NIAB

Fruit

Annual Review 2024

Mario Caccamo, Chief Executive Officer, NIAB

Welcome to the NIAB Fruit Annual Review 2024

The first of these Review magazines was published in 2023 and it was well received by the fruit industry, providing an annual portfolio of our ongoing fruit research projects, in short summary format. The 2024 Annual Review provides updates as well as information on all the new fruit research that has started in the past year. One new project on apple pest and disease control is being funded by The British Apple and Pear Ltd Technical Committee, which started to fund research projects directly for the first time in 2023.

Both the changing climate in the UK and the continuing loss of crop protection products is a recurring theme throughout our work. The precision irrigation and fertigation research we do at The WET Centre, Plum Demonstration Centre and in our new glasshouse and growth room facilities, seeks to use resources more responsibly whilst also investigating how fruit plants respond to higher temperatures. We have also been exploring ways of managing soil health and nutrition in vineyards using crop covers, whilst much of our crop protection work is understanding how to harness naturally occurring organisms on fruit plants and in the environment, to prevent the build up of damaging pests and diseases.

The grape and wine industry continues to expand rapidly in the UK and during the past year we have appointed an experienced scientist to lead the work programme in both our research vineyard and research winery. With funding support from The East Malling Trust, we have equipped the new winery with state-of-the-art fermentation tanks and a chemical analyser which allows us to start oenology research using the grapes from our vineyard. As the only research winery in the UK, we are currently working with wine producers and industry bodies to develop priorities for research funding.

The work of our Growing Kent & Medway Team continues to help and support the food, drink and horticulture sectors. Now in its third operating year, the programme has been investing £5 million in research and development grants, ten of which have been directly benefiting fruit growers. It also awarded 'Business Innovation Vouchers' to eleven businesses, five of them in the fruit industry to support their innovative ideas, and in 2023, financial support was awarded to seven innovative research projects to improve sustainable production through the GK&M 'Business Sustainability Challenge'. You can read more about most of these projects in this year's Review.

Oliver Doubleday, Chairman, East Malling Trust

East Malling Trust – supporting NIAB research at East Malling

As a charity and company limited by guarantee, The East Malling Trust (EMT) has supported the delivery of innovation for the horticultural and particularly the fruit industry from the East Malling site in Kent since 1913.

As owners of the East Malling site, EMT provides and maintains the infrastructure from which NIAB fruit science is delivered. EMT's recent success with developing the site has enabled financial support for larger projects such as the recent £6.7 Million of EMT co-funding provided towards the GreenTech Hub for Advanced Horticulture, including new research glasshouses and winery buildings, via the successful Growing Kent & Medway project. EMT has more recently provided funding to equip the NIAB Wine Innovation Centre. Along with infrastructure support, EMT is helping with delivery of research projects e.g. through the £1 Million EMT Director's award for Horticulture leveraging over £5.7 Million of government funded research to date. Some of the projects supported by the EMT Director's award are highlighted in this edition of NIAB Fruit Review and EMT are also pleased to see the investment in early career researchers through the Director's award.

With the imminent launch of its science and impact strategy, EMT looks forward to further exciting developments linked to the East Malling site and the new successful innovations these will deliver for the UK horticultural industry. All of this activity is made possible by the tireless and unpaid work of EMT's knowledgeable board of trustees who are always keen to hear the views of the industry and wider stakeholders about the future innovation needs of the sector. You can learn more about the trustees at eastmallingtrust.org/the-trustees/.

NIAB trials services and glasshouse services at East Malling

NIAB's work at East Malling has gained recognition around the world through its employment of enthusiastic scientists from a wide range of disciplines who have become experts in their field. Together, they have engaged directly with fruit growers to develop solutions to their problems and help to increase yields and fruit quality, allowing local growers to remain profitable and compete on the world stage. In addition to our traditional fruit research, we now provide a range of trials services and glasshouse services to support the fruit industry.

Adrian Harris, Horticultural Trials Co-ordinator • adrian.harris@niab.com

Trials services

We offer a range of technical support through bespoke trials services, technical innovation, independent evaluation and commercial demonstration, all of which is accredited by ORETO, ISO and GEP. Specifically, we offer help in crop protection, crop production systems, vines and wine production, variety and novel crop trialling, true-to-type DNA fingerprinting and growing media trials. Crucially, the work we do is independent, authoritative, comprehensive and impartial. For further details visit niab.com/services/field-trials.

Emma Easton, Head of Glasshouse Services • emma.easton@niab.com

Glasshouse services

NIAB has a full range of glasshouse and growth room facilities that are used by our research scientists at both our Park Farm (Cambridge) and East Malling (Kent) sites. The facilities at East Malling were constructed in 2021/22 with funding from Growing Kent & Medway, The East Malling Trust and Kent County Council. They include state-of-the-art glass, allowing our scientists to replicate the very best glasshouses that are used by the industry, making our research relevant to current commercial practice.

NIAB scientists work collaboratively with industry partners to develop projects designed to find solutions to crop production problems commonly faced by the commercial fruit sector. The glass is equipped with a full range of irrigation facilities, lighting design and screens for night break lighting or sun-shading. We have climate-controlled compartments with heating and cooling facilities, which are also fitted with black out blinds. The growth rooms have independently controlled environmental conditions and range in size.

Examples of how the glass is currently being used include research on tomatoes to study crop nutrition and heat stress, investigating methods of reducing the breeding cycle for apples, and studying the performance of strawberries bred at East Malling at a range of temperatures. The growth rooms allow research into Total Controlled Environment Agriculture (TCEA) systems enabling us to study the full yield potential of fruit plants under optimum growing conditions. For further details visit niab.com/services/glasshouse.

Finding out more about NIAB fruit research

NIAB's fruit research is predominantly managed at our East Malling site, where our staff are divided into three teams (see right).

We also have our **Horticultural trials services** team led by Adrian Harris.

To keep the industry informed about our research and the results that we produce, 'NIAB Fruit' has been set up to disseminate our latest news and information. NIAB Fruit's outreach programme will provide:

- **Annual Review** – digital and printed versions
- **Electronic Factsheets** – providing guidance to the industry on crop management and crop protection issues
- **International research updates** – offering summaries of overseas research visits and international conferences and symposia
- **Web archive of information** – including the Apple Best Practice Guide, SWD and relevant research information at niab.com
- **Technical webinars** – providing presentations on the latest research results
- **On-site events** – short events to appraise the industry of our research and demonstration work
- **Growing Kent & Medway information** – updates and events from the Growing Kent & Medway Innovation Cluster

Anyone wishing to receive information from NIAB Fruit should register at: horticulture@niab.com

For further information, contact Scott Raffle, NIAB Knowledge Exchange manager:
Scott.raffle@niab.com
Tel: 07712 131769

PEST AND PATHOGEN ECOLOGY (PPE)

led by Dr Michelle Fountain

CROP SCIENCE AND PRODUCTION SYSTEMS (CSPS)

led by Dr Mark Else

PLANT GENETICS (PG)

led by Professor Dan Sargent

New Projects 2023/24

NIAB has begun work on a series of fruit research projects this year which all seek to make fruit production more sustainable. Whether developing more sustainable methods for improving crop health and crop protection, producing plants in a more sustainable way with reduced inputs, or improving the efficiency and speed of fruit plant breeding, all seek to increase efficiency of production in ways that are sympathetic to the environmental problems growers face today.

CROP SCIENCE AND PRODUCTION SYSTEMS

Mark Else, Head of Crop Science & Production Systems

Title: Optimising the propagation environment in TCEA systems to maximise strawberry yield potential in all production systems

Funder: Defra Farming Innovation Programme

Industry partners: Vertical Future, Berry Gardens Growers Ltd, The Blaise Plant Company Ltd, Cocogreen Ltd, Clockhouse Farm, Delta-T Devices, Hugh Lowe Farms Ltd, Linton Growing Ltd, University of Reading

Term: June 2023 to May 2026

Total Controlled Environment Agriculture (TCEA) growing systems offer a potential solution to our expanding population, climate change and food security. The strawberry industry is keen to employ such systems in the propagation of high quality planting material. Working with a multi-disciplinary team of researchers, technology companies and growers, NIAB scientists will develop a method to produce high quality, virus-and disease-free strawberry plant propagules with assured high cropping potential in TCEA systems.

Developing strawberry plants with high cropping potential

PLANT GENETICS

Dan Sargent, Head of Plant Genetics

Title: Turning over a new leaf: Use of state-of-the-art phenotyping and genomics to breed for cost reducing plant architecture in strawberry

Funder: Growing Kent & Medway

Industry partner: Edward Vinson Plants Ltd

Term: April 2023 to March 2025

To reduce both growing and harvesting costs, strawberry growers need plants with both an open habit and good fruit presentation. Working with Edward Vinson Plants Ltd, NIAB aims to develop molecular markers to help breed new strawberry varieties with improved plant architecture. They will use cutting edge machine-learning technologies to capture data on plant architecture and use this, along with information about the DNA of the strawberry plants to develop new tools to achieve their goals.

Aiming to develop improved strawberry plant architecture

PLANT GENETICS

Amanda Karlstrom, Plant Breeder and Geneticist

Title: Next generation apple breeding for resilient UK production
Funder: Growing Kent & Medway
Industry partner: Worldwide Fruit Ltd
Term: June 2023 to March 2025

The control of fungal diseases in apple significantly adds to production costs. The long-term aim of the industry is to breed apples with resistance to these diseases. However, breeding is a long-term process and typically takes 20-25 years from crossing to release. In this project NIAB is working with Worldwide Fruit Ltd to develop novel breeding methodologies that will enable a shorter breeding cycle for apple and ensure a faster route to market for resistant varieties. The methodologies will include the use of genomic selection, marker assisted selection and speed breeding.

Novel breeding methodologies might cut the time to release new apple varieties

PEST AND PATHOGEN ECOLOGY

Michelle Fountain, Head of Pest and Pathogen Ecology

Title: Novel approaches to pest and disease control in apples and pears
Funder: British Apples and Pears Ltd
Term: April 2023 to March 2024

UK apple and pear growers list pest and disease control as their highest research priority and to this end, British Apples and Pears is funding NIAB to investigate novel approaches. They will try to harness beneficial endophytes for canker control and reduce overwintering inoculum for scab control. Inoculating trees with earwigs will be investigated to control woolly apple aphid. Precision monitoring, semiochemical and biological manipulation will be investigated to control hard bodied pests, while IPM approaches will be reviewed for future UK codling moth control.

Novel techniques for controlling pests and diseases in apple and pear

PEST AND PATHOGEN ECOLOGY

Xiangming Xu, Director of Research

Title: Sustainable management of apple canker

Funder: Biotechnology and Biological Sciences Research Council

Industry partners: Worldwide Fruit Ltd and Avalon Fresh

Term: October 2023 to September 2025

In this BBSRC funded project, NIAB will study a bacterial endophyte (from the genus *Sphingomonas*) associated with both scion tolerance and canker control, and also known to promote plant growth, to understand if it persists from season to season or whether repeated application is necessary. In addition, the scientists will study the impact of soil pH, soil organic matter and nutrient levels and type, on the development of canker symptoms from latent infection that occurred in the nursery. This could help growers to select sites with minimal risks to canker development during tree establishment.

Investigating new approaches to controlling apple canker

PEST AND PATHOGEN ECOLOGY

Matevz Papp-Rupar, Plant Pathology Research Leader

Title: Exploring the links between soil microbiome and carbon sequestration in a cross-section of agricultural soils (arable, pasture, orchards)

Funder: Growing Kent & Medway Business Innovation Voucher

Industry partner: Verdant Carbon

Term: June 2023 to May 2024

Orchards provide a natural sink for carbon dioxide but we need to improve our understanding of how the soil microbiome can be manipulated to improve soil carbon storage capability. NIAB will work with Verdant Carbon to understand the links between soil microbial abundance/ diversity, and the volume of carbon sequestered in different agricultural crops (arable, pasture, orchards). The aim is to identify any correlations between levels of specific soil microbes and soil carbon content across the soil profile (10-100 cm), and between soil management practices (regenerative and conventional).

The soil microbiome could hold the key to improved carbon storage in orchards

PEST AND PATHOGEN ECOLOGY

Sarah Arnold, Applied Entomology Researcher

Title: Precision pollination for improved nutrition and shelf-life
Funder: Innovate UK: Better Food for All
Industry partners: AgriSound, CHAP, PheroSyn and Biobest
Term: September 2023 to August 2025

Are we achieving complete levels of pollination to maximise nutrition and shelf-life in protected strawberry? AgriSound has developed a sensor that employs acoustic detection methods to detect and count functional groups of insects, including pollinators. NIAB will test if it can measure pollinator activity within strawberry crops and if it will allow growers to detect areas of high or low pollinator activity which could negatively affect the crop. The team will also assess new tools (produced by PheroSyn) that will redirect insect activity from areas with excessive pollination to those with insufficient pollination.

Research is targeted at improving the precision of pollination in strawberry

PEST AND PATHOGEN ECOLOGY

Charles Whitfield, Crop Protection Scientist

Title: DCM: Digital Crop Management for glasshouse pests and diseases
Funder: Innovate UK: Defra and UKRI Farming Innovation Programme
Lead partner: Fotenix
Industry partners: Abbey View Produce, British Tomato Growers Association, Fargro, Fotenix and Thanet Earth
Term: January 2023 to May 2026

Traditional crop scouting often identifies issues after damage has already begun. This work will utilise the latest diagnostic technology and agronomic knowledge to co-develop a crop scouting service, informed by spectral diagnostics (wearable and mounted diagnostic hardware) that can detect the early establishment of any event which adversely affects yield, and which can be integrated within crop management systems. The work will focus on glasshouse tomatoes and peppers, but the results will benefit growers of other protected crops, allowing them to implement management and control earlier.

Developing a more accurate crop scouting system in protected crops

Charles Whitfield, Crop Protection Scientist

Title: POME: Precision Orchard Management for Environment

Funder: Innovate UK: Defra and UKRI Farming Innovation Programme

Lead partner: Hutchinsons

Industry partners: The Acclaimed Software Company, Outfield, Fotenix, Antobot, NP Seymour, Chemicals Regulation Division, Avalon Fresh, AC Hulme, Plumford Farm, New Barn Farm, University of Kent and Loughborough University

Term: October 2023 to September 2027

There is substantial variation between trees in commercial orchards in terms of vegetative growth and size, and even greater variation in yield. A previous Innovate UK project has developed a prototype orchard 'Precision Variable Rate Spray' system that can take account of tree size and apply a measured volume of spray to match the size and canopy density of individual trees. This project will further develop techniques to quantify canopy density, fruit load and presence of pests and diseases, and calculate yield estimates and prescription maps to manage tree growth, crop load and spray application.

Developing techniques to quantify crop load

Xiangming Xu, Director of Research

Title: Predicting strawberry fruit infection by *Mucor* and *Rhizopus* using climatic conditions and pathogen inoculum levels

Funder: Biotechnology and Biological Sciences Research Council

Industry partner: Berry Gardens Growers Ltd

Term: June 2023 to November 2023

Strawberry growers need to be able to predict when soft rots caused by *Mucor* and *Rhizopus* might occur, allowing them to implement control at the optimum time. Previous research began the process of developing models to predict the risk, but further data is still needed to complete, validate and finalise the models for use in practice. This new project aims to obtain further data on the incidence of *Mucor* and *Rhizopus*, weather conditions and the level of airborne inoculum within a specific period in commercial strawberry crops, to complete the work.

Developing models to predict the risk of Mucor or Rhizopus

Francis Wamonje, Entomology Research Leader

Title: A phenology-perceptive integrated biocontrol programme for large raspberry aphid (*Amphorophora idaei*) control: PHENCONTROL

Funder: Growing Kent & Medway

Industry partners: Asplins PO, Biobest and Rumwood Green Farm

Term: May 2023 to April 2025

With a lack of effective control measures available for large raspberry aphid under glass and polythene structures, UK growers need effective biocontrol measures for the pest. NIAB will test a strategy to deploy *Micromus angulatus* (brown lacewing) for predation of aphid eggs and spring hatching female aphids, when temperatures are still low. They also aim to develop an optimal parasitoid species mix which will spread uniformly across the plantation, whilst investigating novel ways of spreading *Chrysoperla carnea* (green lacewing) across plantations to control hot-spot outbreaks of aphids.

Developing a biocontrol programme for large raspberry aphid

Matevz Papp-Rupar, Plant Pathology Research Leader

Title: Reducing the risk of oomycete pathogens, thrips and weevils for sustainable, coir based soft fruit production

Funder: Biotechnology and Biological Sciences Research Council

Industry partner: Overland Ltd

Term: March 2023 to November 2023

Despite the UK soft fruit industry moving production almost entirely into coir substrate, a number of persistent pests and pathogens continue to require management and intervention. This project is studying the biology of pests, pathogens and biocontrol agents in both virgin and recycled coir. The research aims to investigate the diversity and function of the microbiome in recycled and virgin coir substrate, and in particular survival and efficacy of biological control agents in virgin and recycled material.

Seeking ways to reduce the risk of oomycete pathogens in coir

PEST AND PATHOGEN ECOLOGY

Matevz Papp-Rupar, Plant Pathology Research Leader

Louisa Robinson-Boyer, Plant Microbial Interactions Research Leader

Feli Fernandez, Senior Plant Breeder

Title: Improving propagation efficiency and production sustainability in intensive cultivation systems for a Kent-bred raspberry variety

Funder: Growing Kent & Medway

Industry partners: Blaise Plants and Recoir

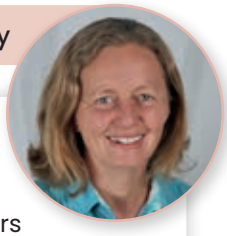
Term: May 2023 to April 2025

The annual demand for high quality long-cane raspberry material is continuing to rise, but demand is outstripping supply and the quality of plants purchased is not always uniform with survival rates lower than growers would expect. This project will investigate the use of commercially available beneficial microorganisms in raspberry propagation to improve plant establishment with fewer inputs, with the aim of increasing the survival rate of the plants whilst enhancing plant uniformity and final yields.

Improving raspberry plant establishment

PEST AND PATHOGEN ECOLOGY

Michelle Fountain, Head of Pest and Pathogen Ecology



Title: Innovative push-pull control of spotted wing drosophila, an invasive pest of fruit crops

Funder: Innovate UK

Industry partners: Russell IPM, Rumwood Green Farm, University of Greenwich (NRI) and WB Chambers

Term: April 2023 to March 2025

Growers are under pressure to reduce reliance on conventional spray products to control SWD. Recent research has identified chemical repellents that cause a reduction in egg laying in strawberry, whilst monitoring traps have been used to reduce overwintering populations in habitats adjacent to fruit crops in the winter. This project will combine these methods and evaluate a 'push-pull' approach using innovative long-lasting, biodegradable repellent formulations. The system will be compatible with IPM programmes and if successful, will reduce industry reliance on spray control products.

PEST AND PATHOGEN ECOLOGY

Matevz Papp-Rupar, Plant Pathology Research Leader

Title: Development of sustainable recycled growing media

Funder: Growing Kent & Medway

Industry partner: Overland Ltd

Term: April 2023 to March 2025

Soft fruit growers are heavily reliant upon virgin coir for their production but the material and transport costs have been increasing recently and are becoming unaffordable. Overland Ltd has worked with NIAB to develop a way to recycle coir that offers better crop yields and quality than directly re-using or composting the coir. In this project they will further optimise their recycling processes to reduce the risk of pests, pathogens and weeds and decrease the energy input. They will investigate potential microbiome imbalances in recycled media and the scope for further reducing disease risks using biocontrol microbes.

CROP SCIENCE AND PRODUCTION SYSTEMS

Belinda Kemp, Viticulture & Oenology Research Leader

Supporting the needs of a burgeoning grape and wine industry

NIAB's research site at East Malling was established in 1913 in response to a burgeoning apple and pear industry which needed research help to develop higher yields of higher quality fruit. Through the ensuing years, we have worked closely with fruit growers to identify priority research that has helped to solve the pressing production and storage problems of the day.

Some 110 years on we have a new burgeoning grape and wine industry in the UK which has expanded dramatically over the past ten years (Figure 1). In response, NIAB developed a research vineyard which was first planted in 2015. Early plantings were used principally to demonstrate the performance of a range of varieties, and their clones, on different rootstocks and different training systems, as well as several methods of weed control and their impact on vine nutrition and grape chemistry.

The rapid increase in both grape and wine production in the UK now demands more sophisticated research to solve new and emerging problems faced by both growers and winemakers. In response, NIAB recognised that it needed greater research knowledge and expertise in this sector and appointed Dr Belinda Kemp in April 2023 to lead this work. Belinda brought eighteen years of experience working in the wine industry in England, New Zealand and most recently Canada, where she headed up oenology research at the Cool Climate Oenology and Viticulture Institute (CCOVI), Brock University in Ontario.

Belinda's arrival coincided with the building and development of a new research winery, the Wine Innovation Centre. Funded by the East Malling Trust, Kent County Council and Growing Kent & Medway, it will allow Belinda to carry out oenology research using grapes from the NIAB research vineyard to understand the impact that interventions in the vineyard have on the characteristics of the wine they produce.

Since her arrival at East Malling, Belinda has been developing links and relations with grape growers, wineries, academic collaborators, trade bodies, vineyard and winery suppliers and government departments, to identify the industry's research needs, and as a result, she is setting up working partnerships to secure research funding from a range of bodies. To ensure our research meets the latest needs of growers, the research vineyard is being re-structured with in-kind help and input from VineWorks, and some of it is being replanted with Chardonay, Pinot Noir and Pinot Kors, a disease resistant variety. The vineyard and winery are both unique in that they are the only ones of their kind in the UK and will allow us to undertake work that will benefit industry by exploring new avenues and develop solutions to priority challenges.

The Winery has been fitted with state-of-the-art fermentation tanks (Figure 2 - overleaf) designed to our unique research specification with each one containing remote computer control and automatic temperature control. A new rainwater capture system has also been fitted containing a reverse osmosis filtration system, providing purified water for use in the winery as well as for laboratory analysis. Without this, the high calcium content of

Figure 1. The UK grape and wine industry has expanded dramatically

our local water would leave a residue resulting in calcium tartrate instability in our winery tanks and cause issues with the tartrate crystallisation stability of the wines.

A laboratory adjoining the winery houses a newly installed 'SPICA' analyser, the only one of its kind in the UK. It will allow us to carry out a wide range of fast and accurate chemical analyses, measuring compounds throughout our wine production that we were unable to do before. This will allow us to manage the chemical composition of the wine chemistry appropriately, and according to wine style.

One ongoing project in the research vineyard has been investigating the impact of cover crops on soil health in vineyards and is being managed by NIAB's Flora O'Brien. This is reported on in the article below.

Figure 2. The fermentation tanks have automatic temperature control

CROP SCIENCE AND PRODUCTION SYSTEMS

Flora O'Brien, Root and Soil Biologist

Title: Increasing productivity and sustainability in UK viticulture: investigating the potential impact of groundcover management practices on soil health, yields and juice quality, and emissions

Funders: Defra Farming Innovation Programme and The East Malling Trust

Industry partners: Chapel Down (English Wines PLC), Gusbourne Estate Ltd, T. Denne & Sons Ltd, University of Greenwich (NRI) and Vinescapes Ltd

Term: May 2022 to April 2024

NIAB's soil scientists are increasingly aware that poor soil health can give rise to inconsistent yields and juice quality in vine growing, which can lead to costly interventions in the vineyard and winery. Cover crops could play a significant role, by enhancing soil health through their effects on soil carbon content, hydraulic conductivity, biodiversity, and soil structure. Improvements in soil health could improve the tolerance of vines to environmental stress and could also potentially enhance aspects of wine quality. Legumes are commonly used in cover crop mixes, and they can bring the added benefit of increased soil nutrient availability, thereby reducing the need for fertiliser applications. Vine growers could benefit by learning more about the benefits of crop covers, the best species to use, how they might enhance soil health and crop quality, and how best to manage them.

The project

NIAB is investigating the potential impact of vineyard groundcover management practices on soil health, yields, juice quality and emissions. It will also lead to grower guidance on bespoke cover crop mixes to alleviate soil compaction and improve soil nutrition. Insights produced from this work will support the industry's transition towards net-zero carbon emissions. The work is being carried out in commercial vineyards (Chapel Down and Gusbourne) and in the NIAB research vineyard at East Malling.

Results to date

The aim of the work was to compare soil health, vine growth and wine quality between a range of inter-row cover crop treatments, as well as different under-vine management of a herbicide strip, mechanical weed control strip, and a control using weed strimming alone. The crop cover mixes included phacelia, faba bean, an annual mix of rye and vetch, and a perennial mix containing creeping red fescue and three clover species. The control treatment consisted of alleyways that were maintained as before, with natural/spontaneous vegetation that is regularly mown.

Poor seed establishment of the cover crops was encountered in the first year of the experiment (2022) due to the extremely hot and dry conditions that prevailed from March onwards. Consequently, the project team decided to compare two different methods of ground preparation prior to drilling: soil

cultivation and the use of the herbicide glyphosate. Different management approaches have been taken depending on the soil types in the commercial vineyards and research vineyard included in the study. Although some further weather-related problems were encountered in 2023, there was sufficient establishment of some mixes to allow useful information to be recorded and scientific analysis to be undertaken.

Some statistically significant results were recorded in soil analyses that were carried out in autumn 2023 where the faba bean established particularly well on all sites allowing comparisons to be made. There were significantly higher concentrations of soil phosphorus (P) in the faba bean treatment at both the Gusbourne and Chapel Down trials relative to the control (Figure 3), but no differences were found at East Malling. Previous research has shown that increased soil P may be related to rhizosphere acidification caused by faba bean root exudation which can increase the mobilisation of both organic and inorganic P sources. Potential benefits of increased soil P include enhanced tolerance of the grapevine to copper toxicity, and, in some instances, increased number and weight of clusters and berries. However, it will need careful monitoring since excess soil P can have a negative impact on berry quality.

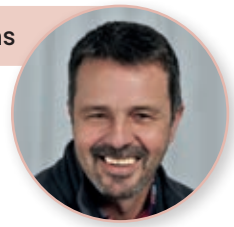
So far, leaf nutrient analyses have revealed no consistent results across the three sites and there was no correlation detected between leaf and soil analysis results. Although there were no significant effects of the bean crop covers on total nitrogen (N) content of soil or leaf, chlorophyll levels were significantly higher in the bean treatments at both the Chapel Down and Gusbourne sites. In terms of grape juice quality, significantly higher levels of yeast assimilable nitrogen (YAN mg N/L)) were recorded in juice from the faba bean cover crops relative to the control, mainly due to the increased ammonia content. This suggests that there was an increase in soil N availability in the bean treatments (although not detected in the soil analysis to date), since both chlorophyll and YAN are known to be indicators of vine N status.

Figure 3. Faba beans have shown nutritional benefits on the commercial sites

The scientists are currently unsure as to the main cause of this, but it could be explained by N inputs from the beans, the reduced competition for growth between the vines and alleyway vegetation following glyphosate application prior to drilling, or specific plant interactions. Further soil analysis will be conducted to investigate this finding. Increased YAN content could be a significant benefit to the winemaker, since it could reduce the amount of supplemental N (from sources such as diammonium phosphate – DAP and other yeast nutrient products) that needs to be added to the juice in order to meet the threshold YAN content that is necessary for fermentation to take place. This reduction in additional N could help to lessen both the financial and environmental costs associated with the winemaking process.

It is hoped to continue the work further in 2024 to carry out more analysis, the results of which will enable the project partners to gain insights into the impact of cover cropping on soil health and vine performance which can then be shared with stakeholders.

Mark Else, Head of Crop Science & Production Systems



NIAB WET Centre demonstrates the latest technology to improve resource use efficiency

Since 2017, the NIAB Water Efficient Technologies (WET) Centre at East Malling has been demonstrating NIAB's water use efficiency research in an environment that replicates commercial practice (Figure 1). Its aim has been to lead the industry in responsible and efficient use of water whilst also showcasing the latest irrigation and tunnel technologies, and investigating ways of improving resource use efficiency and productivity for soft fruit growers.

It has been made possible through funding provided by the Centre partners including Berry Gardens Growers Ltd, Cocogreen, Delta-T Devices and Netafim who have been an integral part of the Centre since its inception. They have been recently joined by Yara, along with associate member H L Hutchinson, with all taking an active role in shaping the work of the Centre and providing product knowledge and technical support each season. This industry support is, in turn, used to leverage funding from UKRI, particularly Innovate UK (IUK) funding for research projects to further increase the level of precision required to produce soft fruit in today's demanding market.

Some of the early work at the Centre demonstrated the magnitude of water savings that the industry could make if it employed some of the most advanced technology and this has helped commercial growers to improve their own water use efficiency. Research carried out at East Malling between 2011 and 2013 showed that the UK industry average use of water for an everbearer strawberry crop amounted to 82 m^3 per tonne of Class 1 fruit produced. Typically at the WET Centre, a figure of 43 m^3 has been achieved through the use of precision irrigation technology. Interestingly, a best practice survey carried out by NIAB in 2023, showed that the most efficient grower had used 60 m^3 for an everbearer crop. This demonstrates an improvement over the past ten years, but further progress is still possible.

A crucial feature of the WET Centre has been the division into a 'commercial area', which mirrors typical commercial practice, and an 'advanced area', which incorporates the latest technologies to more precisely control the polytunnel phytoclimate. Not only can visitors to the site view this in action, but our scientists are able to make direct comparisons of fruit yield and quality between the two areas and report their results to the industry, allowing businesses to make informed decisions over whether to implement such technology on their own sites.

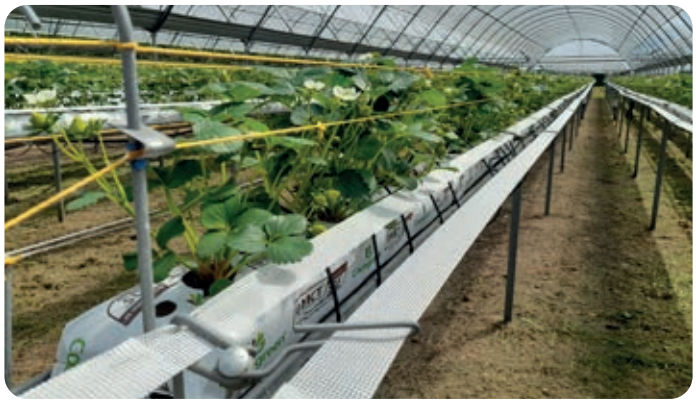
Comparisons between the commercial and advanced areas in recent years have demonstrated significant differences in fruit yield using the everbearer Malling™ Champion. In 2020, Class 1 yield was found to be 5% higher in the commercial area, perhaps a result of the higher levels of shading in the advanced area, lowering the photosynthetically active radiation (PAR – Figure 2) at the canopy by 3-7%. It is thought that the increased steelwork associated with the roof vents in the advanced tunnels reduces light levels sufficiently to cause this yield difference, and this effect is probably exacerbated by the relatively large rainwater collection gutters. However, the more flexible venting control resulted in a 1°C reduction in temperature in June and July and up to 7°C in August 2020, and so the improved internal climate control from auto-venting could have significant benefits in hotter years.

Yield differences have also been recorded between seasons, with Class 1 yields of Malling™ Champion in 2021 being 22% lower than those recorded in 2020. The amount of accumulated PAR has been measured each season and

Figure 1. The WET Centre demonstrates best practice in water use

Figure 2. Measuring photosynthetically active radiation

Figure 3. Yield differences are consistently measured between tunnel rows



the lower yields in 2021 could be attributed to lower light levels. The differing yields between the commercial and advanced areas, coupled with differing light levels, prompted the science team to start investigating whether differences in PAR were responsible for the variability in yields between individual rows in the advanced area. Our research so far has shown a strong correlation between light availability (PAR) and Class 1 yields, with the latter differing by as much as 12% in rows just 2 metres apart within one tunnel bay. This equates to a yield differential of over 11 tonnes per hectare.

There are six rows within each tunnel bay and further investigation revealed that the middle rows (3 and 4) were producing higher yields than the outer rows (1 and 6), with the highest yield being produced in Row 4 (Figure 3). Using an array of precision environmental sensors manufactured by Delta-T Devices, a correlation was found between the highest yields per row and the amount of light reaching the canopy, so a comparison was made between Row 4 with Rows 1 and 6. Row 4 was found to receive 2 hours more PAR per day than Row 1, but strangely, despite both being outside "leg" rows, Row 1 produced higher yields than Row 6.

Like other plants, strawberry has a light saturation point, when photosynthesis plateaus, even with further increases in light levels. We discovered that the efficiency of photosynthesis is highest in Row 4 and also higher in the morning than in the afternoon. We are now testing if the higher-than-expected Class 1 yields in Row 1 could result from the peak in early morning PAR coinciding with the peak in photosynthetic efficiency. The results will inform our next steps to optimise the available light to each row at key times during the day using different techniques and technologies. In 2024, we will install LED lights over the leg rows.

Most recently in 2023, we have been investigating the performance of the everbearer strawberry Malling™ Ace at the WET Centre. In contrast to Malling™ Champion which was planted at a density of eight plants per metre in a staggered layout in the coir bag, we reduced the density of Malling™ Ace to six plants per metre, planted in a single line. Commercial grower experience of planting Malling™ Ace at this lower density had unexpectedly resulted in higher yields per plant. Lower density planting also improves air movement around the plant, reducing humidity, and leading to improved control of powdery mildew, to which Malling™ Ace is sensitive. The plants produced an average of one kg per plant, and despite some early symptoms of powdery mildew being identified during weekly crop monitoring, a spray programme relying on products with both preventive and curative properties, ensured that little fruit was lost to the disease.

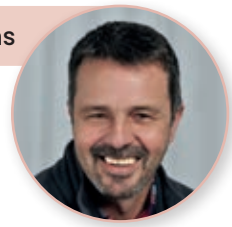
However, unexpectedly in 2023, different yield patterns emerged across Malling™ Ace. For the first time, the yields picked from the 'advanced area' were higher than the 'commercial area' and yields picked from the normally highest yielding Rows 3 and 4 were not as high as some of the other rows. The accumulated PAR in 2023 did not follow the pattern we have seen previously. Levels of fruit waste were also higher in 2023 than previous years. Our scientists are analysing these surprising results to try to understand the reasons behind them.

As well as growing Malling™ Ace at a lower plant density in 2023, we also compared the use of five drippers with seven drippers per bag and studied the impact on yield and water use. It was found that the bags with seven drippers produced higher yields (15 g more fruit per plant – 1.4% increase), but also used 3.2 litres more water per plant (10.5% increase).

The Centre has recently expanded to include raspberry tunnels where we are currently growing Malling™ Bella for an EDTDirectION-led IUK-funded project on reducing fertiliser inputs and greenhouse gas emissions, using a combination of nitrogen-demand modelling, real-time NPK sensing and precision fertigation. The latest results on this are reported in a separate article on the following page of this Review magazine. We have also started to test new irrigation technology from Netafim to see if water and fertilisers can be distributed more evenly through the rootzone in a crop where Class 1 yield losses from inadequate fertigation scheduling are common.

Anyone wishing to learn more about the NIAB WET Centre or potential involvement in the work carried out there should contact wetcentre@niab.com.

Mark Else, Head of Crop Science & Production Systems



Matching nitrogen supply with demand in raspberry fertigation

Title: SMARTFert: Integrating nutrient demand models in AI-based sensors with precision-dosing rigs to improve resource use and productivity, and reduce waste and emissions in commercial raspberry production

Funders: Innovate UK and The East Malling Trust

Industry partners: Netafim UK Ltd (Lead), Berry Gardens Growers Ltd and EDT DirectION

Term: August 2020 to February 2022

There is pressure on growers to use fertiliser products more efficiently. Not only have fertiliser costs risen sharply over the past two years, but overuse is wasteful and in the case of excess nitrogen, it is converted to nitrous oxide which is deemed to be 300 times stronger than CO_2 at trapping heat in the atmosphere, so there are strong environmental arguments for using nitrogen more effectively. Too much nitrogen can also lead to excessive plant growth, which directly increases water use, cane management, and picking costs, whilst also increasing the risk of fungal disease and reducing light levels in the crop canopy.

The project

NIAB collaborated with industry partners in this Innovate UK project to match the supply of nitrogen to the demand made by Malling™ Bella raspberry plants at the NIAB WET Centre (Figure 1). The scientists adapted an existing nutrition model called VegSyst, which had previously been used with tomatoes in the south of Spain. In 2021, the model was calibrated for raspberry by using environmental data along with dry weight and nutrient composition of leaves, stems and fruit.

Figure 1. We sought to match nitrogen supply to the demand in Malling Bella raspberry

In 2022, the model was validated by using it to forecast nitrogen use in Malling™ Bella at the WET Centre. The model estimated water requirements of the plants by measuring evapotranspiration, and using crop coefficients embedded in the model, NIAB scientists were able to calculate how much nitrogen the plants were using. The fertiliser recipes were subsequently up-dated every two weeks, to return the quantity of nitrogen that the plant had used. The model was compared to a standard commercial control that was fed using a standard fertiliser regime irrespective of water use and weather conditions. Employing the model across the season reduced nitrogen use by 63% and water use by 39% compared to the commercial control, but it resulted in a significant reduction of Class 1 yield (3.5 kg per plant compared to 4.2 kg per plant in the control). On investigation, the model had overestimated how much water the plants were using due to inaccurate coefficients, resulting in too little nitrogen being applied. NIAB therefore funded an extra year of work to re-validate the model in 2023.

Figure 2. The N-Model (right) reduced nitrogen use by 76%

Results

In 2023, a different approach was taken where instead of using the embedded crop coefficients to work out how much N the plants would use, the NIAB team estimated water requirements from the volume of water the plants were actually using. Every two weeks, the fertiliser formulation was adjusted based on how much water the plants had used in the previous two weeks, along with the environmental variables such as temperature.

The results were much improved. Compared to the commercial control, the N-model gave rise to a 76% reduction in nitrogen (Figure 2) and 37% less water. There was a small 6% reduction in yield which was caused by smaller berry size (5.2 g average berry weight compared to 5.6 g in the commercial control). However, this yield reduction was not statistically significant. The N-model also resulted in less leaf and cane biomass compared to the control treatment, where extra labour was needed to thin canes and remove leaves.

The NIAB team has successfully demonstrated the N model in other strawberry and raspberry varieties, giving rise to reductions of nitrogen supply between 60-90% and reductions in water use between 20-50%. The reductions vary widely during the season and also between varieties, but the model is dynamic, and accounts for changing nitrogen use depending on environment fluctuations throughout the season.

It is planned to refine the model further by incorporating weather and water use forecasts to supply what the plant needs rather than applying it retrospectively. NIAB also wants to investigate nutrient availability in the coir. Our scientists have a good understanding of how nutrients are made available to plants from the soil, but our knowledge is currently limited in coir substrates (Figure 3). A new Innovate UK project is also planned to investigate the use of in-line sensors so we can study nutrient delivery in real time, allowing us to make adjustments to feed recipes more easily.

Figure 3. Raspberry grown in coir substrate

Mark Else, Head of Crop Science & Production Systems

Growers take hands-on approach at NIAB's Plum Demonstration Centre

The Plum Demonstration Centre (PDC) at East Malling has been evolving since the first tree was planted in 2016. Originally created to showcase best practice in plum production (Figure 1) funded by Innovate UK to try to reinvigorate the UK industry, the Centre was then funded by the AHDB between 2019 and 2022, but with the demise of the horticultural levy body, a new funding mechanism had to be found. Since 2022, the Centre has been financially supported by a consortium of UK plum growers, many of whom have become actively involved in steering the research work that is carried out at the Centre.

There are currently three main areas to the Centre. The first and most established is a rootstock/tree architecture plot where performance of Victoria is compared on different rootstocks and different training systems and where yield data has been collected every season since 2017. The second is a plot containing the varieties Victoria, P6-19 and P7-38 that was originally covered with protective polythene tunnels to assess the cropping potential under protection, but the grower funders decided to discontinue this as the returns available for plums at present are not sufficiently high to make tunnel production financially viable. Instead the rows have been left uncovered and the plot has been used to compare tree management systems. The third plot is a replicated variety trial where 23 different varieties and selections have been established and their yield and performance are being compared on the Wavit rootstock.

The Victoria rootstock/tree architecture area contains plots of three rootstocks (Wavit, St. Julian A and Pixy) on four different architecture systems (Narrow A Frame, Narrow Table-Top, Super Spindle and Oblique Spindle). The rootstock VVA1 is also included, but only for the Super Spindle and Oblique Spindle architecture systems. Single rows of St. Julian A rootstock with Fan and Candelabra training systems are also included for observation. The Narrow A Frame and Narrow Table-Top trained trees are planted at a density of 2,381 trees/ha while the Super Spindle and Oblique Spindle trees are planted at a density of 4,762 trees/ha. The Fan and Candelabra trees are planted at 1,587 trees/ha. The area has been producing fruit for seven years, so following the 2023 harvest,

Figure 1. The Plum Demonstration Centre is a showcase for best practice

accumulated yields per tree and per hectare were assessed by the funders.

Over the seven years, from the replicated plots the highest accumulated yields per tree have been picked from the Wavit/Narrow A Frame, St. Julian A/Narrow Table-Top, Wavit/Narrow Table-Top and VVA1/Oblique Spindle systems in that order. However, the Spindle trees are planted at double the density, so the highest accumulated yields per hectare have come from the VVA1/Oblique Spindle, Pixy/Super Spindle, St. Julian A/Oblique Spindle and Wavit/Narrow A Frame trees in that order. The Fan system produced the highest total yields per tree and third highest yield per hectare, but this was only an observation plot. No statistical analysis could be carried on these results, so they only offer observational guidance to the growers.

In the tree management plots in the tunnel area of the Centre, some useful observations were made in 2023. The area consists of four tunnel bays with eight rows (two rows per tunnel bay). Within the eight rows, four are Victoria, with two rows of Malling™ Elizabeth (P7-38 – Figure 2) and two rows of P6-19, all on Wavit rootstock and trained as a Narrow A Frame. Of notable interest in 2023 was the difference in growth and yield in Row 3 (Victoria) compared to the other rows of Victoria. Row 3 had been pruned and managed differently from all other rows in the tunnel area. The tops were removed and sides pruned with a hedge cutter in the second week of July 2022, following the longest day and this stopped all growth from the remainder of the year. As a result, this row was the most balanced in terms of growth and had the best fruit set and yield potential of all the rows in the area in 2023. In all the other rows, pruning was delayed until May 2023. In addition, half of Row 3 was root pruned using a blade at 40 cm from the trunk. In 2023, this half row produced higher yields than the rest of the rows. This pruning strategy has been repeated and will be assessed again in 2024.

Figure 2. Malling™ Elizabeth is being assessed in two areas of the centre

NIAB scientists are also investigating irrigation requirements of the trees in this cropping area and have installed soil matric potential sensors at 15 cm, 30 cm and 45 cm depth and a volumetric moisture content sensor at 45 cm under representative trees. This work will help us to better understand the demand for water and fertiliser by plums at different stages during crop development, and to identify the optimum soil moisture deficit at which to irrigate. NIAB plans to secure new sources of funding to work with the Centre funders to improve our knowledge of precision irrigation and fertigation of plums.

In the variety trial area, yields have been accumulated over the 2022 and 2023 seasons and to date, Tophit has outperformed all other varieties (31.3 kg/tree) followed by Jubileum (20.5 kg/tree), Victoria (20.1 kg/tree) and Topend Plus (18.6 kg/tree).

Feli Fernandez, Senior Plant Breeder

Raspberry and blackberry breeding

Title: The East Malling Rubus Breeding Consortium

Current funders: Blaise Plants, East Malling Services, Lubera, Onubafruit, Perfection Fresh, Tobi and WB Chambers

Previous funders: Berry Gardens Growers Ltd and The Greenery

Term: April 2015 to March 2025

Raspberry breeding began at East Malling in the 1920s and the early crossing and selection work focused on improvements to existing varieties of the European raspberry (*Rubus idaeus*). Early releases included the floricane-fruiting varieties Malling Promise and Malling Jewel. From the 1950s, the programme began to incorporate desirable traits from other Rubus species including resistance to cane disease and aphids, and fruit quality traits such as firmness and brightness. The 1970s saw the early results of these hybridisation efforts with the release of Malling Delight and Malling Leo.

Autumn Bliss, released in 1983, had genetic contributions from ten different Rubus species in its pedigree and constituted a major breakthrough for season extension as the first primocane-fruiting variety of significant yield and quality to be made available to UK growers. Octavia, released in 2002, was extensively grown for a few years to bridge the gap between main season floricane varieties and the primocane crop, until scheduled cropping of stored long-cane reduced the industry's reliance on very late season floricane-fruiting genotypes.

Until 2003, the programme was funded by government (Defra) with HDC funding variety trials only. Between 2003 and 2008, industry funding and steering complemented public funding to ensure that the programme aimed to meet the needs of growers. Autumn Treasure, a very pest and disease resistant primocane variety, was released in 2008 and has found a niche in the garden market along with the yellow-fruited Autumn Amber released in 2012. From 2009 until 2015, funding was secured through a range of short-lived arrangements with an overarching aim to focus on fruit quality and productivity that led to the establishment in 2015 of the East Malling Rubus Breeding Consortium; a programme running, at the moment, until March 2025.

Figure 1. Malling™ Bella has attractive berries

Figure 2. Malling™ Bella displays its fruit well to pickers

The project

The breeding programme budget is currently split between raspberry (65-70%) and blackberry (30-35%), although the pipelines for both crops are at very different stages since the blackberry programme was only initiated in 2018 and is therefore still in its infancy. Of the raspberry budget, one quarter is spent on floricane fruiting varieties, one quarter on strongly primocane fruiting varieties and half on primocane-fruiting types suitable for double cropping. The blackberry budget is split evenly between floricane and primocane material. Key breeding objectives for raspberry include excellent fruit quality and shelf-life, high yield and large fruit size, simple cane architecture with ease of picking followed in importance by pest and disease resistance and environmental adaptation. For blackberry, the priority objectives include fruit quality, a long shelf-life and high yields of large berries, although thorn free canes are also essential, especially for primocane types.

Figure 3. Malling™ Charm has bright berries which are pale red in colour

Results

The most recent and successful primocane varieties to be released are Malling™ Bella and Malling™ Charm.

Malling™ Bella is a mid-season primocane variety, which is well adapted to UK and southern European conditions. It is suited for double cropping and long-cane production. Berries are attractive (Figure 1), mid-red in colour with excellent flavour and shelf-life. Mean berry weight is 6.5-7g and the fruit maintains good size throughout the season. Growth habit is upright, with well displayed fruits (Figure 2), allowing for rapid picking. To date, no major disease issues have been reported for the variety. Malling™ Bella is proving very popular with Spanish growers and in the UK, it is increasingly being employed for long-cane production. In Spain in 2023, Malling™ Bella stood up well to extreme heat and lack of water, showing good resilience to arid conditions. This suggests that it can withstand climate change better than some other varieties.

Several agronomic trials are in progress with Malling™ Bella at present. These include research to match the supply of nitrogen to plant demand (reported on elsewhere in this publication), the number of chilling hours required for optimum long-cane yields, the optimisation of long-cane propagation, and the response to dormancy breaking treatments in low-chill conditions.

Malling™ Charm is an early primocane-fruiting variety, which is suited to cool climates and not suitable for double cropping. The establishment of tray plants for this variety has been shown to be slow with much better performance obtained from the second season, so trials for alternative plant types are planned. The berries are attractive, bright and pale red in colour (Figure 3), with excellent sweet, juicy flavour. Berries are large, with average weight of 6.7g. Growth habit is upright with well displayed fruit (Figure 4), allowing fast picking. No major disease issues have been reported for Malling™ Charm so far.

Figure 4. Malling™ Charm produced upright canes

Feli Fernandez, Senior Plant Breeder

Long history of apple rootstock breeding leads to release of M.200

Research at NIAB's East Malling site has been synonymous with rootstock development since the site was first established in 1913. The very first director of the then Wye College Fruit Experiment Station established a programme to study factors affecting growth and yield, and in particular the influence of rootstocks on tree growth. This led to the collecting and characterising of previously commercialised apple rootstocks from UK and continental nurseries; followed by the propagation and release of distinct selections with well-defined effects on precocity and vigour of tree growth, including M.9 (dwarfing). These first releases and subsequent ones derived from breeding at East Malling such as M.26 (semi-dwarfing) and M.27 (very-dwarfing) were grouped under the Malling (M) series label. The Malling/Merton (MM) series, developed jointly with the John Innes Institute – then located at Merton Park (Surrey) and now known as the John Innes Centre (Norwich) – aimed to produce rootstocks suitable for overseas territories such as Australia and South Africa where woolly apple aphid (WAA) was, and still is, a major problem.

Rootstocks from both series have been adopted in all apple growing regions across the world. M.M.106 (semi-invigorating) was probably the most popular of the Malling Merton series; it is still grown commercially (e.g. in cider orchards) but is progressively being replaced by other rootstocks of similar vigour and better disease resistance (e.g. M.116). M.9 has been the most widely-used apple rootstock both in the UK and across the world. Its dwarfing nature changed the way that apples are produced enabling higher density orchards to be planted and allowing for more efficient and quicker harvesting. Virtually all dessert apples grown in the UK are still grafted onto M.9 but, to remain competitive, growers increasingly require slightly more vigorous and robust rootstocks with better pest and disease resistance.

The East Malling Rootstock Club (2008-2020) was a commercial partnership with INN (International New varieties Network) and AHDB (UK grower levy board). It was set up to continue the evaluation of a

Figure 1. NIAB is breeding for a rootstock with vigour between M.9 and MM.106

pre-existing pipeline that had been developed with a focus on orchard and nursery performance and the generation of new breeding populations with a strong focus on pest and disease resistance. With climate change in mind, we aimed to select and breed rootstocks more tolerant of extreme weather events such as drought or waterlogging, whilst also identifying resistance to insect pests and pathogens. Those biotic and abiotic adaptation traits are needed in combination with other factors including ease of propagation, a commercial vigour range of between M.9 and M.M.106 (Figure 1), and higher yielding than those of other available rootstocks. A slight increase in vigour is needed by some growers who have to plant on soils previously used for apple production and which might suffer from apple replant disease. Organic growers also need greater vigour to compensate for a more complex nitrogen supply or greater weed control constraints.

Early work at East Malling on the relationships between anatomy and rootstock vigour enabled early screening of seedling material in the rootstock breeding programme. Whilst very labour intensive, this marked an important beginning in the process of shortening the historic 'wait and see how the plant turns out' approach to plant breeding. By investigating the anatomical basis, and later the physiological and genetic basis of the traits and attributes targeted in a breeding programme, research teams at East Malling and other programmes have aimed to speed up the long cycle of releasing a new rootstock.

Historical public-funded projects and recent PhD studentships at East Malling have developed a range of laboratory and genetic resources allowing us to identify DNA regions (markers) associated with traits of interest to the industry and therefore targets for selection by breeders such as dwarfing, crown rot, woolly apple aphid and canker resistance. Using those markers and others developed by researchers elsewhere to preselect parents and seedlings before the traits can be observed in the plants themselves, is part of NIAB's strategy for 'marker-assisted breeding'.

Figure 2. Trees recently grafted onto M.200

In combination with work from other research projects at NIAB (i.e. fast/speed breeding), marker assisted breeding enhances our ability to breed varieties with improved quality traits, whilst reducing the time it takes us to identify the elite progeny arising from a conventional cross made by the breeders.

However, the most recent release from the programme at NIAB at East Malling, M.200, was developed in the most 'conventional' of fashions. The seedling was pre-selected as dwarfing, based on root anatomy in the 1970s following a cross made in 1971 between Robusta 5 with Ottawa 3. M.200 has been extensively tested both in the UK and in continental Europe for over 20 years including recent trials at two sites in France, one in Germany and one in Italy. It is also part of an ongoing rootstock trial run by the EUFRIN group in 12 European countries.

On average, M.200 is 35% more productive and 15-20% more vigorous than M.9 – with some variability seen between different sites and scions – producing a similar profile of fruit size ranges. Trees worked on M.200 (Figure 2) show a seamless graft union creating a very stable tree and, to date, they have performed well on replanted soils in continental Europe. It appears to offer a better range of tolerance than M.9 to a range of diseases. Whilst not fully resistant, M.200 is more tolerant than M.9 to crown rot (*Phytophthora cactorum*), apple canker (*Neonectria ditissima*) and fireblight (*Erwinia amylovora*). It is also easy to propagate and we look forward to seeing established UK orchards soon. At present, M.200 can be ordered through the French propagator Dalival.

Amanda Karlstrom, Plant Breeder and Geneticist

Groundwork for developing improved apple crispness

Title: Enabling marker-based breeding methods for apple crispness
Funder: Horticultural quality and food loss network
Industry partners: University of Greenwich (Natural Resources Institute), Worldwide Fruit Ltd (WFL)
Term: April 2022 to December 2022

Flavour and fruit texture are the most important fruit characteristics affecting consumer's liking of apple varieties (Figure 1). Fruit texture is composed of both firmness and crispness and successful post-harvest storage of apples depends on reducing the decline in firmness and crispness to a minimum. In breeding new varieties, apple breeders would benefit from identifying genetic markers which confer high levels of firmness and crispness. Breeders have already suggested that alleles at two regions of chromosomes 3 and 16 of the apple genome may be associated with fruit texture, but further work is required to validate this and identify genetic markers that are linked to firmness and crispness.

The project

This short-term project set about studying the texture profile of 63 apple varieties following one month of storage to determine whether the alleles on chromosomes 3 and 16 on the apple genome are indeed associated with fruit crispness.

Results

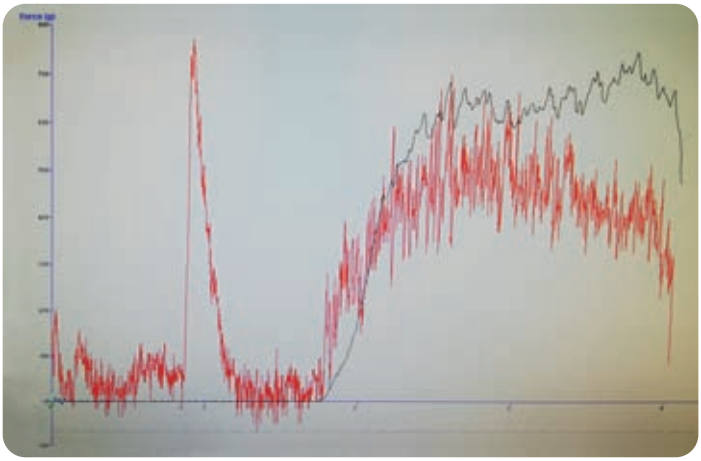
The NIAB team used a texture analyser coupled with a microphone which captures the acoustic emissions as a probe penetrates apple flesh. Using this 'acoustic-mechanical texture profile' approach, they studied the texture profile of 63 heritage varieties from the National Fruit Collection and eight commercial varieties. A multivariate analysis was conducted from the obtained acoustic-mechanical parameters. The resulting data (Figure 2) was used to determine whether there is an association between variety texture profile and those alleles that have previously been shown to be connected with higher fruit crispness in apple.

Apple varieties with the 'crisp' allele on chromosome 3 had higher coordinates for the first principal component and lower for the second component compared to those without the allele. These results indicate that the varieties with this allelic variant had less firm fruit but with a particular crisp dimension, confirming what had previously been suggested. Despite this, the team were unable to successfully identify molecular markers that can be directly implemented in breeding.

However, the work did successfully use acoustic-mechanical texture measurements to describe the texture profile of apple varieties. Such an approach can be adopted by breeders and variety developers to aid in the selection process of apple genotypes with improved post-storage texture. In the past, selections have been based on sensory evaluations which are difficult to reproduce and are unreliable when large numbers of varieties are being assessed. There may also be opportunities to use such acoustic-mechanical texture measurements in other fruit crops bred at NIAB. The project results have also provided the framework for similar future studies and aided in the understanding of components of apple fruit texture.

Figure 1. Flavour and texture affect consumers liking of apples

Figure 2. A multivariate analysis was carried out on acoustic mechanical parameters



Tom Passey, Principal Scientific Research Assistant

Seeking new control products for apple scab

Title: Understanding if and how alternative products can control apple scab for future incorporation into apple scab strategies

Funders: Horticulture Crop Protection Ltd and British Apples and Pears Ltd

Term: April 2023 to March 2024

Apple scab is one of the most serious aerial diseases (Figure 1) of apple across the world, which if not controlled, causes significant yield and financial losses. UK growers have traditionally relied upon conventional fungicides to gain economically viable control, but the number of active ingredients approved for use in the UK is diminishing and at the time of writing, UK apple growers expect to lose approvals for crucial active ingredients such as captan, dodine, mancozeb and myclobutanil. Alternatives are urgently needed and these need to be suited to IPM programmes and organic production.

The project

British Apples and Pears Ltd and Horticulture Crop Protection Ltd (HCP – formerly the horticulture crop protection team in AHDB) have funded NIAB to manage a screening trial to test the efficacy of various products at controlling apple scab. The original trial was scheduled to take place in 2022, but had to be aborted as the high temperatures and dry weather in that year were not conducive to scab infection, so the work was postponed until 2023. Products selected for assessment included those already authorised for use on other crops in the UK or those with a chance of being authorised here, along with those already authorised for use in organic production.

The list included bacterial biocontrol products, inorganic compounds, plant elicitors and a plant elicitor/metal compound. Two conventional fungicide products, Core (a.i. captan) and Difference (a.i. difenoconazole) were included as a commercial control, along with an untreated control. The NIAB pathologists were not only keen to assess the product efficacy, but also understand if each offered preventive properties, curative properties, or both. Potted trees were inoculated with *Venturia inaequalis* (the pathogen causing scab) and treated either the day before or the day after inoculation. The potted trees were held under protection (Figure 2) to avoid natural scab infection spreading from outside.

Figure 1. Typical symptoms of apple scab

Results

In the first two experiments in 2023, there was insufficient natural scab infection on the untreated control trees to provide any meaningful results, but in the third experiment, scab infection was found on all the uninoculated trees. One product (plant elicitor/metal compound) appeared to have efficacy both pre- and post-inoculation. One product (plant elicitor) appeared to reduce scab when used pre-inoculation (preventively), and an inorganic compound appeared to reduce scab post-inoculation (curatively).

All three products have been coded by HCP Ltd. Further research is needed to assess each coded product over a full season. For those that perform well through the season, HCP Ltd will seek to gather the necessary data to apply to the Chemicals Regulation Division (part of the government's Health and Safety Executive) for on-label or EAMU authorisation. Further work also needs to assess the products' potential for incorporation in an IPM scab control programme.

Figure 2. Potted trees were held under protection to avoid natural scab infection

Novel approaches to controlling apple canker

Apple canker (Figure 1) caused by the pathogen *Neonectria ditissima*, continues to give rise to 10-20% tree losses per year in young orchards, in the early years after establishment, and it is still considered one of the highest priorities for research by UK apple growers.

Previous NIAB research funded by AHDB (Project TF 223) used the biocontrol product Trianum G (*Trichoderma harzianum*) in newly planted orchards and stoolbeds. The product showed some promise in reducing the incidence of canker development, but it is currently only authorised for use on protected crops. This project also demonstrated that using secateurs incorporating a pesticide dispenser achieved significant reductions in number of canker infected pruning wounds. Applying Folicur (tebuconazole) either alone or in combination with BlocCade (a physical acting barrier to spore germination) gave best results.

NIAB has been working on two new apple canker research projects in the past year.

PEST AND PATHOGEN ECOLOGY

Matevz Papp-Rupar, Plant Pathology Research Leader

Title: New treatment programmes for control of apple canker

Funder: AHDB

Term: May 2022 to June 2023

The number of fungicide products authorised for use on apple in the UK has diminished rapidly in recent years. Much of the research work carried out by NIAB and other organisations has been investigating novel approaches to controlling apple canker, seeking to increase tree health and the tree's ability to withstand infection. Although this has the potential to find a sustainable solution, research of this kind is time consuming and does not always yield quick answers for growers. The AHDB kindly funded this short-term research project to test some alternative spray products that had not been previously tested against apple canker.

The project

The aim of the work was to test the efficacy of biocontrol agents, plant extract products and novel chemical fungicides against the apple canker pathogen. All the tested products were either already available on UK/EU markets in 2022, but not registered for apple, or in the final stages of registration.

The trial focused on leaf scar and wound protection after harvest and during the leaf fall period, when most canker infections occur in the UK. All products were compared to water control and standard treatment (captan/tebuconazole/captan at 20%/50%/80% leaf fall).

Figure 1. Branch dieback caused by Neonectria ditissima

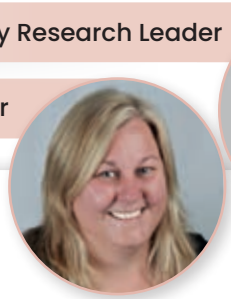
Results

A Trichoderma based biocontrol product and a conazole based fungicide offered some decrease in canker incidence on infected trees, but only at lower inoculum levels of naturally infected wounds.

As the biocontrol product is only authorised for use on grapevines and the conazole fungicide is not currently authorised on any crops in the UK, further research is urgently required.

Matevz Papp-Rupar, Plant Pathology Research Leader

Louisa Robinson-Boyer, Plant Microbial Interactions Research Leader



Title: Enhancing orchard ecology for improved resilience to climate change and apple canker disease

Funders: Growing Kent & Medway and The East Malling Trust

Industry partner: Avalon Fresh

Term: May 2022 to October 2024

Despite spending a significant number of years researching ways of controlling apple canker using both conventional and novel approaches, control options continue to be expensive, time consuming and can have limited impact. NIAB's Pest and Pathogen Ecology team are increasingly seeking to harness existing ecosystems on fruit farms as an alternative way of gaining natural control of both insect pests and diseases of fruit crops. Using Growing Kent & Medway funding and partnering with Avalon Fresh and Agrovista, it was considered the right time to find ways of enhancing orchard ecology to increase the trees' resilience.

The project

This project is exploring novel approaches such as biocontrol, alternative spray programmes and soil amendments for improved tree health and resilience with the hope of improving canker management practices.

The first objective is assessing the use of commercial mycorrhiza and Trichoderma based products applied to newly planted Gala orchards in both drought and waterlogged prone soils to improve tree establishment and potentially reduce canker impact. Canker incidence, tree mortality and tree growth is being recorded every six months to compare treatments.

The second objective is seeking to improve resilience of older, established orchards. Mycorrhizal fungi are believed to improve soil drainage, soil health and nutrient uptake, to enhance tree health, tree growth and the ability to withstand pathogen infection. Different tools for increasing mycorrhiza in the orchard are being tested such as: planting wildflower species that are known to support the growth of naturally occurring and introduced mycorrhiza (Figure 2); a modified root pruner supplied by Agrovista which dispenses mycorrhizal inoculum directly to tree roots during root pruning. The effect of the treatments on the amount of mycorrhizal fungi and fruit yield are being tested.

Finally, a range of novel substances are being assessed in a newly planted orchard which has been artificially infected with apple canker (*Neonectria ditissima*) at a high inoculum level. Products authorised for use in the UK but not currently registered on apple are included, along with biocontrol products with antimicrobial properties, which are being applied both with and without biostimulants and defence elicitors.

Figure 2. Some wild flower species can support the growth and development of mycorrhiza

Results to date

The results from the Year 1 trial assessing the use of novel substances in a newly planted orchard indicated that hydrated lime (e.g. building grade Hydrated Lime Blue Circle) applied three times (20%, 50% and 80% leaf fall) at the rate of 50 kg per ha in 300 L of water, significantly reduced canker incidence. The results are in line with the research findings from The Netherlands where this approach is used in overhead irrigation. In Year 2 the dose and timing of hydrated lime application will be optimised and tested in combination with other products.

Xiangming Xu, Director of Research

Fundamental research into cherry canker

Title: Predicting the emergence of host-adapted bacterial phytopathogens
Funders: Biotechnology and Biology Science Research Council, NERC and the Scottish Government
Partners: University of Birmingham and Imperial College
Term: July 2020 to March 2024

Bacterial pathogens can cause significant commercial damage and in the case of cherry, *Pseudomonas syringae* (*pathovars syringae* and *morsprunorum*) can cause up to 70% tree loss. Cherry growers have recently lost the use of copper based control sprays, so new forms of management are required.

It is known that during the autumn months, this bacterial pathogen enters woody tissue through leaf scar wounds on cherry trees, leading to infection of the woody tissues (Figure 1) as the trees move into dormancy. The bacteria overwinter and give rise to canker lesions on branches. In spring, the bacteria are washed by rain onto leaves and blossom. *P. syringae* survives through spring and summer on the surface of cherry leaves (as epiphytes) without causing disease symptoms. During the summer, this pathogen may infect fruits leaving necrotic spots, and/or enter leaves through the stomata causing leaf spot symptoms and eventually 'shot-holes' in the leaves.

This BBSRC, NERC and Scottish Government funded project offers the chance to undertake fundamental research into the spring/summer stage of the lifecycle of the pathogen when the bacteria are living freely on the surface of leaves as epiphytes.

The project

The project is examining how populations of these epiphytes change on the leaf surface and how they vary in time and space in both the crop and in wild settings. It is also investigating how the populations are influenced by the environment, how they are associated with plant species other than cherry, how agronomic practices affect the populations, and whether the pathogenicity of bacterial isolates are affected by the host or the environment.

Figure 1. Infection of woody tissue in cherry

Results to date

The project initially investigated how the environment was influencing populations of *P. syringae* (pathovar *syringae*). Cherry orchards and related plant species in nearby woodland were surveyed in Kent, south-west England, Herefordshire and Scotland. Leaves were sampled in spring and autumn over two years, using different varieties (Sweetheart, Penny, Lapins and Kordia). The wild species sampled included wild cherry, cherry plum, blackthorn, wild strawberry, hawthorn and Ash. Molecular sequencing techniques were used to study the population dynamics. The results revealed that the proportion of potentially pathogenic isolates of *P. syringae* is far higher in Kent and south-west England, particularly in cherry orchards. In contrast, the proportion in Scotland was close to zero. It is now important to find out why the proportion is so low in Scotland and if this is influenced by climate. This could have relevance to cherry production and management in different regions of the UK.

Work was recently done at East Malling, to investigate the impact of covering the trees with tunnel films and the influence of nitrogen application. Currently, data are being analysed and results from the work will allow NIAB to assess how the pathogen population changes with different cultural practices.

A third study area is examining the genetic factors that affect adaptation of *P. syringae* to its host. The question the scientists wanted to answer was whether pathogen isolates that are pathogenic can pass their pathogenicity to isolates that are non-pathogenic? Can evolution of the genetics of the bacterial pathogens occur rapidly? It was found that on a single leaf surface, there is great variation in the pathogenicity of the bacterial isolates, but also that pathogenicity can be transferred by a phage (bacterial virus) from a known pathogenic strain to another non-pathogenic strain.

The final piece of research seeks to understand if we are able to use genomic information to predict whether a particular isolate of *P. syringae* can infect cherry.

Answers and knowledge generated from this project may influence practical management of bacterial canker on commercial cherry farms.

Xiangming Xu, Director of Research

Biocontrol in strawberry

Title: Biocontrol of horticultural diseases in apple and strawberry using cover crops and biopesticides

Funder: EU Eranet

Term: April 2021 to March 2024

Strawberry growers have fewer conventional fungicides authorised for use on their crop than ever before and for the soil/substrate borne pathogen *Phytophthora cactorum*, are limited solely to the use of Paraat (dimethomorph). In recent years, biocontrol agents (BCAs) offering some control of aerial diseases like Botrytis and powdery mildew, as well as root and crown diseases such as Phytophthora, have been evolving and gradually becoming available to strawberry growers. However, in commercial practice, growers have not always found them to offer such reliable control, and their efficacy is sometimes adversely affected by temperature and humidity both during and after application. Our understanding of their population dynamics relative to climatic conditions can be crucial to their efficacy.

The project

In this project, NIAB scientists are working on three BCAs commonly used in strawberry to obtain ecological knowledge and to develop models to predict their fate in the environment following their application, so that we can optimise the timing of their use. The focus is on *Trichoderma asperellum* (T34 Biocontrol – authorised for use in permanent protection full enclosure strawberries for Pythium and Fusarium control), *Gliocladium catenulatum* (Prestop – authorised for use on strawberry for control of Phyotphthora and other root diseases) and *Bacillus subtilis* (Serenade – authorised for use on outdoor and protected strawberry for Botrytis control). The work falls into several objectives.

Results to date

The initial work developed a qPCR method for quantifying the viable population size of *Trichoderma asperellum*. This and similar methods already in place for *Bacillus subtilis* and *Gliocladium catenulatum*, are being used in the duration of the project to study its survival around strawberry crowns and roots.

Work has also been carried out to test whether *Trichoderma asperellum* and *Gliocladium catenulatum* can be detected on strawberry roots following coir-drench inoculation at the single and double commercial dose. Both were found to have a high survival rate on root surfaces in coir (Figure 1). Over time, a slight decrease in population of both occurred between 8 and 16 days after inoculation, suggesting that both can survive in coir for at least two weeks. Further data was gathered in 2023 and analysis is ongoing.

Figure 1. Assessing roots following use of biofungicide drenches

A further study has been made to model the survival of *Gliocladium catenulatum* and *Bacillus subtilis* on flowers after application at full open flower stage. For *Bacillus subtilis*, the populations fluctuated among replicate inoculations and in some cases, populations dropped after 24 hours, but then returned to their original levels after 48 and 72 hours. These results suggest that its survival is unlikely to be an issue, although the rapid turn-over of flowers may necessitate frequent applications. *Gliocladium catenulatum* population sizes on flowers appeared to remain very stable over time, indicating high survival under the experimental conditions used. In 2023, further work was being done to differentiate between introduced strains and resident strains of both *Gliocladium catenulatum* and *Bacillus subtilis* on flowers.

Another trial in 2023 aimed to determine the extent to which different formulations of *Gliocladium catenulatum* and *Bacillus subtilis* affect microbial survival on leaves and flowers and resulting efficacy against *Botrytis cinerea* on flowers

In order to reuse spent coir for strawberry production, one key requirement is to avoid pathogen inoculum build-up in the spent coir substrate from the previous crop. A large experiment is being conducted to assess whether microbial treatment of spent coir could significantly reduce pathogen inoculum build-up. To date, there have been no statistically significant differences between treatments, and few conclusions have been drawn so far.

Francis Wamonje, Entomology Research Leader

Improving our ability to investigate and manage apple sawfly

Title: Apple Sawfly: Developing extraction methods to acquire adult insects for pheromone identification

Funder: The Worshipful Company of Fruiterers

Term: February 2023 to December 2023

Apple sawfly larvae can cause serious damage (Figure 1) if left uncontrolled in apple orchards. With the loss of several broad-spectrum spray products and a period of activity that coincides with blossom when conservation of pollinating insects is vital, alternative control measures are needed. Previous attempts to identify the sex pheromone have been hampered by an inability to rear sufficient numbers of adult sawfly, so there is a pressing need to develop methods of collecting and rearing sufficient adults to allow pheromone identification, which might lead to future development of novel monitoring and control tools.

The project

Working with commercial apple growers, NIAB aimed to develop effective protocols for isolating apple sawfly larvae and/or pupae from orchard soils by sieving and/or flotation. They employed systems that have been experimented with by Wageningen University in The Netherlands. If successful, it would provide them with larvae or pupae that can be reared into adults for use in entrainment experiments. Any adults reared would be maintained individually to ensure adults remain virgin as pheromone production by female sawflies generally decreases after mating. The emerging adults would also be used for pheromone collection at NIAB by entrainment of volatiles for processing by colleagues at The University of Greenwich for use as pump-priming data for a future project aimed at sex pheromone identification.

Results to date

The team experimented with collecting apple sawfly pupae using the Netherlands' flotation method. This was proven to work on the clay soils used in the project. The procedure includes digging soil samples to 30cm depth from below the tree canopy, removing surface vegetation, distributing a layer of soil in trays (Figure 2), adding water and leaving samples to soak, gently breaking up large soil clumps, and stirring samples to release organic matter. Any floating apple sawfly cocoons were collected. Using this method, the team collected over 80 pupae for incubation into adults.

Adult sawflies began emerging from pupae in mid-March. NIAB set up the entrainment of headspace volatiles, by placing adults on Prunus flower trusses. Headspace volatiles are collected over 24 hours. So far, 12 adults (4 male and 8 female) have been entrained for collection of volatile organic compounds for pheromone identification. This work is ongoing, and it is anticipated that it will proceed into analysing the volatile organic compounds collected at The University of Greenwich.

Figure 1. Apple sawfly ribbon scar caused by larvae

Figure 2. Collecting soil samples in trays to collect apple sawfly pupae

Francis Wamonje, Entomology Research Leader

Progress towards forest bug control

Title: Development of pheromones for innovative management of forest bug, an emerging pest of orchards in England

Funders: Defra Farming Innovation Programme and The East Malling Trust

Partners: Agrovista UK Ltd, Avalon Fresh, Russell IPM and University of Greenwich

Term: May 2022 to April 2024

Since the withdrawal of the broad-spectrum insecticide chlorpyrifos in 2016, growers and agronomists have been finding increasing numbers of new insect pests in apple and pear that had previously been controlled. In some cases, insects that had not been considered as pests for a generation or more of fruit growers, have gradually been reappearing. The forest bug (*Pentatoma rufipes*) is one such pest.

Like many other shield bug species, such as brown marmorated stink bug, forest bugs produce a sticky defensive secretion with a strong smell which can contaminate fruits such as raspberry and cherry, but the bug is considered to be harmless outside of harvest time. It may even provide benefits to growers through feeding on other pests, such as caterpillars and aphids. However, in apple and pear, the pest can be rather more damaging.

Overwintering forest bug nymphs (2nd instar – Figure 1) feed early in the season on developing buds, flowers and fruits (shortly after flowering). The nymphs are particularly difficult to detect as their bodies appear similar to the tree bark and are well camouflaged. They can also squeeze their 3 mm, small flattened bodies into the cracks and crevices of tree bark to find some shelter from the cold. Their feeding only becomes apparent long afterwards when developing apples and pears become distorted and pitted (Figure 2), and the flesh becomes discoloured. Brown lesions develop in the fruit flesh at the site of the forest bug stylet insertion, and the lesions harden, giving the fruit a 'stony' texture at harvest.

Fruit losses of 10% at harvest are common but occasionally, much higher levels of 40-50% damage have been reported, so management and control measures are becoming increasingly necessary. There is only one generation of forest bug per year and only spring control measures are generally used before or after flowering, to target the overwintering nymphs before they start to feed. With fewer effective control products available than ever before, a novel management strategy needs to be found.

Figure 1. 2nd instar nymphs are camouflaged on tree bark

Photo: Jonathan Michaelson

Figure 2. Forest bug damage to Gala apples

The project

This project aims to identify and synthesise a pheromone for forest bug which can then be used as a lure in traps which will allow growers to monitor for the presence of the pest and allow the industry to work towards novel approaches to control.

Results to date

Orchards have been sampled for the pest and methods to rear it in the laboratory have been developed, whilst entrainment methods have been used to collect components of its sex pheromone. Scientists at the University of Greenwich are analysing their composition with the intention of synthesising them for use as a chemical lure in monitoring traps. Once synthesised, prototype dispensers for these lures will be manufactured and developed within a monitoring trap.

Additional work is in progress to develop the optimum design of trap which could be deployed once the lure is fully developed. The use of chemical repellents in the field is also being investigated. If successful, this might lead to the testing of a 'push-pull' approach to control which NIAB has previously achieved with capsid pests in strawberry.

Michelle Fountain, Head of Pest and Pathogen Ecology

Non-chemical control options for woolly apple aphid

Title: Novel approaches to pest and disease control in apples and pears
Funder: British Apples and Pears Ltd
Term: April 2023 to March 2024

British Apples and Pears Ltd is funding NIAB to investigate new approaches to controlling a range of pests and diseases. In 2023, we have been working on apple canker and apple scab control whilst reviewing IPM techniques for codling moth and brown marmorated stink bug control. In addition, precision monitoring, semiochemical and biological manipulation has been investigated to control pests such as apple blossom weevil, capsids and sawfly.

The final part of the work sought to develop natural control methods for woolly apple aphid (WAA), currently one of the most challenging pests for apple growers to manage (Figure 1). The pest used to be successfully controlled by broad-spectrum spray products, but the most effective of these have been withdrawn. Batavia (spirotetramat) currently has an EAMU authorisation to control woolly apple aphid, but weather conditions and application timing are not always optimum for effective control. Rootstock resistance also used to contribute to control, but recent research by a NIAB PhD study demonstrated that WAA has at least partially overcome such genetic resistance in some rootstocks. Alternative natural and biological control methods need to be assessed.

The project

Earwigs (*Forficula auricularia*) are important generalist predators in both apple and pear, of many pest species including aphids. In pear, previous Defra funded research demonstrated that earwigs contribute significantly to the predation of pear sucker. Wignests were developed in an Innovate UK project and offer shelter for earwigs, spiders, anthocorids and other predators, and where earwigs have been present in such wignests in apple orchards (Figure 2), a reduction in incidence of pest damage caused by codling moth and aphids has been recorded. The wignests are commercially available through Russell IPM. This project set about assessing if earwigs housed in wignests and deployed in apple trees hosting WAA, could reduce WAA colonies and colony size.

Results

Large numbers of earwigs were harvested from other habitats in May and June 2023, housed within wignests and then deployed in apple trees in three different WAA affected orchards. Plots both with and without wignests were compared for WAA numbers in July and August.

Overall, placing wignests containing five earwigs each in apple tree canopies did not significantly reduce the numbers of WAA in apple trees in one season. However, a trend was seen, especially on one of the sites, which demonstrated an overall reduction in the numbers of WAA on shoot leaf nodes, especially in the middle of the growing season (July and August) following the deployment of earwig loaded wignests at the end of June. These results are encouraging, so it has been suggested that this work might be continued to examine the long-term impacts of relocating earwigs to apple orchards both to assess if earwigs return to the wignests in subsequent years, and also to test if re-inoculating the refuges with earwigs in a second year might reduce the WAA numbers further.

Further research might also seek to develop methods of harvesting and redeploying earwigs which are less reliant on labour. Additional research might address recent reports of fewer earwigs in orchards which might have been brought about by changing cultural practices such as less frequent mowing and the incorporation of cover crops.

Figure 1. Woolly apple aphid is particularly difficult to manage

Figure 2. Earwigs housed in wignests could reduce woolly apple aphid populations

Surveying and reviewing control strategies for brown marmorated stink bug

Brown marmorated stink bug (BMSB, *Halyomorpha halys*) is an invasive pest established in many European countries, causing significant crop damage in apples and pears in countries such as Italy, where temperatures favour two generations per year. NIAB has been working on the pest in recent years both to monitor its presence and movement in the UK, and to learn more about potential control strategies should it become established here. Two projects were funded in 2023.

PEST AND PATHOGEN ECOLOGY

Francis Wamonje, Entomology Research Leader

Title: Brown marmorated stink bug (*Halyomorpha halys*) surveillance in the UK

Funder: Defra

Term: March 2022 to February 2024

NIAB has been monitoring BMSB since 2018 and has observed adults, more recently females, free in the environment within England. In this project, Defra has funded NIAB to continue to monitor for adults in the environment (Figure 1), search for immature stages to determine if populations are establishing in the UK, intercept BMSB emerging from overwintering sites, and collate expert confirmed public findings.

The project

The surveillance work took place between May and November 2023 with help and support from the Royal Horticultural Society and the Natural History Museum. Sentinel pheromone traps were deployed at a total of 36 sites in 2023, some six more than 2022. The traps were located across a range of sites including inner-city municipal gardens (Figure 2) in London, south-east England and the Bristol Channel, motorhome and caravan storage sites, sites where previous records of BMSB catches have been confirmed and other sites where climate change models have predicted establishment, such as Norfolk.

Results

A total of seven BMSB sightings were made across these sites in 2023, slightly lower than the sightings reported in 2022 (10) and 2021 (11). In contrast to 2022, the weather conditions were colder in early 2023, which might explain the lower numbers of sightings. However in contrast to the previous years sightings, numbers of adults recorded at each site were larger in 2023.

For instance, over 200 adults were recorded in a campervan that had returned to Yorkshire from France. Further monitoring traps were deployed in and around the site to intercept any adults that may have evaded the original trap. Six live adults were sent to NIAB and held in culture for three weeks. Both male and female adults were recorded but no eggs were laid in that time. Further catches have been made in campervans also in northern England and Scotland, and although southern England is expected to be more

Figure 1. Adult brown marmorated stink bug

vulnerable to the pest due to warmer weather conditions, should BMSB reach warmer overwintering habitats such as inner cities, they could potentially become established in these northern areas of the UK.

To date, only adults have been found and no other life stages of the pest, indicating that there are no breeding populations yet in the UK. However, given the consistent year-on-year recovery of adult stages and the occurrence of them on pheromone traps, our reasoned assessment is that it's only a matter of time before establishment occurs in the UK. It is hoped that monitoring can be extended into 2024 and 2025.

Figure 2. Monitoring in municipal gardens

PEST AND PATHOGEN ECOLOGY

Michelle Fountain, Head of Pest and Pathogen Ecology

Title: Novel approaches to pest and disease control in apples and pears – Review of BMSB

Funder: British Apples and Pears Ltd

Term: April 2023 to March 2024

British Apples and Pears Ltd is funding NIAB to investigate new approaches to controlling a range of pests and diseases. In 2023, we have been working on apple canker and apple scab control whilst seeking natural control methods for woolly apple aphid and IPM techniques for codling moth control. In addition, precision monitoring, semiochemical and biological manipulation has been investigated to control hard bodied pests. Part of this work has included a review of brown marmorated stink bug control strategies.

The project

The review included a complete literature search which aimed to summarise tested and successful BMSB monitoring and control strategies from around the globe that might be tailored for use by UK apple and pear growers.

Results

The review emphasised the devastating destruction that can be caused by BMSB in apple and pear crops, leading to adverse economic impacts that can escalate rapidly following the establishment of the pest in new regions. This has been exhibited in massive financial losses to Italian and North American fruit crops within a couple of years of initial detection of the pest.

Fundamental research has provided more understanding of aggregation pheromones, host attractions, microbial symbionts, and molecular knowledge that could lead to advances in biotechnological control methods. Significant progress has been achieved with imported Asian egg parasitoids for biological control, demonstrating their ability to adapt to new environments and their contribution to substantial egg mortality, without having adverse effects on native species.

At present, conventional broad spectrum spray products offer the most effective control of BMSB, but more sustainable and environmentally friendly approaches are needed. Further research needs to focus on optimising monitoring procedures, deploying more selective control agents, and integrating these with both cultural tactics and biological control agents to develop more sustainable integrated pest management solutions.

The review proposed a series of future research objectives and made some positive recommendations to growers on how to manage the pest. These included deploying pheromone-baited traps before spring emergence to monitor BMSB populations and establish treatment thresholds for the growing season, as well as conserving native generalist egg predators like shield bugs, assassin bugs, and ants that can contribute to mortality. Crop exclusion netting might be considered and close crop monitoring employed to identify when pest thresholds warrant application of selective control products. The industry should also work with appropriate government departments to seek approval for employing commercially available Asian egg parasitoids in Europe.

Developing non-chemical control strategies for SWD

Since the arrival of spotted wing drosophila (SWD – *Drosophila suzukii* – Figure 1) in the UK in 2012, NIAB has collaborated with others to lead two major AHDB funded projects to improve our knowledge and understanding of how to manage SWD in UK conditions, and more recently, to develop novel control strategies that do not rely on conventional chemical spray control. Most recently, they have been engaged in projects focusing on the use of bait sprays for control and assessing potential resistance in strawberry and raspberry varieties to damage from the pest.

PEST AND PATHOGEN ECOLOGY

Michelle Fountain, Head of Pest and Pathogen Ecology

Title: Assessing the impact of bait sprays targeted to control spotted wing drosophila on beneficial and non-target insects

Funder: The Worshipful Company of Fruiterers

Industry partners: Microbiotech Ltd (Lead), Russell IPM and Berry Gardens Growers Ltd

Term: February 2022 to January 2024

In AHDB Project SF/TF 145a, NIAB collaborated with Microbiotech to investigate the use of bait sprays as a means of controlling SWD in commercial fruit crops. The theory behind the technique is that bait sprays can be used in combination with spray control products to help to attract the SWD adults to feed on the spray product, improving the likelihood of control. When compared to the spray control product on its own, it offers the potential to gain the same level of control with a lower rate of product. This would have the added benefit of reducing the risk of residues occurring and the development of resistance to the product.

Figure 1. Adult Male SWD

The AHDB work identified that the adjuvants Combi-protec or Probandz (both commercially available for use) were successful baits for SWD and these have been tested with control products on strawberry, raspberry, and cherry over the past three seasons. The scientists have repeatedly found that, compared to full coverage foliar sprays of plant protection products (PPPs), the same control of SWD can be achieved when mixing a Combi-protec or Probandz with a significantly reduced rate of a PPP and applying the spray to a reduced area of the crop canopy (Figure 2). In effect, the bait attracts adult SWD to feed on the sprayed part of the leaf canopy, ensuring that the insect ingests the PPP, leading to its death, and significantly reducing damage to fruit.

It is legal to use Combi-protec or Probandz as adjuvants with standard or EAMU authorised control products and some commercial strawberry and raspberry growers have already started to successfully employ it with standard and EAMU authorised Tracer (used at half rate or less) and are achieving effective results. However, there have been concerns raised as to the impact that these bait sprays may have on beneficial and other non-target insects.

Figure 2. Bait spray applied as a band of large droplets to raspberry

The project

The Worshipful Company of Fruiterers funded the NIAB team to investigate the impact that such bait spray treatments may have on six non-target insect species including Orius (commonly used in soft fruit production for thrips control), ladybirds (voracious predators of aphid pests), lacewings (common natural enemy of aphids), earwigs (a generalist predator of a range of pests found in orchard crops), and hoverflies (voracious predator of aphids).

Results

Using a series of laboratory bioassays which exposed groups of beneficial and non-target insects to Plant Protection Products (PPPs) with or without bait, compared to bait alone and a water control, the potential impact of PPP:bait mixtures on non-target insects was determined.

The results of the toxicity studies separated the insects into three broad groups; 1) adult hoverflies, adult earwigs, *Orius*, 2) adult *Drosophila melanogaster*, and 3) lacewing (Figure 3) and ladybird larvae.

In the first group, bait + spinosad or spinosad alone had a detrimental impact on the insect's life expectancy although the speed of kill differed between insect groups.

For the second group, the bait + spinosad treatment was faster acting than spinosad applied without bait, presumably because the species, closely related to SWD, was attracted to, and fed on the insecticide, more readily.

No detrimental impact of the treatments was observed on the third group.

Spinosad appears to be no more toxic to beneficial insects than if applied in the same size droplets without bait, except for the non-target insect, *D. melanogaster* where the speed of kill was faster when a bait was added. Baits alone had no detrimental effect on any of the insects.

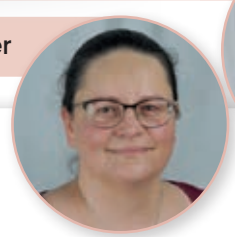
In conclusion, baits added to PPPs and applied indirectly as large droplets are no more toxic to beneficial insects than full foliar sprays. In principle, exposure to PPPs should be reduced because less product is applied to the crop, and usually away from the fruit. This is likely to have benefits for biocontrol programmes for SWD and other pests.

Figure 3. Lacewing larva

PEST AND PATHOGEN ECOLOGY

Michelle Fountain, Head of Pest and Pathogen Ecology

Feli Fernandez, Senior Plant Breeder



Title: Screening for resistance to spotted wing drosophila in strawberry and raspberry accessions

Funders: Growing Kent & Medway and The East Malling Trust

Industry partner: Asplins PO and WB Chambers

Term: May 2022 to October 2024

Although UK growers are still heavily dependent on conventional spray products to provide effective control of SWD, progress has been made in finding alternative approaches, including the use of precision monitoring in the winter months, use of bait sprays and the development of Sterile Insect Technique (SIT) by commercial company BigSis.

However, one approach to control that has yet to be fully explored is fruit variety resistance to the pest. Ripening soft and stone fruits are highly attractive to adult SWD, with the female making an incision in the skin of the fruit and laying eggs under the surface. The resulting larvae feed on the flesh of the fruit, leading to fruit collapse and an unmarketable product. If any accessions (varieties, selections or species) of soft fruits are found to have berries that are less attractive to SWD or that inhibit egg laying or larval emergence, we could then investigate the fruit traits that are associated with this and utilise such traits in fruit breeding programmes.

The project

In this project, NIAB is screening many accessions of strawberry and raspberry, initially to identify if any show tolerance to SWD and then the mechanism of resistance.

In the first year, the focus was on strawberry and the NIAB team chose a wide range of strawberry genotypes based on their origin and

pedigree. The material tested was diverse (Figure 4), ranging from the old English bred June-bearer variety 'Cambridge Favourite', to the large, firm Californian variety day-neutral type 'Diamante'. The range included differing traits like skin colour, skin firmness, flesh firmness, size, and sugar levels (Brix). The aim was to identify any correlations between fruit traits and emergence of adult SWD from the fruit.

A total of 76 accessions were planted in replicated plots in a commercial strawberry production farm, by kind permission of WB Chambers. Fruit was picked throughout the season, brought back to NIAB laboratories where fruit traits were assessed and the fruit exposed in containers to adult female SWD. The number of eggs laid in each variety was recorded and the adult females then removed. Following 14 days, the number of emerging adults was counted from each of the original berries.

Results to date

The results so far on strawberry have been very promising, as there was found to be statistically significant variation in the numbers of adults emerging from berries between the 76 accessions included. The genotypes used were grouped together based on the level of emergence. For those genotypes where a lack of emergence was found, some fruit quality traits were correlated. In particular, the levels of Brix and the skin colour appeared to influence the level of SWD emergence from fruit.

Figure 4. A wide range of strawberry material has been tested for resistance to SWD

Figure 5. Raspberries being assessed for attractiveness to SWD

Photo: Washington State University

In 2023, the results from 2022 were being validated by re-screening those genotypes which showed either high levels of emergence or low levels of emergence. A similar exercise is being undertaken for raspberries (Figure 5), looking at a wide range of accessions, including red, purple and black coloured raspberry.

Michelle Fountain, Head of Pest and Pathogen Ecology

Understanding the impact of landscape complexity on pest and disease control

Title: Agrobioconnect: Connections in the landscape. Role of landscape complexity in agroecosystem sustainability

Funder: Defra SusCrop ERA-Net

Industry partners: Berry Gardens Growers and Avalon Fresh

Term: February 2023 to January 2026

Intensive horticultural practices which focus on expansive cropping with little consideration to a patchwork of habitat within a landscape, can lead to a homogenous growing environment which does not deliver ecosystem services and can require increased inputs to obtain pollination and pest control. In the past, fruit crop management has not always taken account of biodiversity and the farm ecosystem, and the use of some crop protection products may have exacerbated non-target pest and disease problems in a crop. With fewer authorised conventional spray products available than ever before, NIAB researchers are increasingly working with growers and other industry partners to harness naturally occurring, introduced beneficial arthropods and biocontrol agents, to develop novel and more sustainable crop protection strategies.

We understand that increased biodiversity on a farm can lead to more resilient ecosystems (Figure 1), which give more long-term assurance of pollination and pest regulation. However, these require a holistic understanding of the ecological mechanisms at work including understanding how landscape structure and complexity affect the supply of 'agroecosystem services', or put another way, the ability of the landscape structure to provide natural forms of pest and disease control.

Figure 1. Increased biodiversity on a farm can lead to more resilient ecosystems

The project

In this project, NIAB is one of a European science partnership. The partners are investigating the effect of landscape complexity over time and land cover/productivity dynamics on the above and belowground ecosystem services in a range of European agricultural landscapes. The relationship between the landscape complexity and the resulting ecosystem services provided, will be analysed by linking data from remote

Figure 2. NIAB has been studying landscape complexity across 18 different strawberry farms

satellite sensors to biodiversity data that is collected in the field.

Results

NIAB's work began in 2023 by studying the landscape complexity across 18 commercial strawberry farms in the UK (Figure 2). Using satellite images of each farm, they asked people to rank the images based on the landscape complexity of each from the highest to the lowest. Ten people ranked all 18 sites while 17 people ranked a five-site subset of sites. There was reasonable agreement about the extreme high and low heterogeneity sites, but less consensus over the intermediate-heterogeneity landscapes. An academic project partner from Italy is currently performing a more detailed Geographic Information System analysis.

NIAB's next task has been to study the impact of heterogenous landscapes on biodiversity on the strawberry farms. We have been specifically measuring parasitoid and pollinator biodiversity. This has involved walking through crops and around the field margins and hedgerows, recording bees, aphids and their parasitoids. This data will be analysed alongside the satellite landscape heterogeneity data to see if a more diverse landscape results in a more diverse set of pollinators and pest regulation services. In the first year, we recorded 20 bee species and five aphid species (black bean aphid, melon/cotton aphid, potato aphid, strawberry aphid and a Staegeriella species). The aphid colonies have yielded a total of 541 parasitoids, ranging from 0-11 parasitoids per aphid colony. The knowledge that we develop will inform relationships between landscape parameters and ecosystem services.

NIAB is currently working to develop a DNA barcoding methodology that will identify bees and aphid parasitoids more readily. This will provide the whole scientific team working across Europe with a reliable and easily replicable tool for species-level taxonomic resolution. The goal is ultimately to produce a database of genetic information about parasitoids and bees so that farmers and growers can measure the biodiversity on their farms to inform land management decisions. For example, those that score very low on biodiversity may consider what habitat improvements could be implemented to improve beneficial insect numbers and diversity on farms (e.g. aphid parasitoids). Those that already score highly can identify the habitats of importance so that these can be maintained or further improved.

The findings of the work will ultimately guide policy and actions on fruit farms to adapt to climate change.

Michelle Fountain, Head of Pest and Pathogen Ecology

Developing wildflower mixes dedicated to UK fruit crops

Title: BEESPOKE

Funder: European Regional Development Fund

Industry partners: Policy makers, research institutes and agronomists from seven different North Sea region countries including UK, Belgium, Netherlands, Germany, Denmark, Norway and Sweden

Term: April 2019 to March 2023

NIAB was a partner of BEESPOKE, an EU funded project which sought to increase the number of pollinators and crop pollination on a local and landscape scale by providing expertise, tools and financial knowledge to support growers across the North Sea region. Flower rich semi-natural grassland is the main habitat that supports pollinators, but by 1984, in lowland England and Wales, the area had declined by 97% compared to the previous 50 years, with only 7,500 hectares remaining by 2010. Fruit crops benefit from wildflower rich habitats, not only in the provision of pollinators to maximise yields, but also for the provision of beneficial insects which help to regulate populations of insect pests. Fruit farms therefore will benefit from the establishment of flower rich habitats, which can help to replace at least some of the semi-natural grassland area that has been lost.

The project

One of the aims of the project was to develop a range of seed mixes for planting on farms to help reverse the decline in pollinators. These have been targeted at the types of pollinators needed by each crop type. Some were sown at demonstration centres such as NIAB's East Malling site (Figure 1) to evaluate how effective they are by increasing not only the levels and types of pollinators visiting the strips, but also whether they increase numbers in the crops, and whether this has a subsequent impact on crop yield and quality.

Results

Both this project and a literature review carried out by NIAB (*Impacts of wildflower interactions on beneficial insects in fruit crops*) confirm that provision of wildflower habitats on fruit farms will invariably be neutral or positive in terms of increasing numbers of pollinators or beneficial insects. They will increase the numbers of pollinator visits to the crop and in some crops, which are less attractive to bees, enhance production or yields. The benefits tend to increase with time following sowing and establishment of wildflower areas, and for this reason, perennial mixes tend to be more beneficial. Even in the early years, a reduction in certain pest species such as aphids or codling moth (apple) is observed, but most significant impacts are seen from three to four years onwards with an increase in predator/prey ratios.

When setting about developing BEESPOKE wildflower mixes for our different UK fruit crops, NIAB gave serious thought to the structure, size and composition of the areas to be established and how they should be managed.

It is important to include species that provide height to the mix, which provides improved habitat for insects and an increased biomass which is good for carbon capture. As a result, mowing should be kept to a minimum (Figure 2) and if it must

Figure 1. Wildflower demonstration area sown at NIAB's East Malling site

Figure 2. Mowing should be kept to a minimum

be carried out, it is better to mow every other crop row or in the case of large wildflower areas, only half the area. Ideally, the height should be maintained at a minimum of 20 cm. If there has been little rainfall, a single cut in the autumn may be all that is needed.

Although semi-natural habitats are important habitat for pollinators and beneficials, alongside ditches, native hedgerows and woodlands (for nesting and shelter), purpose-sown flora can be tailored to specific needs, so growers can gain a lot of pollen and nectar resource from a small area. Some studies recommend a minimum of 6% natural habitat and ideally up to 10%. In addition, a total of 1 km of flowering hedgerow per farm can be sufficient to support six common pollinator species. It is generally felt that several small habitat rich areas are more beneficial than one large area for supporting butterfly and parasitoid species. Should one large area fail or be damaged in any way, there are no alternatives, so several smaller areas provide a fall back in case of failure of one. Different areas can also host different seed mixes to further diversify on-farm biodiversity.

The seed mixes should ideally provide diversity of species which complement wildflower species that are already present in or around the farm. The mix should provide flowers outside of the crop flowering period, thereby extending the provision of pollen and nutrients, which can maintain insect population stability and fecundity. Late flowering species help insects to complete their lifecycle thereby helping them to survive from year to year.

When developing an optimum seed mix for each fruit crop, the scientists considered which bee (Figure 3) and hoverfly species most commonly visit the crop, which non-crop flowers they visit most often, and which are likely to thrive in a sown area or regenerated strip. They undertook literature searches to identify the pollinators that visit each crop and ranked them according to the frequency of their visits. Having chosen the top five or six pollinators, they considered the non-crop wildflowers most commonly visited by each pollinator and produced a final choice of seed for each fruit crop including annuals, perennials, biennials and weed species that will attract the five or six pollinators. Not all species will thrive on every site, and for each mix, there is a caveat that some flowering species may have potential to harbour crop pests or diseases, allowing growers to make informed decisions about their final choice of mix.

Some flower species were included repeatedly in a number of the crop mixes, including bird's foot trefoil, dead nettle, clover, yarrow, hawksbeard and dandelion. Some are long flowering species and some are late flowering.

NIAB has now produced guides to selecting suitable seed mixes for all UK fruit crops and these can be found on the BEESPOKE website at: https://northsearegion.eu/beespoke/. In addition, other very helpful guides, evaluation tools and publications for growers have been produced as part of the project and are available on the website, including 'Monitoring pollinators', 'Estimating pollination potential', 'Establishing perennial wildflower areas' and 'Supporting pollinators and farmland biodiversity'.

Figure 3. The scientists considered which bee species most commonly visit the crop

Matevz Papp-Rupar, Plant Pathology Research Leader

Ongoing research into coir recycling

Title: To evaluate the extent of biological, chemical and physical changes between virgin, re-used and recycled coir

Funders: Overland Ltd and Growing Kent & Medway

Term: April 2022 to March 2024

Over the past two decades, there has been a major shift in strawberry and raspberry production from soil into soilless substrates. With the phasing out of soil fumigants, it was becoming increasingly challenging to gain economically viable control of soil-borne diseases. In addition, the declining margins being made from soft fruit production has increased the need for growers to produce consistently high yields across all plantations. As a by-product of the coconut industry, coir is more sustainable than peat, so it has become the preferred substrate for most growers and has helped them to produce consistently higher yields. However, with increasing demand for coir and limited volumes available to buy, the cost of this substrate has risen sharply. The carbon footprint associated with shipping it from Asia is also a modern day concern.

The rising costs of the raw material and need to reduce shipping costs has increased the pressure on growers to find ways of extending its life. However, there has been some reluctance from the industry to use coir more than once due to concern over disease and weed build-up, coupled with yield decline. NIAB has been working with Overland Ltd to investigate the potential of re-using, composting or recycling coir (Figure 1).

Initial work was done in an EU funded Interreg project called Horti-Blue C, where coir bags used for strawberry production were re-planted by removing the original plants and planting fresh plants into the same planting holes. It was found that where the coir was clean and devoid of pathogens, Junebearer varieties would tolerate such replanting with little decline in yield. However, everbearer varieties performed less well, with yield decline of 6-7% occurring year on year. This is thought to be caused by a reduction in air filled porosity (AFP) of the coir as it gets older. Overland has developed an automated process to recycle coir from strawberry bags which included removal of bags from the tunnel, removal of plastic, plant leaves and roots, to leave clean coir. The coir is then sterilised and treated in various ways before making it available for use. Overland funded NIAB to carry out further work to assess how the coir changes over time. It was found that the water holding capacity increases while the AFP decreases, the extent of this varying with different coir manufacturers. Changes also occur in pH, electrical conductivity and nutrient content. Interestingly, levels of crown rot (*Phytophthora cactorum*) tend to increase in re-used and composted coir compared to virgin, but not in recycled coir that Overland is producing.

The current GK&M project

Overland and NIAB secured further funds from Growing Kent & Medway to accelerate the research and bring sustainable coir media into commercial strawberry production. The aims of the project are to: 1) develop energy efficient and robust procedures to eliminate pest, pathogen and weed risks in recycled material; 2) to demonstrate the use of recycled

Figure 1. NIAB has been investigating the re-cycling of coir

media on commercial scale and develop wrap around agronomy advice; 3) compare lifecycle analysis of the virgin and recycled coir to measure economic and environmental gains of recycled media.

Results to date

At the commercial site (Kelsey Farms), the everbearer variety Katrina was planted in virgin Legro coir bags and compared to Overland's recycled coir as well as re-used coir (planting directly into used bags). Each of the three coir types was used in nine commercial tunnels (over 3,000 bags per coir type) and irrigation was run independently for each coir type. Sadly, during harvest the virgin and re-used coir were mistakenly picked and recorded together, so the recycled coir was compared to both virgin and directly replanted together. The yields were similar (ca 1.3 kg per plant) and no differences were found in pests (thrips), weeds or crown rot pressure between coir types. There were however, visual differences in plant growth. In the recycled coir, plants appeared to be stronger and cropped earlier than the virgin coir bags. The plants grown in recycled media also used 12 % less fertigation volume over the season. The reduction in water use in recycled material was especially prominent during hot days. The grower was very happy with the performance of the recycled media and its management, and the trial will be repeated in 2024.

At the East Malling site, the everbearer variety Malling™ Supreme was planted in small trials in both virgin and recycled Legro and Cocogreen coir. Separate irrigation rigs were used for recycled and virgin media but not for each coir brand. The two recycled coirs used 4% less water than virgin which was mainly because of reduced need for wetting up recycled material at the start of the season and reduced water use on the hot days due to its higher water holding capacity. The total yield from recycled coir was slightly lower than the virgin coir and this difference was statistically significant when comparing Legro recycled and virgin coir. This was due to the fact that virgin materials of both brands were very comparable in terms of water demand, but recycled materials with different previous growing histories were not. Namely, Legro recycled material had much higher water holding capacity compared to recycled Cocogreen. This meant that recycled Legro coir was consistently over irrigated and recycled Cocogreen consistently underirrigated resulting in slight yield reduction. This reinforces the need for the use of different coir types with irrigation/fertigation regimes, or at least using separate valves.

To date we have demonstrated that recycling coir offers much better potential than either re-using or composting coir and can achieve strawberry yields and quality comparable to virgin material. The rate and level of physical and chemical degradation does vary depending on the coir type, manufacturer, and growing history but we believe that cost effective coir recycling is possible with little yield reduction. Further work is planned to optimise the recycling process to better preserve and improve the physical properties, mitigate any chemical imbalances and residual, pests, weeds and pathogens which might be linked to the slight yield decline. Additionally, root microbiome of strawberry grown in virgin and recycled coir is being investigated to identify any other microbial imbalances.
An economic and environmental impact analysis of recycling coir will also be carried out and will include total costs and environmental impacts of substrate production/ recycling, use on the farm and disposal.

Supporting fruit researchers of tomorrow

Researchers at NIAB's East Malling site have been supporting the fruit industry since 1913 and, over the ensuing years, we have been able to develop and train new generations of scientists to work in fruit and horticulture research. With reduced funds available to support their development, NIAB was pleased to team up with lead partner Berry Gardens Growers Ltd in 'The Collaborative Training Partnership for Fruit Crop Research' (CTPfFCR), a training scheme for new scientists.

Funded by the Biotechnology and Biological Sciences Research Council (BBSRC) along with industry partners AHDB, Berry Gardens Growers, Marks and Spencer, the National Association of Cider Makers, Worldwide Fruit Ltd and the Worshipful Company of Fruiterers, the programme aims to deliver a high-quality training programme for doctoral students, delivering independent, highly-employable scientists in strategically important research and development areas.

Since its inception in 2017, twelve students have been awarded PhD's and it is anticipated that by the time the scheme ends in September 2025, 38 researchers will have been trained. Four of the qualified students are already working in fruit research roles spanning academia and industry. Carlota Gonzalez-Noguer (Figure 1) is now a Quantitative Crop Physiologist with NIAB at East Malling and Raymond Kirk is the Chief Technology Officer of a start-up business, FruitCast, who plan to be offering a crop forecasting service to strawberry growers in the next few years. Christina Conroy is employed as a Technical Account Manager at Berry Gardens Growers, and Chris Cook has joined the USDA-ARS Kalcsits Lab and the Somera Lab at Washington State University investigating the barriers to and benefits of AMF colonisation in apples to both improve productivity and reduce disease pressure. Although not directly involved in fruit, Eithne Browne has secured employment as a research scientist working for Teagasc in Ireland, investigating the potato, faba bean and barley microbiome, and Matteo Luberti is working for the gene sequencing company Illumina.

Figure 1. Carlota Gonzalez-Noguer is now working for NIAB as a quantitative crop physiologist

All of the projects being worked upon, and those completed, have been grouped into four categories including: artificial intelligence and robotics; crop science and production systems; genetics; and pest and pathogen ecology. They were all developed by research scientists working with the CTP's fruit industry partners to identify high priority topics which need investigation to ultimately benefit fruit growers. Most of the students have worked with research supervisors at NIAB's East Malling site, whilst some others have been based at the CTP's partner universities including Cranfield, Essex, Harper Adams, Lincoln, Nottingham and Reading. Within their four-year training period, the students also receive the opportunity to experience the sector first hand by spending time with the CTP's industry partners in their businesses in order to widen their knowledge of the industry.

At the time of writing, a number of students are either writing-up or have submitted their theses for assessment. The students from the final two cohorts of the scheme continue their research on a wide range of topics.

On apple, at East Malling, Hayden Tempest has been investigating the predation of woolly apple aphid by earwigs using radio tagging while Hamish McLean is investigating potential biological control methods for apple canker. Katie Stewart is working on novel methods for controlling apple scab and Haidee Tang is using climatic and imaging data to predict apple fruit ripeness.

On cherry, at the University of Reading, Adam Gregg has been studying the genetics behind natural

Figure 2. Ece Moustafa is researching water relations in raspberry and their impact on fruit yield and quality

resistance to bacterial canker and aims to identify genetic loci that will aid resistance.

At the University of Lincoln, Philip Johnson aims to develop and control a novel, low-cost, soft robotic arm manipulator for harvesting blackberries while Katherine James is creating images of model strawberry plants, that could be used by plant breeders to improve the phenotypic traits of new varieties so that they are, for example, more suited to robotic strawberry harvesters. At the University of Reading, Emily Johnstone is investigating ways to maximise optimum strawberry fruit size for sale to multiple retailers, by manipulating nitrogen input and strawberry growth.

Also on strawberry, at East Malling in a project seeking to improve CO_2 uptake by stomata in strawberry crops and increase their yields, William Atkinson is experimenting with light and other environmental cues both to increase stomatal density and stomatal opening, while Camila Gonzalez is working with the genetics team, using a combination of genetic mapping and gene editing to understand the control of flowering.

On raspberry at East Malling, Ece Moustafa is trying to understand the legacy effect of short-term water stress and its impact on fruit size and quality (Figure 2). Importantly, Ece is also determining how quickly raspberry plants recover from water stress events, which will be very useful information for growers in the future as our climate becomes warmer. Deborah Babalola aims to understand the genetic control of primocane versus floricane fruiting habit and earliness of fruiting in both raspberry types.

Back to strawberry, and at the University of Essex, Mengjie Fan is investigating the use of blue light with the intention of boosting yields late in the season, whilst at Harper Adams University, Laura Martinez is studying why the potato aphid, a common pest of strawberry, is not reliably controlled by aphid parasitoids.

Comprehensive information on all the completed and ongoing projects can be found on the dedicated website at: ctp-fcr.org.

Dr Nicola Harrison, Programme Director, Growing Kent & Medway

Growing Kent & Medway

NIAB is the lead research partner in Growing Kent & Medway, a world-class research, innovation and enterprise cluster that is supported by UKRI's 'Strength in Places' fund. Working with our partners at the University of Greenwich, the University of Kent, Canterbury Christ Church University and Locate in Kent, our mission is to invest in sustainable innovation and technologies to help the horticultural and plant-based food and drink industry in the Kent and Medway region to continue to thrive.

Led by NIAB's Dr Nicola Harrison, Growing Kent & Medway supports businesses of any size; from a 'Kitchen Table' startup to a large multinational. We bring together industry, scientists, technologists and entrepreneurs to stimulate innovation. We have invested in new research facilities and technical expertise, business support activities, and grant funding to help businesses to grow.

Our programme of work, which began in 2021, is also supported by a number of Kent-based businesses including Berry Gardens Growers, Richard Hochfeld Group, Smurfit Kappa, Thanet Earth, Worldwide Fruit and The Kent and Medway Economic Partnership.

We are managing our investment through several areas of activity which include the development of new research facilities, research funding grants and business enterprise support. This support includes free business mentoring, food accelerator programmes and business masterclasses, along with bringing together the region's expertise in areas such as alternative proteins, sustainable production, sustainable packaging and skills.

Early work

Initial funds were used to build and develop high quality, state-of-the-art research facilities for the horticultural, food and drink sector. At NIAB's East Malling site, Growing Kent & Medway funds were pooled with those from Local Growth Funds from Kent County Council and the East Malling Trust to build our 'GreenTech Hub for Advanced Horticulture'. These state-of-the-art facilities include brand new glasshouses (Figure 1), polytunnels and growth room facilities allowing NIAB to undertake cutting-edge research to support horticultural industries. New facilities were also built for the University of Kent (Biotechnology Hub) and University of Greenwich (Medway Food Innovation Centre) to provide the industry with technical support and modern research and development facilities. In September 2023, Canterbury Christ Church University was welcomed into the programme, and through this partnership, the new Industrial Agri-engineering Hub was launched.

In 2022, Growing Kent & Medway led the Growing Green programme, a government-funded pilot training scheme that sought to provide the knowledge, tools and funding to reduce carbon emissions, helping businesses on their journey towards 'net-zero'. This was a pilot programme which aimed to work with businesses to develop their understanding about what aspects of reaching 'net-zero' they needed help and support with, allowing Growing Kent & Medway to put further support programmes together to ensure that they reach their ultimate targets. For the participating horticultural and fruit businesses, the most commonly occurring decarbonisation goals included renewable energy, energy efficiency, water conservation options, and alternative fuels, with several novel approaches being identified. The Growing Kent & Medway team now has an improved understanding of the decarbonisation challenges facing this sector and aims to deliver further resources and events, whilst seeking new funding opportunities for the region's businesses.

Figure 1. New state-of-the-art glasshouse facilities were developed at NIAB's East Malling site

Research funding grants

Through Growing Kent & Medway, £5 million is being spent on innovation grants ranging from £5,000 to £350,000 for innovative projects that aim to solve problems in

Figure 2. GK&M research grant is being used to develop ways of extending the storage life of cherries

horticultural, plant-based food or drink production.

The first round of collaborative research and development grants were awarded in 2022 and five of these were of particular interest to fruit growers. The University of Greenwich is working with fruit marketing company Norton Folgate to develop viable methods of extending the storage life of cherries beyond the few days that are currently achieved in low temperature air stores (Figure 2). The University of Kent is working with farming company Regeneration Earth to study the benefits of incorporating biochar into a 'living land' field and to identify the best management techniques to maximise these benefits.

NIAB is working with three horticultural businesses. With Thanet Earth, ways of increasing levels of iron and ascorbic acid (Vitamin C) in tomato are being studied, not only to make the crop more nutritious, but also to increase the plants' ability to withstand higher temperatures brought about by climate change. With Asplins PO, NIAB is investigating the ability of different strawberry and raspberry varieties to withstand spotted wing drosophila attack, and with Avalon Produce, novel approaches to improve apple tree health and resilience are being explored, with the aim of improving canker management practices. Progress on these three projects is reported on elsewhere in this Review magazine.

A second round of collaborative research and development grants was launched in the autumn of 2022 and successful applicants were announced in 2023. These five new fruit research projects began in 2023, all being led by NIAB. Working with Edward Vinson Plants Ltd, NIAB's plant genetics team is trying to develop molecular markers to help breed new strawberry varieties with improved plant architecture, which will improve fruit presentation to pickers and reduce the harvesting costs. With Worldwide Fruit Ltd, NIAB plant breeders seek to develop novel breeding methodologies that will enable a shorter breeding cycle for apple, and ensure a faster route to market for resistant varieties.

With Recoir and Blaise Plants, NIAB is investigating the use of commercially available beneficial microorganisms in raspberry propagation to improve plant establishment with fewer inputs, with the aim of increasing the survival rate of the plants whilst enhancing plant uniformity and final yields. With Asplins PO, Biobest and Rumwood Green Farm, NIAB is trying to develop improved biocontrol methods for large raspberry aphid, and with Overland Ltd, NIAB seeks to improve the recycling methods of used coir, with a view to reducing pest and disease carry-over. More details of this second round of projects are available in the 'New Projects' section of this publication.

Business innovation vouchers and prototyping and demonstrator fund

One of the remits of Growing Kent & Medway is to support and enhance sustainability and circularity within horticultural, food and drinks businesses. To this end, 'Business Innovation Vouchers' have been made available to support innovative ideas that businesses need to research and develop. These might help to reduce carbon emissions, reduce resource use, reduce water or food waste in production processes, or develop more sustainable packaging. The vouchers contribute 50% of the research costs in projects costing between £20-60,000, thereby funding between £10-30,000, depending on total project cost. This money effectively pays for a research organisation, while the business benefiting pays the other half, either in cash or 'in-kind' contributions.

In the first round of Business Innovation Vouchers, 11 projects were funded, five of which are relevant to fruit production. The University of Kent is working with Sharpak Aylsham to develop a more sustainable soaker pad for use in raspberry punnets, and they are also working with J.L. Baxter & Son to explore the bioactive and nutrient components of 'Nashi pear juice', which is purported to have a number of health benefits (Figure 3). The University of Greenwich is working with A.C. Hulme & Sons to develop improved long-term low oxygen storage of Gala apples, and also with Edward Vinson Ltd to select raspberry

Figure 3. J.L. Baxter is exploring the nutrient components of their Nashi Gold pear juice

breeding material with improved texture quality. NIAB is working on a project with Verdant Carbon to understand the links between the abundance and diversity of microbials in soils and the potential for storing carbon.

A second round of Business Innovation Vouchers closed in January 2024. A competition for a 'Prototyping and Demonstrator Fund' also ran until January 2024. The grants of up to £150,000 will develop and deliver new technologies for the sector. Details of the winning projects from both funding competitions will be announced later in 2024.

Business sustainability challenge

In the spring of 2023, Growing Kent & Medway launched the first round of the 'Business Sustainability Challenge' allowing businesses with innovative ideas to bid for grants to fund work between £10-50,000. Project ideas had to support sustainable production, products or packaging in the horticulture or plant-based food and drinks sector. Seven innovative projects were supported and began in 2023.

Nim's Fruit Ltd is developing new convenient food products from rescued fruits and vegetables. Grow Up Farms is a vertical farming producer of leafy greens that is working to recover and re-use its wastewater collected from its building run-off. Canterbury Brewers and Distillers at The Foundry is experimenting with the production of speciality mushrooms, using waste grain, water, CO_2 and energy generated by its whisky production (Figure 4). Totally Natural Solutions is developing new, more sustainable hop products that will help brewers to create no- and low-alcohol beers with improved sensory characteristics. Tensei Ltd is experimenting with the use of bio and agricultural waste within injection moulded polymers to reduce the need for virgin and recycled plastics. Evogro who make vertical farms for hospitality operators and homes, is developing a novel method of seed delivery suitable to produce microgreens, salad leaves and herbs in their vertical farming systems. A.C. Hulme & Sons is investigating ways to improve the energy efficiency of their apple cold stores, without compromising the quality of the fruit. Applications for the second round of the 'Business Sustainability Challenge' close on 30th April 2024.

Business mentoring support

Growing Kent & Medway provides free mentoring support for the self-employed or small and medium-sized enterprises to help businesses to grow. Up to 12 hours of free one-on-one mentoring is offered, along with group networking sessions. Help is offered in areas including market research, sales, people management, finance and legal, through to supply chain development or marketing strategies.

One of the mentors is Mike Stoker, who has a lifetime of experience working in farm management, agronomy and as a technical specialist in plant nutrition, and currently works as a business development agronomist with Orion Future Technology Ltd. In 2022, Mike joined the team of mentors to help a range of new startup businesses and new recruits to the food, drink and horticultural sector in Kent. Most recently he has used his industry knowledge and business contacts to find employment for two young men who were keen to find work in the food industry, but had no knowledge of the sector or where to start. One is now working as an irrigation manager for a vegetable producer in north Kent, while the other is employed as a spray operator for a major tree fruit producer. Mike has also worked with a new startup business in Margate that is growing oyster, lion's mane and shiitake mushrooms. Mike used his knowledge of fruit storage to help to resolve a production problem that the business would never have considered.

Figure 4. Canterbury Brewers and Distillers seeks ways of producing speciality mushrooms using waste products

All of our mentors offer their time and expertise for free, to help to support new and developing businesses and new entrants to the industry. Many of them derive great pleasure and satisfaction in being able to draw upon their own experiences to help and support the businesses of tomorrow.

Food accelerator programme

Another valued form of support provided by Growing Kent & Medway is the 'Food Accelerator Programme'. This is open to small to medium size businesses and startup companies developing a plant-based food or drink product, and it helps to transform business ideas into commercial reality. The programme provides technical, business and financial support through masterclasses, in-person workshops, expert guidance, monitoring schemes and peer-to-peer training. Participating businesses also have access to the technology hubs and facilities available through the research organisations.

The food accelerator programme lasts for four months and starts by making an initial assessment of the business idea, before carrying out a 'needs assessment' and developing an action plan. A business model is created by working with the business school at the University of Kent along with outside mentors and experts, and new food products may also go through a validation and prototyping process, which involves the Medway Food Innovation Centre. Examples might be testing the nutritional content of a product, how to package it or how to scale it up successfully. Finally, the business is helped to prepare its product for the market, how to seek funding to help with this, and the business also receives advice on where to pitch the product in the marketplace.

One recent beneficiary of the 'Food Accelerator Programme' is Philip Doubleday, a fruit grower from north Kent, who has been developing a new 'Morello Cherry Wine' (Figure 5). His idea for the product was borne from his grandparents who grew four Morello cherry trees in their garden and created a recipe for a fortified cherry wine that they called 'Cherry Brandy'. Philip learnt how to make the wine, and on realising that it was popular, scaled up production from four trees to four hectares. He benefited from 'Rural Development' funding to build a winery, but realised that he needed help to convert his new venture into a successful business.

Figure 5. Philip Doubleday has been developing a Morello Cherry Wine

After several years of developing his product, he felt that he needed to 'accelerate' the business for it to take flight. He believed that he had an innovative and unique product but he lacked the knowledge and experience in branding and marketing and a raft of other things you need to think about when setting up a new business. Philip freely admitted feeling rather alone when setting up his business but joining the 'Food Accelerator Programme' helped him by being surrounded by like-minded entrepreneurs who were also taking a risk by starting, or scaling, their business.

As a result of the programme, Philip has learnt a huge amount from a network of producers and found the various workshops offered by the programme to be invaluable in helping with the branding and messaging of his product. Philip cites the series of Masterclasses as being particularly helpful on marketing strategies, how to fix your website, hazard analysis of critical control points (HACCP) and the cost of setting up your own food/drinks business. Philip was also afforded the opportunity to speak to technical experts and to tap into technology resources at The University of Greenwich where he was able to learn more about the exact composition of his wine. Philip is now looking at opportunities to utilise the waste products from his production process, and is tapping into the business mentoring programme for further support.

Find out more about Growing Kent & Medway

For comprehensive information about how Growing Kent & Medway operates and the help it provides to the horticultural, food and drink businesses in the region, visit growingkentandmedway.com/.

NIAB

Fruit

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