining and make the snacks more attractive to consumers.

Yield vs Quality

Value of an 11 tonne sample from a **10% yield increase** with **20% bleach**

£350 / tonne contract price at maximum 10% bleach

-£30 / tonne bleach deductions based on -£3/% over 10%

£320 x 11 tonnes = £3520

Value of 10 tonne sample based on **no yield increase** with **5% bleach**

£350 / tonne contract price at maximum 10% bleach

+£15 / tonne bleach bonus based on +£3/% under 10%

£365 x 10 tonnes = £3650

Value of an 11 tonne sample from a **10% yield increase** with **5% bleach**

£365 x 11 tonnes = £4015

Justin Barrett, Askew & Barrett

5.0 TIMELINE FOR IMPACT

Groups were asked to review the trends/drivers, enablers, barriers, opportunities, markets and technologies and create a roadmap, giving a timescale for impact. Below is a table summarising the results.

0-3 Years	3-5 years	5-10 years
Trends & Drivers		
Demand for plant-based protein Vegan nutrition- 16% of new products Drive for gluten free, allergen free	Improved greening legislation Standards and quality assurance Improved biostimulants Change in policy will recognise environmental benefits and other value Change in cultivation practices such as ploughing, min-till Reduced crop area	Increasing exports of peas and plant-based protein. A source of non-GM protein
Health agenda – need to improve health of population and manage NHS spend. Changing perceptions on food consumption	Protein plan for UK Increase amino acid profile: 0.93–1.00	Peak meat and population growth Climate change impacts growing area Policy change on public procurement of foods
Improving farm logistics – increased scale of farming and tighter control on timing of operations	If nothing happens pea production will decrease	Pea yield stability Increase in land rent Water use efficiency policies
Reduced access to EU-plant protein – UK currently 30% self-sufficient Market risk from Brexit ie tariffs will increase cost of exports	Reduced imports of protein and peas	Private and public investment in R&D is market value driven
Enablers		
Improved understanding of the pea crop physiology, to increase yields and stability Better knowledge of factors impacting crop establishment Dedicated agronomists with field experience	Improved nitrogen fixation Understand health parameters Understanding of the key micro-nutrients Clarity required over protein quality and functionality Biostimulants	Increased yields to make the quantity more consistent
Policy that supports sustainable crops Staff training – need to retain and develop staff Improved knowledge exchange to share basics of pea production including dos and don'ts Online training and use of video Creation of industry-wide research collaborations If UK farmers can earn money growing peas they will do so long term growing contracts will increase confidence and demonstrate value	Improved infrastructure for processing new products and new ingredients Funding for research that supports vertical integration Develop simple crop protocol on how best to grow peas with recommendations for each end-user market Creation of value share across the supply chain Crop insurance Funding for R&D and grower incentives Increase proportion of pea in animal feed	Collaboration with large R&D investing countries eg Canada

Barriers		
It is a specialist crop that is sensitive to its environment Bird damage (40% loss) bruchid, aphid, soil nematodes Peas are seen as unglamorous crop Loss of crop protection and diquat Pressure from more valuable alternatives Reduction in government incentives and subsidies	Resistance to agri-chemicals Need new better varieties to maintain and improve yields Little opportunity to move to new areas as limited by access to factory Does breeding select for poor nodulation?	Varietal breakdowns Lack of resistance to disease Contract plant breeding
International standards Infrastructure needed for gluten free milling Time taken to secure funding reduces competitive benefit of research (esp. dietary health benefits) Need for improved dissemination of information about technology	Weather patterns become too extreme Removal of land from food production due to increase in countryside stewardship and fuel production Pressure on land use as more land used for fuel production	Coping with climate change and reduction in water Backlash against microbial products if not correctly regulated
Fragile market with spikes in price and supply and demand	Canadian exports increasing creating threat to markets	
Opportunities		
Rhizobia inoculants to improve nodulation of pea crops and n-fixation Research needed to understand what micronutrients a plant absorbs from the soil, eg how important is sulphur? Speed breeding	Research to address new market opportunities – removal of bitter taste, protein quality, browning Enhanced breeding, better methods of selection Technology to improve land-use economy Improved pea varieties to support new processed food products Development of improved winter peas, hardier and disease resistant Breeding for better root structure Better understanding of genetics that drive variety (protein, starch, taste) Bleach reduction technologies	Identify and screen for novel mutations Protein profiling and quality improvement Crispr, advanced gene editing Improved crop modelling
Creation of Farming Practice Guide Development of novel pea-based ingredients Benchmarking programmes for grower to grower improvement	Evidence-base for health benefits of legumes in the diet Research to understand the microbiome, to determine beneficial and non-beneficial microorganisms Improved soil health resulting from peas could be rewarded by UK agricultural payment support scheme	Develop varieties that could be grown further north, and mature earlier Development of pea starch as a biodegradable film (Trigger.EU) Recommended lists based on market requirements
Crop nutrition Improving soil quality (N) for next crop Promoting awareness of sustainability benefits Improved pest management, use of monitoring systems, alternative methods of control	Super strains of rhizobia Independent evaluation of technology and innovation Understand insect resistance Alternative break crop to oil seed rape or sugar beet	Soil health – understanding the problems, roots and rhizobia, organic matter, improved water infiltration reduces need for irrigation Breeding for new climates (eg North UK) UK centric breeding programmes Development of improved disease tolerance and enhanced nodulation Alternative pest controls

STC trialling the use of lasers for pigeon control Remote sensing of weeds, spot spraying and laser weeding. Greater use of geostationary satellites Greater use of Digestate and compost to boost performance	Improved seed treatments Improved farm machinery for smaller crops Robotics AI and precision data Better crop models to understand physiology	Disease resistant peas Pest repellent crops eg pigeons, aphids
New markets		
Quality standards create user pull Products with low glycaemic index – pea pasta, pea biscuits, pea bread	Increased use of pea products in processed food Organic market sector (may be limited?) Improved colour retention on cooking would increase attractiveness for consumer	New products eg for baking, taste, browning Industrial non-food uses eg starch for films
Alternative proteins Vegan market – flexitarian diets Coeliac gluten-free foods, free from	Aquaculture including peas and poultry	Healthy food, prescription diets, reduced human and animal diseases
Consumers on low budgets need cheap sources of protein	Asian markets	Opportunity to tackle malnutrition via high resistant starch
Sports nutrition and protein drinks		Products with high resistant starches for diabetics

6.0 PRIORITIES FOR DEVELOPMENT AND INVESTMENT

In a plenary session the outputs were collated and the following themes were identified for prioritising.

1. Soil Health and Improved Rhizobia Performance
2. Crop Nutrition
3. Good Farm Practice and Evidence Based Technology
4. Alternative Pest Control
5. Alternative Disease Control
6. Breeding for improved plant physiology and growth
7. Development of New Food Markets

These priorities were presented to the delegates and they were asked to identify specific opportunities

Table 1 – Improved understanding of the genome
Facilitator: Roger Vickers PGRO
Challenge: How can we breed for yield and quality consistency?

Table 2 – Soil health
Facilitator: Becky Howard, PGRO
Challenge: What are the perfect conditions for pea production?
Challenge: How can we optimise root development and plant establishment?

Table 3 – The microbiome and soil health
Facilitator: Charlotte White, ADAS
Challenge: How can we understand how to manipulate the microbiome to increase pea yields?

Table 4 – Independent evaluation of technology
Facilitator: James Wallace, IAR Agri Ltd
Challenge: How can we evaluate the benefit of new technologies and approaches?

Table 5 – Creating a template for Integrated Pest Management
Facilitator: Jonathan Clarke, John Innes Centre
Challenge: How can we evaluate the benefit of new technologies and approaches?

Table 6 – Agronomic decision support tool
Facilitator: Teresa Penfield, John Innes Centre
Challenge: How can we develop a dynamic decision support tool for growing peas?

Table 7 – Increasing yield and resilience of peas
Facilitator: Debbie Harding, BBSRC
Challenge: How can we capture an opportunity to understand roots and rhizosphere?

Question:	*How can we breed for yield and quality consistency?*		Group 1
Need	Yield stability is a main limiter to producer confidence and the realisation of the value.	**Summary**	Mapping the genome – identifying markers relating to yield characteristics.
Response	To build a consortium around a carefully defined project.	**New capability**	Robust yield factor evaluations Quicker breeding techniques.
Challenges to address	Identifying yield limiting factors and genes. Climate and soil variability in testing Deploying speed-breeding techniques. Approval of technology – CRISPR? Evaluation of nutrient uptake. Root architecture and mass and structure.	**Benefit**	Overcome current limitations
		Industry value	The whole supply chain benefits from stability and predictability. Industry benefits through access to protein, fibre. Health benefits from starch. The environment benefits from increased crop production of peas.

Existing capability:	**Key issues:**	**Requirements:**
JIC and universities. Breeders.	Feedback down the chain. Desired traits. Pea nutrition – requirements – Evaluations and knowledge of stability of demand and price.	Project consortium, research, PhDs, funding, facilities (labs/trials).

Question:	*What are the perfect conditions for pea production?*		Group 2
Need	We are not at maximum potential for pea yield and still don't understand why. There is a need to minimise supply chain instability, reduce waste, reduce risk	**Summary**	Developing more informed decision making for soil management in peas.
Response	To reduce risk in pea production and create stability throughout the supply chain. This would be achieved by creating a decision matrix tool for improved pea production. The aim would be to capture information where it already exists and generate new data to fill the gaps. This would include fundamental research on the soil microbiome.	**New capability**	Definition of soil health New soil categorisation based on soil type and quality
		Benefit	Expansion/benefit for other crops The benefit will be limited by the need for rotation but the aim would be to maximise productivity of the land available
Challenges to address	The scale of the objective and the variety of conditions that need testing Variety is a variable Causality is difficult to quantify, need to look at specific interactions	**Industry value**	Pea groups, agronomy groups, processors, land agents

Existing capability:	**Key issues:**	**Requirements:**
NIAB, JIC, PGRO, ADAS, Exeter Uni, JHI, Warwick Uni – has strengths in soils agronomy, disease and diagnostics	KE, IP for diagnostics and remove sensors	Funding and collaboration.

Question:	*How can we optimise root development and plant establishment?*	Group 2
Need	Improved rhizobia will lead to better establishment, improved crop nutrition and contribute to nitrogen available to follow-up crops.	**Summary** Improve pea roots and develop 'super' rhizobia.
Response	To breed pea varieties with improved rooting and to create bespoke rhizobial strains to enhance yield and performance.	**New capability** New rhizobia strains Technologies to improve inoculation, storage, and shelf-life of inoculants
Challenges to address	To identify the variation in rooting response to rhizobia (germplasm) Impact of complexities caused by climate on testing.	**Benefit** Reduce N inputs – reducing costs and environmental impacts
		Industry value Legume technology, Plant works, Agchem, Advisors
Existing capability: NIAB, JIC, PGRO, Exeter Uni, JHI, Notts Uni, UK Pulses, LSPB – knowledge of rhizobia and expertise in the UK to study root ideotye	**Key issues:** IP	**Requirements:** Elite and diverse pea germplasm. New and current rhizobia. Investment

Question:	*How can we understand how to manipulate the microbiome to increase pea yields?*	Group 3
Need	Peas yields constrained by disease. Increasing the health of the pea will increase yields and profitability and improve farm rotation.	**Summary** We aim to understand underlying soil health and disease issue which limit pea yields through a long term research project.
Response	Increase pea yields and reduce reliance on imports	**New capability**
Challenges to address	Setting up the most appropriate experiments to address the question. Multiple 4-5 year experiments to cover the rotation. Including appropriate controls and lots of replicated sampling. Big data and the analysis; meta transcriptomics Selecting the right sites for field trials.	**Benefit** Increase yields to compete in international market.
		Industry value
Existing capability A lot of relevant expertise in UK research industry eg JIC, NIAB, ADAS, RR. Relevant industry to exploit the results, eg legume technologies, innovative and open-minded farmers to take up products.	**Key issues:** Biostimulants and inoculants produced may fall under new regulation.	**Requirements:** Money – £1million to £2 million.

Question:	*How can we evaluate the benefit of new technologies and approaches?*	Group 4
Need	To improve pea productivity	**Summary** Facilitate the independent evaluation of new technology.
Response	To provide data to help end-users – growers, agronomists – to decide whether to adopt an innovation. To provide a 'NICE" for pea crops that would demonstrate that a product performed well in the field.	**New capability** Protocol for testing – including criteria and analysis Knowledge of field projects and scaling
Challenges to address	Industry uptake and trust Field scale assessment – difficult to find trial plots Output to be descriptive, but who would manage the process?	**Benefit** A vendor independent scheme to enable objective assessment. To avoid wasteful expenditure on technology that will not provide a return on investment
		Industry value Growers and agronomists
Existing capability: ADAS field testing, PGRO to manage process, YEN field lab, Sustainable landscapes project	**Key issues:** Industry participation and sharing of results	**Requirements:** Government funding for 5 years to pump prime. PGRO levy and technology provider contribution

Question:	*How can we create an alternative pest control system against aphid, pea moth and weevil?*	Group 5
Need	Current controls provide a barrier to entry of new chemistry – considerations include: regulation, market size, durability, gap in the market, need for proving ground for cross crop products	**Summary** Create a durable, integrated, pest management system, at an acceptable cost and time effective.
Response	An alternative approach to pest control.	**New capability** System structure Product evaluation/development Regulatory frameworks and value
Challenges to address	Knowledge gap, skills gap Standard practices (change) Confidence (validation) Understanding the financial model (user/supplier) Composition of the toolkit/system	**Benefit** Improve crop performance
		Industry value Those to benefit would be primary producer, processor, agronomist, environment
Existing capability: RRES, Newcastle University, University of Hertfordshire, NIAB Research, Precision AG, Drone SATS, IUT, Weather forecasting, agronomists, AG Chem, DEFRA, AHDB, FERA, PSD	**Key issues:** System use, system evaluation trials and implementation, approval	**Requirements:** R&D. Trials. New products for testing

Question:	*How can we develop a dynamic decision support tool for growing peas?*	Group 6	
Need	To mitigate risk of global competition and improve resource (water/nutrients) efficiency.	**Summary**	Collect and integrate crop and environmental data to provide appropriate best practice.
Response	To support dynamic decision making with enhanced decision support. Improve productivity and profitability to benefit the supply chain as a whole.	**New capability**	4 centres, agritech, big data, data integration Data sharing – promote a new mind-set Policy change to drive data sharing Automated and accurate data collection through good collaboration
Challenges to address	Funding (AHDB) Farmer beyond peas. PGRO. Availability – UK only? Levy body? Beyond UK – global sharing data – giving away data for nothing. Cheap imports Policy pull for data for incentives. Knowledge exchange for value.	**Benefit**	Improve productivity and profitability
		Industry value	Supply chain

Existing capability: Traceability – compared to overseas. Big data/Agrimetrics, University research output, PGRO, NIAB, Map of Ag, Agronomists (challenge protecting data), ADAS, YORA, monitoring tools, NFU, AHDB, satellite data	**Key issues:** Data sharing – willingness, connectivity and compatibility, skills – up skilling the next generation – value of data and data management.	**Requirements:** Change to policy to ensure data collection through incentives and Knowledge Exchange Database formation, data analysis, modelling and support tool development. £50,000 to £1million on-going development, farmer-owned, upskilling the next generation of farmers.

Question:	*How can we capture an opportunity to understand roots and Rhizosphere?*	Group 7	
Need	To optimise yield, increase sustainability and improve value generation.	**Summary**	Understand, predict and adjust soil properties to get the best yield/crop. To determine the best rhizobia.
Response	To encourage scientists to study this subject – link pure science to innovation.	**New capability**	Big data – outputs. More research in soil science and yield response.
Challenges to address	Science, lots of soil types and loads of variables. Microbiome, what's in it, what's beneficial and what's not? Activity of nodules – if compromised – alternative nitrogen source required. Effect of weather/climate on soils. Earthworms declining, how to increase populations?	**Benefit**	Increase resilience of crop to eg climate change. Nb. Peas are sensitive to the environment and might be an indicator of an issue that will arise for other crops.
		Industry value	Growers

Existing capability: Soil Security Programme – some projects but ending soon. N.Fixation not specific to pea. PGRO and ADAS PEA-YEN companies developing soil sensors.	**Key issues:** Gathering data – automated collection. Farmers need incentives to do this.	**Requirements:** Scientific and technical expertise. Growers to supply data. Money. Motivation. Tenacity. Determination.

APPENDIX: ORGANISATIONS REPRESENTED AT THE WORKSHOP

Charlotte White
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Roger Sylvester-Bradley
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Stephen Francis
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Christine Lilly
Technical Manager
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David Robinson
Head of crop Dynamics
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Paul Sheldrake
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Healy Group

Alexander Jevons
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