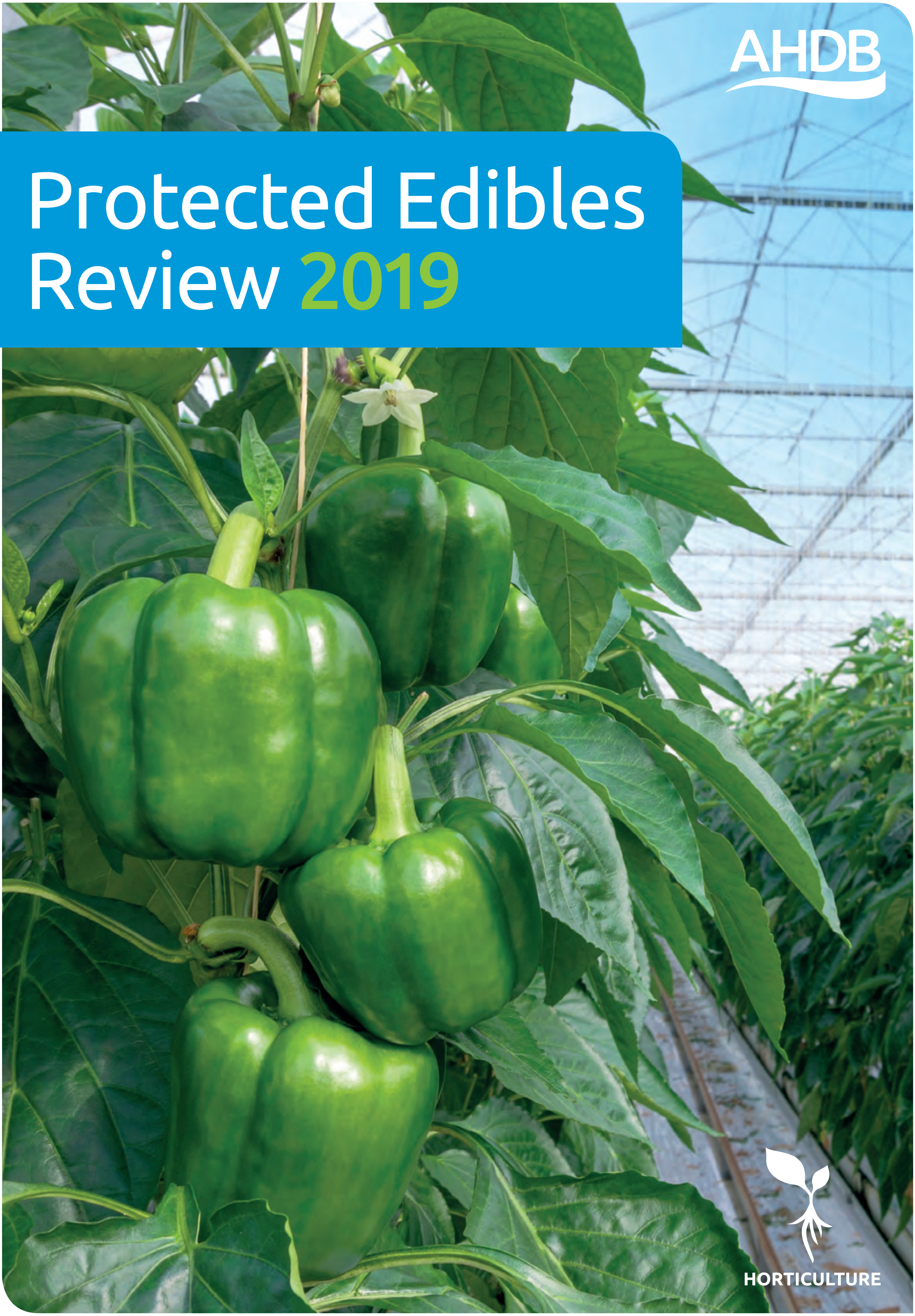
Protected Edibles Review 2019



AHDB

HORTICULTURE

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Meet the team

AHDB Horticulture contacts

Nathalie Key
Knowledge Exchange Manager
T: 024 7647 8918
E: Nathalie.Key@ahdb.org.uk

Nikki Harrison
Senior Research Manager
T: 07391 016 507
E: Nicola.Harrison@ahdb.org.uk

Bolette Palle Neve
Crop Protection Scientist
T: 024 7647 8884
E: Bolette.Palle-Neve@ahdb.org.uk

Elected members

Will Forbes, G's Growers Nurseries Ltd, Cambridgeshire

Matthew Simon, Smallford Nurseries, Hertfordshire

Steve Helm, Lincolnshire Herbs, Lincolnshire

Phil Morley, APS Salads Ltd, Middlewich

John Cappalonga, Gee Vee Enterprises Ltd, Essex

Chris Durnford, North Moor Lane, East Yorkshire

Ian Hammond, Valefresco Ltd, Warwickshire

Kimberly Dawson, G's Fresh Mushrooms, Littleport

Foreword

Looking back on 2018, a trying year in many respects for our sector with the warmest summer on record, increasing labour issues and the continuing challenges of managing pest and disease pressures old and new, I wonder what this year will bring us?

Probably even more of the same! The shortages of labour will increase, energy prices are going up, we have new pests and diseases coming our way and margins are under severe pressure. Then overlay this with the whole uncertainty of Brexit and this year looks to be even more challenging.

Yet despite this, I remain positive about the future of British Horticulture and the role our sector in particular can play in producing greater quantities of high quality healthy fresh food for the UK consumer.

We have a growing, aging population and there is an increasing awareness of the need to eat more healthily. Meat consumption is decreasing and trends like flexitarinanism are gaining strength. So there is certainly going to be strong market demand for fresh produce and with Brexit maybe British fresh produce too?

However, as an industry we will need help to deal with these challenging times. This is where I think AHDB is well placed. The ongoing work with grower associations to compile risk registers to help focus in on relevant crop concerns and highlight where we as an industry believe the priorities are, has been hugely useful. We now have documents that can be used to help prioritise work and inform others as to what we need, thereby increasing the opportunities for collaborative funding and more research.

Unsurprisingly, the top priority is crop protection and the work AHDB does on getting EAMUs approval is essential for us. However, looking forward to a world with less and less pesticides becoming available, big strategic projects are critical. The popular SCEPTRE programme has been extended with SCEPTREplus and the results of the first year can be found on page 5.

Complementary to this is the specific work on biopesticides which has begun in the AMBER project outlined on page 6.

Labour is a very topical subject among us all at the moment and the recent workshops on Lean have been well received and there is now a desire to continue the knowledge transfer activity in the form of the SmartHort campaign. SmartHort aims to improve management practices for the existing workforce and to identify new technologies and innovation, such as automation, robotics or artificial intelligence, which could play a role in providing longer-term solutions. If this is an important topic for your business, SmartHort 2019 is a conference dedicated to driving innovation into horticulture. Though fully booked, you can register to live stream at **ahdb.org.uk/smarthort**

Finally, I wish to highlight the opportunity for you to become involved in deciding what future work to fund. There are just two Protected Edible and Mushroom Panel meetings a year and your input is critical to keep the research delivering for your business. We welcomed new panel members for a three year term in January, but there are still a couple of vacancies. If you're interested in applying, please get in touch or visit **horticulture.ahdb.org.uk/panel**

Rob James
Protected Edibles
Panel Chair

Pests and diseases

Future of many crop protection products looks uncertain

Last year saw a number of challenges for the protected edibles sector both in terms of challenging pests and diseases, but also in terms of question marks over the future of some very important active ingredients. Some of these question marks have been carried into 2019 and we will keep growers updated through our monthly Crop Protection Newsletter.

For tomato growers, 2018 had a challenging start with some growers seeing serious symptoms of late blight in young plants very early in the season. It quickly became apparent that this was a new strain of *Phytophthora infestans* and we had to act quickly to get an EAMU secured for the product Ranman Top to give growers a tool which would help them with this damaging disease. Later in 2018, we also secured an EAMU for the product Carial Star to add another option for growers.

Pymetrozine was one of the actives which was due to be renewed in Europe in 2018. Unfortunately, a decision of 'non-renewal' was reached. Most of the UK pymetrozine users were transferred from Syngenta to Adama earlier in the year and as a result of this change we have had to apply to have a number of EAMUs moved to the new Adama products. However, growers need to be aware that these approvals will now be withdrawn. At the time of writing, the final use-up date has not been confirmed for UK authorisations.

We continue to look for products which fit within an IPM programme and in 2018 we secured EAMUs for a number of biopesticides such as Botanigard, Karma and AQ10. These have all been issued for use in protected leafy vegetables and herbs.

The need for control options for *Fusarium oxysporum* in protected lettuce is of very high priority for us, but although we have conducted trials as part of SCEPTREplus and looked globally for suitable products, the options for growers still remain limited. SCEPTREplus trials showed that Basamid works well under the right conditions and the biopesticide T34 also looked promising. We will continue to look for additional options in discussion with colleagues in other Member States.

Protected oriental cabbage is a crop group which we have focused on in the last couple of years. Growers of these crops have very few products available to them and we were therefore thrilled when we were successful in obtaining EAMUs for Signum and Movento. The latter was obtained using data which was generated by the Dutch growers and we are grateful to our Dutch colleagues for sharing this with us.

Finally, we were very pleased to see how quickly an urgent request for use of the caterpillar product Coragen in leafy vegetables and herbs was handled by CRD during the hot and dry summer of 2018. This application relied on North American residue data supplied by FMC and it shows how we can achieve a successful outcome quickly when we all work effectively together.

"We continue to look for products which fit within an IPM programme and in 2018 we secured EAMUs for a number of biopesticides"

AHDB project code: **CP 165**
Term: April 2017 to March 2021
Project leader: Ed Moorhouse, Agrifood Solutions and Rosemary Collier, Warwick Crop Centre

SCEPTREplus is a programme of research designed to assess the effectiveness of new or emerging crop protection products. The targets for SCEPTREplus are chosen following consultation with sector panels, grower associations and GAP analysis survey, to help plug critical gaps in growers' crop protection armoury. To improve efficiencies and where appropriate, a model crop approach to trials is being taken with results extrapolated on to other crops.

Results

The first year trials for protected edibles crops looked specifically at two-spotted spider mite on tomato, downy mildew on lettuce, and pythium on cucumbers.

Two-spotted spider mite (*Tetranychus urticae*), TSSM, is a significant economic pest of glasshouse tomatoes and other protected crops, causing visible damage to leaves and reducing yield, currently options are limited. The aim of this trial was to confirm products for inclusion in the trial, and evaluate the efficacy of selected products for control in glasshouse tomatoes. The trials found all products tested significantly reduced TSSM numbers in comparison to the control. This included three, low risk to the Integrated Pest Management (IPM) programme products. This trial has identified a number of safe and effective products for controlling two-spotted spider mite.

Downy mildew is a priority target disease in many outdoor and protected crops, including cucumber, lettuce, brassicas, onions, herbs, peas and beans, soft/cane fruit, vines and ornamentals. The number of products available are limited in number and effectiveness and growers require alternative control measures to be identified. Novel conventional fungicides and biopesticides were tested for effectiveness against downy mildew using protected lettuce as a functional model crop. Nine products were trialled. The level of disease was low-moderate throughout the trial. The standard programme performed as would be expected – it reduced downy mildew infection levels to a certain extent, but did not completely control the disease. One biological product gave statistically significant levels of control compared to the untreated at the first two assessments. At the end of the trial, all conventional products gave significant levels of downy mildew control compared to the untreated plots. Several conventional fungicides tested have potential for future commercial use and will go forward to further trials.

Root rot of cucumber caused by *Pythium aphanidermatum* can lead to significant crop losses, weakening and even killing young plants when transplanted onto previously infested, re-used rockwool slabs. Safe, effective and approved treatment options are limited and identifying new products active against Oomycete pathogens will be of benefit to a number of crop sectors.

Symptoms developed slowly in the crop, potentially because ambient temperatures and radiation were low for the time of year and, as a result, plants were less stressed. All plants survived for the duration of the trial as a result of the low-moderate disease levels.

One new conventional pesticide and one biopesticide significantly reduced disease symptoms in the pythium trial but further work under higher disease pressure would be necessary to check efficacy and crop safety under higher temperatures.

Trials are currently in progress for pest targets of aphids, tomato leafminer (*Tuta absoluta*), tomato russet mite (*Aculops lycopersici*) and southern green stink bug (*Nezara viridula*) and disease targets include lettuce fusarium wilt, downy mildew and root rots.

Visit **horticulture.ahdb.org.uk/sceptreplus** to find out more.

The next generation of crop protection tools

AHDB project code: **CP 158**
Term: January 2016 to December 2020
Project leader: Dave Chandler, University of Warwick

Biopesticides are plant protection products based on living microorganisms, plant or microbial extracts, or pheromones and other 'semiochemicals' that modify the behaviour of a crop or the pests or diseases that attack it. They generally pose a low health and environmental risk and many need no routine residue monitoring. All registered biopesticides have passed stringent efficacy tests, but some growers find their effectiveness compromised by factors such as application techniques, equipment, environmental conditions or because there's a lack of advice on how to get the best from them.

The project

Identifying what constitutes best practice, and helping growers to adopt it, is likely to improve the results from using biopesticides. The project is recording growers' experiences and expected results from a biopesticide when applied on a typical nursery. It will then look at what growers could do to improve the performance of biopesticides through, for example; timing and frequency of applications, nozzle selection, achieving suitable environmental conditions and integrating the products with other pest and disease management measures such as biological and cultural controls. The improved regimes will then be tested in nurseries to measure their impact.

Results

The first year's work focused on benchmarking the performance of biopesticide products against pests and diseases in trials on commercial protected crops. The biopesticides were applied by the host growers to naturally occurring population levels of pest and disease according to the product manufacturer's standard instructions. Five trials were done with microbial biopesticides applied on the following combinations; aphids on an organic pepper crop, western flower thrips on chrysanthemum, powdery mildew on cucumber, botrytis on cyclamen, root rots on choisya and dianthus. It is important to note that these are not conventional efficacy trials, but were intended to identify areas where biopesticide management has potential for improvement. In three trials, it was possible to compare the biopesticides against the current plant protection product used by the grower. In these cases, at the natural levels of pest/disease occurring in the crop, biopesticides gave similar levels of control as the standard product.

Overall there were a number of areas where improvements to biopesticide management could be made. Spray application has potential to be more efficient and effective. For example, by altering the total water volume used in order to increase the proportion of the spray that is retained on plant surfaces. Microbial biopesticides are slower acting compared to conventional pesticides. This can be a problem for pests that have short life cycles, as there may not be enough time to kill a large amount of the pest population, before the next generation appears. Finally, there is a general lack of information available to growers about how long biopesticides remain active on the crop after being sprayed.

These issues are being tackled through the AMBER project. This includes work to determine how different sets of spray parameters, such as water volume, pressure and forward speed, affect the amount of biopesticide that adheres to the crop. Mathematical models will be used to understand how biopesticide efficacy is affected by the speed at which different types of pest develop. The objective is to better understand the pest population threshold below which biopesticides should be applied for best effect, and to identify ways to slow down the growth of short lifecycle pests to make them more susceptible to biopesticides. Experiments are also being conducted to measure how long some biopesticides survive on the crop, in order to help inform the best timing and frequency of spray applications. Visit **bit.ly/AMBERproject** to find out more.

Following up on fusarium

AHDB project code: **CP 17/18-1006**
Term: December 2017 to March 2018
Project leader: Andrew Taylor, University of Warwick

In response to the confirmed outbreak of lettuce fusarium wilt in the UK, AHDB commissioned Dr Andrew Taylor, University of Warwick, to produce a technical review on the current available knowledge to help UK growers manage this potentially damaging disease.

The project

Lettuce fusarium wilt caused by *Fusarium oxysporum* f. sp. *lactucae* (FOL) was confirmed as a new disease to the UK in October 2017. It appears the main way FOL is transmitted is through infested soil, which can be spread on farming equipment, trays, pallets, plants and footwear.

Results

Lettuce FOL is primarily soilborne so crop hygiene is essential to prevent spread of the fungus between lettuce crops, glasshouses, nurseries and plant propagators. Therefore, crop hygiene procedures across lettuce propagation and growing businesses were reviewed and where possible, access to cropping areas are restricted.

Quaternary ammonium compounds are one of the most effective disinfectants for FOL but are often unsuitable for use in lettuce production systems. Moreover, many disinfectants are less effective in the presence of soil. Trays and pallets moved between growers and propagators need to be thoroughly cleaned of soil and plant material to enable these disinfectants to be effective.

Where the disease has been confirmed on-site, soil from affected beds should not be rotovated or spread to other areas of the nursery. Growers should not bury affected material in soil or add it to discard piles or compost areas, plant material should be uprooted and burned, or put in a covered skip for landfill.

Under the AHDB SCEPTREplus project funds have been made available for trials to test the efficacy of conventional and biological products that could be used during propagation and cropping, or for soil disinfestation. These trials are underway at the University of Warwick. New AHDB-funded work commenced in project FV/PE 458 in autumn 2018 to further investigate the biology and management of lettuce fusarium wilt, including pathogen survival, infection thresholds, temperature range and disinfectant activity. The development of diagnostic tools for lettuce FOL will also be included in the research.

For more information growers can access the full technical review and new project information available on the AHDB website: **horticulture.ahdb.org.uk/lettuce-fusarium-wilt-and-root-rot**

Keeping the casing clean

AHDB project code: **M 062**
Term: October 2015 to April 2017
Project leader: Ralph Noble, NIAB EMR

Sporgon (prochloraz-manganese) has been the only approved fungicide available to the UK mushroom industry, although when this project started, Vivando (metrafenone) was also approved for mushroom crop disease control in France and Spain. Sporgon provides good control of wet bubble (*Mycogone perniciosa*), moderate control of dry bubble (*Lecanicillium fungicola*) and weak or ineffective control of cobweb (*Cladobotryum* species). There has been reported resistance in some *Lecanicillium fungicola* isolates to prochloraz. In this project, the efficacy of Sporgon and Vivando in disease control was compared with that obtained with a further fungicide, Shirlan (fluazinam) and a biopesticide, Cedress (*Pseudomonas chlororaphis* MA342).

The project

Fungicide-degrading microbes can break down Sporgon and other pesticides into inactive by-products, thereby reducing the efficacy of an applied dose. This project aimed to reduce degradation of fungicides by stimulating a microbial population in the casing that is antagonistic to the microbes that degrade fungicides. A series of experiments were conducted to assess the effects of different fungicides, biopesticides and casing additives on fungal disease control, mushroom yield and fungicide residues and degradation. Details of the application rates for the fungicide and biopesticide products are given in the report to project M 062. The pathogen isolates used for the tests were obtained from recent disease outbreaks on UK mushroom farms. Casing treatments that are effective in inhibiting degradation of fungicides were then tested against standard casing for control of fungal diseases in experiments on mushroom farms.

Agar plate tests on the sensitivity of pathogen isolates to fungicides were conducted. The plate tests measured the mycelial growth rate and spore germination at a range of fungicide concentrations in the agar. The tests were then compared with disease control results obtained in pot mushroom cultures using the same doses of fungicides in the casing.

Results

A *Lecanicillium* isolate that showed resistance to Sporgon in agar plate tests was also resistant to Sporgon in a pot culture test. However, agar plate test results did not fully reflect potential disease control with fungicides in pot culture tests. At 20 ppm in agar plate tests, metrafenone was less inhibitory to mycelial growth and spore germination of *Lecanicillium* isolates than prochloraz. However, Vivando provided better dry bubble disease control than Sporgon in a pot culture test when used at 20 ppm of active ingredient in the casing. Vivando provided good control of dry bubble disease irrespective of the Sporgon resistance of the *Lecanicillium fungicola* isolate.

Vivando and Sporgon were equally effective in controlling wet bubble disease but Vivando also provided some control of cobweb disease. At the rate used, Shirlan did not control disease or affect mushroom yield. However, Shirlan has potential for disease control if tested at a higher rate since it was very effective in suppressing pathogen growth in agar plate tests at concentrations that did not affect mushroom mycelium. Cedress suppressed wet bubble disease, although the effect was not quite statistically significant, but did not affect dry bubble or cobweb diseases. It did not affect mushroom yield or cause blotch even though it is a *Pseudomonas* species.

When recommended application rates of Sporgon or Vivando were used, prochloraz or metrafenone were found in first flush mushrooms at levels just above their detection limits and well below their EU maximum residue


Dry bubble disease


Wet bubble disease


Cobweb disease

level (MRL) for mushrooms. At the rate used, Shirlan was not detected in mushrooms. The MRLs for prochloraz, metrafenone and fluazinam in mushrooms are 3, 0.4 and 0.05 mg/kg respectively.

During a mushroom crop, Sporgon in the casing degraded by 46% compared with 81% for Vivando and 77% for Shirlan. The rate of Sporgon degradation was reduced by adding 25% recycled, cooked-out casing to fresh casing. This did not affect mushroom yield compared with using fresh casing alone.

Salt is widely used for covering patches of diseased mushrooms on growing beds but this has an adverse effect on the subsequent use of the spent compost in casing or growing media by increasing the electrical conductivity. A 70% clay: 30% salt mixture was as effective in suppressing regrowth of pathogens and diseased mushrooms as salt, but with a smaller effect on spent mushroom compost electrical conductivity.

Since the project ended, Vivando has been approved for use on mushrooms in the UK.

Future Developments in Disease Control

Shirlan and fungicides that are approved for other crop uses should be screened at a range of concentrations for efficacy against mushroom pathogens and effect on mushroom cropping. This should broaden the range of available active ingredients and reduce the risk of pathogen resistance to Sporgon and Vivando. This work has also shown that the composition of the casing can be modified to prolong the efficacy of an applied fungicide dose, possibly by introducing competitors to the microbes that break down the active ingredient. The influence of casing additives, such as recycled casing, on fungicide efficacy in disease control, particularly in later flushes, should be investigated further. Biopesticides for control of fungal pathogens in mushroom crops are restricted to bacterial products, since the mushroom is also a fungus. Cedress (*Pseudomonas chlororaphis* MA342) has shown suppression of wet bubble in this project; the efficacy of other bacterial biopesticides in fungal disease control should also be tested; they may also suppress bacterial blotch.

Action Points for Growers

1. Resistance of mushroom pathogens to Sporgon is a significant problem for the industry and growers should constantly review their disease control strategies to reduce reliance on fungicides
2. Where growers suspect that wet or dry bubble is not being controlled by Sporgon they should check the prevalent pathogen(s) on the farm for prochloraz resistance (this can be done in the laboratory)
3. Vivando should be used as an alternative or intermittently to Sporgon to reduce the risks of fungicide resistance and microbial breakdown of prochloraz e.g. in spray tanks
4. Sporgon should not be used primarily for control of cobweb since it will not give effective control, while increasing the above risks. Vivando provides some control of cobweb disease
5. The effect of addition of 25% recycled, cooked-out casing to fresh casing on the efficacy of Sporgon in disease control should be explored since this may reduce the rate of prochloraz break down in the casing
6. Where there is a market for spent compost, the use of 70% clay: 30% salt as a disease covering material should be considered since it will have a less negative effect on subsequent use than using 100% salt

Macrosiphum euphorbiae

Myzus persicae

Concentrating on aphids

AHDB project code: **PE 027**
Term: July 2015 to October 2015
Project leader: Tom Pope, Harper Adams University

Aphids are one of the most serious pests of protected pepper crops grown in the UK. There are four key species of aphid pest; the peach potato aphid (*Myzus persicae*), the foxglove aphid (*Aulacorthum solani*), the melon and cotton aphid (*Aphis gossypii*) and the potato aphid (*Macrosiphum euphorbiae*). Crop damage typically occurs when large populations of aphid retard and distort plant growth. In addition, honeydew produced by aphids can lead to the growth of sooty moulds on foliage and fruit. The foxglove aphid presents an additional problem in that its saliva contains toxins, which cause yellowing, twisting and distorting of the young leaves and necrotic spots on the fruit.

The project

Tom Pope reviewed and collated current knowledge of controls and biology of aphid pests affecting pepper crops. He also spoke to key industry representatives, including growers, insecticide and biological control distributors and seed companies. Knowledge gaps were identified and opportunities to adopt controls used in other countries or on other crops were investigated.

Results

Pope concluded that Integrated Pest Management (IPM) is well established and widely used by UK protected pepper growers, but found that there is a lack of information on the biology and control of hyperparasitism and that growers were keen to find alternatives to insecticides to manage the issue. If the range of biological controls could be extended, in particular the use of predators, to control aphid pests this may help to improve control and reduce hyperparasitoid problems by reducing the reliance on *Aphidius colemani*.

Alternative options for insecticides and biopesticides need investigating for efficacy and their compatibility with IPM programmes. To date there has been relatively little work research investigating hyperparasitism, however, the literature review completed in this study highlighted the potential of a system in which the behaviour of hyperparasitoids may be manipulated. Additionally, the importance of physical barriers and pesticide application technology were highlighted as being key to the management of aphid pests of pepper crops. Assessing the potential of using screens over vents and doors to prevent sporadic invasion by large numbers of aphids would be another useful research angle, particularly to determine the cost-effectiveness of this approach.

Looking forward, solutions may come from breeding. Recent research at Wageningen University in the Netherlands has screened pepper accessions for resistance to *M. persicae* and found three aphid resistant pepper accessions which could produce aphid resistant pepper varieties in the future.

Leaf bacteria on our side

AHDB project code: **CP 120**
Term: October 2016 to September 2019
AHDBSTUDENTSHIP
Project leader: Robert Jackson, University of Reading
PhD student: Kristina Grenz

Some of the bacteria that live on leaf surfaces have potential to act as biocontrol agents, particularly against aphids and thrips. A previous AHDB studentship (project CP 082) tested 140 bacterial samples from a variety of plants and found ten to be promising against aphids. A strain of *Pseudomonas poae* (*P. poae*) shows particularly potent activity, causing a 70% reduction in aphid populations with no damage to the treated plants or non-target insects.

The project

This follow-up studentship aims to make the bacterium more efficient as a biological control agent using a process known as 'experimental evolution', in which appropriate traits are identified and selected for cultures. The process includes tests to check whether improvements come at no cost to other traits; for instance, a greater degree of toxicity to aphids may be at the expense of slower bacterial growth on the plant.

Student Kristina Grenz is looking to increase the level of aphid 'kill' caused by *P. poae* and reduce the time it takes for the bacterium to be effective. She also wants to improve bacterial colonisation on leaves and extend its persistence on the plant to minimise the number of applications needed, potentially achievable by encouraging *P. poae* to form biofilms.

If it is to be used successfully in an Integrated Pest Management (IPM) greenhouse setting, it is vital to understand the effects *P. poae* may have on natural enemies already employed against aphids. The next step of this project is to observe any negative impacts of *P. poae* on *Aphidius colemani, Orius laevigatus* and *Macrolophus pygmaeus*, all popular in combating aphids and thrips. Investigations are also underway into how the bacteria and its derived isolates affect the behaviour of aphids and how they colonise plants.

Results so far

So far most of the work has concentrated on *P. poae*'s ability to survive on leaves. Kristina has had some success in improving its ability to form biofilms colonies able to adhere to surfaces and start communities that can withstand environmental changes, allowing the bacteria to survive longer on the plant. One isolate in particular has proven extremely successful at forming strong biofilms. She has also been successful in improving *P. poae*'s ability to kill aphids, with some isolates now having a higher kill rate than wild type bacteria. However, trade offs have been seen between the two evolved lineages. Biofilm formers are significantly poorer at killing aphids, and less motile which may impact their ability to spread throughout a plant. Isolates selected for killing aphids are poor at forming biofilms but retain their motility and may have more potential as a biocontrol agent than the wild type *Pseudomonas poae*.

The seedborne identity

AHDB project code: **PE 024**
Term: September 2015 to August 2017
Project leader: Philip Jennings, FERA

Downy mildew in basil is a devastating disease caused by the plant pathogen *Peronospora belbahrii*. The disease was first reported on sweet basil (*Ocimum basilicum*) in the UK during the summer of 2010. Although new to the UK, the disease is endemic in many parts of Europe, North America, Africa, Asia and South America.

Zero tolerance from retailers to blemishes and the rapid spread of downy mildew under favourable conditions has led to complete loss of crops grown under glass and up to 80% losses in the field.

Typically, early symptoms start as a pale yellow, or yellow-white area (see image below). These initial symptoms can be easily missed as they resemble those caused by nutrient deficiencies, such as magnesium or nitrogen. Like other downy mildew pathogens, sporulation occurs almost exclusively on the underside of leaves showing the chlorotic symptom. Spores are produced during favourable weather conditions and are purplish grey to black in colour (see image on page 13). A prolonged period of overnight leaf wetness, whether caused by, condensation, rain or from irrigation is required for successful spore germination and infection. The spores produced on the underside of leaves will not survive unfavourable conditions for more than a couple of days.

Previous work on basil downy mildew has determined the conditions required for sporulation, however little work has been done to address the sources of infection, conditions required for infection or the most effective ways to control the disease. Project PE 024 set out to examine how the disease might spread by looking at whether the pathogen was seedborne, what alternate hosts existed, conditions required for infection and what were the most effective strategies to control the disease.

Typical early symptoms on basil leaves

Establishing whether the pathogen occurs in UK seed stocks would allow the industry to set in place measures to remove the source of infection. The measures taken would depend on whether the pathogen is truly seedborne (systemic) or existing as a contaminanton the seed surface. Basil downy mildew has been shown to be seedborne, with levels of infection as low as 0.02% (2 seed in 10,000) leading to visible infection of crops. However, it was unclear whether the pathogen was truly seedborne (systemic) or simply a contaminant (structures surviving on the outside of seed). Results from AHDB-funded project PE 024 suggested that the pathogen was systemic in seed with a high proportion of seed-lots tested contaminated with DNA of *P. belbahrii*. However, growing of plants from contaminated seed did not result in disease development. It is unclear whether the DNA detected in seed was non-viable due to seed treatments, such as heat treatment, or whether the contaminated seed were present at a rate lower than could be detected in the screen set up. Further investigation in a follow-on project, PE 024a, has shown that the presence of *P. belbahrii* DNA in seed can lead to viable infection of basil plants. The level of infection observed has been low and a correlation to the level of *P. belbahrii* DNA is currently being examined through screening of seed with different levels of *P. belbahrii* DNA.

Limiting spread

Spread through dispersal of spores is dependent on the presence of a susceptible host species. In addition to sweet basil, coleus (*Solenostomon scutellaroides*) and Agastache species (both belonging to the Lamiaceae family) have been reported as natural hosts for *P. belbahrii*. Alternate host studies carried out in project PE 024 looked at 14 plant species from across the Lamiaceae family and showed that lavender, common sage and catnip were also susceptible to infection by *P. belbahrii*. Profuse sporulation was observed on lavender, with little or no sporulation noted on common sage and catnip. All the alternate hosts identified were crops of one type or another, so growers should take care if growing these along with basil. The lack of weed crops as alternate hosts should make disease management easier as there appears to be no route for overwintering/ spread of *P. belbahrii* via weed species.

Infection experiments showed that spore production and infection of basil plants by *P. belbahrii* does not occur during daylight. This suggests that, where practicable, it would be advantageous to minimise the period of overnight darkness as much as possible.

Infection of basil by *P. belbahrii* occurs over a wide range of temperatures (between 5 and 25°C), with the optimum temperature for infection being between 15 and 25°C. High humidity and prolonged moisture on the leaf surface (greater than four hours) is also required for infection.

Sporulation on the underside of basil leaves

Use of fungicides

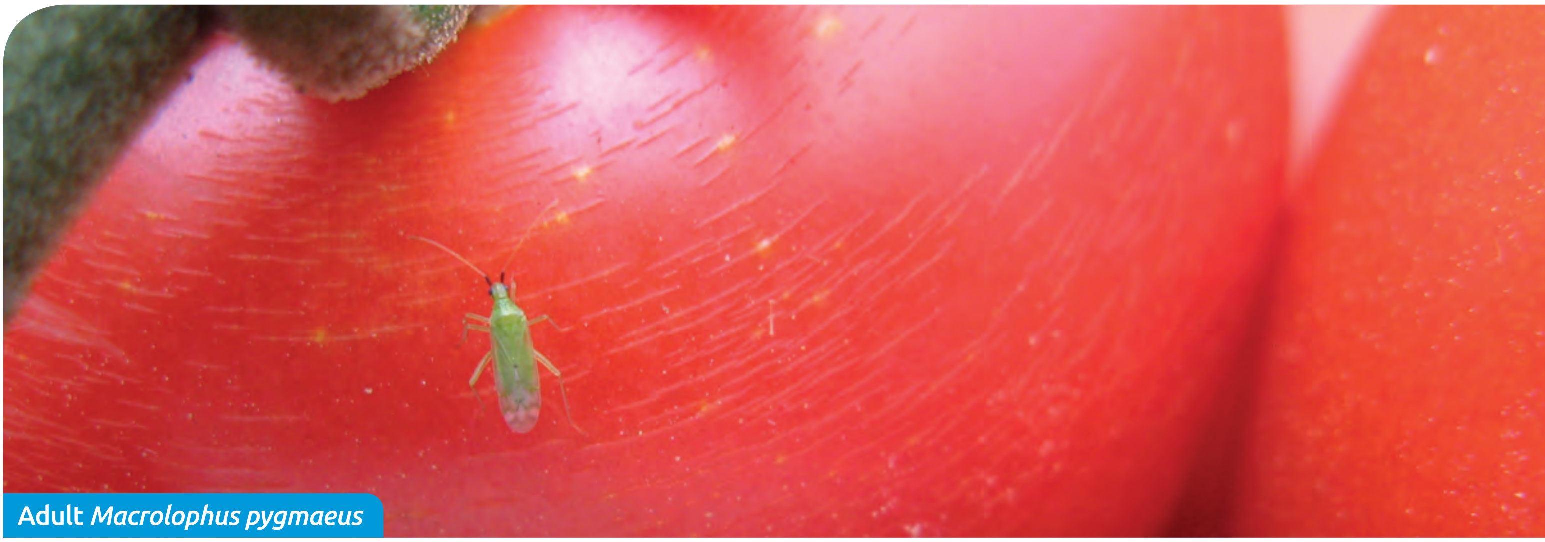
Fungicides do not have curative activity against downy mildew pathogens, so fungicides should only be applied as seed or protectant treatments. Several active ingredients, screened in project PE 024, were shown to provide good disease control in protected and outdoor crops (Table 1). A number of these products offered good protective activity when applied up to 10 days before infection and so could be used in a weekly fungicide programme to prevent the disease.

> "Where practicable, it would be advantageous to minimise the period of overnight darkness as much as possible"

Downy mildew pathogens are recognised as being prone to developing resistance to fungicides. Therefore, fungicides should be used in a planned resistance management strategy alternating different modes of action (as indicated by FRAC codes in Table 1) to reduce the chances of further resistance developing. It should be noted that resistance to metalaxyl-M has been reported in *P. belbahrii* isolates collected in the UK, so products containing this active ingredient may not provide control in all instances. The frequency of metalaxyl-M resistance in the UK basil downy mildew population is being investigated in project PE 024a. The dry summer of 2018 meant that only a limited number of isolates were sent for testing, however all the isolates sent were resistant to metalaxyl-M. This finding underlines that metalaxyl-M should not be used as a first line of defence against basil downy mildew.

Table 1: Fungicides shown to have activity against basil downy mildew in AHDB project PE 024 with UK approval for basil

Active ingredient	Example product	FRAC code	UK approval (November 2018)
metalaxyl-M + mancozeb	Fubol Gold	4 + M	Off label for outdoor and protected basil
mandipropamid	Revus	40	On label for outdoor and protected basil
dimethomorph	Paraat	40	Off label for outdoor and protected basil
fluopicolide + propamocarb HCl	Infinito	U + 28	Off label for outdoor basil
dimethomorph + mancozeb	Invader	40 + M	Off label for outdoor basil



Adult *Macrolophus pygmaeus*

Absoluta control package

AHDB project code: PE 028
Term: July 2015 to December 2015
Project leader: Rob Jacobson, Rob Jacobson Consulting

AHDB project code: PE 032
Term: April 2017 to December 2017
Project leader: Roly Holt, Pollards Nursery

AHDB project code: CP 162
Term: October 2016 to September 2019
AHDBSTUDENTSHIP
Project leader: Chris Bass, University of Exeter
PhD student: Charles Grant, University of Exeter

The South American leafminer *Tuta absoluta* has been causing concern for growers since its first sighting in the UK in 2009. AHDB have worked with the industry and funded a series of work to keep ahead of the pest. In the latest three projects Rob Jacobson, Roly Holt and Chris Bass look to strengthen the Integrated Pest Management (IPM) programme.

The projects

In 2015 project PE 028 investigated potential resistance to several chemicals in the IPM programme and investigated alternatives that could support the existing strategy. In 2017 project PE 032 considered a mating disruption pheromone. Further work evaluated the mortality effects of high volume sprays of three fungicides and one insecticide and a systemic application of an insecticide on three different 'strains' of Macrolophus (a released biological control) at different stages in its life cycle. Project CP 162 a PhD studentship at the University of Exeter is investigating the molecular basis of resistance in Tuta aiming to produce DNA based diagnostics that will give growers information on 'real time' population level resistance.

Results so far

In project PE 028 the bioassays confirmed that *T. absoluta* populations at two locations in the UK exhibited high levels of resistance to spinosad. It is hoped that level of resistance may decline over several generations if the selection pressure from spinosad applications is eliminated. None of the tested strains showed significant levels of resistance to chlorantraniliprole although resistance has been reported in southern Europe. It was therefore concluded it would be important to further investigate the potential of emamectin benzoate to provide an alternative to chlorantraniliprole in the UK.

Various alternatives options to spinosad are discussed but the most promising candidate was thought to be azadirachtin, with further research needed to determine its efficacy via the irrigation system and compatibility with other biological control agents.

In project PE 032 the mating disruption product, Isonet-T provided a very effective alternative to spinosad for slowing down *T. absoluta* population growth in the early season.

Evaluation of the high volume sprays (azadirachtin, fenpyrazamine, isopyrazam and penconazole) applied at their label rates found all the products caused a significantly higher mortality hazard than the water-treated control at some stage and all the products can have some adverse effects on Macrolophus survival. However, most of the significant effects represented less than 25% mortality of the insects being tested. Spinosad applied via the irrigation resulted in 'harmful' mortality of adult Macrolophus and 'moderately harmful' mortality of nymph strains. Project CP 162 has confirmed resistance to chemicals used in the IPM strategy and has determined the molecular basis for this resistance. Rapid DNA resistance tests are under development. The work will also monitor new mating disruption control products and to assess the ability for *T. absoluta* to reproduce asexually.

The full story to date on *T. absoluta* control can be found in AHDB project series PC 302, PE 020 and Factsheets 03/10 Tomato leafminers and 02/14 A robust IPM programme for *Tuta absoluta*.

Rapid disease testing

AHDB project code: **CP 137**
Term: November 2013 to May 2018
Project leader: Alison Wakeham, University of Worcester (moved to Warwickshire College Group May 2017)

AHDB project code: **CP 137a**
Term: September 2018 to August 2019
Project leader: Roy Kennedy, Warwickshire Colleges Group

In the airborne environment, many plant diseases are able to spread between cropping systems. By laboratory analysis or a field based lateral flow test, AHDB funded research has provided development of systems to monitor field inoculum (plant pathogenic spores) in bio-aerosols on a daily or weekly basis. By identifying inoculum in air samples, growers are able to time sprays more effectively and make informed decisions as to which type of fungicide application to make and the most appropriate timings.

The project

A laboratory test to monitor glasshouse air samples for *Mycosphaerella melonis* (Myco) spore presence has been developed. With knowledge of Myco inoculum, this project aimed to expand work carried out in project PE 001 and provide improved timing of fungicides to increase their efficacy. Diagnostic probes into the two species found in the UK (*Podosphaera xanthii* and *Golovinomyces orontii*) have also been developed for use within an integrated disease management system for the effective control of powdery mildew on cucumber.

Mycosphaerella leaf infection

Results

Air samplers have been used to monitor glasshouse air samples for spores which spread Myco and cucumber powdery mildew. Laboratory and a 10 minute on-site test (making use of a lateral flow device – LFD) for analysing air samples have been used to estimate low, moderate and high risk warnings of Myco inoculum in air samples.

Time between infection and disease symptoms can be as short as two weeks. A suggested control regime for each risk level has been compiled to help growers make decisions on how to manage spore levels and this is detailed in the 2016 annual report.

During 2017, further development of a rapid test for cucumber powdery mildew was successfully completed but the sensitivity of the test was poor. Only samples where in excess of 1000 – 5000, powdery mildew spores were detectable as positive results. The sensitivity of the LFD device needs to be improved if better results are to be obtained. Alternatively, another form of spore trap may be better for spore collection and retention.

It was decided to focus on improving the LFD test for Myco, which had been the main consideration in the first two years of the project. A new piece of work – project CP 137a will develop antibodies for use in the test which have improved stability for detection of Myco. The project team are working with a commercial partner, Mologic Ltd, to bring an LFD product to market for cucumber growers.

Looking to automation to lower labour

Many horticultural systems are labour intensive, particularly at peak times of the year such as planting or harvesting. The protected sector tends to have a more consistent labour requirement as some crops need considerable husbandry during the season and harvest can stretch for months, or harvest can be on a shorter than annual cycle such as mushroom production. Although pressure for numbers of staff may not be as intense as soft fruit or field vegetable production there is always the need for reliable, good quality, seasonal workers.

Growers in the Protected Edibles and Mushrooms (PEM) sector have reported problems with labour issues such as recruitment (not able to find staff to employ or staff failing to arrive), quality (lower skills, an older demographic, poor performance) and retention (lower than previous levels of returnees, staff not finishing the season contract). Many growers have voiced concerns as to how future labour demands will be met. The issue has been prioritised by the industry and while there is heated discussion in the political arena, AHDB is looking at practical solutions to the problem.

The SmartHort campaign, has been initiated to help. It has two clear strands; to make sure the industry is resilient to labour challenges, by improving management practices for the existing workforce, and to identify new technologies and innovation, such as automation, robotics or artificial intelligence, which could play a role in providing longer-term solutions.

The protected sector is well placed to benefit from automation advances, as the more controlled cropping environment is arguably more inviting for researchers and innovators to work with. There are many technological advances in development globally for the sector and some of which are starting to appear on the market.

Harvesting has been identified as a priority area for automation and several researchers and companies are working on salad/herb picking. A few examples being: an EU funded project 'SWEEPER' and a project led by Queensland University of Technology have developed prototype sweet pepper harvesters, Panasonic introduced a prototype tomato harvester last year at Tokyo's International Robot Exhibition and two American companies are also developing prototype machines, Root AI and Four Growers. Israeli company Metiomotion have developed GRoW (Greenhouse Robotic Worker), its first use has been in selective robotic harvesting of greenhouse tomatoes. Danish company OnRobot have developed 'cobot' grippers that are being used to help staff harvest herbs.

"There are many technological advances in development globally for the sector and some of which are starting to appear on the market"

AHDB is involved in work to underpin the science of such technologies, for example, two PhD projects (CP 170 and CP 172) which are summarised on the next page. These automation projects combine practical robotic engineering with cutting-edge 'Deep Learning' artificial intelligence vision systems with genuine commercial viability. Through the SmartHort campaign, AHDB will be offering growers the opportunity to participate in study tours to view automation and robotics in action, so look out for details in the monthly email.

Imaging strawberries with a UV camera

Can insects help with harvesting?

AHDB project code: **CP 170**
Term: August 2017 to July 2020
AHDBSTUDENTSHIP
Project leader: Michael Mangan, University of Exeter
PhD student: Zeke Hobbs, University of Sheffield

Automation of labour intensive horticultural processes such as fruit and flower harvesting is considered critical to securing the long-term future of the agri- and horticulture industries in the UK, yet technological challenges remain. This work addresses the crucial, and relatively poorly resolved problem of using cameras and vision systems to perceive fruits and flowers in challenging outdoor environments. It should provide novel bioinspired approaches which will underpin the vision systems that drive robotic harvesting systems. Inspiration will be taken from insects (e.g. bees, fruit-flies and aphids) that use visual cues invisible to humans (e.g. ultra-violet and polarised light) and thus potentially overlooked by engineers.

> “Harvesting has been identified as a priority area for automation”

Using a specially developed camera mimicking the vision system of insects, a novel image database of key fruit and flower produce at various stages of their growth and health across weather, lighting, and housing conditions will be collected. This work will apply the same biorobotic methodologies that have been successfully used in prior work, for example, long-range navigation in insects visually locating fruit in complex and dynamic environments. It is hoped the work will aid in the design of novel sensors for robotic harvesters and the development of greenhouse spectral filters which disrupt insect vision.

Discovering the robotic touch

AHDB project code: **CP 172**
Term: October 2017 to September 2020
AHDBSTUDENTSHIP
Project leader: Fumiya Iida, University of Cambridge
PhD student: Luca Scimeca

With robotics technology becoming ever more sophisticated as a result of the advances in a range of industries, and costs falling, automated harvesting is now a fast-moving area of research in horticulture. There are clear advantages for field vegetables, some of which are still largely harvested by hand, particularly with the current uncertainty surrounding access to enough workers in the future. But the delicate nature of some crops, the market demands for blemish-free produce and the element of decision-making involved makes it especially challenging. The University of Cambridge’s Biologically Inspired Robotics Laboratory, where this studentship is based, focuses particularly on robotics that take lead from studies on animal biology. The laboratory’s team has already designed a robotic arm equipped with artificial hands and various sensors, such as cameras, laser range-finders and tactile sensing devices, which can pick up and set down ‘soft’ objects and has undergone initial trials on lettuce crops at G’s Growers. This new project will see the equipment, mounted on a mobile pedestal, further developed and modified to include data-processing so that the robot can ‘learn’ – adjusting to variation in the size of lettuce head and adapting to different environmental conditions. The scope of the investigation includes analysing other stages in the handling of the harvested product – such as inspection, trimming, overwrapping and packing – to see whether a robotic solution would be feasible. The platform will be tested further in the field on lettuce types which differ in their shape and size, such as Iceberg and Little Gem, but trials may also be extended to other vegetables, such as celery.

Smart ideas

With rising labour costs and a reduction in numbers of seasonal workers in the UK, Grace Emeny explains what AHDB are doing to help address the labour challenge in your business

While crop protection research remains at the heart of our activity at AHDB, we understand from talking to growers that access to affordable labour has become one of the biggest concerns for nearly all horticultural businesses.

Estimates put the latest season shortfall of staff in horticulture at 15 to 17%. The NFU labour provider survey revealed there was a 29% shortfall in seasonal labour in September 2017, and levels were expected to dip as low in 2018 too.

With around 70% of the UK's horticultural workforce coming from Romania or Bulgaria, and only one in every thousand seasonal workers coming from the UK, the need for access to seasonal labour from overseas is evident.

> "We've launched the SmartHort campaign to make sure the industry is resilient to labour challenges"

Speaking exclusively in the August 2018 issue of ***The Grower***, Farming Minister, George Eustice, said he was confident that a new policy would be brought in once the transition period from leaving the European Union had ended in 2020.

Even if the government agree a permanent seasonal agricultural worker scheme, following the two year pilot scheme announced, there is still a need for our industry to think about long-term sustainable and affordable labour solutions to protect productivity and profitability.

We have therefore launched the SmartHort campaign to make sure the industry is resilient to labour challenges, from rising wage costs, to difficulties in recruiting and retaining staff. The campaign has two clear strands; to look at improving management practices for the existing workforce and to identify new technologies and innovation, such as robotics and automation, which could play a role in providing longer term solutions.

Smart labour management

Through workshops, case studies, videos and publications we will be sharing the principles and benefits of introducing management techniques such as Lean, Champion and Continuous Improvement.

We believe these can make a difference to businesses of all shapes and sizes to improve labour efficiency, and can apply throughout the production system from picking to packing. Importantly, we want to help businesses to be confident that they are getting the best out of the workers that they have.

MPL, a specialist Lean consultancy, visited six diverse businesses at the start of the project and identified clear commonalities for areas of improvement and we are using this knowledge to build the activity within the campaign. For instance, we noticed there was very limited investment in management training for supervisors,

so through our skills and education team at AHDB, we've launched a series of supervisor training courses.

Eight Labour Efficiency workshops which ran around the UK to introduce the concepts of Lean, Continuous Improvement and Champion proved extremely popular with growers. Due to high demand, more workshops designed to help you get the most from your workforce will be taking place again this year. We are also developing three strategic labour efficiency sites, where you will have the chance to follow the progress of horticultural businesses with the input of an experienced management and business improvement consultant.

Smart technology

Over 84% of horticultural growers plan to invest in automation or robotics to help off-set labour challenges, according to a survey conducted by AHDB in 2017.

As part of the SmartHort programme we will be seeking to help identify and assess the value of different kinds of smart technology available, both in the UK and overseas. This could be to directly off-set labour with automating repetitive tasks, or to bring big data to the production system to help improve productivity by off-setting waste or reducing yield loss.

Last summer, 20 growers joined us for a study tour to The Netherlands to look at new developments in automation and robotics. While specifically looking at new technologies for glasshouse crops, the advancements seen will likely lead to new solutions and innovation for field crops too.

Deep learning, a type of machine learning, was a key trend and has significant potential to play a role in horticultural production, including improving pest and disease detection and monitoring. Deep learning, put simply, is a systems ability to learn to recognise patterns in digital data, such as an object within an image, by teaching itself to learn what the data means. Google search algorithms use this technology to learn to recognise say, a cat, within images, without having to be 'told' there is a cat in every single image online.

Wageningen University and Research (WUR) have used this technology to develop a system that can detect disease in seed potatoes out in the field before symptoms are visible to the human eye.

Images are taken by a hyperspectral camera, and a classifier is built in that can learn to distinguish between stem and leaf disorders.

WUR have also used deep learning to develop smart yellow sticky traps that can learn to detect and count automatically any white fly and beneficial insects caught.

> "Each business will have the opportunity to leave with a tailored plan to implement efficiency savings"

One of the key lessons from the study tour was that while there have been huge leaps in the development of automation, realistically this is still a long way from commercial reality to have any impact in the short-term on labour shortages. Instead, what we're seeing is partial mechanisation, using robotics and automation to support the more complex horticultural tasks such as harvesting. For example, automated trolleys are already working commercially in glasshouses, taking harvested products to the packhouse, alleviating the labour used to transport goods so they can focus on picking produce.

We'll be exploring the future of automation and robotics at SmartHort 2019, a free two-day conference dedicated to driving innovation into horticulture. Guest speakers from around the world will be sharing some of the most impressive and exciting technological developments that could change the way you grow.

It is also an opportunity to discover the latest high-tech advancements, meet the people behind the innovation and find out how to invest in the technology that could make a positive impact in your business.

The SmartHort 2019 Conference is now fully booked, but you can watch the live stream and ask questions to our expert speakers by registering at **ahdb.org.uk/smarthort**

To find out more about the SmartHort campaign and how it could help your business, contact **gracie.emeny@ahdb.org.uk**

Resource Management

In terms of resource management, many of you will have heard of GrowSave, which has been helping the cropping industry take energy saving actions in their businesses for the last 10 years.

What you may not realise is that AHDB has a resource management team that works across all sectors in AHDB. Members of the team come from the crop sectors (potatoes, cereals and horticulture), but have also branched out into grassland, working with the livestock sectors. The resource management team is a one-stop shop for specialists on water, soils, nutrition, growing media, the agri-environment and precision farming (related to labour issues as well).

A lot of the research that we are doing now will help the industry answer the challenges presented in Defra's 25-year environment plan. It is essential that our research is leading the way to new developments useful to industry.

Opposite is a selection of the work the team is involved in, relevant to the Protected Edibles and Mushroom (PEM) sector **(fertinnowa.com)**.

Water

Despite the PEM sector being generally better prepared than other sectors regarding water storage, the prolonged dry period has highlighted areas for improvement concerning water security. As well as producing guidance documents for water management for crops such as potatoes, we are currently involved in FERTINNOWA, an EU project on sustainable water and nutrient use in fertigated crops. You can download the free ***Fertigation Bible*** for a comprehensive look at technologies to make fertigation more efficient.

Soil

This year we published a guide ***Soil Management for Horticulture***. It contains information on targeted agronomy, managing crop variability and using data from sensors.

AHDB's GREATsoils programme is intended to support growers to assess and manage the health of their greatest asset. As part of this, a factsheet on ***Short-term green manures for intensively cultivated horticultural soils*** has been produced, which is useful for those of you growing high value salad rotations **(ahdb.org.uk/greatsoils)**.

Growing media

When pressure from the government started to mount for the horticultural sector to phase out peat use by 2030, AHDB and Defra commissioned a 5-year project to transition to sustainably sourced growing media materials. The main aim of the project was to build a predictive model to help growing media manufacturers introduce alternative materials into the market. The model is generally successful, but requires tweaks for practical agronomic use. This work sits alongside the monitoring work AHDB and the HTA has done on peat use, and work carried out by the Growing Media Task Force.

Crop nutrition

The Crop Nutrient Management Guide (formerly RB209), will be updated over the next five years, with nutrient information on protected ornamental crops, particularly information regarding fertigation.

Precision agriculture

We have a programme of work aimed at bringing the benefits of precision agriculture to growers by using technology to increase efficiency and reduce waste through continuous marginal improvements. Precision agriculture has an important role to play in improving labour productivity and efficiency, and we are funding robotics research to develop sensing and handling technology to find and manipulate crops and to automate repetitive tasks. We have also created SmartHort, a hub of information about the contributions technology and improved efficiency it can make to horticulture. This will also be the theme of a two-day AHDB conference in March 2019.

As always, we are keen to deliver for our levy payers, so if there is a gap that you feel the resource management team could help with, please tell us about your ideas.

GrowSave tops 1000 participants

Energy management has always been an important element of growing under protection. In a constantly changing arena growers are keen to keep up with the latest technology developments and advancements that can help them improve energy efficiency.

There is also the legislative side to comply with, the complex energy markets to understand, and how to make the most of government schemes and incentives for individual businesses.

Since 2007, the GrowSave programme, operated by FEC Energy, has been fulfilling this role for growers, keeping them updated through a variety of communication channels **(growsave.co.uk)**.

The work has been steered by industry representatives from edible and ornamental nurseries, to meet changing needs and develop the most effective way of getting the messages out.

Communicating with growers

The website has been developed as a one-stop shop for all things energy related and continues to be updated with energy and climate data, event notes, research information, technical updates, news and blogs. The important energy topics of the day are covered in ***Energy News***, a supplement to AHDB ***The Grower*** magazine three times a year. Energy snippets have been included in a GrowSave column in each issue of the magazine. There have also been overseas study tours to Canada, Belgium and The Netherlands. The most recent workshops have included air movement and humidity control.

Over the years GrowSave has attracted many growers to get involved, and some have returned year on year to ensure they are up to speed with the latest thinking. During the course of the project over 1,000 attendees have taken part in meetings and events. The project's projects online and social media visibility has been boosted via a dedicated twitter account. Videos of events are now being published in full online giving growers unable to make events the ability to catch up in their own time. The current contract with FEC Energy runs until August 2019 and in the remaining time more video and animated presentation content will be developed.

The future

Over the last 12 months, GrowSave has engaged with a trial study group investigating the techniques of Next Generation Growing, a Dutch energy saving initiative. The lessons learned from this will be shared with the wider horticultural community and the team will be keeping an eye on future developments in this area.

GrowSave project leader Ed Hardy predicts the future of horticulture, like many other industries, is likely to include developments in new technologies and an increase in automation. With wireless sensors becoming more popular, due in part to their versatile nature, data collection is easier than ever. With more data comes the possibility of better insight into existing practices through intelligent analysis and interpretation. Automation and reduced reliance on a human workforce could be invaluable to the horticulture industry, especially considering the uncertainty surrounding the labour market and Brexit.

The trend for increasing fossil fuel prices looks set to continue, so reducing reliance on fossil fuels would make financial sense – achieving this is often easier said than done. One possibility is the adoption of Next Generation Growing techniques, pioneered by Dutch growers over the last decade.

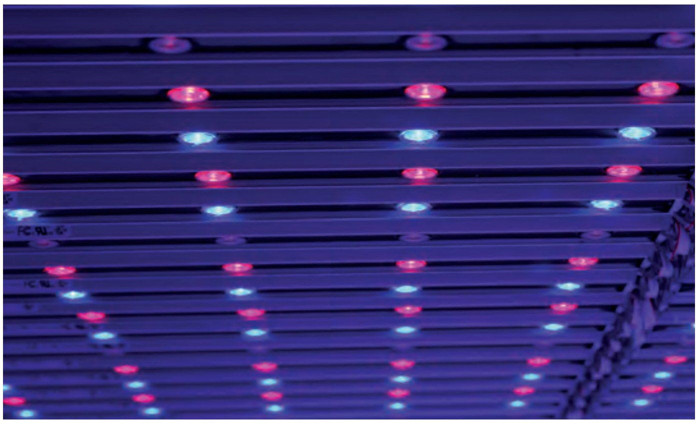
“The trend for increasing fossil fuel prices looks set to continue”

Another option is to use renewable sources. The popularity of the Renewable Heat Incentive scheme has meant significant uptake of renewables in recent years, and has led to a reduction in the costs of these systems. Battery technology has also moved on and become more affordable. Aside from the financial incentive to move towards more sustainable sources of energy, it is likely that legislation will be a strong driving force when it comes to imposing change.

Project round-ups

AHDB project code: CP 085 Securing skills and expertise in crop light responses
Term: October 2012 to September 2017
Project leader: Martin McPherson, Stockbridge Technology Centre
Fellowship researcher: Phillip Davis

This horticultural fellowship explored the impact of different ratios of red/blue and red/far-red light on a range of crops, ultimately focusing on the economic implications of advances in the energy efficiency of LED lighting. In the final year, a model was designed and used to simulate the effects of different lighting strategies on crop production costs. The maximum theoretical LED efficacy for all colours of light was calculated, growers are now able to input their own lighting requirements and calculate the economics implications; these calculators are available on the GrowSave website.



AHDB project code: CP 125 Understanding crop and pest responses to LED lighting to maximise crop quality and reduce PGR use
Term: April 2014 to March 2017
Project leader: Phillip Davis, Stockbridge Technology Centre

This project looked at how LEDs can be used to manage aspects of crop growth and quality, and how insect pest monitoring is affected by different light wavelengths. All the protected edibles species tested were sensitive to changes in light quality, but a balance needed to be found to maximise growth rate and optimise morphology. A model has been developed to help growers select the appropriate LED lights for specific crop applications.

The colour of sticky traps used for insect pest monitoring changes under different light wavelengths. A range of colours were tested to investigate the behaviour of aphids, two-spotted spider mites and biocontrol agents on various crops grown under different light treatments. Pests appeared to do less well under the LED light regimes used in the trials, but light quality was also found to influence the effectiveness of biocontrol agents.

AHDB project code: CP 164 SPECTRA: Whole plant spectral response models
Term: July 2016 to June 2019

AHDBSTUDENTSHIP

Project leader: Simon Pearson, University of Lincoln
PhD Student: Gulce Onbasili

PhD Student Gulce Onbasili is investigating whole plant responses to light quality. Trials began looking at lettuce growth under different LED lighting boards in the first year and experimentation is ongoing. She will eventually use data derived from project CP 125 to validate a model that can predict different plant responses to light.

> “A model has been developed to help growers select the appropriate LED lights for specific crop applications”

AHDB project code: CP 105 Integrated protection of crops through enhancing endogenous defence mechanisms
Term: October 2014 to September 2017

AHDBSTUDENTSHIP

Project leader: Adrian Newton, James Hutton Institute
PhD Student: Daniel De Vega Pérez

The project aimed to identify compounds, known as resistance elicitors, which if primed and expressed in a focused, specifically targeted way, can stimulate plants to elicit a naturally occurring defence response to help improve crop protection.

For this project, PhD student Daniel De Vega Pérez concentrated on a single plant-pathogen system: *Botrytis cinerea* on tomato plantlets, testing a range of treatment types and regimes. One of the main findings has been that elicitors can protect tomatoes, aubergines and thale cress against *B. cinerea* in a concentration-dependent manner.

Understanding the trade-off between the value of 'primed' plant defences and the costs in terms of potential lost yield will be crucial in learning how to best use elicitors cost-effectively.

AHDB project code: CP 117 Investigating the cause and potential treatment of coriander yield decline
Term: October 2014 to September 2017

AHDBSTUDENTSHIP

Project leader: Ian Singleton, Newcastle University
Student: Kate Fraser

This project aimed to determine the cause of coriander yield decline (CYD) by combining microbiology and plant sciences expertise. Having established a yield decline effect using a variety of soil types in greenhouse conditions, MPhil student Kate Fraser used a range of approaches to assess coriander plants and soil. She focused on the Illumina Next Generation Sequencing (NGS) technique to investigate soil microbial communities. Results indicated that coriander cropping leads to a change in the soil microbial community composition, but no single bacterial species could be implicated in yield decline. The phenomenon may result from a change to the overall function of the microbial community present. This suggests that practices such as tilling after coriander growth, or adding soil amendments could help to alleviate decline by 'resetting' the soil communities to change their overall function.

> "Coriander cropping leads to a change in the soil microbial community composition"

AHDB project code: CP 117a Coriander: Potential management options for yield decline
Term: March 2017 to July 2018

AHDBSTUDENTSHIP

Project leader: Ian Singleton, Edinburgh Napier University
Student: Amanda Jones

Project CP117 was taken forward by MRes student Amanda Jones in project CP117a, where she examined potential soil management strategies that could change the soil microbial community. Through a series of glasshouse experiments, the study showed that management practices which indirectly altered soil microbial communities, with a harrowing technique, impacted the severity of CYD, but were not effective in preventing it. Sterilisation and drying of crop soils effectively treated CYD in two different cropping systems. Results of the soil microbial community studies give further evidence to suggest a fungal cause in the problem, particularly in the case of CYD in a grower's field soil.

AHDB project code: CP 136 Development of Oomycete LFDs
Term: June 2015 to June 2018
Project leader: Tim Pettitt, University of Worcester

Test kits based on lateral flow devices that can identify the presence of a phytophthora or pythium in a sample are available. However, they are unable to identify which species are present, whether they are alive and can sometimes produce a 'false positive' result. This project involved developing new antibodies for individual species or closely related groups of phytophthora or pythium pathogens, and working on a test kit to show if the pathogens are viable. This is useful in monitoring the effectiveness of treatment systems for nursery irrigation water. It also involves developing a rapid clinic-based test that would enable simultaneous diagnosis for a number of different oomycete pathogens in a single sample at the same time.

AHDB project code: CP 138 Transition to responsibly sourced growing media
Term: January 2015 to December 2019
Project leader: Barry Mulholland, RSK ADAS Ltd, Quadram Institute Bioscience and Stockbridge Technology Centre

This project aims to provide a mechanism for the UK Horticulture industry to ease the transition from a dependence on peat, by evaluating responsibly sourced growing media blends as economically viable alternatives to peat in commercial crop production systems. The project will provide a science based quantitative tool for growing media formulation, which will increase the confidence of commercial growers in these alternatives and facilitate their uptake. So far, the prototype blends performed well on commercial nurseries, and generally crops were as good as the nursery standard, but with variability between crops. Trials are beginning to show the choice of growing media blends are likely to be crop specific. By taking a set of materials with a certain set of physical properties similar to those of peat, it is possible to grow plants in a range of crop sectors, and produce high quality plants

AHDB project code: CP 140 Optimising the use of biocontrol agents to improve the control of *Botrytis cinerea*
Term: October 2015 to September 2018

AHDBSTUDENTSHIP

Project leader: Xiangming Xu, East Malling Research/University of Worcester
PhD Student: Gurkan Tut

This study obtained ecological knowledge on biocontrol agents (BCAs) available in the UK and used this to develop strategies for applying BCAs to improve efficacy against *Botrytis cinerea* (*B. cinerea*) on lettuce and strawberry crops. Specific concentrations of BCAs are required to eliminate or supress pathogens, so it is important to be able to measure how much viable biocontrol organism is present on the crop. This study has characterised the dose response curves of *B. cinerea* to Serenade ASO and PreStop on lettuce leaves.

Data is currently being analysed to provide growers with information on optimising the application of Serenade and PreStop for better control of *B. cinerea*.

> "Specific concentrations of BCAs are required to eliminate or supress pathogens"

AHDB project code: CP 143 Increasing crop yield and resource use efficiency via root-zone CO_2 enrichment
Term: October 2015 to September 2018
AHDBSTUDENTSHIP
Project leader: Ian Dodd, Lancaster University
PhD Student: Estibaliz Leibar-Porcel

This PhD studentship is investigating whether local introduction of CO_2 to the plants root-zone in soilless culture systems could provide a viable alternative to conventional aerial CO_2 enrichment. In the first set of experiments, Estibaliz Leibar-Porcel has shown that applying 1500 ppm root-zone CO_2 to aeroponically grown lettuce plants stimulated growth by 20% in comparison to crops grown at ambient root-zone CO_2 (400 ppm), when trialled in the glasshouse and controlled environment rooms. Releasing CO_2 by adding bicarbonate (1-5 mM) to hydroponic solutions increased shoot growth of lettuce and pepper by 10-20%. She is now investigating the mechanisms of growth regulation.

AHDB project code: M 063 Identification, detection and control of Pseudomonas species causing bacterial blotch
Term: May 2015 to April 2018
Project leader: John Elphinstone, Fera Science

This project was devised to ensure that the full diversity of *Pseudomonas* species, currently causing significant losses to the UK mushroom industry, is known and can be detected and controlled early to avoid potential losses and maximise yield. Characterisation of the bacterium by whole genome analysis has enabled development and confirmed the specificity of a molecular test for detection of '*P. gingeri*' and a previous test developed for *P. tolaasii*, the cause of severe brown blotch. Irrigation of mushrooms with 0.3% w/w $CaCl_2$ solution reduced the incidence of blotched mushrooms under commercial conditions. Sodium chloride now has an approval in the basic substance programme.

AHDB project code: PC 281b Microorganisms in the irrigation water of hydroponic crops grown in closed systems
Term: October 2014 to March 2016
Project leaders: Tim O'Neill, ADAS and Matt Dickinson, University of Nottingham

Root pathogens of tomato are widespread, potentially devastating and difficult to diagnose. Project PC 281a found that a relatively stable microbial population was present on roots from planting, and microbial diversity on roots was greater in closed systems. Project PC 281b aimed to use two diagnostic techniques to characterise and quantify microorganism populations in irrigation water, and assess the risk of root disease when tomato crops are grown in closed irrigation systems with recirculation of the nutrient solution.

It was found that microorganism species richness increased in irrigation water as crops aged, and the abundance of common tomato pathogens increased. Disinfection treatment lowered species richness and removed a variety of common pathogens, with the full slow sand filter, and UV the most effective treatments. The conditions necessary for root-infecting pathogens to cause severe root disease remain poorly understood, between crop hygiene and water treatment should be maintained as precautionary measures.

AHDB project code: PE 021a Optimised CO_2 enrichment management for long-season tomato production
Term: May 2017 to March 2018
Project leader: Ewan Gage, ADAS

The project was established to address the potential for LED supplementary lighting to drive increased CO_2 use efficiency in a commercial tomato crop. CO_2 uptake and use in the canopy layers of a crop grown with supplementary interlighting in lower canopy were measured for comparison with a conventionally-grown crop. This lighting had a significant effect on the lower canopy, with lower leaves of the interlit crop showing significant increases in response to light and CO_2, allowing leaves in the lower canopy to be more productive for longer. This project demonstrated the potential for supplementary lighting to enhance CO_2 offtake and yield output by the crop by driving photosynthesis in the lower canopy.

AHDB project code: PE 022a Pepper: Improved control of Fusarium internal fruit rot
Term: July 2015 to March 2017
Project leaders: Tim O'Neill, Sarah Mayne, Dave Kaye, ADAS

Internal fruit rot of sweet pepper has been an increasing problem worldwide, causing some losses on production nurseries and a frequent cause of rejection by packhouses and product returns from supermarkets. This project investigated and found that pepper seeds can be a source of *F. lactis* and *F. oxysporum* leading to growth of the fungi on rockwool propagation cubes. They have also investigated the impact on fruit infection provided by several applications of Serenade ASO and the effect of biopesticides/plant resistance inducers on flowers and fruit. Conversations with Dutch researchers have revealed that assessing risk of fruit rot through measurement of Fusarium spore levels is of interest to their growers, and the effect of glasshouse climate change strategy on incidence of Fusarium fruit rot is also being considered.

AHDB project code: PE 025 Development and deployment of genotype-specific LAMP assays for monitoring Pepino mosaic virus (PepMV) in tomato
Term: September 2014 to August 2017
Project leaders: Tim O' Neill, Sarah Mayne, ADAS

The aim of this project was to establish rapid on-site testing of tomato plants for three different strains of Pepino mosaic virus (PepMV) and to increase understanding of PepMV symptom severity and persistence on nurseries. A new strain-specific molecular test was produced to identify the three major strains. All three strains were found to be present in the UK with mixed strain infections in some UK tomato crops. General best practice clean-up methods are effective to prevent reinfection, but some viable PepMV can persist from year to year, so care should be taken to avoid introduction of additional strains of PepMV. It was found that irrigation water can be a source of PepMV but that pasteurisation was able to remove the virus at two sites monitored.

AHDB project code: PE 023 Hormetic UVC Treatments for Control of Plant Diseases
Term: July 2015 to September 2016

AHDBSTUDENTSHIP

Project leader: Gilbert Shama, Loughborough University
PhD student: George Scott

Hormesis is a dose-response phenomenon where low doses of a stressor bring about a range of positive responses in the organism undergoing treatment. This project investigated whether high-intensity, pulsed polychromatic light (HIPPL) sources were able to delay colour and texture changes during ripening and induce resistance against *Botrytis cinerea* on mature green tomato. Treatments using both HIPPL and low-intensity UV-C (LIUV) sources were also conducted to assess their ability to induce disease resistance against *B. cinerea* and *Penicillium expansum* on red-ripe fruit. The HIPPL source was shown to successfully induce resistance and delay ripening on cv. Mecano, with a 16-pulse treatment giving comparable levels of disease resistance and delayed ripening to the established LIUV treatment. The use of HIPPL reduced treatment time by 97.3% to 10 seconds.

AHDB project code: PE 026 A study to review the scientific literature on the environmental risks of releasing non-native species of bumblebee (*Bombus terrestris*) for crop pollination
Term: April 2015 to October 2015
Project leader: Dave Chandler, Warwick University

AHDB project code: PE 031 Tomato: An investigation into poor pollination performance by the native bumblebee, *Bombus terretris audax*
Term: April 2017 to October 2017
Project leader: Philip Pearson, TGA Technical Committee

AHDB project code: PE 031a Phase 2 of an investigation into poor pollination performance
Term: January 2018 to December 2019
Project leader: Philip Pearson, TGA Technical Committee

Permission to use non-native bumblebees in unscreened glasshouses was withdrawn at the end of 2014. AHDB and the tomato industry responded by commissioning a review of non-native species release risks (project PE 026) and have followed up with two projects, project PE 031 and project PE 031a, investigating the poor pollination performance encountered by growers using the native bumblebee *Bombus terretris audax* (Bta). Project PE 031 summarised the experiences and opinions of growers. The general belief is that Bta are less vigorous than the previously used non-native sub-species and more likely to fail to provide adequate pollination should conditions be sub-optimal for their performance. These results produced many questions so a follow-up project, PE 031a, is investigating some of the issues concerning growers including; Bta biology and behaviour, Bta colony life and the influence of environmental conditions on flower quality and pollen flow in the small fruiting cultivars.

AHDB project code: PE 029 Tomato: Evaluation of biological treatments, biocides and an improved diagnostic for control of root mat disease
Term: January 2016 to December 2018
Project leader: Dave Kaye, ADAS

Root mat disease of tomato is caused by strains of *Rhizobium radiobacter* carrying a root-inducing (Ri) plasmid. This project aimed to identify effective ways to diagnose the presence of root mat disease, before severe infections can occur, and to test biological approaches to managing the disease. The efficacy of several commonly used biocides at crop turn-around were also investigated to identify the most effective products available to growers. Carbon Gold (an insoluble biochar based product containing beneficial microorganisms) performed well in the 2016 and 2017 trials and gave the best control, followed by a mixture of Serenade ASO and Trianum P.

The efficacy of four biocides were compared in laboratory conditions. Chlorine-based biocides were found to be significantly more effective than hydrogen peroxide-based biocides at killing *R. radiobacter* at the concentrations and exposure times tested.

AHDB project code: PE 030 Tomato leaf mould: occurrence, disease management and potential for improved control
Term: April 2016 to March 2017
Project leader: Dave Kaye, ADAS

Tomato leaf mould caused by *Passalora fulva* is a destructive foliar disease. The incidence and severity of tomato leaf mould in the UK is variable. This project aimed to document disease management practices currently used against *P. fulva* and propose changes to improve control. Amistar, continues to be the industry standard and provides good control. The combination of a fast life-cycle and rapid mutation rate makes the development of resistance of *P. fulva* to fungicides a serious concern. It is critical that any disease management strategies incorporate cultural practices alongside fungicide use, including using different fungicide groups to minimise the risk of selecting for fungicide resistant strains. Growers successfully manage the disease by a combination of measures; plant protection products, humidity control, hygiene, de-leafing hard, rotation and floor coverings.

AHDB project code: FV/PE 455 Eliciting the phytochemical basis of flavour to recommend agronomic practice for improved and consistent characteristics
Term: October 2017 to September 2021
Project leader: Carol Wagstaff, University of Reading

Herb flavour is highly variable in composition and intensity according to differences in cultivar, agronomic practice, climate and growing season. This project will identify the extent of flavour variation in three commercially important herbs. This project hopes to enable growers to tailor their cultivation practices to optimise herb flavour in their growing system, whether this is in a protected or an open field environment, towards a flavour that is desirable and liked by consumers. Flavour analysis will be done using Gas Chromatography-Mass Spectometry. Knowledge exchange is planned such that growers will be trained how to qualitatively and quantitatively assess herb flavours using sensory panel assessment.

Photography

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Produced for you by:

AHDB Horticulture
Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

T 024 7669 2051
E comms@ahdb.org.uk
W horticulture.ahdb.org.uk
@AHDB_Hort