AHDB Agriculture & Horticulture DEVELOPMENT BOARD

HDC

Impact on horticulture through collaboration

IMPACT ON HORTICULTURE THROUGH COLLABORATION

INTRODUCTION

Welcome to this Horticultural Development Company (HDC) review which has been published to show the tremendous value of collaborative approaches to R&D and to highlight what has been achieved over the past 15 years thanks to Defra's Horticulture LINK scheme. This programme was a prime example of government departments stimulating links between industry and academic partners and so helping to achieve huge impacts in terms of the uptake of novel techniques.

HDC was involved in many of the projects presented in this document and played a pivotal role in publicising the results as widely as possible to the industry. Even now HDC is still involved in many of the remaining projects which will run to early 2015.

The depth and breadth of these projects reflects very much the diverse nature of the horticultural industry – from developments in biological control to remote crop maturity sensing for automated harvesting, to image-driven weeding systems. Many of these projects have yielded results already taken up by industrial partners; others have generated new information which has led to continued development by academic partners into new crop sectors. All the outcomes have demonstrated the robust nature of the scheme and the real impact of the programme.

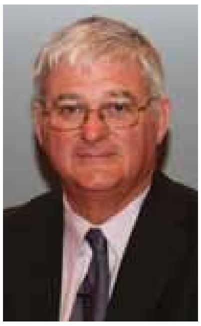
"MANY OF THESE PROJECTS HAVE YIELDED RESULTS ALREADY TAKEN UP BY INDUSTRIAL PARTNERS; OTHERS HAVE GENERATED NEW INFORMATION WHICH HAS LED TO CONTINUED DEVELOPMENT BY ACADEMIC PARTNERS INTO NEW CROP SECTORS"

As the horticultural levy payer organisation working on many of the projects, HDC must recognise and thank the various members of Defra who have been instrumental in overseeing the scheme. In particular we thank Sue Popple and her science team and David Cole, the HortLINK co-ordinator, who at all times took the trouble to listen to the partners and their ideas, and guide and encourage them to fulfil the tasks set for the projects.

We also thank the HortLink Project Management Committee, made up of industry representatives and scientists who dealt with the concepts and proposals and then acted as sounding boards for the consortia. Latterly, this group was steered so professionally by Mary Bosley, assisted by David Cole.

Neil Bragg
Chairman, HDC

FOREWORD



Our horticultural industry is experiencing unprecedented times. Challenges such as climate change, the erosion of applied research – the fundamental connection between science and application – economic pressure in terms of costs versus reasonable income, labour availability and resource management; all sit heavily at the forefront of a grower's mind along with the uncertainty for future investment.

Research and development is essential to improving practice, increasing knowledge and developing innovative approaches to address key issues. Innovation across all disciplines of horticultural production is an essential foundation on which to build a thriving future industry.

As a grower and chairman of a Horticulture LINK project (SCEPTRE), I applaud the concept of collaboration and appreciate how this approach has the ability to reach across all aspects of horticultural food production and distribution and, by extension, into the ornamentals industry. The development of partnerships has real impact on genuine issues such as crop protection, agronomy, growing media and labour.

By bringing together the scientist, the funder, the grower and the retailer, we are able to share not only costs but valuable knowledge and expertise. HortLINK has been a marvellous example of true collaboration in an industry not renowned for that trait.

"BY BRINGING TOGETHER THE SCIENTIST, THE FUNDER, THE GROWER AND THE RETAILER, WE ARE ABLE TO SHARE NOT ONLY COSTS BUT VALUABLE KNOWLEDGE AND EXPERTISE"

Dramatic changes in government policy, food security and the need to redress the imbalance between home production and imports are just some of the obstacles that confront us. However, with continued collaboration we can build innovative partnerships to address them. In the future, the Horticultural Development Company must play a pivotal role in the development of these partnerships and projects. By working closely with grower associations and the wider horticulture industry, HDC must deliver targeted research and knowledge exchange programmes to improve efficiency and productivity, forging a stronger, more unified, world-class industry.

David Piccaver
Chairman, J E Piccaver & Co

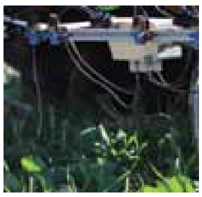
CONTENTS

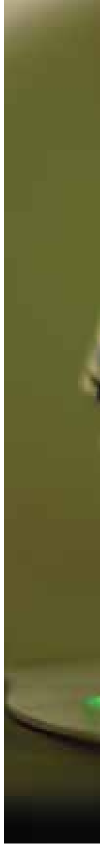
COLLABORATIVE RESEARCH TODAY

CASE STUDIES

MEETING FUTURE CHALLENGES

REFERENCE SECTION





EVOLUTION OF COLLABORATION

How developments in agriculture, food and environmental policy have shaped the provision of horticultural R&D

Practical innovations in horticulture typically result from many years of basic and applied research, which may cost anything from a few thousand pounds to several millions, and may take anything from a few years to several decades to complete.

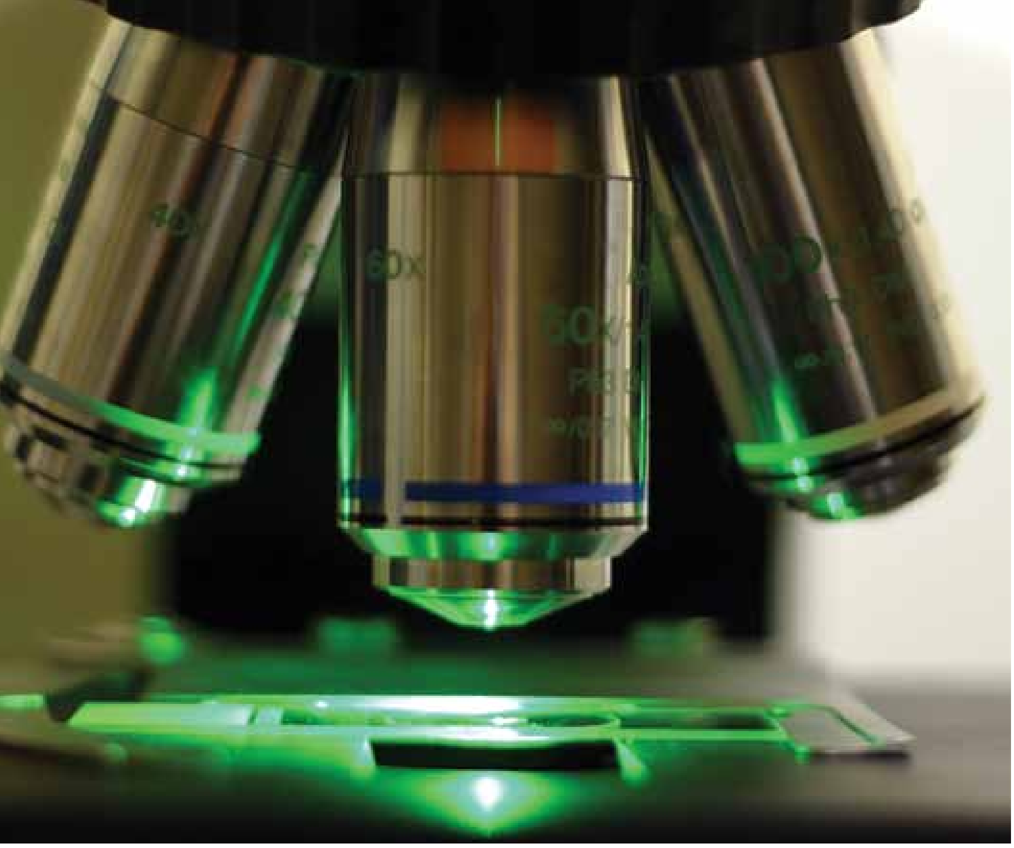
Many innovations arise from ‘blue-sky’ research by universities, research institutes or, sometimes, commercial companies. Some may be adapted from other industries or crop sectors in which the basic research has already been done. Others may come from applied researchers, agronomists or growers grappling directly with the technical problems of crop production in commercial practice. But even the most practical innovations are usually built on deep foundations of basic science of some kind.

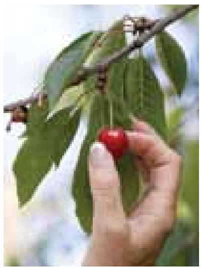
Various applied research, development and knowledge exchange mechanisms and processes are then needed to translate the results of basic science into commercial practice.

The post-war intensification of UK agriculture was driven jointly by the Agricultural Research Council (which became the Agricultural and Food Research Council in 1983) and the Ministry of Agriculture Fisheries and Food, which became the Department of the Environment, Food and Rural Affairs (Defra) in 2001. The research council funded most of the basic scientific research, and MAFF/Defra most of the applied research and advice provided to farmers and growers. Parallel industry investment in crop protection and husbandry systems flowed through product development by the various agrochemical and machinery manufacturers. Plant breeding has been done in tandem by various public and commercial crop breeding programmes.

The research and knowledge transfer involved was done by the universities, research institutes, agricultural and horticultural colleges, and the National Agricultural Advisory Service (subsequently the Agricultural Advisory and Development Service, ADAS), augmented by various private consultancies.

In the early 1980s, with rising food mountains and falling food prices, the UK government began to argue that the amount of public funding provided for applied agricultural R&D was excessive, and a programme of progressive reform began: applied research organisations and facilities were selectively closed, transferred or sold; associated research programmes were rationalised; ADAS, which did most of the government-funded applied knowledge transfer, was scaled down in size and scope, and eventually privatised. Industry was invited to pick up an increasing share of the cost of all near market work and HDC was set up in 1986 to fund applied horticultural research and associated knowledge transfer. The highly successful government LINK schemes, including Horticulture LINK (HortLINK), were set up to fund work of common interest to government and industry, and to build collaboration between industry and researchers.





"APPLIED RESEARCH, DEVELOPMENT AND KNOWLEDGE EXCHANGE IS VITAL TO TRANSLATE THE RESULTS OF BASIC SCIENCE INTO COMMERCIAL PRACTICE"

Over the 20 years of its existence, HortLINK and its predecessor brought together numerous consortia of academic and applied research scientists, technologists and industry partners, and generated rigorous pre-commercial R&D of practical relevance and value to growers on a wide variety of strategically important subjects. There have been many successful examples, some of which we feature in the following pages. The final HortLINK grants were awarded in 2010 and the programme is now closed to applications. The final project runs until 2015.

The Agricultural and Food Research Council was succeeded by the Biotechnology and Biological Sciences Research Council (BBSRC) in 1994, which remains the lead funder of basic research in biological sciences in the UK.

UK government policy on horticultural research has been the responsibility of Defra's Horticultural Crop Sciences Research Unit. Its research priorities report published in 2006 set out five priorities:

- Agriculture and climate change
- Sustainable water management
- Resource efficient and resilient food chain
- Sustainable farming systems and biodiversity
- Plant health.

The Scottish Office/Scottish government has funded Scotland's particular R&D needs. Since 1981 these have been met by the Scottish Crop Research Institute – which was amalgamated with the Macaulay Land Use Research Institute in 2011 to form The James Hutton Institute. The Scottish Agricultural College provides additional tactical research and advice to industry.

HDC was incorporated into the Agriculture and Horticulture Development Board (AHDB) in 2008.

A guide to the organisations currently funding R&D for horticulture, including collaborative projects, is on p54.

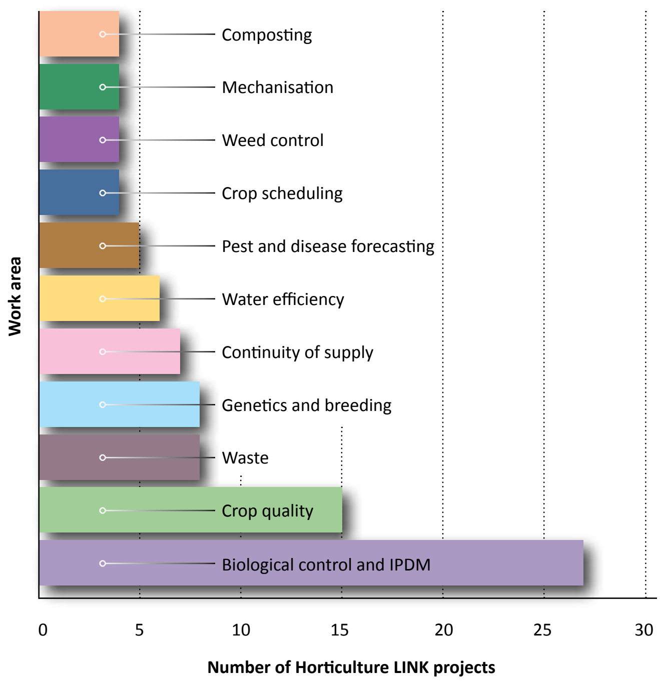
CHAIN REACTION

The Horticulture LINK programme has shown just how much can be achieved through collaborative R&D

Since the inception of the government's Horticulture LINK programme, around 70 projects have been set up to deliver research focused directly on UK horticulture's needs. A total of almost £42 million has been invested in these projects, with government and industry having shared the total cost almost equally.

It's that even split between government and industry investment that is the beauty of the HortLINK programme and one of the reasons for its success. By structuring it in such a way that the industry itself co-funded the work, the government ensured all industry partners had a say in how the funds should be spent, which in turn made sure that the research answered the questions the industry wanted resolving.

HortLINK projects by work area



By the very nature of scientific research, it's not always possible to deliver results that will have an immediate impact on an industry like horticulture, but as the case studies in this review show, those who have taken part in the programme have been well satisfied with what the projects were able to achieve. And all the projects have extended our knowledge of each topic researched – in many cases to the point where findings have been further developed in 'near market' projects funded by HDC.

For example, although scientists working on molecular breeding for root rot resistant raspberries (HL0169, see p10) weren't able to cure the disease directly, they have given breeders a new tool to speed up delivery of disease resistant varieties to the industry.

The project is one of the 7% of HortLINK consortia to have used molecular genetics to find a solution to an industry problem. Perhaps unsurprisingly, more than a third of all projects focused on biological control and integrated pest and disease management, accounting for 38% of the total.

An important strength of the programme is that the work has been spread evenly across a vast range of industry challenges, including crop quality (21% of the projects), waste (11%), continuity of supply (10%), water efficiency (8%), pest and disease forecasting (7%), crop scheduling (6%), weed control (6%), mechanisation (6%) and composting (6%).

Similarly, the projects have reached out to all sectors of the industry. One

WHAT IS HORTICULTURE LINK?

LINK has been the government's principal mechanism for supporting collaborative research partnerships between UK industry and the research base. The HortLINK programme was launched in 1996 and its aims were defined as:

- To improve the sustainability of the horticultural industry
- To improve knowledge and understanding of processes and factors which determine the performance of the horticultural industry
- To enable access by the horticultural industry to innovative ideas and technology by involving a wide range of research institutes and university departments
- To promote wider awareness of the benefits of advanced horticultural techniques/methods, especially to small and medium sized enterprises.

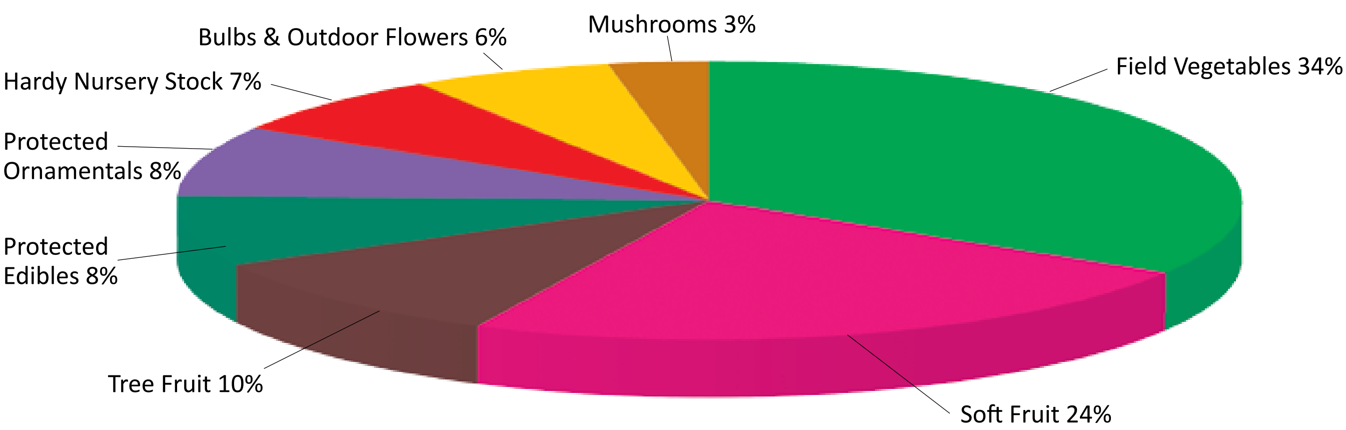
The programme supported pre-competitive collaborative research in the following priority areas:

- Efficient use of resources, especially energy, water and growing media
- Novel and more efficient production and harvesting systems
- Efficient, environmentally acceptable and sustainable pest and disease control, contributing to integrated crop management systems
- Technologies to ensure the availability of quality UK produce at times required by the market
- Crops targeted to provide novel or proven food products, including protective and beneficial components of diet
- Reduction and management of waste in production and processing
- Exploiting genomics for improving horticultural crop quality and productivity.

third of the projects have been directly relevant to field vegetable production, the largest sector by value. About 24% of the projects had value for soft fruit, 10% for tree fruit, 8% each for protected edibles and protected ornamentals, 7% for hardy nursery stock, 6% for bulbs and outdoor flowers and 3% for mushrooms.

It is virtually impossible to calculate the programme's financial benefits for each sector but the case studies that follow show how HortLINK results are now guiding growers in their business practices and how collaborative funding targeted at finding solutions to key problems has helped horticultural businesses.

Proportion of HortLINK projects by crop sector



FASTER ROUTES TO NEW VARIETIES

In a series of collaborative research projects, the industry is using new knowledge about plant genetics to breed tastier fruit and vegetables that can be grown with less impact on the environment

Plant breeding has the potential to help achieve many of the goals that growers want to win: new varieties with better pest and disease resistance would mean less reliance on chemical controls; drought tolerance would help cut water use; better eating quality could stimulate markets and even improve people's health.

In the past, breeding crops for specific traits has been hampered by the difficulty of selecting the right parental lines to cross, and the time it took to conduct the extensive glasshouse or field trials over a number of years to find the seedlings with the right combination of characteristics for the market.

New knowledge of plant genetics is changing all that, and a series of Horticulture LINK projects (HL0169, HL0170 and HL0195) on raspberry breeding is showing how the use of modern genetic science can dramatically speed up the introduction of new varieties without recourse to 'genetic engineering' technology.

Raspberry has a relatively small number of genes on just seven chromosomes which have been mapped by scientists at SCRI (now The James Hutton Institute), famous for its work on raspberry breeding, with funding from the Scottish government. Armed with that information, geneticists and breeders have since been able to pinpoint regions of the genome which are linked to key traits such as disease resistance or aspects of berry quality such as colour, size and flavour.

It has also made it possible to pick out 'genetic markers' linked to those traits, which accelerates the breeding process. Potential parental lines, or offspring from crosses, can be screened for the genetic marker by simple, quick laboratory tests rather than looking for the characteristic itself or the genes that control it. If the offspring from a cross has inherited the marker, it is highly likely that it has also inherited the trait that the marker is linked to.

One area where genetic marker technology has come into its own has been in the search for improved resistance to phytophthora root rot, which had long been a breeding target for raspberries at SCRI. The disease is a major challenge for growers wanting to produce high quality berries with minimal fungicide use and while some newer releases such as Cowichan offer some resistance, customers prefer the eating quality of older, often more rot-prone varieties.

So a HortLINK consortium backed by Defra, the Scottish government and HDC set out to widen the pool of root rot resistance available to breeders.

The starting point was a population of seedlings produced by cross-breeding the modern root-rot susceptible variety Glen Moy with the old North American variety Latham, which has good root rot resistance but bears small fruit on very spiny canes. The diversity of characteristics in the seedling population – some of which were expected to inherit good fruit and cane characteristics from Glen Moy as

Raspberry breeding in progress at The James Hutton Institute

well as root rot resistance from Latham – enabled the genes responsible for these traits to be mapped by correlating their disease susceptibility in glasshouse and field trials with 'genetic fingerprint' data.

The gene maps revealed two regions on two chromosomes that carry most of the genes associated with root rot resistance. One of these controls root

"INVESTING IN THIS LEADING TECHNOLOGY WILL PAY DIVIDENDS FOR RASPBERRY BREEDING IF IT SPEEDS UP THE IDENTIFICATION OF NEW SELECTIONS WHICH BEAR EXTENDED SHELF-LIFE CHARACTERISTICS"

Peter Thomson, raspberry grower

vigour which led breeders to conclude that the better the root system, the more tolerant the plant. This trait can be easily assessed visually in a season by measuring spawn density and diameter around the mother plant. The second region seems to be associated with phytophthora resistance. Markers were identified in each of these regions – genes whose functions are not yet known but which give a clear pattern on genetic fingerprints which could be used to short-cut the selection of potential new phytophthora resistant breeding lines.

Until the advent of marker assistance, breeding for specific traits such as root rot resistance was slow and expensive because of the time it takes to grow raspberry seedlings and then test them in trials. It can take up to nine years to establish whether a seedling has the right combinations of traits to make a good new variety – using the gene map and markers could cut that by about four years.

The project identified a number of selections from the Latham x Glen Moy cross with useful root rot resistance and the first crosses from them were made in 2010. The linkage markers are already being used to screen seedlings from other SCRI breeding programmes for resistance.

Marker-assisted breeding can also help develop varieties with better looking, better flavoured berries with a longer shelf-life. Such characteristics often have more complex genetic control than disease resistance, making it harder to target a specific fruit quality trait using traditional selection methods. So two further HortLINK projects, using clones from the Latham x Glen Moy cross, have been helping scientists to understand which regions of the raspberry genome are responsible for particular aspects of fruit quality.

In the first, trained sensory panels compared fruit from the Latham x Glen Moy clones grown in a range of growing conditions.

The panel found some variation in taste between two seasons but the main consistent differences in flavour and appearance were between open and protected crops – berries were larger, brighter in colour, and sweeter from plants grown under protection.

Correlating the results from the sensory panel tests with genetic analysis of the seedlings is finding the genes governing fruit flavour and appearance so their location on the chromosomes can be mapped. So far, genes responsible for fruit colour – including anthocyanin compounds which are believed to have a role in protecting against some diseases such as cancer – and some volatile compounds that contribute to flavour have been identified. The genetic analysis will allow scientists to select seedlings with the make-up likely to produce berries with the best combination of flavour and properties likely to benefit human health.

In the second project, the consortium is focusing on the genes involved in berry firmness and shelf-life.

Breeders already look out for the seedlings that bear firm berries with the potential to last well after harvest as part of the selection process but the genetics involved is even more complex than that related to disease resistance and eating quality, so to target such traits is even more difficult.

Fruit from both field- and tunnel-grown seedlings of the Latham x Glen Moy cross have been assessed for softness by two methods – a texture analyser and a breeder's expertise. Results have been correlated so that fruit from potential breeding lines or possible new varieties can now be tested very quickly using the analyser.

Comparing the firmness measurements with the plants' genetic fingerprints has found 16 genes likely to have a role in fruit softening, which have been added to the genetic map. Those implicated in cell-wall breakdown and regulation of turgor pressure are most closely associated with firmness scores but further research is needed before we can say they are definitely responsible for regulating softening.

The firmness and shelf-life characteristics of fruit from 22 different clones from the Latham x Glen Moy cross, representing a range of firmness scores, were compared with those of both parents and three commercial varieties over seven days of cold storage. Fruit from six of the clones remained significantly firmer than all others during the test.

Work is now under way to investigate how the genes associated with softening may be involved with different ripening stages and whether different irrigation regimes could affect their expression in the fruit.

Experiments simulating the shock forces experienced by punnets of raspberries during transport have indicated that some varieties are prone to more rapid softening caused by shock or vibration.

If the project's findings about the genetics of fruit softening can be used to breed new raspberries with a longer shelf-life and all the eating qualities shoppers look for, it could save up to £2.5 million of wasted fruit each year.

NEW VEGETABLES FOR A CHANGING CLIMATE

Genetic mapping and marker-assisted breeding techniques are being used in a HortLINK-funded project to produce varieties of purple sprouting broccoli with more predictable harvest schedules.

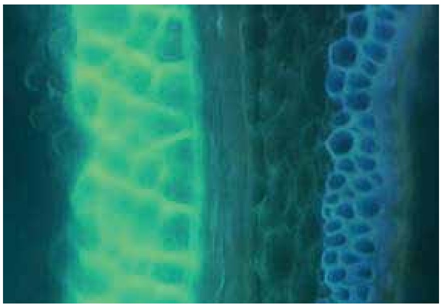
Climate plays a big part in the seasonality of production of 'flowering' brassicas such as cauliflower and broccoli. In purple sprouting broccoli, for example, a cold spring followed by two or three warm weeks brings on all the varieties together, leading to a glut. The majority of varieties are harvested between March and May.

A HortLINK feasibility study (HL0186), by UK vegetable breeder and seed supplier Elsoms Seeds working with the BBSRC's John Innes Centre, used the latest genetic screening technology coupled with knowledge about the genetic control of flowering responses to temperature, and data from field trials in Cornwall and Lincolnshire, to draw up a genetic map of purple sprouting broccoli and identify the genes that affected crop maturity date.

The study resulted in a four-year HortLINK project (HL0197), due for completion in 2013, that aims to develop techniques that can be used in breeding programmes to introduce a more predictable response to weather patterns in brassicas and other vegetable crops.

For purple sprouting broccoli alone, extending the season outside the current three-month period could grow the market but the knowledge gained should also be applicable to other brassicas including broccoli/calabrese and cauliflower, and it will help inform breeding in other overwintered crops such as carrot and parsnip where early bolting can be a problem.

Climate change is predicted to lead to a 5ºC rise in average winter temperatures before the end of the century which won't suit current varieties of overwintered crops so the work will also help protect the future security of UK supply of these vegetables.



Peat's unique physical characteristics depend on the structure of the partly decomposed sphagnum moss (top right) that it is made of. A new composting process has been developed to retain the corresponding structures in vegetable tissues (centre right and right)

DESIGNER GROWING MEDIA SOLVES TWO PROBLEMS IN ONE

Two LINK projects harnessed food industry expertise to help growers and food processors turn crop wastes into a potential peat substitute

With growers and processors of vegetable and salad crops facing costs of anything up to £110 per tonne to dispose of organic wastes, R&D that can turn that material into a commercial product looks a good investment; more so if that product helps solve another problem facing all commercial growers – how to cut the amount of peat used in their growing media without compromising crop quality or the commercial sustainability of their businesses.

Peat is partly decomposed plant material – sphagnum moss – so composting vegetable production and processing waste to produce a growing medium should be simple. But peat has proved indispensable in everything from vegetable propagation to tree and shrub production, its unique physical characteristics based on the structure of the sphagnum moss which give the aeration, water holding capacity and drainage that commercial growers need.

WASTE OR RESOURCE?

Project partner Lincolnshire Herbs produces pot-grown culinary herbs for supermarkets and has been researching alternatives to its peat-based growing media since 1998.

"The composting process could make a big difference to our waste disposal. Our crop waste is 80% peat and the soft plant material does compost very quickly so we could produce a good quality recycled peat medium which has potential for use in the ornamentals industry," says managing director Patrick Bastow.

"We are taking what we have learned in the LINK project and are working with equipment manufacturers to start our own trials using in-vessel technology for a closely controlled composting process. It has the potential to turn a £30,000 a year waste disposal cost into income."

Vegetable and salads industry crop and processing waste has a very soft tissue structure by comparison which breaks down very quickly in normal composting to give a material that's fine as a soil amendment but far too dense and structureless as an ingredient in a growing medium.

In two Horticulture LINK projects, Keith Waldron at the Institute of Food Research (IFR), Norwich, took existing food industry knowledge about plant tissue structure and microbial breakdown to define the key characteristics of peat-based growing media; and investigated the structural changes that take place when plant tissue is composted. In the first project, HL0172, he showed that if the process could be controlled, food processing and crop waste could be composted to the point where enough of the tissue's cell structure is retained to produce a growing medium with the characteristics that growers need.

This was followed up by HL0179, which looked at the cell structure of a wide range of food processing wastes and at composting biology – both in ordinary 'windrow' composting in the open and in a novel composting bioreactor at IFR. The bioreactor was used to compost different kinds of wastes in a precisely controlled way to help scientists identify a composting process that would result in consistent material for growing media for crops such as pot plants, nursery stock and herbs.

The resulting materials have been tested on a range of crops in one of the most extensive programmes of reduced-peat plant trials in the UK. So far they have demonstrated that the compost could replace up to 75% of the peat in horticultural growing media. Even at the highest incorporation rate the compost was generally as effective as the industry standard growing medium.

The trials involved considerable development work by project partner and growing media supplier Bulrush Horticulture in controlling the nutrient status of the end product. The trial crops included species chosen to give a rigorous test of various growing media recipes containing the compost, in a range of conditions. This included a medium suitable for block-raised vegetable plants, considered one of the biggest challenges for peat replacement materials.

"There have been two very significant results for us as growing media suppliers," says Bulrush director Neil Bragg.

"First, we now know much more about how to control the composting process to preserve plant structure; second, we have a better feel for what ingredients to include in the feedstock. We are working with grower partners to see how this new knowledge can be used to produce composted materials to use in growing media. There's no reason why we shouldn't see commercial media that use ideas from this project in three to five years."

Bragg and Waldron also see scope for what's been learnt in the project to help the composting industry produce better materials for use in substrates.

"There are opportunities to use the knowledge we've generated about compost characteristics to improve standards for all growing media ingredients," adds Waldron. "And it will be possible to predict how well a growing media ingredient is likely to perform before running expensive crop trials."

Members of the project consortia agree that the work could end up saving growing media suppliers as much as £12 million by eliminating the costs associated with the variability of some peat-reduced media; and the products themselves could be worth between £10 and £15 million in the growing media market if they were to account for a conservative 5-10% of the sector.

PROMISING TRIALS PERFORMANCE

"One of the most important outcomes has been the ability to quantify what makes a good growing medium," says Steve Carter, a director of Fleurie Nursery which is part of the Farplants group, one of the project's consortium members.

"That's led to the idea of a principal component analysis technique to pre-select alternative materials that are most likely to work before starting nursery trials."

The nursery hosted growing trials of the composted material produced by Waldron's process on a wide range of short-term and longer term nursery stock crops, in blends at up to 75% with peat.

"In most cases it looks as if it will work well as part of a blend but we may need a wider range of grades or mixes than we need with current peat-based media," says Carter.

ON THE SCENT OF COMPOSTING EFFICIENCY

LINK research aimed at reducing environmental impacts led to cost savings for mushroom producers

Compost is an essential component of mushroom growing. But its production can also be accompanied by certain odours – and by the 1990s the spread of housing development meant many mushroom farms had become closer to residential areas. As a result growers were starting to look for ways to ensure that how they made compost gave no cause for complaint from their new neighbours.

Producing mushroom compost in windrows in the open makes it difficult to maintain the well-aerated conditions that prevent odours from building up. One solution was to enclose the process totally, but the investment needed would have been prohibitive for all but the most profitable farms in a sector where margins are notoriously tight and import competition fierce.

By 1997 research had already identified poultry manure as the raw ingredient of mushroom compost responsible for most of the odour. A Horticulture LINK project (HL0126) which started that year set out to find alternative sources of nitrogen to poultry manure which would not only reduce the risk of odours but result in a better quality compost that increased crop productivity. It also developed a quick, reliable method of measuring odours objectively and identified composting microbes that were particularly good at metabolising and eliminating the compounds responsible for the odours.

A number of alternative nitrogen sources, to replace poultry manure, were indentified but there remained the problem of odours from recycled water from the composting process. This was tackled by a follow-up HortLINK project (HL0163), which also tried to improve the efficiency of the composting and spawn-running process – the precursor to cropping.

Project research leader Ralph Noble discovered that mushroom crop performance can be affected by the origin of the straw in the compost – where it was grown and how much nitrogen fertiliser it received having the biggest impact. Straw grown at high fertiliser rates was easily broken down and gave the highest yields, as did straw that had been stored dry for a year rather than used fresh. Compacting compost too tightly into trays slowed spawn running and reduced yield.

And, just as in the composting process itself, improving the aeration of recycled water during its treatment cut the risks of odours dramatically. The project resulted in a simple chemical test growers could use to test the effectiveness of their treatment system.

Mushroom crop performance can be affected by the origin of the straw in the compost

STEPS TO SHRINK OUR WATER FOOTPRINT

Collaborative research is helping growers match irrigation to crop needs more accurately. This is not only cutting water use but can lead to better quality fruit, vegetables and ornamental plants

Even in a dry year, only about 2% of all the water abstracted in England and Wales goes to irrigate horticultural crops. But because this tends to be concentrated in the drier parts of the country and at drier times, the industry is investing heavily in R&D to reduce its 'water footprint' and to ensure its future water use can be scientifically justified.

There is significant scope for most growers to save water – HDC chairman Neil Bragg believes many irrigation practices are only about 30% efficient. But the water costs saved from using less is proving to be less important than the indirect financial gains from reduced fertiliser use, lower labour costs and significant improvements to crop quality.

Strawberry growers, for example, could be saving 30% or more on their fertiliser bills, judging by the experience of one grower taking part in a Horticulture LINK project (HL0187) that's developing water-saving irrigation regimes for tunnel-grown strawberries.

Kent grower Andrew Chesson says most strawberry growers probably over-water to be on the safe side. But there has been no difference in Class 1 yields from a trial on his farm comparing his standard regime with the project's water-saving strategy, while under the test schedule 30% less water had been applied by half-way through harvest.

"For most growers using liquid feed, the more water you apply the more fertiliser you use," says Chesson. "In 2010 we cut water use by 40% and saved 30 to 35% in fertiliser on the trial beds over the season." Trials by three other grower members of the HortLINK consortium gave similar results with water savings of between 20 and 40%, particularly striking figures since these are already water-conscious businesses using trickle irrigation, the most efficient method available.

The water-saving technique developed in the project uses probes in the soil beneath the roots to monitor soil matric potential – a measure of how hard the plant has to work to absorb moisture – and trigger irrigation at pre-set values. A key part of the research focused on how to vary the schedule through the season so that fruit development was not restricted by water availability.

It's designed to apply only as much water as the crop needs but the research team, led by Mark Else at East Malling Research, also showed that the crop can be 'acclimatised' to using less water, by tightly controlling irrigation so that the roots dry just enough to signal, by 'drought' hormones, to the leaves to

Below: soil probes monitored water availability to the plant

"BY THE END OF THE SEASON WE HAD SAVED 40% OF THE WATER AND 30 TO 35% OF THE FERTILISER ON THE TRIAL BEDS, WITH NO REDUCTION IN CLASS 1 YIELDS"

Andrew Chesson (pictured), Kent strawberry grower

reduce transpiration. Such techniques include regulated deficit irrigation and partial root drying.

The project has shown that growing strawberries on the dry side can improve both fruit flavour and shelf-life without reducing yields; content of vitamin C and other compounds, such as antioxidants, with human health benefits are increased too.

Growing the crop with less water also reduces foliage growth which makes fruit quicker to pick.

Helping the hardy nursery stock industry to use less water on container crops is a bigger challenge because of the wide range of crop species involved and the diversity of irrigation systems already in use on nurseries, some of which are inherently more efficient than others.

So an industry consortium shaped two consecutive HortLINK projects (HL0132 and HL0168) that were particularly wide in scope – ranging from simple techniques growers could use to save water by improving the efficiency of their existing irrigation systems, to

Use of overhead sprinklers tends to lead to over-irrigation

"THE TECHNOLOGY THE PROJECT DEVELOPED TO AUTOMATE IRRIGATION HAS BEEN ONE OF THE BIGGEST BENEFITS OF OUR INVOLVEMENT"

Dave Hooker (pictured), Hillier Nurseries

highly sophisticated manipulation of crop quality using controlled drought irrigation regimes.

The first project concentrated on identifying opportunities for further research rather than coming up with fully developed solutions growers could use right away. The results suggested, however, that water use could be cut by up to 75% and the need for labour-intensive pruning reduced or even eliminated by precisely controlled drought regimes or, possibly, by triggering plant defences against drought with novel fertigation treatments.

It identified the widespread use of overhead sprinklers as one of the key obstacles, finding that most beds were over-irrigated by 30 to 300%, as growers had to compensate for uneven water distribution. Such systems could never be controlled accurately enough to realise the potential of deficit irrigation.

But the potential was clear. In small-scale trials, plants responded to accurately controlled drought irrigation regimes, such as regulated deficit or partial root drying, by restricting shoot growth to conserve water – making the more compact habit that buyers look for. Even the mildest drought, where a plant is supplied with 20% less water than when typically well-watered, was enough to reduce shoot growth by a third. All plants tested reduced the amount of water they lost to match that received.

The project also made discoveries about the plants' hormonal response to drought, pointing the way to opportunities for treatments involving plant hormones or pH buffer solution sprays to stimulate the drought response without the danger of under-watering.

Of more immediate interest to growers, though, was the work with two of the project partners, Skye Instruments and Delta-T Devices, that showed how irrigation scheduling could be made more accurate by measuring the crop's evaporative demand for water or by monitoring moisture levels in the growing media.

The follow-on HortLINK project, HL0168, looked at how some of these key findings could be implemented:

● Further studies on sprinkler distribution patterns and scheduling based on moisture sensors were undertaken to help growers get the best from inherently inefficient overhead systems.

● Evaposensors (Skye Instruments) and GP1 probes (Delta-T Devices) were successfully used to schedule deficit irrigation and so control plant growth. This has been developed further in an HDC-funded project.

● A prototype gantry irrigation system was designed to improve irrigation uniformity and thermal imaging was tested to monitor plant water status.

● Alkaline buffer solutions sprayed onto well-watered crops were shown to stimulate a drought response which could cut water lost by the plants.

It was also one of the first projects to look at treating roots with rhizobacteria to modify the plant's response to the hormone ethylene which plants produce when stressed. This led to further more detailed HDC-funded work on using rhizobacteria to help plants resist stress in the supply chain.

For many growers, taking up the ideas generated by these HortLINK projects requires a change in the way they think about water. But some are already embracing the technology. Nursery consultant Chris Burgess says the project "really bridged the gap between the science and commercial application."

For example, Bill Godfrey, who grows herbaceous perennials at his Surrey nursery, is a convert to measuring

"THE PROJECT REALLY BRIDGED THE GAP BETWEEN THE SCIENCE AND COMMERCIAL APPLICATION"

Chris Burgess (pictured), nursery consultant

evapotranspiration to schedule irrigation: "Matching irrigation to the water lost by the plant has been a goal for us for over 20 years; now at last we can do it! It completely takes the 'guesstimation' out of irrigation and it has made an enormous improvement in our use of water. It saves water, time, effort and money."

Hillier Nurseries hosted a number of the HortLINK project trials, including installation of a prototype irrigation gantry. "It's now clear that much of the variability in a nursery stock crop is down to variability in irrigation, and to how different plant species take up and use water which we still don't understand," says container production manager Dave Hooker.

"The whole project, really, has been about how to manage irrigation better to improve crop uniformity, which in turn means lower labour costs and less waste and that has huge financial implications. For me, the technology the project developed to automate irrigation has been one of the biggest benefits of our involvement."

Hooker says being able to automate irrigation control using in-crop moisture sensors has slashed the time spent adjusting the irrigation system from once a day to once a week. Plant quality has been improved and losses due to over-watering reduced. "Where we might have seen 3% losses before, we're down to 1 or 2%," he says. "And that's on top of the savings in water use."

The work has also forced the business to think about how it uses water to manage the crop. "For example, we've learned we can't use deficit irrigation to manage crop growth until we have a more even standing surface for the containers so that's the next area of research for us," he says.

PRECISION IRRIGATION FOR FIELD VEGETABLES

Overhead irrigation is no more efficient for field vegetable crops than in nursery stock yet three-quarters of field vegetables are irrigated using overhead methods as there is no truly viable alternative. Just as in nursery stock, overhead systems are not only likely to apply more water than the crop really needs, they may also be contributing to uneven growth and maturity.

However, it is possible to combine knowledge of soil, crop and equipment management practices to improve uniformity of water delivery through 'precision irrigation' and that's what is being investigated in a four-year HortLINK project (HL0196) that started in 2009.

Project leader Jerry Knox is aiming to develop an intelligent irrigation management system which integrates soil moisture sensing, wireless communication and variable delivery, to increase crop quality but cut water use.

The project will design, develop and test a system and evaluate techniques (including thermal imaging) for monitoring crop water stress. The crop measurements will be used to calibrate the soil moisture sensor readings that will trigger irrigation.

Studies on lettuces and onions have already shown how soil moisture, crop water status and irrigation distribution can vary while thermal imaging crop sensing equipment has been tested to estimate plant water status and find out how it relates to soil moisture variability.

The next stages will investigate the performance of irrigation systems and develop technology to vary the application of irrigation by sprinklers and booms.

INTEGRATED PEST AND DISEASE MANAGEMENT: FRUIT

New varieties and a better understanding of pest and disease biology is helping fruit growers rely less on chemicals

Research into pesticide-free management systems may benefit organic growers of apples and pears, who account for only a small proportion of the national orchard area, but it's hugely significant for conventional growers of tree fruit too. The need to minimise detectable chemical residues in fruit coupled with a shrinking range of chemical pesticides that growers can use means modern fruit production is increasingly dependent on scientifically proven and cost-effective cultural and biological techniques for pest and disease control.

Results from a Horticulture LINK project on integrated pest and disease management (IPDM) in organic apple orchards (HL0150), completed in 2005, were the foundation on which many of the developments over the last five years or so have been based. The project's main aim was to shape a strategy for disease control, especially of scab, but the results proved useful to all growers wanting to cut their pesticide use and some of the experience gained fed into HDC-funded work to design a 'zero residues' orchard management system.

One of the key findings was the role that newer apple varieties could play because of their inherent disease resistance. Five dessert and four cooking varieties were recommended for their suitability for organic production, together with the quality of their fruit, to growers and the project's supermarket partners, Waitrose and Sainsbury.

"The project proved it was essential to start with planting varieties that have good tolerance or resistance to the major diseases," says Adrian Barlow of English Apples and Pears. "Retailer involvement in the project was vital, it helped them understand why trying to produce the major conventional varieties organically was not viable.

"We came up with a good shortlist of varieties with the right combination of pest and disease resistance and productivity, and eating or cooking characteristics."

In a five-year commercial trial in an established organic Fiesta orchard, the IPDM strategy that the project designed led to a 50% boost in yields compared with the grower's standard control programme. Financial returns were also consistently higher, averaging £17,600 per ha under the experimental system compared with £10,300 per ha from the grower's own programme.

"Some very large orchards have since been planted and there has been an increase in organic apple production in the UK as a direct result of the project," says Barlow. "We haven't completely replaced organic apple imports as we need them out of season, but in the UK season there has been significant import replacement and all against the backdrop of general decline in sales of organic produce."

The project's findings on control of rosy apple aphid led to both organic and conventional growers completely altering their approach to timing control measures, he adds. And the project led to changes in the kinds of plants used by growers to attract beneficial insects, and to new thinking about soil fertility, mulching and weed control which are also having an impact now on conventional orchards.

The project's results proved useful to growers of both organic and conventionally produced apples

IPDM DEFINED

Growers can no longer afford to base their crop protection strategies on simple routine applications of pesticides. Integrated pest and disease management (IPDM) not only offers a more effective solution for most crops, it is an approach now demanded by most of the horticulture industry's major customers.

IPDM integrates cultural practices, management techniques that make the most of natural enemies of pests, introduced biological control agents and specifically targeted crop protection products (chemical pesticides or biopesticides) to keep pest and disease pressure below the level where it causes an economic impact.

Developing IPDM needs a multidisciplinary approach and collaborative R&D: biologists, agronomists, engineers, crop protection product suppliers, growers and their customers all have a contribution to make.

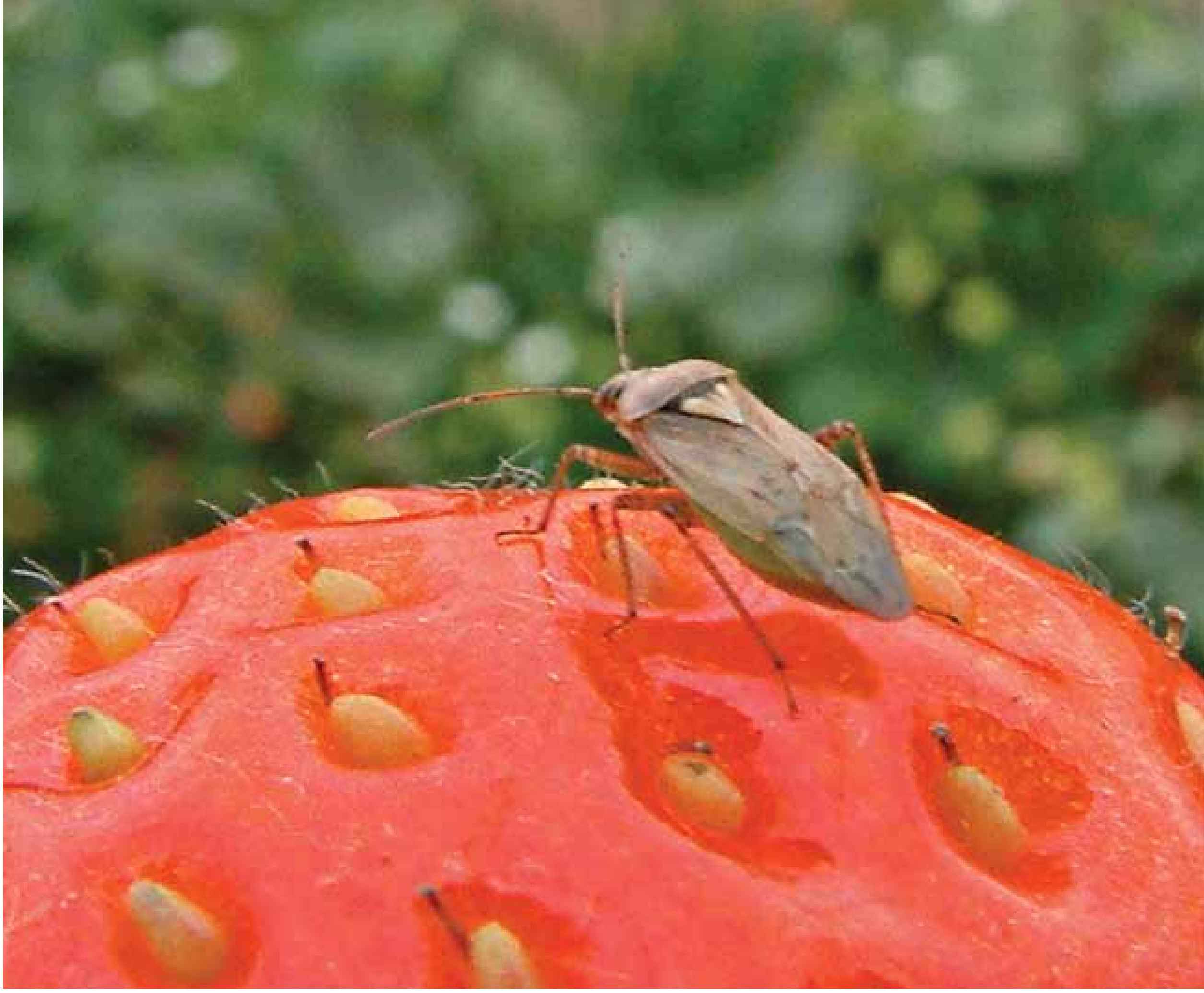
Prevention, based on cultural practices that minimise risk, is a fundamental component of IPDM. For example, in many crops grown under protection, better control of irrigation or humidity can greatly reduce outbreaks of some fungal diseases.

But cultural practices alone are rarely enough. Scientific research into the biology and life-cycles of invertebrate pests, fungal pathogens or biological control agents is central to shaping the risk forecasting systems that can help growers time sprays better – reducing chemical use while making treatments more effective. Scientific research which delivers sound knowledge on the strengths and side-effects of different chemical pesticides and biopesticides is essential for getting the best results from an integrated programme.

On the following pages we highlight how collaborative research has taken fundamental new knowledge about a crop and its key pests and diseases and used it to put together best practice IPDM techniques, many of which growers are already using successfully.

"ORGANIC APPLE PRODUCTION IN THE UK HAS INCREASED AND THERE HAS BEEN SIGNIFICANT IMPORT REPLACEMENT AS A DIRECT RESULT OF THE PROJECT"

Adrian Barlow, English Apples and Pears



European tarnished plant bugs can be detected up to two months earlier in strawberry crops than previously possible thanks to early warning traps (pictured below right) designed to be used with their pheromones as a lure

A similar approach is now being taken to develop an IPDM system for stone fruit in a HortLINK project due to finish in 2014 (HL0189), following Defra research that revealed how much fruit was lost from orchard pests and diseases and from rots after harvest. Losses in the orchard averaged about 20%, despite pesticide treatment, equivalent to 220 tonnes of national cherry production, worth £400,000 a year, and 2,820 tonnes of plums worth £3.2 million. Storage losses ran to about 50% in both crops. The key culprits are brown rot, aphids, plum fruit moth and light brown apple moth and the project is looking for novel biological controls that industry can subsequently exploit.

Findings so far point to possible mating disruption of moth pests and a novel approach whereby aphids are infected with biocontrol fungi which have been introduced by ants.

The project has already resulted in new advice on spray timings so that growers can target pesticides better.

Results from scientific research into insect pheromones and other natural chemicals which signal the presence of mates, or of host crops, are becoming a key element of IPDM management for both tree and soft fruit growers.

For example, pear sucker is a particularly devastating pest of pears but years of trials on conventional pesticides have been unable to find a reliable control. It is present in every commercial pear orchard. A modest assumption that it causes losses of just 10% would add up to £2.9 million a year.

All that was known about the pear sucker's sex pheromone was that it existed, until HortLINK project HL0194 brought together a consortium of scientists, industry suppliers and growers who not only identified the pheromone's components but found out how it could be used to improve control of the pest. How orchards could attract more beneficial insects such as anthocorid bugs that are predators of pear sucker has also been studied – planting willow and hazel is one way.

Collaborative research into pest pheromones is also helping soft fruit growers tackle one of its most damaging groups of pests – capsid bugs. Capsids are now such a problem across horticulture that the HDC-backed HortLINK project HL0184 draws on partners from both the soft fruit and protected edibles sectors.

It's the lack of effective monitoring tools that has prevented growers from controlling capsids as well as they need to – attacks by common green capsid were particularly bad on strawberry in 2011.

Using world-leading expertise in insect pheromones at East Malling Research and the Natural Resources Institute, this project has been working on practical pheromone lures and traps for monitoring European tarnished plant bug and common green capsid along with the nettle capsid, a serious pest of glasshouse peppers. Three pheromone compounds from female European tarnished plant bugs have been successfully used in a mix to attract males and a sex pheromone for the common green capsid has been identified.

The project was extended for two years to further develop the findings into practical use for growers. A trap designed to be used with the pheromone for the European tarnished plant bug has given excellent results as an early warning system – the capsid can be detected up to two months earlier in strawberry compared with traditional ways of monitoring – and has recently been tested in commercial crops to see what number of capsids caught should trigger action by growers.

Tom Maynard of Windmill Hill Farm, a grower member of the consortium, says the industry has been fortunate

“NEW MONITORING TECHNIQUES WILL HELP US TO CONTROL CAPSID PESTS BETTER WHILE REDUCING OUR USE OF CHEMICAL PESTICIDES”

Tom Maynard, soft fruit grower

in having this research conducted by a top-class team of scientists: “We will shortly have access to new monitoring techniques which will help to control these pests better while reducing our use of chemical pesticides,” he says.

The work on capsids shows how collaborative research can solve individual pest or disease problems for soft fruit growers. But two other HortLINK projects have taken this kind of thinking even further, combining the findings from several strands of work on all the key pests and diseases on protected raspberries (HL0175) and strawberries (in HL0191) into complete IPDM programmes that improve control and reduce reliance on pesticides, especially during the fruiting period.

The work on raspberries, completed in March 2011, focused on the five principal pests and diseases of protected crops: aphids, raspberry beetle, raspberry cane midge, powdery mildew, and fruit and cane botrytis. Control measures have been improved for botrytis, powdery mildew and aphids. New ways of monitoring raspberry beetle and raspberry cane midge were found which help pinpoint attacks.

As a result, HDC has published a full set of new IPDM guidelines for growers. They marry cultural techniques such as managing cane density to avoid conditions that encourage pests and diseases; use of aphicide sprays after fruiting to control overwintering populations; and use of pheromone traps to monitor raspberry cane midge. "It's just the type of new advice raspberry growers need," says Steven Kember, agronomist for consortium member Berry Gardens Growers.

The work on strawberries continues, looking for ways to manage powdery mildew, botrytis, black spot, capsids, aphids and strawberry blossom weevil that can be fused into an IPDM programme for the crop.

Work on some of the individual pests and diseases has already produced results useful to growers. For example, it's been shown that an aphicide applied after cropping in October or November greatly reduces overwintering aphid populations, making control of this pest easier the following spring.

There are some more novel ideas emerging, too. Trials on controlling European tarnished plant bug showed that a 'bug vacuum', front mounted on a tractor and passing over the crop once per week, reduced numbers by as much as 40%. Work has also shown that sweet alyssum is an excellent trap plant for the pest.

CONTROL OF WFT

Western flower thrips is an increasing problem on protected strawberries and is now widely resistant to most insecticides. A five-year Horticulture LINK project due to end in 2015 (HL01107) has already identified and synthesised components of the pest's sex pheromones for use in monitoring traps, and is well on the way to developing a model to predict its population growth in different weather conditions. Biological control using predatory mites and bugs looks to have potential and this approach could be combined with the use of trap plants – a variety of the bedding plant alyssum is proving attractive to both the pest and to the predatory bug *Orius laevigatus.*

Raspberry growers now have full guidance on integrated pest and disease management

INTEGRATED PEST AND DISEASE MANAGEMENT: VEGETABLES AND SALADS

Cauliflower was at less risk from cabbage root fly damage when grown with lettuce as a companion

Joint projects are showing how companion plants and wildflower field margins can help protect crops from pests

Pests that attack the roots of vegetable crops are among the most difficult to control, particularly as growers are trying to avoid using persistent insecticides on the soil, seed or young plants.

Collaborative research projects are an ideal way in which to exploit new insights into pest biology, to develop practical techniques that growers can use, and several under the Horticulture LINK scheme have focused on long-term pest problems in vegetables.

Companion planting, where other plant species are grown alongside the crop to sidetrack crop pests, is not a new technique. But there had been little scientific study of how companion planting worked, or how to improve it,

The right mix of wildflowers in field margins could reduce pest populations in vegetable crops

TEAM EFFORT

Koppert UK, a supplier of biological control agents, is a member of the HortLINK consortium researching the impact of field margins on crop protection in vegetables.

"We are particularly interested in finding out if there is a role for parasitic wasps in helping to manage pest populations," says product development and registration manager Karen Girard.

"At this stage it is hard to know if there will be a commercial outcome for us. But if we were not involved we'd never know. HortLINK projects have enabled us to take part in research which would be very difficult for us to do in any other way."

The company is also a member of the SCEPTRE consortium. "We'd never be able to undertake this kind of project alongside growers, other suppliers and university scientists on our own," says Girard. "One of the biggest benefits has been making such contacts so that even where there may not be an immediate commercial outcome it's hard to predict what the project could lead to."

until a HortLINK project (HL0174), led by Rosemary Collier at Warwick HRI (now Warwick Crop Centre), explored its use to manage cabbage root fly on cauliflower. The project took forward ideas from earlier research by Collier and her colleagues that it was simply the colour, size and shape of the companion plants, rather than any complex biochemical mechanism, that governed their effectiveness in distracting pests from colonising the crop.

Experiments using artificial plants made of green cardboard found that the area of green surface, rather than any scent, was responsible for diverting the pest before it found its favourite host, with the time it spent on the 'wrong' plant the reason why the technique worked.

A list of more than 200 potential companion species was narrowed down

BENEFICIAL MICROBES GIVE CROPS A BETTER START

Some crop diseases are caused by fungi or bacteria which can survive in soil or on the surface of seeds and infect the seedling as it begins to grow. Such diseases can either kill or weaken the seedlings, leading to patchy crop establishment and uneven development; or they can spread systemically within the growing plant and cause damage later as the crop matures.

In a series of Horticulture LINK projects, which have more recently been followed up by a consortium funded by the Technology Strategy Board, the industry has been finding out how to treat seeds with beneficial microbes which can establish themselves as the seed begins to germinate to help protect the young crop against disease.

The work began in 1999 (HL0138) when a consortium including breeder and seed supplier Elsoms Seeds and seed technology company Germains linked with researchers at Warwick HRI (now Warwick Crop Centre) to explore ways of applying beneficial microbes – such as species of the trichoderma fungus, known to help protect some plants against fungal pathogens – to seed during the seed production process. This was the first time such 'biopriming' had been investigated in the UK.

The idea was taken further in a second project (HL0167) when beneficial microbes likely to help protect against soil-borne 'damping off' diseases that can kill seedlings were successfully applied to carrot and onion seed during normal commercial seed priming (a treatment used to bring seed in a batch to the same 'readiness to germinate').

One of the most promising results was with onion. Emergence of seed primed with a strain of the beneficial bacterium *Pseudomonas fluorescens* was improved while seed primed with a beneficial trichoderma fungus yielded more, and heavier, bulbs at harvest.

"ONION SEED PRIMED WITH A BENEFICIAL FUNGUS YIELDED MORE, AND HEAVIER, BULBS"

Various combinations of microbes tested on carrot seed all improved emergence.

A consortium set up in 2010, which includes Elsoms and biological control supplier Becker Underwood and is part-funded by the Technology Strategy Board, is now seeing whether biopriming can help control seed-borne diseases such as itersonilia canker in parsnips and neck rot in onions. The work is looking at a range of beneficial microbes, some of which are already registered for other crop protection uses.

Consortium members Warwick Crop Centre and Plant Health Solutions are providing further scientific expertise, along with Vegetable Consultancy Services, when the most promising treatments are trialled in the field.

to 16 based on their size and shape and the likely extent of competition for the cauliflower crop, which were taken forward for trials. Lettuce, grown as a companion, eventually proved the best and most consistent at reducing cabbage root fly damage to the crop though it was still not as effective as some insecticide treatments. And despite the competitive pressure from the companions, the crop plants in most of the companion plant treatments yielded good quality curds.

As well as identifying appropriate companion species, the project developed a way of raising young crop

FULL STEAM AHEAD

One of the most valuable aspects of collaborative research programmes such as Horticulture LINK is that they can enable researchers to take a long-term view, rather than having to find immediate solutions to current problems that projects funded solely by industry can demand.

In HortLINK project HL0136, for example, an entirely new way of using the old technique of steam sterilisation to treat soil-borne pests and diseases emerged from a completely fresh approach.

Numerous attempts had been made to develop steaming equipment to treat large areas of soil but they were rarely economical or effective enough for two key reasons. First, steaming relied on conventional boilers to heat relatively large volumes of water so was costly in fuel and, second, penetration of the soil depended on steam under pressure – which was rarely able to disinfect to the depths crop roots reached.

Project leader Michael Wilson of Aberdeen University realised it wasn't necessary to treat soil with steam at 100°C under pressure, but that a temperature of 70°C was adequate. And instead of boiling water in a tank, he designed a steam generator based on a hot cylinder to heat a film of water sprayed onto the cylinder's surface.

The second innovation was that instead of trying to force the steam down into the soil, the machine lifted the soil as it passed across the field. The soil is heated as it travels along a conveyor and is deposited back on the field. Not only is this method of heat transfer far more efficient – using 20% less energy than a typical boiler-powered soil steamer – but the equipment could treat soil to controlled depths.

Although many beneficial soil organisms survive heating to 70°C, just as they do in composting, the project's consortium members realised there would still be a partial vacuum in the microbial ecology of soil after steaming which could be re-colonised by pests and pathogens. So the project included research on the benefits of incorporating compost after treatment to promote a healthy soil microflora.

It took eight years of research before the system was ready to be scaled up for field testing using a prototype steamer (pictured) built by specialist agricultural engineering company Jones Engineering of Doncaster. The tractor-pulled machine lifts formed beds, steams and re-lays the soil and then re-forms the beds ready for planting.

Preliminary costings showed it could treat 1ha to a depth of 25cm for about £2,000 which compared favourably with disinfectant treatments at over £4,000 per ha.

"AN ENTIRELY NEW WAY OF USING THE OLD TECHNIQUE OF STEAM STERILISATION EMERGED FROM A COMPLETELY FRESH APPROACH"

plants and companions together in modules for planting out.

"The project has laid the foundation for further development of companion planting to disrupt egg laying by pests such as cabbage root fly," says Collier. But further research will be needed to refine the technique, for instance finding lettuce varieties with the right physical characteristics to distract the pest without competing so much with the crop.

The technique has obvious environmental benefits if it helps growers to reduce use of insecticide and it could be applied to all leafy brassica crops. Trials showed that companion planting for cauliflower cost £25-60 per ha (using four companion plants per module), so the cost could come in at less than standard seed treatments.

Growers have been able to cut out almost entirely insecticide use in some protected crops such as tomatoes thanks to integrated pest management that relies on biological control agents. Field vegetable growers can't use biocontrols in the same way – the growing environment is simply too open and variable – but an ongoing HortLINK project is showing how field environments could be managed to favour natural enemies of pests which contribute to their control.

The project (HL0192), led by Lancaster University, is studying field margins around vegetable crops to encourage a diverse community of beneficial insects. Seed mixtures based on 22 flowering plant species have already been designed that support several kinds of beneficial insects including bees, hoverflies and parasitoid wasps without encouraging crop pests. Some of these are potential 'banker plants' which are hosts to, for example, benign aphids early in the season that help populations of aphid predators to build up before the aphid pests arrive.

The project, which is also drawing on knowledge from current European biodiversity research, is now measuring the impact such established field margins are having on pest populations in crops. The work has been extended with additional HDC funding to develop a database of suitable flowering plants and beneficial insects to help growers choose the plants that best match their situation.

The project is also showing how field margins could be used in a trap-crop approach – attracting the pest from the crop to 'trap plants'. For example, chervil and yellow mustard attract egg-laying females of pests such as cabbage root fly but don't provide the right conditions for the larvae to survive. Such trap plants could also be sprayed.

HARNESSING BEE POWER

Growers of protected crops such as tomatoes and peppers have probably been the most successful at adopting integrated pest and disease management in the UK. The enclosed environment of the greenhouse can be controlled to reduce pest and disease risks and to manage populations of biocontrol organisms, compared with the outdoor environment for field crops. Few tomato growers, for example, use any chemical pesticides routinely and this has given their fruit an important marketing advantage over imported produce.

Some pesticides still need to be used to back-up cultural and biological methods but growers are increasingly interested in achieving this by using biopesticides rather than agrochemicals. This is because biopesticides are less likely to upset carefully established populations of beneficial organisms, because they leave no pesticide residues on the produce and because, for an increasing number of pest species, chemical controls are simply not available.

One difficulty with using biopesticides based on live beneficial organisms, such as insect-pathogenic fungi, is targeting them effectively at the pest. They are often less persistent and the number of repeat sprays that may be needed can make their use uneconomic.

Bumblebees are widely used as pollinators in UK tomato crops (pictured) and one HortLINK project has been investigating whether they could deliver certain biopesticides to the plant at the same time. The consortium includes biopesticide suppliers Fargro and Syngenta and pollinator supplier The Red Beehive Company and the research is being undertaken by Stockbridge Technology Centre and Fera.

The initial feasibility study has shown that bumblebees can carry agents effective against whitefly and aphid to both tomato and pepper plants. Both pests are becoming more difficult to control under the IPDM systems growers currently use.

In the study, evidence from the numbers of whitefly and aphids on tomato and pepper plants before and after treatment with fungal biopesticides suggests the biopesticides had done their job without harming the bees or affecting their ability to pollinate the crop and without interfering with existing biocontrol agents.

The consortium is now hoping to develop their findings into technology growers will be able to use in practice.

INTEGRATED PEST AND DISEASE MANAGEMENT: ORNAMENTALS

Researchers have worked with the industry to turn new knowledge about the biology of pests, diseases and beneficial organisms into practical crop protection techniques

Growers of ornamental plants don't come under the same pressure to minimise chemical residues as growers of edible crops, but they are still looking to cut their dependence on chemical crop protection for a variety of reasons.

For example, the range of chemicals that can be used on trees, shrubs, pot and bedding plants, bulbs and cut flowers is diminishing; and some pests, such as western flower thrips, are already resistant to some of those that remain. The diversity of ornamental crop species can also make it difficult to find chemical products that are crop-safe to all plants on any one nursery. And of course, ornamentals growers face the same environmental and operator safety legislation as any other grower.

Just as in the edible crop sectors, the Horticulture LINK programme has been highly effective at enabling researchers to work with ornamentals growers and their customers to exploit new knowledge about the biology of pests, diseases and beneficial organisms and turn it into practical management techniques.

For growers working with trees, shrubs and hardy herbaceous plants in containers, vine weevil is probably the single most important pest, causing losses estimated at £30 million a year. Most of the damage is caused by the larvae which eat the roots, often killing the plant, but adults feeding on the leaves usually renders a crop unsaleable.

For growers of pot and bedding plants, the most difficult pest to control is western flower thrips. Its feeding on flowers and foliage leads to scarring and flecking but it can also transmit a virus which inflicts its own damage.

Both pests spend part of their life-cycle in the growing media where they are difficult to control with all but the most persistent chemicals. However, the insect-pathogenic fungus *Metarhizium anisopliae*, which lives in soil and is native to the UK, was identified as a candidate biological control or 'biopesticide' which had potential to control both pests and a HortLINK consortium was established to investigate the practicalities of using it commercially (HL0171).

Trials on a range of crops and in a range of different growing media showed that *M. anisopliae* was effective, especially if used in combination with very low doses (1% or 10% of the recommended rate) of approved pesticides when it gave, in some cases, complete control of vine weevil larvae. Analysis showed

The diversity of ornamental crop species can make it difficult to find chemical products that are crop-safe to all plants on any one nursery

this combination of biological and chemical control made for a particularly cost-effective treatment.

Used alone, metarhizium was more effective against western flower thrips than the best pesticides in the trials, reducing adult emergence from pupae by up to 90%.

Using the fungus in treatments with insect-pathogenic nematodes – already commercially available at the time of the project – led to significantly better vine weevil control than with either measure on its own, with up to 100% control achieved in some trials.

Biological controls can sometimes be difficult for growers to use in practice but the project demonstrated that metarhizium could be incorporated into the growing media before potting.

A metarhizium-based biopesticide was approved for use in the UK after completion of the HortLINK project which meant a pool of information on its use was already available to help growers use it effectively.

When it comes to narcissus, the UK leads the world in production. The national crop extends to 4,300ha which yields about 30,000 tonnes of bulbs and 600 million cut flowers a year: 30% of the bulbs and 40% of the flowers are exported. To keep its competitive edge, production has intensified, but that in turn has led to increasing problems with pests and diseases.

Two HortLINK projects (HL0129 and HL0178) have helped bulb growers reduce their reliance on chemical fungicides and pesticides to control white mould and smoulder diseases, and the increasingly troublesome bulb-scale mite.

In the project on white mould and smoulder, initial studies on the biology of the diseases revealed critical relationships between temperature and leaf moisture and the role of leaf damage, caused by wind, hail

Vine weevil costs hardy nursery stock growers £30 million a year through the damage it does to plant roots; collaborative research confirmed the effectiveness of the metarhizium fungus as a biological control

or crop operations, in increasing the risk of infection. For example, if the leaves were wet for about six hours, infection could only occur at around 12°C. But if the leaves stayed wet for longer, infection could occur anywhere between 4 and 16°C.

Researcher Gordon Hanks and his team developed a mathematical model for infection risk based on temperature, duration of leaf wetness and the probability of leaf damage, as a first step in designing a forecasting system to enable growers to target fungicides more effectively and so reduce the number of applications they had to make. Trials were also run to prove the effectiveness of a range of newer fungicides against these diseases.

"Before the project, growers were routinely spraying up to six times against smoulder and white mould," says Hanks, now an industry consultant. "With better knowledge of the risk factors and newer, more effective fungicides, that has been cut to two or three to get the same control."

Feeding by the bulb-scale mite not only renders bulbs more susceptible to smoulder disease, but infestations on glasshouse-grown cut flower and pot plant crops multiply rapidly causing distorted leaves, stems and flowers.

There are no approved chemical controls and growers have to rely on hot water bulb dips. A HortLINK project, which ran in parallel with an HDC-funded PhD studentship looking at the pest's biology, discovered that the patchy and sporadic distribution of mite infestations in fields was probably associated with the planting of infested stocks – the mites don't appear to spread far from individual infested bulbs.

A BIOLOGICAL ANSWER TO FLY PESTS

Sciarid and shore flies live in or on the growing media which supports containerised plants and are difficult to control in protected ornamentals and herbs. Sciarid larvae damage roots and stems while the presence of shore flies is enough to make a crop difficult to market. Together they are estimated to cost the industry around £11 million a year in lost income. Current chemical and biological controls are not always reliable – and if growers are asked to use more composted material in their growing media, which is particularly attractive to both pests, the problem could get worse.

So when growers and consultants began noticing sciarid flies which had been naturally infected by a fungal disease, a consortium was quickly assembled to undertake a HortLINK project (HL0193) on the potential of exploiting it as a biological control. In fact, the group of researchers, growing media suppliers, growers and biocontrol specialists was said to be one of the most comprehensive ever assembled for crop protection research in these crops.

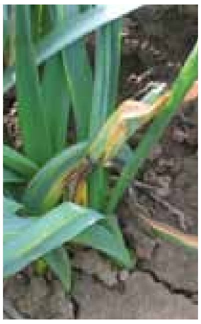
The project identified the fungus as *Furia sciarae*, which could offer some promise as a potential control measure. Indeed, 'natural' infections on nurseries probably already play a role in keeping the pest in check and appear to be unaffected by the fungicides used on crops.

Research undertaken by the project into the life-cycle of the fungus, particularly how it infects the sciarid fly, was the critical first step in understanding how to use it in pest management, whether as a biopesticide product or by providing advice to growers on how to increase the impact of natural infections.

"THIS IS AN EXCITING PROJECT. THE CONSORTIUM IS A GREAT TEAM COVERING MANY AREAS OF THE INDUSTRY WORKING ALONGSIDE BRILLIANT SCIENTISTS. TOGETHER WE'VE MADE SIGNIFICANT PROGRESS"

Russ Woodcock, technical manager at bedding and pot plant producer Bordon Hill Nurseries

The UK leads the world in narcissus production: 30% of the bulbs and 40% of the flowers are exported



Research has revealed a critical relationship between weather conditions and smoulder infection risk

The project was unable to find any chemical treatments more effective than hot water dips, but it did result in new advice to growers about hygiene practices to reduce the dust and debris accumulating in bulb stores which can harbour the mites. More promisingly, it also identified the potential of biological control using a commercially available predatory mite native to the UK.

A follow-up project funded by HDC has been investigating in more detail the effectiveness of hot water dips against the mite, as the HortLINK consortium felt that either the currently recommended temperatures or dip durations were not adequate or that the tank water temperature was not being maintained evenly.

For growers of pot plants and cut flowers, HortLINK work has come up with new advice to help improve control of botrytis, a disease which was responsible for losses of around £7 million a year on nurseries.

One project showed how, during production, botrytis risks could be reduced by better humidity control, especially at night. An increase of just 1% in numbers of marketable plants, through fewer losses from botrytis, would be enough to offset the additional cost of the heat used to manage humidity, but trials which imposed a night-time heat boost actually achieved an increase of 14%.

New fungicides were also tested and the project was able to advise growers on a programme which used fewer sprays but of more effective products, especially when starting early before symptoms appeared.

The project cast new light on the importance of symptomless, or latent, infections which was explored further in follow-up HortLINK and HDC-funded work. The HortLINK project, which involved retailers and packers as well as growers, focused on identifying the critical points in the supply chain where changes to environmental conditions could slow or prevent development of latent infections and thus prolong the shelf-life of flowers and pot plants.

“BETTER KNOWLEDGE OF RISK FACTORS HAS HELPED BULB GROWERS HALVE THE NUMBER OF SPRAYS AGAINST SMOULDER”

Gordon Hanks, bulb industry consultant

A STRATEGIC ALLIANCE

The SCEPTRE project is seeking the new approaches to crop protection essential to safeguard the future of UK horticultural production

The limited chemical crop protection choices that some growers are increasingly having to contend with is caused by the collision of several key factors.

One reason is changes to legislation, not just in product approvals but also in standards of environmental protection, which is reducing both the number of products on the market and the opportunities to use them. Another is climate change, which is subtly altering the kinds of pest, disease and weed problems that growers are facing. And a third is the development of resistance in target organisms to certain active ingredients where there were only one or two that were effective in the first place.

The new active substances introduced by crop protection companies target major world crops such as cereals but few become registered by their manufacturers for use on horticultural crops because of the market's small size in relation to the costs involved.

Biopesticides and biological control agents offer an alternative approach to crop protection and have long been used against pests in protected crops. They are largely unexploited on outdoor crops, where the environment is less manageable. Few biopesticides have emerged for disease control in the UK and none are registered for weed control.

So there is an urgent need to find new materials and methods for horticultural crop protection – including more modern pesticides, new biopesticides, and ways to integrate these with cultural techniques and with monitoring systems that help growers make decisions on when controls are called for.

Designed by HDC in consultation with growers and researchers, the SCEPTRE project, which began in spring 2011, addresses key gaps in crop protection. Co-funded by Defra through the Horticulture LINK scheme and widely supported by growers and the crop protection industry, SCEPTRE is conducting some of the research needed to help secure label and off-label approvals for new pesticides and biopesticides, and develop sustainable integrated management programmes for use on edible crops.

"The gaps we are facing in the range of crop protection products available to us makes this vital work," says salad leaves grower and SCEPTRE consortium chairman David Piccaver. "It's crucial in helping the industry address one of Defra's key objectives, increased UK productivity for improved food security. At a time when public funding is under pressure, it is an act of good faith by Defra.

"The project has already reinvigorated interest in horticultural crops from suppliers of both chemical and biological crop protection products and we are already seeing more products

"THIS IS A GOOD WAY OF TESTING NOVEL WAYS OF PROTECTING CROPS"

David Piccaver,
SCEPTRE consortium chairman

and formulations being made available for testing."

The first year has focused on trials to assess new products with potential to solve some immediate crop protection gaps. In the next stages of the project there will be more emphasis on the development of integrated pest management strategies to identify sustainable control measures for key pest, disease and weed problems.

Three cross-sector teams of crop protection specialists are working on the pest, disease and weed problems that have the greatest impact on the profitability of crop production.

The work programme is flexible so can take account of significant new pest

SCEPTRE PROJECT SUPPORT

The SCEPTRE (sustainable crop and environment protection – targeted research for edibles) project (HL01109) is sponsored by the Department for Environment, Food and Rural Affairs through the Horticulture LINK programme and led by the Horticultural Development Company.

The academic parties are ADAS UK, Allium & Brassica Agronomy, East Malling Research, Rationale Biopesticide Strategists, The James Hutton Institute, STC Research Foundation and University of Warwick.

The industrial funders are Agriculture and Horticulture Development Board (as HDC), BASF, Bayer CropScience, Belchim Crop Protection, Berry Gardens Growers, BerryWorld, Dow AgroSciences, DuPont (UK), The Fresh Produce Consortium, H&H Duncalfe, International Produce, J E Piccaver & Co, Koppert UK, Marks & Spencer, Stewarts of Tayside, Syngenta Crop Protection UK, Total Worldfresh. See www.hdc.org.uk/sceptre for more details.

Target pests and diseases in 2011 included (clockwise from top left) aphids, caterpillars, botrytis and mildew

problems or losses of key pesticides as they arise.

Targets in the first year included aphids on lettuce and raspberry, powdery mildew on apple and cucumber and annual broadleaf weeds in field vegetables and strawberry.

VALUED BY SUPPLIERS

"SCEPTRE is a hugely valuable project for us to be involved with – one of the most valuable I've seen the industry put together," says Jon Ogborn, vegetables technical manager for SCEPTRE consortium member Syngenta, which supplies crop protection products to growers.

"It gives us an opportunity to evaluate uses of our products on targets that we couldn't justify doing ourselves. And it enables independent researchers to help find new ways of integrating them into programmes with products from other suppliers and alternative techniques. Results from a project like this can give us the incentive we need to look more closely at a new use ourselves and that could mean solutions arriving in the hands of growers more quickly."

"SCEPTRE has generated a huge amount of goodwill across the crop sectors and with suppliers and the Chemicals Regulation Directorate which can only help speed up availability of anything which looks promising in the trials," says Piccaver.

"In the short term we should see some relatively quick improvements in the range of controls available to growers for pests, diseases and weeds. In the longer term, this is a good way of testing novel ways of protecting crops to reduce reliance on chemicals and to find more acceptable actives, cultural techniques and integrated biological systems.

"I also see SCEPTRE as a platform from which other projects will flow."

For suppliers of crop protection products, such as Syngenta Crop Protection UK and Bayer CropScience, membership of the SCEPTRE project consortium offers the opportunity to take part in research on horticultural

The first season of herbicide trials has identified an experimental product with great promise on a range of vegetable crops

crops which would otherwise be hard for them to justify on purely commercial grounds.

"For us, supporting growers is important," says Bayer's development manager for horticulture Richard Meredith. "It's about optimising what can be achieved with the limited tools available and helping to maintain the overall health of the industry, which is clearly important to all the participants in the project.

"And by being involved in a consortium, we are learning more about the needs of the industry and how best to develop our products across the complex range of horticultural crops.

"If the project helps growers use products more effectively, then there are multiple benefits for the grower and the environment with a better job done initially and potentially less need for follow-up applications. Helping growers integrate a range of products also reduces the chance of resistance developing so helps prolong the products' useful life."

VALUED BY GROWERS

"It is very difficult to imagine how the horticultural industry would be able to control pests, diseases and weeds and deliver to the food security agenda in future without a programme such as SCEPTRE in place," says soft fruit grower and SCEPTRE consortium member Harriet Duncalfe.

"The first year has shown some very promising results for soft fruit, particularly in identifying products for the control of the soft rot fungi mucor and rhizopus, potential novel insecticides for aphid control on raspberry, new insecticides for European tarnished plant bug and new products and methods for weed control.

"Work on other horticultural crops in the project will have positive implications across all the sectors including ornamentals, such as how to control western flower thrips, two-spotted spider mite, and powdery mildew, downy mildew and botrytis."

Meredith says previous HortLINK projects the company has supported show the value of such a collaborative approach: "The work at East Malling [in HL0191 on strawberries] which included a study on the timing of treatment for aphid control using one of our insecticides is something we would not have carried out ourselves, given the off-label approval, but it has brought clear benefits in how the product can be better used to improve crop quality and reduce residues, which is just what customers are asking for."

The industry is being kept up-to-date with progress on a dedicated HDC SCEPTRE web page and by its monthly technical journal, *HDC News*.

Although SCEPTRE is working exclusively on edible crops, the range of major pests, diseases and weed species affecting ornamental plants is similar, which means that the ornamentals industry should benefit too, when potentially useful novel products come to light.

WEED CONTROL IN THE PICTURE

Linking the latest image analysis software to novel designs of implements is reducing growers' dependence on herbicides

Weed control is a perennial challenge for vegetable growers – made more difficult these days by a shrinking choice of herbicides, concerns over ground water contamination and increasing customer pressure to minimise herbicide use on crops such as leafy salads and brassicas. Hand weeding, though, depends on having enough workers to do the job as well as having deep pockets.

But what if you could marry the cost-effectiveness of a mechanical hoe with the accuracy of hand weeding? That was the target for a Horticulture LINK project (HL0173) which has resulted in the development of commercially available kit – and has led to further work on automatic spot spraying for row crops.

This whole area of work, led by Tillett and Hague Technology, Silsoe, has been enabled by vision guidance software, where forward-looking images captured by digital cameras mounted on the implement are analysed by a computer which then guides the cultivator to keep it on track.

The company's imaging and crop row technology was applied to a commercial steerable inter-row cultivator. A special rotating cultivating disc was also designed which, coupled with a vision system which could distinguish between crop and weed plant, arcs around crops in the row but hoes any weeds between them, the rotation of the disc synchronised with the machine's forward movement and information from the camera about the crop and weed positions.

The outcome of the work was an experimental prototype which was estimated could halve the need for hand-weeding in organic crops or conventionally grown salad crops and save one herbicide application as well as increase yields in a conventionally grown brassica crop, giving a payback on investment in less than two years.

Two commercial models of the weeder are now available from consortium partner Garford Farm Machinery: the Robocrop guided inter-row hoe, which can travel at a speed of 12 kilometres an hour, and the Robocrop InRow weeder, which can work round three plants per second per row. The innovation was recognised by a Queen's Award for Enterprise in 2010.

Thane Goodrich, general manager of salad and baby-leaf grower Intercrop, describes the development as "the biggest story to come out of all the HortLINK projects." The company uses both an in-row weeder and a three-row, three-camera inter-row machine. "They get heavy use as they represent one of our few remaining weed control strategies due to the continuing loss of herbicides," he says. "The inter-row

The vision-guided in-row weeder in trials

camera guided system gives us a faster speed of output. This means less driver fatigue and allows operations to carry on for longer."

While the HortLINK project has made great advances, there are still limitations to mechanical weed control, particularly when the ground is wet or where perennial weeds or volunteer potatoes are the target. In these situations, growers still rely on selective herbicides, which kill the weeds without damaging the crop. But the range available has been reduced by approvals legislation and not all of those remaining are safe to all crops.

So further HortLINK work has been investigating the use of vision systems

"FOR ME, THIS MACHINERY IS THE BIGGEST STORY TO COME OUT OF ALL THE HORTLINK PROJECTS. OUR WEEDERS GET HEAVY USE AS THEY REPRESENT ONE OF OUR FEW REMAINING WAYS TO CONTROL WEEDS"

Thane Goodrich (pictured), Intercrop

to discriminate between weed and crop, using the information to control a spray rig to target individual weeds or weed patches and avoid treating the whole crop.

One project (HL0183) has demonstrated the technology needed to detect and spot spray volunteer potatoes in a range of vegetable crops.

A full-scale rig, tested in field trials in 2009, uses image analysis from cameras mounted above each of three beds treated in a single pass, both to identify the target weeds and to guide each bed section independently. Sprays are applied with a nozzle which produces a large droplet to minimise crop contamination and drift.

"HIGH PRECISION SPRAYING SHOULD OPEN UP THE CHOICE OF HERBICIDES AVAILABLE"

Nick Tillett (pictured), Tillett and Hague Technology

The spot-spray nozzles with their fast-acting individual solenoid valves

The experimental vision-guided spot sprayer on trial in a leek crop

The trials showed that 75 to 95% of the volunteer potatoes in onion, carrot and parsnip crops can be controlled in a single pass, with low levels of crop damage. All volunteers that survived were small plants at the time of treatment.

A follow-up project (HL01102) is fine-tuning the technology for use on a wider range of weeds, with onion, leek and sugar beet as the test crops.

“The advantage of high precision spraying to individual weeds, or clusters of weeds, is that, in principle, it should open up the choice of herbicides available,” says project engineer Nick Tillett.

“For example, if the application volume can be reduced to a tenth or even a hundredth of that normally used, the risk of those herbicides showing up in ground water are significantly diminished. And accurate targeting and low volumes allow use of herbicides that would not normally be regarded as crop-safe.”

The research has also contributed to innovation in other areas of spraying technology, for instance in a new design of spray nozzle. Nozzle manufacturer Hypro has developed a novel oscillating ‘alternator’ nozzle especially for this work which has a very small and sharply defined spray ‘footprint’ and which can be switched on and off within 15 milliseconds. It has proved successful in targeting volunteer potatoes and other large weeds but the large (1,000µm) droplets it produces, while good at minimising drift, don’t work well against small weeds.

So the company has developed a cassette assembly that can accept nozzle inserts of different designs – the oscillating nozzle for large broadleaf weeds or an ‘even-spray’ insert that produces droplets of about 300µm for tackling patches of smaller weeds, including grasses.

In trials during 2011, 95% of volunteer potato plants above the selected size threshold of 4cm were detected and treated. Analysis of spray dye deposits showed that the potato plants received a dose around 20 times higher than the crop that immediately surrounded them. Crop plants further than 30cm from the target were completely missed.

There’s still one season’s trials to be completed in the project, when the consortium plans to measure weed control performance, crop damage and work rates at a field scale, from which data can be analysed to show how the system stacks up economically.

HARVESTING SEEN WITH A NEW EYE

Automated harvesting, which could save growers hundreds of pounds per hectare by cutting the need for manual labour, is developing from the results of a collaborative research project that began a decade ago

It's relatively easy for any of us to use our senses of touch and sight, in combination with intelligence and training, to decide whether a lettuce, cabbage, cauliflower or broccoli spear is ready for picking. Once we've made that decision we have superb 3D vision and dextrous limbs and hands to manipulate cutting knives to remove and trim the plant, and deliver it to a cup conveyor on a field harvesting rig. For harvesting gangs, it's almost a reflex action.

But when you stop and think how you would describe each element of that process, let alone how you would emulate those actions using mechanical or electronic sensors and mechanical manipulators, you'll understand why commercially viable automated harvesting of leafy field vegetables is such a difficult challenge for agricultural engineers.

Selective mechanical harvesting has been a priority for lettuce and leafy brassica growers for some time, since it would reduce labour costs and potentially improve crop consistency. One of the key hurdles to overcome is a reliable and cost-effective means of assessing crop maturity automatically. It is straightforward enough to design a machine that would harvest a cauliflower crop in one pass but, even with all the progress in plant breeding to improve uniformity of maturity, any labour savings would be nullified by losses from the heads that weren't quite ready to cut.

Cauliflower harvesting is one of the key challenges. Gauging the maturity of cauliflower heads is particularly difficult because they are usually obscured by leaves. The successful development of a selective cauliflower harvester would, potentially, offer sensing and handling solutions that could apply to lettuce, cabbage and broccoli, too.

The Horticulture LINK Caulicut project (HL0148), which started in 2000, brought together a group of Lincolnshire growers with a leading agricultural machinery manufacturer and experts in sensor technology and image processing to investigate how mature curds could be selected, cut and lifted in one operation.

X-ray images were tested as a means of sensing cauliflower maturity, a job that currently depends on the expertise of harvest gangs

The project research team designed and tested a variety of sensors, cutting and lifting mechanisms and associated control systems.

Mature cauliflower heads are protected by wrapper leaves which sensors need to penetrate. Three different solutions were tested – tactile sensing, x-ray sensing and a novel radio-frequency method. The tactile and x-ray sensors were tested in the field while, in laboratory tests, the radio device showed potential for future development.

Maturity could be measured using x-rays with an accuracy of 95 to 98% though the x-ray equipment available at the time was heavy and expensive for field use. The touch sensor was almost as accurate, identifying 80% of mature heads, and was lighter in weight and less expensive.

A mechanism was also designed to cut and lift mature heads, without damaging them.

Following completion of the HortLINK project, the consortium was awarded a SMART business grant from the Department of Trade and Industry to develop a prototype harvester, which married sensing and cutting mechanisms with a trailer-mounted top-trim unit to prepare the heads to supermarket standards.

Ten years on, machinery manufacturing company Richard Pearson, a member of the original HortLINK consortium, says it is close to marketing a selective harvester for both broccoli and certain varieties of cauliflower. “We’re using many of the ideas that came out of the Caulicut project,” says company chairman Robert Fleet. “Combined with experience gained during development of our automated transplanter, we’ve made a lot of progress in the past year and are now at a point where we are ready to talk to growers about what we feel is a viable selective harvesting machine.”

KNOWING OUR ONIONS BETTER

Finding a way to measure flavour strength objectively for the first time has enabled onion growers to capture a market once dominated by imports

By the mid 1990s UK onion growers were already using the most sophisticated technology in the world. Major investment in developing techniques for production, drying and storage had transformed the quality of home-grown onions and extended the season of availability.

But a major marketing challenge remained. People who chose to eat their onions raw in salads still tended to opt for imported ones – especially from Spain or Chile which accounted for half of all onion imports – because they believed they had a milder flavour. Leading onion growers formed a Horticulture LINK consortium (HL0128) with the Allium & Brassica Centre, university and research institute scientists and supermarkets to find how UK-grown onions could replace at least some of those imports.

With no objective way of measuring the strength or pungency of onion flavour the first job was to devise a quick and reliable test. Results from tasting panels showed a clear relationship between perceptions of pungency and levels of pyruvic acid – a volatile compound released when onions are cut. A pyruvate test had already been developed in the USA but the HortLINK results found that it could be used across the whole range of onion flavour strengths.

"NOT ALL MILD ONIONS HAVE THE SWEETNESS A SALAD DEMANDS"

The test showed that many of the imported onions being sold as 'mild' were in fact stronger flavoured than UK cooking onions. So there was no reason why imported varieties could not be substituted by top quality, home-grown large onions – and it meant that mild onions can be grown just as successfully in the British climate.

For growers, one of the most important elements of the project was an investigation into how flavour could be controlled. The variety's genetic make-up emerged as an important factor. A very mild breeding line was identified and the trademark 'Supasweet' registered to prepare the market for sweeter onions that could be sourced in the UK in season and imported at other times.

Onions could now be classified by means of a simple, repeatable test instead of relying on variable results from tasting panels. That meant they could be labelled with confidence, making it possible to promote sales of genuinely mild onions.

In two follow-up HortLINK projects (HL0164 and HL0181) consortium members have gone on to develop a prototype 'biosensor', based on the pyruvate test, that could be used to measure flavour without the onions leaving the farm. The device they came up with can measure both pyruvate and glucose levels so that onions can be classified both on strength of flavour and sweetness – 'mild' onions don't necessarily have the sweetness that a salad demands.

Using the test to compare onions grown under a range of regimes, the consortium found that pyruvate does not account for all the variation in flavour. Pungency depends on many factors, including soil sulphur, water availability, temperature and storage time, so the test will also help the industry to modify production systems that could tailor onion flavour to the preferences of different customers.

Those involved in the research believe that more than 50% of the 'mild' imports could eventually be replaced by home-grown onions. In the last five years Spanish imports alone have dropped from 90,000 tonnes to an estimated 64,000 tonnes. David O'Connor of the Allium & Brassica Centre says that about 40% of the 'three-in-line' premium packs now sold in the UK hold home-grown onions – none of them did before the project started. This already amounts to as much as 20% of UK-grown packable onions and the figure is still increasing.

A MARKET FOR FLAVOUR

"Horticulture LINK brought together from the outset those who use the research results with those who provide the research, so the whole project is guided to a useful conclusion.

"The whole basis of a flavour market in onions has hung on these HortLINK projects. HortLINK made it possible to secure the commitment and financial input to sort out a long-standing issue that has big implications for UK producers. It also helped raise our profile with major supermarkets and now the results are available to most of the big retail players."

David O'Connor
Allium & Brassica Centre

FIT FOR THE FUTURE

Bill Parker, HDC director of horticulture, explains how the levy body is re-evaluating its role to ensure that it delivers full value to the industry

Although horticulture accounts for just 3.7% of non-grass cropped land in the UK it includes more than 300 crops with a combined home-produced value of around £2.23 billion – with the prospect that growers could increase their output sustainably and significantly.

Increasing the country's horticultural production would create jobs, reduce imports, provide more local food and help improve people's diets. And it's not just about food. Our ornamentals industry is the source of plants for green living landscapes which can help mitigate climate change and improve the quality of life in our communities, making it a vital component of the contribution that horticulture makes to the well-being of the nation.

But to realise these benefits in an increasingly challenging market and low profitability for many businesses, commercial horticulture as a whole needs continued investment in research and knowledge transfer.

In the light of the significant changes to horticultural research funding over the last two to three years, HDC has had to re-evaluate its role to ensure that it delivers full value for the approximately £6.2 million that levy payers contribute each year. This has involved defining carefully what it is that HDC does well now, while also starting to draw in new elements to make HDC a more joined-up and forward-looking organisation. This is particularly challenging as it requires HDC to take a very hard look at the 'state of play' of applied horticultural research in the UK and further afield (including building international collaborations where appropriate) and, from that, to distil a technical strategy for new work.

A forward-looking strategy is vital for HDC as it will define and direct our work programme in a way that has been lacking in the past. As well as allowing HDC to set its forward-looking priorities, it will help us integrate our research agenda better with other funders, particularly in the arena of basic science, with whom it will become increasingly important to collaborate to ensure that all research investment in the industry is pulling in the same direction. The groundwork is being put in place now, and development of the technical strategy will continue within HDC during 2012 and beyond. It is important that levy payers can influence the process, so we aim to fully involve them in setting the strategy.

At the same time, we want to maintain the recognised strengths of our crop sector panels in helping us solve the industry's immediate problems, as HDC has always done and will continue to do, including our ongoing 'extension of use' programme for crop protection products. However, we must ensure that we are smart enough to connect common threads of work that will enable us to deliver better results more quickly for the industry in the most cost-effective way.

The communication and knowledge transfer aspects of HDC's work remain

"CLIMATE CHANGE COULD BENEFIT DOMESTIC PRODUCTION THROUGH LONGER GROWING SEASONS AND A GREATER VARIETY OF CROPS "

absolutely central to ensuring we deliver technical messages and other information that has real value and impact for the industry. Our aim is to make HDC the UK industry's first port of call for technical knowledge. To do this, we need to focus carefully on who our levy payers are, where they are, and what they want to receive from us, particularly as new technology starts to open up innovative channels in the way information is delivered.

With its limited resources, HDC can only be part of the jigsaw in helping deliver the new knowledge the industry needs to drive it forward.

However, as a major funder of applied research, it retains a pivotal role in getting research into practice, and we will seek to use that position to ensure that we use and leverage our resources as efficiently as possible for the benefit of our levy payers.

COLLABORATION, COLLABORATION,

Why funders, researchers and the industry have to work together to address the challenges of food security, climate change and protection of natural ecosystems

Over the last 30 years, the number of independent applied research institutes in the UK with expertise in horticulture has fallen from 29 to six. East Malling Research, Stockbridge Technology Centre, ADAS and the National Institute of Agricultural Botany (NIAB) have become private organisations or charities. The Warwick Crop Centre (formerly Warwick HRI) was incorporated into the University of Warwick but retains an applied R&D remit.

The UK's research capacity and ability to train and foster new technologists has been correspondingly diminished, and critical gaps now exist in the research provision for soil science, plant nutrition, weed biology and other aspects of crop protection including nematology.

In the current economic climate, with government policy as it stands, there is no foreseeable prospect of additional public investment to address this deficiency so the only course of action available is for all funders and researchers to work together to make the best possible use of what funding there is. Without broad collaboration, it will be impossible to address all the challenges associated with national and global food security, climate change and protection of natural ecosystems.

To provide the foundations for such broad-based collaboration, there is now a critical need for a clear, coherent horticultural R&D investment strategy, with which to shape and direct future funding, and balance the needs for short-term problem-solving against those for longer term exploratory work. Key challenges that such a strategy must address include:

• Genetically improving crops to achieve more output (harvest index), more efficient input utilisation (components of yield), higher quality, and to match changing climatic/weather conditions, and exploit the potential offered by new high-output, high efficiency crop production systems
• Developing new crops and associated production systems to exploit opportunities created by lasting change in climate and seasonal weather patterns
• Optimising soil and water use, and meeting increasingly stringent water quality requirements
• Optimising use of energy, engineering, fuel, labour, light, materials, nutrients and precision management tools
• Developing resilient and robust integrated crop protection systems for all field and protected crops with decreasing reliance on synthetic chemical pesticides
• Developing new high-input, high efficiency crop production systems with minimal environmental impact
• Minimising and utilising waste
• Optimising post-harvest processes, including transport and distribution
• Meeting evolving retailer and consumer demands for products of high quality and nutritional/health value.

HDC's investment strategy will be formulated, implemented and

COLLABORATION

"ONLY CROSS-INDUSTRY COLLABORATION AND A COHERENT R&D STRATEGY WILL MEET EVOLVING DEMANDS FOR HIGH QUALITY PRODUCTS"

reviewed in a rolling five-year cycle. Key stakeholders from the UK horticulture industry and research community will be closely involved. The first five-year strategy will be published in 2012.

Exploratory strategic work will be commissioned by the HDC board as needs and priorities are identified and defined. The HDC sector panels will continue to operate as they do now, but will consider future research proposals in the light of the overarching strategy as well as their immediate problem-solving needs.

HDC contractors will be asked to review relevant UK and overseas research comprehensively before submitting proposals. They will also need to form balanced consortia providing all of the expertise required to address the industry's research needs and to assess more critically the potential barriers to uptake and potential impact and value for money to levy payers, and to facilitate suitable co-funding partnerships.

HDC research and knowledge transfer managers will selectively 'horizon-scan' and 'data-mine' on subjects where UK research provision is weak, and will also periodically assess the outcomes, impact and value of major long-term research initiatives in collaboration with co-funders.

AHDB will continue to explore ways in which cross-industry collaboration can be improved and additional external co-funding generated to tackle the major strategic challenges faced by all UK farmers and growers.

INVESTING IN THE FUTURE

Your guide to the organisations and schemes providing funds for horticultural R&D, including collaborative projects

Funding provision for horticultural research is continuing to adapt to new challenges and needs as they arise, and as the industry continues to evolve structurally, commercially and technically. The following is a guide to current sources of funding for R&D relevant to horticulture.

BBSRC

The Biotechnology and Biological Sciences Research Council invests about £450 million a year in bioscience research, of which some £200 million or so is spent on research relevant to agriculture and food. In addition to its core strategic funding and 'responsive mode' grants for basic biological research in universities and research institutes, BBSRC operates three research funding schemes in which agricultural and horticultural businesses may participate directly as co-funders.

Industrial Partnership Awards
IPAs are science-led 'responsive mode' grants. An industrial partner must contribute at least 10% of the full economic cost of each project, in cash. BBSRC contributes the remainder at 80% of full economic cost. Projects are required to comply with the highest scientific standards and to be of mutual value to the research partner and the industrial partner.

BBSRC stand-alone LINK
This scheme remains available for projects meeting the criteria for collaborative pre-competitive research involving at least one industrial partner and one research partner. BBSRC provides up to 50% of the funding. Industry contributions may include an in-kind element.

Research and Technology Clubs
Research and Technology Clubs,

PAVING THE WAY TO CROP IMPROVEMENT

Examples of recently successful BBSRC-funded research on horticultural topics include the development of the Beneforté broccoli variety and the sequencing of the wild strawberry genome.

Developed jointly by the Institute of Food Research and the John Innes Centre, Beneforté broccoli was conventionally bred to maximise content of the phytonutrient glucoraphanin, of which broccoli is our commonest dietary source.

Eating broccoli is associated with reduced risks of coronary disease and some cancers, attributed to its glucoraphanin content. Glucoraphanin is converted in the gut to the bioactive compound sulforaphane, which circulates in the bloodstream. Sulforaphane has been shown to reduce chronic inflammation, stop uncontrolled cell division associated with early tumour development, and induce antioxidant enzyme production. British-grown Beneforté broccoli can now be purchased in the UK.

The genome of the wild strawberry – around 35,000 genes – was sequenced by a multi-national consortium of researchers that included BBSRC-funded scientists at East Malling Research in Kent.

The knowledge is being used to provide strawberry breeders with access to genes conferring improved disease resistance and quality, most of which are thought to have been retained in commercial varieties and so are available for use by breeders.

Because strawberry is closely related to apples, peaches, pears and raspberries, some of the genes identified could also be exploited by breeders of these crops. The UK-based team at East Malling was responsible for assembling the entire wild strawberry genome from its component parts using a map developed in previous work.

including the Crop Improvement Research Club (CIRC) and the Diet and Health Research Industry Club (DRINC), support excellent quality, industrially relevant research on topics of common strategic importance to BBSRC (as set out in its Research with Industry Strategy) and industry. To join a club, companies pay an annual subscription fee based on their size. BBSRC matches the aggregated industry contribution in a 9:1 ratio. Contributions may also be provided by other research funding organisations. Outputs are shared with club members at six-monthly dissemination events, which are also an excellent opportunity to build the club community.

CIRC has proved to be an effective model for funding academic research of relevance to the major arable crops, but is less suited to the more diverse needs of horticulture. BBSRC is therefore considering an alternative mechanism that would allow companies to contribute funding and resources to specific projects, rather than a collective funding pot. All projects will need to provide genuine industry relevance and scientific excellence to be considered for funding. The community-building feature of CIRC would remain a vital element.

Beneforté broccoli

DEFRA

The Department of the Environment, Food and Rural Affairs invests about £29 million a year in agricultural and horticultural research. Its *Evidence investment strategy 2010-13 and beyond* sets out the evidence requirements and scope of Defra's R&D. The strategy also recognises the critical importance of co-ordinating research within Defra, and of collaborating on and co-funding work of common interest with other government departments, research councils and the Technology Strategy Board.

Defra recently re-evaluated its funding strategy in the light of the government's Foresight report *Global food and farming futures* (2011), and recognised three main priorities:

- Sustainable food production
- Climate change adaptation and mitigation
- Protecting ecosystem services.

SCOTTISH GOVERNMENT

The Scottish government invests roughly £70 million a year in environmental, biological and agricultural research.

Around £11 million goes to The James Hutton Institute for long-term directed research to underpin industry capacity. Additional horticultural funding is available through Strategic Research Programmes, which have an annual budget of £33 million, and address major strategic issues such as climate change, land use and food security.

The Strategic Partnerships initiative invests £8.8 million a year in new collaborative initiatives in Scottish universities to address Scottish government priorities for policy development, innovation and scientific excellence.

TECHNOLOGY STRATEGY BOARD

The Technology Strategy Board's Sustainable Agri-Food Innovation Platform (SAFIP) was set up in 2009 to stimulate business-led innovation in the agri-food sector by providing grants to industry/academic research consortia. In addition to running the scheme, the Technology Strategy Board provides 60% of the £90 million public contribution available over the platform's five-year life. BBSRC and Defra are the main co-sponsors, and the Scottish government contributes additional co-funding when appropriate. Match funding contributions from industry partners range up to 50%, depending on project content.

In 2010, the first SAFIP competition invited applicants to seek funding for the development of new approaches to crop protection. Grants totalling £3 million were awarded to 32 collaborative research and development projects, of which 30% were wholly or partly horticultural in focus. In 2011, a second competition, on sustainable protein, awarded grants totalling £16 million to 29 new projects. Future calls will continue to address high priority issues across the industry for which new or existing technologies offer promising commercial development opportunities.

The Technology Strategy Board also finances and runs the Grant for Research and Development scheme, which funds small and medium-sized enterprises (SMEs) to engage in R&D offering potentially significant rewards that could stimulate UK economic growth. SMEs working in any sector may apply throughout the year. Grants are available for proof of market (maximum £25,000), proof of concept (maximum £100,000), and development of prototype (maximum £250,000) projects.

HORTICULTURAL DEVELOPMENT COMPANY

HDC, the horticultural arm of the Agriculture and Horticulture Development Board (AHDB), has become the principal funder of applied horticultural research and knowledge

NOVEL APPROACHES TO CROP PROTECTION

Examples of current horticultural research projects funded by the Technology Strategy Board include the development of molecular markers for resistance to strawberry powdery mildew, breeding for physical resistance to soft fruit pests and pathogens, novel tomato pest control using sterile male insects, and controlling internal rots in onion from seed to store.

In conventional strawberry breeding, pest and disease resistance is selected exclusively using field performance criteria. Resistance developed in this way commonly breaks down within a few years. Marker-assisted breeding is being used to develop varieties with more robust and durable resistance. Traits associated with resistance are identified and matched to DNA sequence data. Markers are then used to label the relevant genes. Selected breeding lines incorporating all the target resistance genes are then tested in the field.

Physical pest and disease resistance traits tend to be more durable than resistance based on physiological mechanisms alone, and are less likely to adversely affect fruit quality. So in raspberry the genes that control leaf trichomes, cane/stem architecture, and plant habit will be identified, mapped, genetically marked, and assessed for their impact on pest and disease attacks.

Small-scale use of sterile male insect release is being developed for control of the South American tomato leaf miner, *Tuta absoluta*, using a novel sterilisation method offering significant cost and environmental benefits over conventional irradiation.

Storage rots in onion are principally caused by neck rot (*Botrytis allii*) and various bacteria. Following the recent withdrawal of thiabendazole seed dressing, novel alternative control technologies are being developed in combination with botrytis-specific PCR immunosensors to assess pathogen load, and novel non-invasive technologies for early detection in store and during grading.

transfer work in the UK. HDC's income is derived from a statutory levy on primary horticultural production, of which approximately £4.5 million a year is used to fund contract applied research and knowledge transfer work.

Proposals addressing the industry's annually updated sector strategies are submitted by the researchers to the HDC sector panels. When projects are relevant to more than one sector, the respective panels may share the cost. Projects also relevant to arable crops or potatoes are sometimes co-funded by AHDB's cereals and oilseeds and potatoes sector divisions.

About half of HDC's research work is on crop protection (integrated pest and disease management systems, chemical and non-chemical weed control and the 'extension of use' programme for crop protection products). The remainder is mainly concerned with variety evaluation, crop input utilisation (energy, nutrition, labour), and the efficiency and output of particular cropping systems.

Adult South American tomato leaf miner

"ABOUT HALF OF HDC'S RESEARCH WORK IS ON CROP PROTECTION. THE REMAINDER IS MAINLY CONCERNED WITH VARIETY EVALUATION, CROP INPUTS AND THE EFFICIENCY OF PARTICULAR CROPPING SYSTEMS"

OTHER UK FUNDERS

The East Malling Trust provides annual underpinning funding to East Malling Research and, together with HDC and the Horticultural Trades Association, co-funds a joint fellowship scheme. This fellowship awards grants totalling £250,000 to established researchers for fostering and developing new applied horticultural research talent.

The Northern Ireland Executive invests about £800,000 a year in agri-food research through competitive calls.

EUROPEAN COMMISSION

The European Commission's Framework Programme 7 (FP7), now nearing completion, will be replaced by the Horizon 2020 programme, of which the aim remains the underpinning of a productive and competitive European economy.

To improve the benefits that UK horticulture derives from Framework funding, applied researchers whose focus has previously been largely or exclusively on LINK and HDC funding, will find it increasingly important to strengthen their links with Framework research consortia and invest more time in Framework project development.

Useful opportunities also exist to share research costs indirectly by collaborating with overseas organisations when research interests overlap, for example on energy and crop protection.

HORTICULTURE LINK PROJECTS

● Highlighted entries indicate projects that are referred to in this review

HL0101 The optimisation of tomato summer fruit quality
October 1997 to September 2000

HL0102 The efficient use of light in bedding plant production
May 1997 to April 2001

HL0106 The impact on onion skin quality of bulb scale and skin development
April 1997 to March 2000

HL0107 Integrated control of grey mould (*Botrytis cinerea*) in container-grown ornamentals
April 1997 to March 2002

HL0108 Integrated control of disease in onion crops
April 1998 to March 2001

HL0109 Improving consistency of cropping in sweet cherries
April 1997 to March 2000

HL0114 White cabbage: reducing losses from internal disorders and improving supply
July 1997 to June 2002

HL0117 Molecular methods for virus detection in fruit plants
September 1997 to August 2000

HL0122 The development of a new generation of horticultural crop forecasting techniques
June 1997 to November 2000

● **HL0126 Development of odour-free mushroom compost by modifying organic and inorganic nitrogen sources and process technology**
August 1997 to July 2001

● **HL0128 UK fundamentals for mild onion production**
October 1997 to March 2001

● **HL0129 Narcissus leaf diseases: forecasting and the control of white mould and smoulder**
July 1998 to June 2002

HL0131 Climatic effects on the vernalisation and curd growth of winter cauliflower and subsequent fluctuations in supply
April 1998 to March 2002

● **HL0132 Improving the control and efficiency of water use in container-grown hardy ornamental nursery stock**
April 1999 to March 2003

HL0133 Improving micropropagation and weaning of slow growing hardy ornamentals (HONS) by application of novel forced ventilation techniques
September 1999 to August 2002

HL0134 Robust product design and prediction for post-harvest pot plant quality and longevity
October 1998 to September 2003

HL0135 Overcoming the loss of methyl bromide with a competitive and sustainable soil-less strawberry production system
October 1999 to March 2004

● **HL0136 Integrated use of soil disinfection and microbial/ organic amendments for the control of soil-borne diseases and weeds in sustainable crop production**
August 1999 to December 2008

● **HL0138 Application of beneficial micro-organisms to seeds using priming techniques**
January 1999 to December 2001

HL0140 Composting of onion and other vegetable wastes, with particular reference to control of allium white rot
January 1999 to December 2001

HL0142 Improving the quality and shelf-life of cut salad products
April 1999 to March 2003

● **HL0148 Selective mechanical harvesting of cauliflowers – CAULICUT**
January 2000 to December 2002

HL0149 Parsnip yellow fleck virus in carrots: development of a disease management strategy
April 2000 to March 2004

● **HL0150 Varieties and integrated pest and disease management for organic apple production**
April 2000 to March 2005

HL0160 Integrated control of slugs in horticulture
September 2000 to August 2003

HL0161 Development of a method of biological control of European foulbrood in honeybees to supersede antibiotic treatments and sanitary colony destruction by burning
July 2000 to October 2003

● **HL0163 Improving the efficiency and environmental impact of mushroom composting**
October 2003 to September 2006

● **HL0164 Defining quality assurance for sweet onions with rapid biosensor analysis**
August 2003 to July 2006

HL0165 Sustainable improvement of vegetable quality, water and nutrient use efficiency using dynamic fertigation
April 2003 to March 2007

HL0166 Early detection of latent botrytis in cut flowers and pot plants for reduction of supply chain wastage
July 2003 to June 2007

● **HL0167 Improved crop health and establishment using beneficial micro-organisms**
September 2003 to February 2007

● **HL0168 Enhancing the quality of hardy nursery stock and sustainability of the industry through novel water-saving techniques**
October 2005 to September 2009

- **HL0169 Molecular breeding for root rot resistant raspberries suitable for low input growing systems**
April 2004 to March 2007

- **HL0171 Development of the entomogenous fungus, *Metarhizium anisopliae*, for control of vine weevil larvae and thrips in horticultural growing media**
April 2005 to May 2008

- **HL0172 Producing high quality horticultural growing media through the retention of plant structure in composted food-processing waste**
October 2004 to March 2006

- **HL0173 Mechanical weed control for integrated and organic salad and brassica production**
April 2005 to June 2007

- **HL0174 Companion planting for pest control in field crops**
October 2005 to December 2009

- **HL0175 Integrated pest and disease control for high quality protected raspberry production**
April 2006 to March 2011

HL0176 Integrated allium white rot control using composts and *Trichoderma viride*
April 2006 to March 2009

HL0177 Biofumigant crops as replacements for methyl bromide soil sterilisation in strawberry production
April 2006 to March 2010

- **HL0178 Integrated control of bulb-scale mite in narcissus**
October 2006 to May 2011

- **HL0179 Producing high quality horticultural growing media through the retention of plant structure in composted food-processing waste 'COMPEAT'**
January 2007 to December 2010

- **HL0181 Optimising and validating rapid biosensor analysis for cost-effective quality assurance**
January 2007 to October 2008

HL0182 Sustaining UK fresh onion supply by improving consumer acceptability, quality and availability
April 2007 to June 2010

- **HL0183 Minimising environmental impact of weed control in vegetables by weed detection and spot herbicide application**
April 2007 to September 2009

- **HL0184 Pheromone technology for monitoring and control of capsid pests to reduce pesticide use in horticultural crops**
April 2007 to April 2012

- **HL0186 Controlling supply, quality and waste of brassica vegetable crops: understanding the causes of variation in maturity of purple sprouting broccoli**
April 2007 to December 2008

- **HL0187 Improving water use efficiency and fruit quality in field-grown strawberry**
April 2007 to March 2012

HL0188 UV-induced hormesis: a novel approach to reduce waste and maintain quality in fresh produce
January to December 2008

- **HL0189 Developing biocontrol methods and their integration in sustainable pest and disease management in plum and cherry production**
April 2009 to March 2014

- **HL0191 Minimising pesticide residues in strawberry through integrated pest, disease and environmental crop management**
April 2008 to March 2013

- **HL0192 Perennial field margins with combined ecological and agronomical benefits for vegetable rotation schemes**
December 2008 to November 2013

- **HL0193 New approaches to microbial control of insect pests in protected crops and their interaction with waste-based growing media**
June 2008 to May 2011

- **HL0194 Exploiting semiochemicals, conservation biocontrol and selective physical methods in integrated management of pear sucker**
April 2008 to March 2012

- **HL0196 Developing precision irrigation for field-scale vegetable production, linking in-field moisture sensing, wireless networks and variable rate application technology**
March 2010 to June 2014

HL0199 Feasibility study into the potential of crop pollinators to act as delivery agents of entomopathogenic fungi for invertebrate pest control
January to December 2010

- **HL01102 Reducing herbicide use in row crops with new targeted application methods treating detected weeds in small patches or spots**
April 2010 to December 2012

HL01103 Non-invasive approaches to identification and automatic rejection of internal defects in bulb onions
March to August 2010

HL01104 Reducing wastage and increasing shelf-life of root vegetables during washing, packing and retailing
October 2009 to March 2011

HL01105 Developing biocontrol methods and their integration in sustainable pest and disease management in blackcurrant production
April 2010 to March 2015

- **HL01107 Biological, semiochemical and selective chemical management methods for insecticide resistant western flower thrips on protected strawberry**
April 2010 to March 2015

HL01108 Optimising field-scale control of fusarium basal rot and white rot of onion using trichoderma amended substrates and pellets and onion residues
March 2011 to August 2013

- **HL01109 Sustainable crop and environment protection – targeted research for edibles: SCEPTRE**
October 2010 to September 2014

For more detail on the projects listed above, search the science and research database on Defra's website at randd.defra.gov.uk

listing continues on p60 >

HORTICULTURE LINK PROJECTS continued

Hort 152 Poised for rapid emergence: what are a seed embryo's pre-sowing requirements to achieve this?
September 1997 to August 1999

Hort 212 Controlling water use of trees to alleviate subsidence risk
April 1999 to March 2004

● **HL0170 Developing a marker-assisted breeding toolkit for premium sensory characteristics in raspberry**
June 2006 to May 2009

HL0190 Development of high profile germplasm for UK production of blueberries
June 2009 to May 2014

● **HL0195 Developing breeding and selection tools to reduce spoilage of soft fruits and wastage in the supply chain**
June 2009 to May 2012

● **HL0197 Controlling supply, quality and waste in brassica vegetables: understanding the genetics of maturity to breed varieties in response to a changing climate**
July 2009 to June 2013

MRS/003/02 Development of physiological, agronomical and genetic tools for increasing the L-ascorbic acid yield from blackcurrant bushes
July 2002 to June 2007

Factsheets on some of the projects can be downloaded from defrafarmingandfoodscience.csl.gov.uk/unit/floatingtable.cfm?id=3

HDC PUBLICATIONS

HDC has produced various factsheets and publications over the years, many as a direct consequence of the research projects it has commissioned

FACTSHEETS

19/11 Control of sclerotinia disease on carrots
18/11 Cucumber green mottle mosaic virus
17/11 HDC mainseason strawberry variety trials 2011
15/11 The zero residue management system for apples
14/11 Leek rust
13/11 Pesticide residue reduction in commercial raspberry crops
12/11 Onion variety trials 2010/2011
10/11 Leafminers of cruciferous salad crops
08/11 Downy mildew of basil
07/11 Beetle and weevil pests of cane fruit crops
06/11 Raspberry variety trials – summer fruiting selections at SCRI in 2010
05/11 Cherry variety trials 2010
04/11 Plum variety trials 2010 – East Malling Research selections
03/11 Plum variety trials 2010 – named selections
02/11 Controlling exposure to dust and bioaerosols on farms growing common commercial mushrooms
01/11 Spotted wing drosophila (*Drosophila suzukii*)
30/10 Onion variety trials 2009/2010
29/10 Brassica variety trials 2009/2010
28/10 Plum variety trials 2009
27/10 Cherry variety trials 2009
26/10 Green manures – implications of economic and environmental benefits on rotational management
25/10 Green manures – species selection
24/10 Green manures – effects on soil nutrient management and soil physical and biological properties
23/10 Tomato spotted wilt virus in protected edible crops
22/10 Control of flea beetles and other key insect pests of leafy salad brassica crops
21/10 Russet mite
20/10 HDC mainseason straw-berry variety trials 2010
19/10 Verticillium wilt of raspberry and other cane fruits
18/10 Host plant range of vine weevil
17/10 Control of powdery mildew diseases on hardy nursery stock and herbaceous perennials
16/10 Coriander bacterial blight
15/10 Septoria blight of parsley
14/10 A robust IPM programme for organic tomatoes
13/10 Monitoring microbial food safety of fresh produce
12/10 Extending the season of strawberry production using a range of plant types and growing systems
11/10 Turnip sawfly: biology and control
10/10 Raspberry variety trials – summer fruiting selections at SCRI in 2009
06/10 Grower system for rearing the predatory beetle *Atheta coriaria*
04/10 Bacterial shot-hole of cherry laurel
03/10 Tomato leafminers
02/10 Boosting biocontrols within IPM programmes
01/10 Bacterial wilt and canker of tomato (*Clavibacter michiganensis* subsp *michiganensis*)

18/09 HDC mainseason strawberry variety trials 2008
17/09 Seed-borne diseases of ornamentals: prevalence and control
15/09 Control of rose downy mildew
14/09 Thrips control on protected ornamental crops
13/09 Guidelines for minimising latent grey mould (*Botrytis cinerea*) in cut flowers and pot plants
12/09 The biology and control of mites in pot and bedding plants
11/09 Impatiens downy mildew
10/09 Energy management in protected cropping: management of CO_2 enrichment
09/09 Energy management in protected cropping: horticultural lighting
08/09 Energy management in protected cropping: the use of screens
07/09 Energy management in protected cropping: humidity control
06/09 Energy management in protected cropping: manipulation of glasshouse temperature
05/09 Energy management in protected cropping: good housekeeping
03/09 Biobeds for treatment of pesticide waste and washings
02/09 Slug control in field vegetables
01/09 Cane management and training of field-grown blackberries and hybrid berries
23/08 Strawberry variety trials
21/08 Onion storage from seed & sets 2007/2008
20/08 Wet heat treatment to sterilise pots for re-use
19/08 Iris yellow spot virus: a potential threat to the onion industry
18/08 New diseases on UK carrot crops
17/08 Control of strawberry powdery mildew under protection
15/08 Pest, disease and weed management in ornamental aquatic plants
14/08 The use of root pruning in apples and pears
13/08 Mushrooms – improving spawn-running performance
10/08 Identification and control of cobweb disease on mushrooms
09/08 Identification and control of dry bubble disease of mushrooms
08/08 Strawberry blossom weevil
06/08 A guide to best practice in handling bought-in plants
05/08 Management of large narcissus fly
04/08 Energy saving in tomato production
02/08 Stemphylium leaf-spot and other foliar diseases of hebe
01/08 A guide to simple and effective nursery trials
20/07 Disease control in cyclamen
18/07 Management of stemphylium purple spot on UK asparagus crops
17/07 Control of volunteer potatoes in vegetable crops
15/07 Control of leaf miners on pot and bedding plants
12/07 Strawberry crown rot
11/07 Mushroom Virus X (MVX) prevention
10/07 Guidelines on nursery hygiene for outdoor and protected ornamental crops
09/07 Soil disinfestation options for cut flower growers
08/07 Integrated management of stock fusarium wilt
07/07 HDC summer fruiting raspberry variety trial
06/07 Principles of strawberry nutrition in soil-less substrates
02/07 Phytophthora root rot of raspberry and other cane fruits
01/07 Sucking insect pests of cane fruit crops
16/06 The control of verticillium wilt in strawberry
15/06 Water quality for irrigation of container ornamentals
14/06 Pesticide spray application for ornamental crops
13/06 Caterpillars of protected ornamental crops
12/06 Cane management and training of field grown mainseason raspberries
09/06 Potato spindle tuber viroid in tomato and new viroid reports
08/06 Spinach leaf spots and their management
07/06 Energy saving in poinsettia production
04/06 Guidelines for the post-harvest handling of cut tulips
03/06 Guidelines for the post-harvest handling of cut lilies
02/06 Guidelines for the post-harvest handling of summer cut flowers and cut foliage
01/06 Capillary irrigation of container grown nursery stock
29/05 Getting the best out of CO_2 enrichment for cucumbers
28/05 Swede midge control in brassica crops
27/05 Winter protection of container grown nursery stock
26/05 Aphids and their control on strawberry
24/05 Guidelines for the post-harvest handling of cut flowers
23/05 Disease control in protected lettuce
22/05 Interpretation of allium leaf nutrient analysis
21/05 Interpretation of brassica leaf nutrient analysis results
20/05 Orchard spraying: opportunities to reduce rates
19/05 Methods and equipment for matching irrigation supply to demand in container-grown crops
16/05 Measuring and improving performance of overhead irrigation for container-grown crops
15/05 Use of chemical disinfectants in protected ornamental production
14/05 Control of whiteflies on protected ornamental crops
12/05 Dithiocarbamate contamination of salad produce and the use of rubber gloves
09/05 Low temperature storage of bedding plant plugs
08/05 The biology and control of two-spotted spider mite in nursery stock
07/05 Securing your water supply for the future
06/05 Soil sterilisation options for soft fruit growers
05/05 Nutrition of container-grown hardy nursery stock
03/05 Angular leaf spot and bacterial leaf blight

HDC PUBLICATIONS

CROP WALKER GUIDES

Alliums
Asparagus
Blueberry
Brassica
Bush fruit
Cane fruit
Carrot & parsnip
Cucumber, tomato and pepper
Herbs
Outdoor salads: lettuce & celery;
Pea & bean
Pot and bedding plants
Stone fruit
Strawberry
Weed identification guide

HANDBOOKS/GUIDES

Air movement in glasshouses
BOPP best practice guide: managing water and preventing pollution on ornamental nurseries
Herbaceous perennials: a guide to the production of container-grown plants
HNS cold storage
Lean manufacturing – achieving efficient use of labour in protected edible crops
Micro-turbine CHP units – their application in protected horticulture
Ornamental plant quality – developing a whole business management system
Slow sand filtration
Soft fruit agronomist handbook
Supplementary lighting of pot chrysanthemums

IDENTIFICATION CARDS

Aphids commonly found in protected lettuce
Caterpillars commonly found in protected lettuce
Herb pests & diseases
Pest and diseases of outdoor and protected cut flowers

WALLCHARTS

Apple orchard monitoring calendar
Apple storage rots and disorders
Pear orchard monitoring calendar
Strawberry analysis chart – optimum ranges
Tomato spotted wilt virus in pepper
UK storage recommendations for tree fruit

HORTICULTURAL R&D LINKS

ADAS
www.adas.co.uk

Agriculture and Horticulture Development Board
www.ahdb.org.uk

BBSRC
www.bbsrc.ac.uk

Cranfield University
www.cranfield.ac.uk

Defra
www.defra.gov.uk

Department for Agriculture & Rural Affairs for Northern Ireland
www.dardni.gov.uk

East Malling Research
www.emr.ac.uk

East Malling Trust
www.eastmallingtrust.org

European Commission Horizon 2020
ec.europa.eu/research/horizon2020

Fera
www.fera.defra.gov.uk

Harper Adams University College
www.harper-adams.ac.uk

HDC
www.hdc.org.uk

Henry Doubleday Research Association (Garden Organic)
www.gardenorganic.org.uk

Horticultural Trades Association
www.the-hta.org.uk

Institute of Food Research
www.ifr.ac.uk

Lancaster University
www.lancs.ac.uk

National Horticultural Forum
www.hortforum.net

Natural Resources Institute
www.nri.org

NIAB
www.niab.com

Scottish government
www.scotland.gov.uk
(for information on Strategic Research Programmes and Strategic Partnerships, go to topics, then research)

Stockbridge Technology Centre
www.stc-nyorks.co.uk

The James Hutton Institute
www.hutton.ac.uk

Teagasc
www.teagasc.ie

Technology Strategy Board
www.innovateuk.org

University of Reading
www.reading.ac.uk

Warwick Crop Centre
www2.warwick.ac.uk/fac/sci/lifesci/wcc/

PHOTOGRAPHIC CREDITS

ADAS, p40 botrytis
Bordon Hill Nurseries, p36
Brian Lovelidge, p25 Adrian Barlow
British Summer Fruits, front cover raspberry; p28
Cathy Knott, p38; p41 herbicide trials
Chris Burgess, front cover and p20 sprinklers
Du Pont, p57
East Malling Research, p27; p40 mildew
Elsoms Seeds, p13
Felix Wäckers, p30
FLPA/Nigel Cattlin, p5 and p35 vine weevil larvae; p33
Gary Naylor, p7 cauliflower harvesting; p37 daffodil crop; p47
HTA, p53 garden centre
Ian Gillott, p4
Institute of Food Research, p55
Institute of Food Research/Keith Waldron, p14 microscope pictures; p16
Intercrop, p43 weeder in use and Thane Goodrich
iStock/dra_schwartz, p7 microscope
iStock/stocknshares, p7 cherry picking
iStock/clarkandcompany, p17
iStock/Eduard SV, p31
iStock/Fotografia Basica, p48
iStock/antonyspencer, p51
iStock/carlofranco, front cover and p52 shopping trolley
Joanna Wood, p19 Andrew Chesson
Lancaster University/David George, front cover bumblebee
Pera, p46
Roger Umpelby, p26; p40 aphids
Syngenta, p40 Jon Ogborn
Thanetearth.com, p7 tomatoes
The James Hutton Institute, front cover flower pollination; p5, raspberry breeding; p11
Tillett and Hague Technology, p5 and p44 spot sprayer; p43 weeder in trials; p45
Tomato Growers' Association, front cover tomatoes
Warwick Crop Centre, front cover laboratory testing; p29; p37 weather station and narcissus smoulder; p40 caterpillars
All other pictures copyright of HDC or Shaddick & Gunn

Published by the Horticultural Development Company as a supplement to HDC News
***Concept:** Ruth Ashfield, Neil Bragg*
***Authors:** Spence Gunn, Bill Parker, Scott Raffle, Steve Tones*
***Additional information:** David Cole (Horticulture LINK programme co-ordinator), Joanna Wood*
***Editorial production:** Shaddick & Gunn, Richard Charnley*

HDC
The Agriculture and Horticulture Development Board
Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

Tel: 0247 669 2051
Email: hdc@hdc.ahdb.org.uk

www.hdc.org.uk