Supporting high-quality industrially relevant research projects on potato and edible horticulture crops

www.bbsrc.ac.uk/hapi
Delivering global food security means providing a sustainable, secure supply of good quality food from less land and with more efficient use of inputs. Food security is a key strategic priority for the Biotechnology and Biological Sciences Research Council (BBSRC) and we are contributors to Global Food Security, a partnership bringing together the food related research interests of the relevant Research Councils, Government Departments, Devolved Governments and Executive Agencies.

The edible horticulture and potato sector is an important component of the food security equation in the UK, is consumer led and has a strong record of innovation. It provides 60% of all vegetables consumed in this country and 95% of all potatoes (excluding processed frozen products), but only produces 10% of the fruit it consumes. The horticulture and potato supply chains face the need to enhance their competitiveness and resilience which link to considerable challenges in terms of increasing production, reducing waste and improving sustainability. Through consultation with industry and related stakeholders from the sector, BBSRC has identified opportunities where targeted research support could help to address these challenges.

In line with its Business Interaction Strategy, and in partnership with the Natural Environment Research Council (NERC), BBSRC launched the Horticulture and Potato Initiative (HAPI) to support collaborative research projects in this area. The aim of the initiative is to support excellent quality, industrially-relevant research and training to help foster productive networks and knowledge exchange between the research base and industry.

This booklet provides information about the research challenges that will be addressed through HAPI, the benefits of industrial participation and case studies of HAPI projects.

“The Horticulture and Potato Initiative provides new opportunities for a forward-looking industry sector to engage with leading academics in pre-competitive research which really matters for their future growth. Leading-edge science has translated into important industry innovations over the years.

HAPI should foster a new injection of knowledge for growth and build a community of research scientists responsive to the needs of industry at a time when rapid scientific advance is coinciding with unprecedented challenges for producers.”

Mark Tatchell, Horticulture Innovation Partnership, HAPI Coordinator
Research Challenges

BBSRC worked with industry to identify a number of important research challenges shown below. Projects supported through the initiative are addressing these challenges through pre-competitive, innovative and excellent science. The multidisciplinary nature of the research crosses the remits of both BBSRC and NERC with both funders providing support.

The research funded through HAPI will enable innovation in the horticulture and potato industry sectors. During the selection process applicants demonstrated the strategic relevance of their research proposals by identifying the prospective impacts and explaining how these will be achieved.

Industry Benefits

Involvement in HAPI provides industry partners with the following benefits:

- Opportunity to work with leading researchers
- Involvement in innovative research to support and strengthen the sector
- Access to new knowledge and tools
- Exposure to a wider industrial and scientific network
- Information and advice relating to Research Council activities
- Public promotion and recognition through the initiative
- Opportunity to help foster succession in the horticultural and potato science base and a pipeline of highly skilled recruits to industry

“As growers we welcome the support which HAPI is bringing to the whole industry. The opportunity to collaborate in high level research and then get involved in effective knowledge transfer to get discoveries working on farms is vital to the development of the UK industry.”

Andrew Burgess ARAgS, Director of Agriculture, Produce World Ltd

iStockphoto © Thinkstock 2013
Controlling dormancy and sprouting in potato and onion

Potato and onion are major UK and worldwide crops required year-round by consumers and processors. As production is seasonal, long term storage is necessary and produce must remain in a high quality state for fresh consumption and processing.

Maintaining tubers and bulbs in a dormant state and suppressing sprouting are top industry priorities. Genetic studies in potato have shown that tuber dormancy is affected by several genes acting alone or in combination, but their identity is unknown.

Glenn Bryan (James Hutton Institute) will lead a HAPI research consortium including academic and industry partners to:

- Identify key genes and regulatory mechanisms that underpin dormancy in potato and onion
- Develop genome-wide data on major genes in onion bulb dormancy and sprouting
- Compare shared and distinctive elements of dormancy and sprouting control in potato and onion, leading to elucidation of key physiological and molecular control steps.

This HAPI project will improve understanding of the biology of dormancy and sprouting to facilitate development of new strategies for storage, and inform breeding of new varieties with better dormancy and sprouting behaviours.

The assembled research consortium provides a wealth of experience in genomics, genetics, molecular biology, physiology, agronomy and storage of potato and onion. Support and participation from relevant companies means the information generated by this HAPI project can readily be translated.

“Extending the lifetime of high quality fresh produce is an exacting challenge and a vital part of the food security equation. HAPI provides an opportunity to capitalise on emerging knowledge, tools and resources in a way in which industry can share in risk and embark on longer term productive relationships with the science base.”

David Cole, Horticulture Innovation Partnership, HAPI Coordinator
Exploiting next generation sequencing technologies to understand pathogenicity and resistance in *Fusarium oxysporum*

The soilborne fungus *Fusarium oxysporum* affects many different crops worldwide and causes some of the most devastating diseases in horticulture. Different forms of the fungus are adapted to different hosts and *Fusarium oxysporum f.sp. cepae* (FOC) which affects onion is a major constraint to production with losses estimated at £11M per annum in the UK. FOC causes a basal rot which is most damaging as bulbs mature in the field or post-harvest in store.

FOC produces long-lived spores, so control is difficult and relies on soil sterilisation/pasteurisation, fungicide drenches or seed treatments. However, these approaches may not be effective, and can have negative impacts on the environment. Furthermore, legislation surrounding chemical treatment of crops and seeds is changing and some products may not be permitted in future.

Plant resistance to basal rot in onion is therefore highly desirable, but so far successful varieties have not been produced for use in the UK. One of the main aims of this HAPI project is to identify the genetic basis for resistance in a selection of new onion lines where basal rot was much lower than in commercial varieties. Identification of genetic markers associated with the resistance as well as production of pre-breeding lines will enable the development of basal rot resistant onion cultivars for the industry. A further aim of the project is to identify FOC pathogenicity genes which could be used as a basis for a diagnostic test to distinguish this pathogen from other pathogenic and non-pathogenic forms of *F. oxysporum*. This may ultimately help farmers to make decisions about disease risk and develop management options.

The HAPI consortium is led by John Clarkson at the University of Warwick and includes East Malling Research and commercial partner Hazera Seeds with additional funding from AHDB Horticulture.

“HAPI is a great opportunity for us to carry out research on onion, an important crop worldwide that has had little science investment in the past. Fusarium basal rot disease is a serious problem for onion growers and there are few effective options for control - hence identifying genetic markers to accelerate the development of resistant onion varieties in this project will be hugely beneficial.”

Dr John Clarkson, Principal Research Fellow Warwick Crop Centre
A HAPI project is using an innovative network-based approach to breed lettuce resistant to two pathogens that affect many food crop species: Botrytis cinerea, which causes fresh produce to rot pre- and post-harvest, and Sclerotinia sclerotiorum, which can be responsible for up to 50% pre-harvest crop loss.

Chemical control of the two fungal pathogens is not ideal as resistance to the remaining few effective fungicides is likely to emerge, yet 90% of UK lettuce crops are treated with fungicides two or three times per season. The financial cost is high: if crops were resistant and required half as much fungicide, farmers would save an estimated £7.1M each year.

The team, led by Katherine Denby (University of Warwick), are experts in modelling complex biological systems, plant pathology and lettuce genetics. This project will translate findings from network models of the defence response of model plant Arabidopsis thaliana to B. cinerea. The researchers will work with plant breeders to combine this network-level approach with quantitative genetics approaches, and use a diversity collection of lettuce to find genomic regions linked to disease resistance.

Previous work suggests that similar genes and pathways may confer resistance to both B. cinerea and S. sclerotiorum. Denby and team will initially test this idea in lettuce, an important horticultural crop, but as these pathogens affect many other species they also plan to test key genes of interest in Brassica vegetables.

“HAPI funding enables us to translate findings and methodologies from the model plant Arabidopsis to important horticultural crops. We can combine novel strategies with quantitative genetics approaches to speed up the identification of alleles and markers for disease resistance. These can be incorporated into breeding programmes to reduce waste and costs of lettuce production.”

Katherine Denby, School of Life Sciences, University of Warwick
New UK potato varieties with late blight and potato cyst nematode resistance, reduced bruising and improved processing quality

A HAPI project is developing new, improved potato varieties with resistance to two kinds of pathogen, reduced bruising, and improved processing quality.

The potato industry is extremely important for the UK economy and food security: UK grown potatoes provide 95% of all potatoes, excluding frozen processed products, consumed in the UK. Yet growth and processing of potatoes are far from efficient.

This project will demonstrate the potential for novel plant breeding techniques to tackle four major issues for the potato industry:

1. **Late blight**, which caused the devastating Irish Potato Famine in the 1840s and continues to cause significant losses in potato crops, and necessitates multiple fungicide applications. Project lead Jonathan Jones (The Sainsbury Laboratory) will use GM methods to put three naturally occurring LB resistance genes into potato.

2. **Potato cyst nematodes** (PCN) damage potato roots, causing an estimated £25.9M loss of crop every year. Genes for two different resistance mechanisms will be put into potato and assessed by project partner Peter Urwin (University of Leeds).

3. Potatoes are often **bruised** in transit. Blackened tubers are not marketable, resulting in increased cost to consumers. Industrial partner Simplot has developed a genetic construct that reduces blackening after bruising. This construct will be put into UK potato variety Maris Piper.

4. During cold storage, potatoes accumulate sugars and asparagine. These sugars combine during processing at high temperatures, for example frying, to make a toxic molecule called acrylamide. Potato plants which are unable to make asparagine and have reduced sugar levels in their tubers have been generated by Simplot. Along with the bruising control construct, this trait will also be put into Maris Piper potatoes.

This project will go beyond breeding potatoes with the improvements listed above. The two pathogen resistance traits will be combined to reduce pesticide use and enable farmers to re-use land rendered unusable after intense potato farming led to increased potato cyst nematode abundance.

The ultimate aim of the project is to show that it is possible to develop a potato containing all four of the above constructs. The resulting potato would have durable resistance to late blight and potato cyst nematode, be less likely to be damaged in transit and would produce crisps and chips containing lower levels of acrylamide.
Every harvest begins with seed, but growers cannot rely on the seed they plant to germinate predictably. Steve Penfield (John Innes Centre) is leading a HAPI project to understand and mitigate the effects of a major, and worsening, cause of problems in seed vigour: climate change.

Although most commercial seed is produced in environments suited for maximising seed quality, seed germination rate varies widely from batch to batch. Previous work by Penfield demonstrates this is likely to be due to subtle temperature changes – even a 1°C change in temperature during seed development has an effect on seed performance.

In this HAPI project, Penfield and partners will look for genes affecting seed quality in order to breed Brassica plants that produce high quality seed in a range of temperatures. Plants with the most promising genetic traits will be tested at international seed production sites that supply the UK market.

Another important part of the seed industry is the treatment of seed with agrochemicals that enhance seed vigour and protect the seed and seedling from damage. Currently around 5% of product is absorbed by the seed, meaning a large amount of chemical is wasted and often ends up in soil or water. In this HAPI project, Penfield and team will also look at seed coat permeability in order to understand the physiology behind permeability and how it affects chemical entry into seeds.

“HAPI is allowing us to translate fundamental underpinning bioscience into seed quality solutions for field vegetable seed producers and growers. Understanding how to manipulate seed quality through genetic improvements, environmental manipulation or improved seed dressings promises to deliver more reliable seedling establishment for growers, and can help breed new varieties with seed performance that is more resilient to climate change.”

Steve Penfield, Project Leader, John Innes Centre
A genetic approach to improving post-harvest quality

The UK loves lettuce: the retail value of UK processed salads is £800M. But it is estimated that 97,000 tonnes of whole head lettuce and bagged salad are wasted in the UK each year, at a cost of £234m. Many people rely on visual cues to determine when to eat or dispose of food, so discolouration of prepared lettuce, which can occur around 3 days after processing, is a big factor in this loss.

David Pink is leading a project which brings together researchers in Harper Adams University, with collaborators at the Universities of Reading and Warwick, to investigate how breeding can help reduce wastage of lettuce. The research team is being supported by funding from HAPI and a number of industry partners.

Growing conditions are known to influence postharvest discolouration in lettuce, but are difficult to control in field crops in the UK. Previous work by the team identified genetic factors that control the amount of pinking and/or browning which develops on cut lettuce leaves. In this project they will increase our knowledge of the genetics of the biochemical pathways connected to lettuce discolouration. The team will also study how the compounds involved in pinking and browning affect how the lettuce tastes and its ability to resist pests and diseases. Exploring the relationship between taste, resistance and discolouration will enable the lettuce breeders to develop improved varieties.

Discolouration after processing affects other fresh produce. This HAPI project will also look at whether genes controlling discolouration in lettuce have a role in controlling browning in other crops and could therefore lead to reducing wastage from pre-packed fruit and vegetables as well as salads.

“HAPI has provided us with the opportunity to work with industry partners across the UK salad supply chain to address their most important quality issue of post-harvest discolouration in lettuce. The fact that industry partners contribute in kind as well as cash means they are truly part of the project delivering important components of the research. “

David Pink, Crop and Environment Sciences, Harper Adams University
Establishing biofumigation as a sustainable pesticide replacement

Nematodes are some of the most important food crop pests and cause substantial yield losses. Environmental concerns about pesticides have led to the withdrawal of two major compounds in Europe and more may be banned in the future. Biofumigation is another method for controlling nematode pests and is of great interest to the industry as a sustainable alternative to chemical controls.

Biofumigation uses naturally occurring chemicals produced by mustards and other brassica species to suppress soil-borne pests and pathogens. The active compounds are released when plants are incorporated into the soil. It is sustainable and potentially has fewer environmental risks than synthetic pesticides, but results in the field are inconsistent and there are no clear guidelines on optimum deployment in different agronomic situations.

Prof. Urwin at the University of Leeds leads a HAPI research project in collaboration with academics at the University of York and the James Hutton Institute together with partners from industry which will characterise the fundamental biochemical and metabolic processes underpinning biofumigation and its effects.

The team are characterising active chemical compounds made by biofumigant mustard species and determining how they vary during the plant’s life cycle and in changing environments. They also aim to find plant chemicals with novel, unexploited activity against pests. Finally, they will carry out glasshouse studies and field trials to analyse the impacts of biofumigants on soil alongside their effectiveness in combatting a range of pests.

The research consortium, which includes growers, levy bodies, agronomists and agri-tech companies, hopes the results of this HAPI research will facilitate optimal, sustainable use of biofumigation strategies in a range of field conditions.

“HAPI represented a unique opportunity to work with the horticultural and potato industries. The sector can be quite fragmented and finding industrial partners with sufficient resource to enter previous calls was difficult. Having an opportunity with the specific HAPI focus and a lower necessary contribution from industry has enabled us to come together to deliver pre-competitive research, which has a broad impact for a number of grower communities.”

Peter Urwin, School of Biology, University of Leeds
Strategies for integrated deployment of host resistance and fungicides to sustain effective crop protection

A HAPI collaboration led by Frank Van den Bosch (Rothamsted Research), involving the James Hutton Institute Scotland’s Rural College and partners from agrichemical and agronomic industries, will develop strategies for durable control of potato blight through integrated use of fungicides and biological resistance.

Fungicides and resistant cultivars are the predominant control measures against most crop diseases. Fungicides and resistant cultivars are the predominant control measures against most crop diseases. However introducing controls imposes a selection pressure on pathogen populations and this leads to them evolving increased resistance to the fungicides or becoming more virulent and able to overcome the plant immune system.

The adaption of the pathogen to the control measures causes them to become ineffective, and in response industry must continuously develop new fungicides and cultivars. This research project will investigate how integrated control, where two or more measures are simultaneously applied, can provide a more durable strategy of preventing crop losses to disease.

The evolution of fungicide resistance and virulence are studied in isolation, despite significant potential interactions between the two processes, so there is limited mechanistic understanding of the effects of combining the two control measures. The research team will use experimental and modelling approaches to quantify the effects of biological and chemical controls individually and in combination, and aim to find the most effective approach for long-term control.

New insights arising from the project will inform industry practices and guidance for growers. Industry partners will work with the researchers to devise and implement an integrated fungicide- and cultivar resistance-based strategy for potato blight. Additionally, the team will work on approaches to develop, parameterise and validate models that can be used more widely to quantify integrated sustainable disease control strategies.

“HAPI is a great opportunity for us to take the first steps in research on integrated use of fungicides and cultivar resistance. Such integrated strategies will help improve the sustainability of disease control. With this project we have a clearly defined practical outcome of a fundamental study into the sustainable use of integrated crop protection methods.”

Dr Frank van den Bosch, Principal Investigator, Rothamsted Research
Developing integrated approaches for pest and disease control in horticultural field crops (IAPAD)

Significant losses of vegetable brassicas have occurred due to Turnip yellows virus (TuYV) infection including tonnes of cabbage. Cabbage is the only vegetable brassica that shows clear visible symptoms (tipburn), but the virus also infects and reduces growth and quality of cauliflower, broccoli, Brussels sprouts and other brassica vegetables, as well as oilseed rape. In total, losses from TuYV cost between £67M and £180M every year in the UK.

TuYV is transmitted by the potato-peach aphid. Control mechanisms include chemical insecticides, insect barriers, pest monitoring and crop resistance to the virus. All four approaches are currently used, and scientists are using brassica varieties with natural resistance to inform breeding programmes to improve biological resistance further.

John Walsh (University of Warwick) will lead a team including industry partners from agrochemical companies, seed producers and agronomists to understand the effectiveness of the four approaches to controlling the virus (cultural, chemical, pest monitoring, biological) individually and in concert. Ultimately, they will generate a support mechanism to help growers decide when to apply which control measure.

The researchers will work with their plant breeding partners to develop genetic markers for resistance to TuYV, leading to improved biological resistance, which in the long term will reduce reliance on chemical control. Support for growers will translate to benefits for food processors and retailers, who will get a more consistent supply, as well as consumers, who should see reductions in price and improved product quality.
Apple replant disease evolution and rootstock interaction

The UK’s apple producing and processing industry is currently growing due to a huge increase in cider consumption worth £3000M per year. Apples are the most important tree fruit grown in the UK, but despite the growth in the industry our annual crop of dessert and cider apples currently meets only a third of national demand.

Replant disease, responsible for up to 50% loss in productivity in commercial orchards, is therefore a serious problem. The visible symptom of a perfect storm of microorganisms and pathogenic nematodes, it causes apple trees to fail to thrive in soil where apples have previously been grown. If the affected trees survive, they fruit late and produce fewer, low-quality fruit. The cost is already high and worsening due to movement to higher density orchards and changes in agri-chemical regulations.

Xiangming Xu’s team at East Malling Research is working with four industrial partners to:

- Unpick the arsenal of pathogens that cause apple replant disease
- Understand interactions between organisms that cause replant disease and apple rootstocks
- Determine why some apple rootstocks are more resistant to the disease
- Investigate the legacy effects of growing rootstocks with greater disease resistance

This project will be an important part of developing an integrated management system for apple replant disease. The team have received financial and in-kind support from two multinational companies and two UK apple producers, who recognise the great economic value of this research for their industry.

Benefits from this research extend beyond commercial horticulture. Improved, integrated approaches to managing replant disease will be of use in traditional and community orchards, which have significant environmental and social value.

“The HAPI initiative helps horticulture take the biggest strides forward by directing the best in science to the biggest issues facing industry.”

Professor Xiangming Xu, Genetics and Crop Improvement, East Malling Research