Tree Fruit REVIEW

AHDB

2018

Detecting fruit maturity earlier than ever

Surveillance of new pests and diseases

Controlling SWD via viral pathogens and behavioural patterns

Apple Sawfly: an elusive pest

Foreword

Welcome to the 2018 Tree Fruit Review annual supplement to AHDB Grower, which summarises the current research AHDB is funding on behalf of tree fruit growers.

The horticultural sector generates value that is out of all proportion to the area of land that is devoted to it – these are not 'minor crops' but instead should be regarded as 'speciality crops'. In that context there is a market failure with respect to crop protection – manufacturers cannot justify the costs associated with obtaining product approvals to protect crops which occupy small areas, relative to, say, cereals and potatoes. For this reason, the sector is heavily reliant on EAMUs. Making the applications is a complex administrative and data-heavy activity, and it is one of the roles of AHDB that growers value highly. It's a high profile, 'front-of-house' activity which helps growers to address immediate problems, but, as the pages that follow testify, it is accompanied by impressive breadth and depth to the research projects which the tree fruit panel commissions on your behalf and which it is hoped will ultimately provide more sustained, secure solutions to the problems that growers encounter.

The tree fruit sector panel comprises growers representing all major tree fruit crops and regions. I am particularly grateful for the support I get from all the members who help me to ensure that our research meets the needs of tree fruit growers.

I am also indebted to AHDB's research manager Rachel McGauley who has managed the tree fruit research portfolio so well since I took on my role of panel chair. Rachel recently went on maternity leave and her role has been ably filled by Katja Maurer, who has considerable experience of working with growers and scientific researchers in the USA hop industry.

We have also been developing new ways of disseminating the results of our research to you each year, while also continuing to organise the tree fruit technical day at East Malling and a dedicated day for fruit agronomists to learn about our research and discuss your research needs.

This publication is designed to give you a brief insight into our tree fruit research projects, and anyone wishing to explore projects in more detail can find full reports on AHDB's website: **horticulture.ahdb.org.uk**

I hope you have a successful harvest season in 2018.

Rob Saunders
Tree Fruit Panel Chairman

Contacting AHDB Horticulture

Tree fruit growers are currently served by Technical Manager Katja Maurer and Knowledge Exchange Manager Scott Raffle.

Katja works with the industry to develop the correct research projects for your needs and to liaise with scientific contractors who undertake the work on your behalf.

Scott's task is to coordinate the dissemination of the information.

They are supported by an administration team.

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This newsletter is brought to you by AHDB

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This publication reports on the findings of AHDB-funded research projects only. Although it reports on the use of pesticides, it is not intended to endorse or recommend the use of any of the products or active ingredients listed. Only products officially approved for use as plant protection products should be applied to control pest, disease and weed problems. Before using any pesticides, growers should refer to the product approval and label recommendation and seek guidance from a BASIS qualified consultant.

Keeping you informed

SmartHort

The rising cost and decreasing availability of labour is one of the most serious challenges facing British horticulture today. AHDB has this year launched 'SmartHort', a programme of activity designed to help tackle the challenge of access to affordable labour and to help drive labour productivity.

The programme has two key elements: helping to improve management practices through the uptake of Lean and Champion principles; facilitating the uptake of new technologies and innovations.

Workshops, study tours and events will be happening around the UK and a range of materials will be available online. To find out more, go to: **horticulture.ahdb.org.uk/labour** or follow **#SmartHort**

GREATsoils

The three-year research programme that has been investigating improvements to soil health, assessment methods and precision mapping for horticulture has now finished, but a range of informative publications and films are now available. These include a practical manual about soil assessment and management, a factsheet explaining how to count earthworms and a guide on optimising soil pH values for better soils.

Innovative Farmers will continue their study group, investigating soil health amendments for top fruit, and research into better soils will continue at AHDB for the benefit of all farmers and growers, with new investment into the Soil Biology, Soil Health partnership.

For more information, visit: **ahdb.org.uk/greatsoils**

Useful resources

AHDB produces a range of materials and resources to help growers tackle the major issues facing the tree fruit industry and to share the latest research developments.

New publications have recently been released to help identify and control key tree fruit pests including *Anthonomus spilotus*, a new pest of pear crops, and plum fruit moth. A wealth of other materials, from the updated Nutrient Management Guide for tree fruit nutrition, to films on harvesting and storing quality fruit, are also available.

It's not too early to secure your place at our annual Tree Fruit Day, which will take place in East Malling, Kent on 28 February 2019.

To find your free resources and to book your place on any of our informative events, just visit: **horticulture.ahdb.org.uk/sector/tree-fruit**

Expanding your business

If you're interested in growing your export business, AHDB will once again be heading to Fruit Logistica in Germany in February 2019. You can book a place on the AHDB stand, which provides growers and exporters with a focused hub to do business and champion the UK's reputation for outstanding food and farming. To find out more, contact: **hort.info@ahdb.org.uk**

Looking at the horizon

With the uncertainty surrounding the impact of the UK's decision to leave the EU on British farming and growing, AHDB has published a series of independent scenario reviews, covering productivity, plant health and protection and UK trade in horticultural products. Available from: **ahdb.org.uk/brexit**

New faces

Dr Katja Maurer has joined AHDB as the research and panel manager for the tree fruit and soft fruit sectors. Katja is a plant microbiologist and her doctorate investigated new strategies to control Verticillium wilt in hops. Katja has previously worked at the Connecticut Agricultural Experiment Station in the USA and her research focused on boxwood blight and the evaluation of the applicability of hop cultivation. To contact Katja, email: **katja.maurer@ahdb.org.uk**

A new Chair for AHDB Horticulture is also set to be announced this summer and more details will be shared with the industry as soon as the position is confirmed.

Stay in touch

If you're not receiving our email alerts for events, EAMU notifications or our newsletters with the latest in crop protection and industry news, please contact **comms@ahdb.org.uk** to make sure we have your correct details.

You can also follow us on: **Twitter, @AHDB_Hort**

New Projects

Two new R&D projects with relevance to the tree fruit industry have recently begun. These were approved by the elected tree fruit panel members and both of them meet the needs of the latest R&D strategy developed by the panel. In addition, a new Collaborative Training Partnership (CTP) programme of research has begun in the past year, which AHDB part funds.

SWD control with yeast

AHDB has been funding research into spotted wing drosophila (SWD) since 2013 through the industry-funded project SF 145. The work has identified that SWD populations reach a peak during the autumn and early winter months. It has also shown that ripening fruits tend to be more attractive to SWD adults than the baits currently used in commercial monitoring traps. In this project, which has identified yeast-attractant strains to other Drosophila species, a PhD student at the University of Lincoln, will test and identify different species and strains of yeast as feeding attractants to *Drosophila suzukii*. Working in collaboration with the entomology team at NIAB EMR, the student aims to use the best attractant strain of yeast in 'attract and kill' systems to reduce the reservoirs of overwintering adult flies after the main cropping period when populations are highest and when no fruits are present to compete with the yeast bait.

CP 171: The use of highly attractive yeast strains for controlling *Drosophila suzukii* (spotted wing drosophila)

Term: October 2017 to September 2020

AHDBSTUDENTSHIP

Project leader: Matthew Goddard, University of Lincoln, and Michelle Fountain, NIAB EMR

PhD student: Rory Jones

Industry representatives: Harriet Duncalfe (H&H Duncalfe) and Oliver Doubleday (G H Dean)

Location: University of Lincoln

Collaborative Training Partnership (CTP) for fruit crop research

The Collaborative Training Partnership (CTP) is a new research programme for UK Horticulture which is jointly funded by the Biotechnology and Biological Sciences Research Council (BBSRC), the AHDB and innovative international businesses. The specific programme for fruit crop research is led by Berry Gardens Growers Ltd on behalf of an industry consortium which collaborates with its principal academic partner NIAB EMR. The programme aims to deliver high-quality research projects while concurrently training the next generation of researchers to support the horticultural industry in the UK. In 2017, one CTP project began which has direct relevance to the stone fruit industry.

This project relates to Project SF/TF 145a and will build upon a number of ongoing research projects at NIAB EMR and NRI investigating novel control methods for spotted wing drosophila (SWD). It will provide the basis for an IPM control strategy targeting *D. suzukii*, suitable for commercial growers of stone and soft fruit.

The research will optimise attractants and repellents and their deployment in order to provide the control. The integration of several control methods to form a push-pull system is a novel idea for this pest and will lead to a significant reduction in the use of traditional crop protection products. Improved understanding of the insect's olfactory sense and searching behaviour will provide the scientific basis for the development of the push-pull system.

CTP FCR 2017 1 – Developing a 'push-pull' strategy for the management of *Drosophila suzukii*

AHDBSTUDENTSHIP

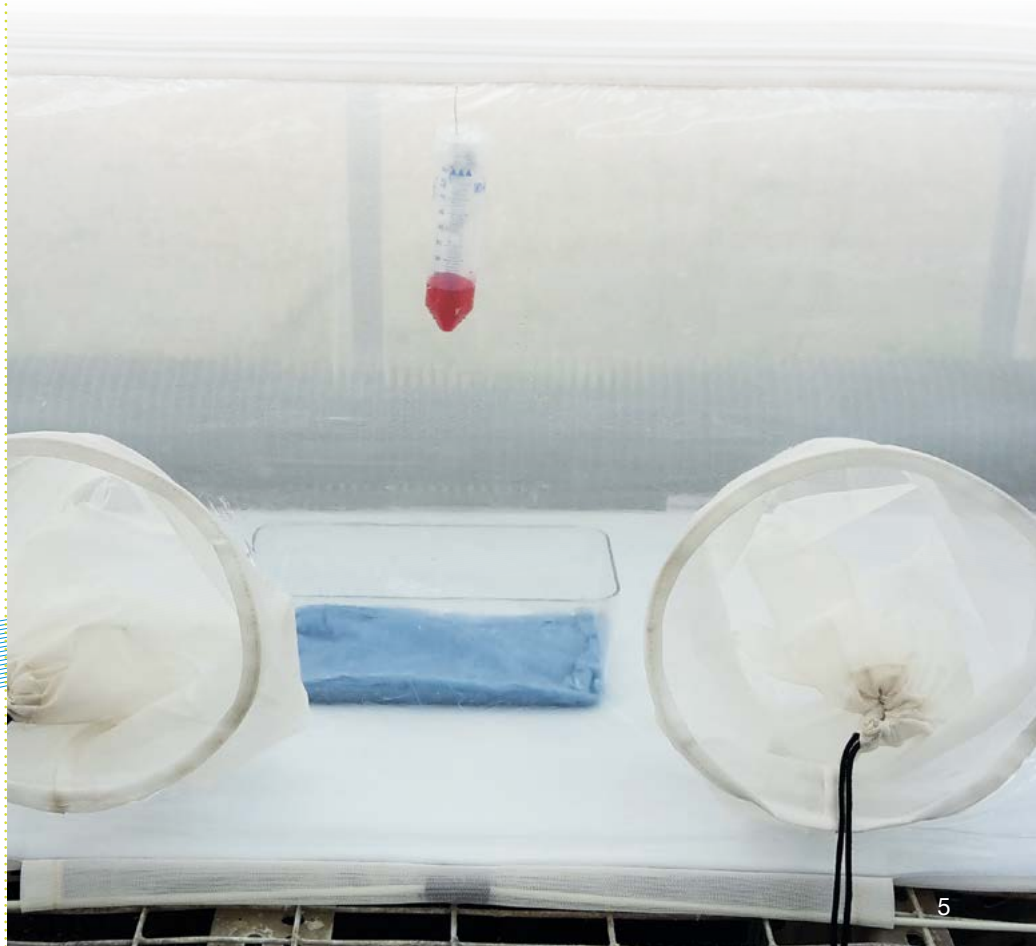
Term: October 2017 to September 2021

Project leaders: Michelle Fountain, NIAB EMR, and Daniel Bray, NRI University of Greenwich

PhD student: Christina Faulder

Industry representative: Harriet Duncalfe (H&H Duncalfe)

Location: NIAB EMR



Crop protection

Growers often refer to crop protection as the 'bread and butter' work for AHDB. Tree fruit marketing and producer organisations have many in-house capabilities to deal with technical challenges and set up their own breeding programmes and quality control/assurance schemes to address these. However, crop protection research and development requires wide-ranging skills, expertise and experience which is often beyond the budget or capability of individual grower groups.

AHDB has been set up with a structure which allows us to commission such expertise and experience to cater for the needs of the whole industry. Much of the crop protection work we do has been comprehensively reported in the 2017 AHDB Horticulture Crop Protection Review magazine which was published and distributed in August 2017. Extra copies can be procured by emailing **hort.info@ahdb.org.uk**

The particular activities of greatest interest to tree fruit growers are our Gap Analysis, Basic Substances, SCEPTREplus and EAMU programme.

Our latest Gap Analysis was undertaken in 2018 by conducting a comprehensive survey of the pests, diseases and weeds that growers are trying to contain. This enabled us to pinpoint the gaps in the measures available for controlling them and hence where we should be focusing our research and development or knowledge exchange work.

Basic substances are defined as 'active substances, not predominantly used as plant protection products but which may be of value for plant protection and for which the economic interest of applying for a full approval may be limited'. Our crop protection managers continually work with scientists, industry bodies and growers to keep abreast of substances which offer potential in crop protection so that we can submit applications for authorisations. They also regularly review authorisations for use in other EU member states which may be of interest.

SCEPTREplus is an AHDB programme of research designed to assess the efficacy of new or emerging crop protection products and biopesticides at controlling pests, diseases or weeds in the full range of horticultural crops. In addition, it is also assessing crop protection solutions which are already approved but being used in a novel way. It is a four-year programme which will link with other crop protection projects already underway. It dovetails closely with the AMBER project on biopesticides as well as IPM projects on tree fruit.

AMBER (Application and management of biopesticides for efficacy and reliability – CP 158) is a five-year project being led by Dave Chandler, a microbiologist and entomologist at Warwick Crop Centre. In essence, it aims to find out what's causing some products not to work as well as they should and what growers can do to improve that. The focus is on certain commercially available biopesticides and on a select number of pests and diseases on crops representing a variety of types. The early results will be turned into a set of general principles that can then be transferred and tested on other crops later in the project.

Perhaps best well known to growers is the continual energy we expend in our quest to secure new approvals, EAMUs and emergency authorisations for crop protection products to fill the gaps, where no alternative products or control measures are currently available to prevent a pest, disease or weed from causing significant economic damage to a crop. To achieve this, we have developed very good links and working relationships with the Chemicals Regulation Directorate (CRD), agrochemical manufacturers, the EU Minor Uses Coordination Facility, overseas regulatory bodies and other foreign minor use facilities such as the USA's IR-4 programme.

In the past year, AHDB crop protection manager Vivian Powell and KE manager Scott Raffle have worked tirelessly with the soft- and stone-fruit industry, and in particular SWD Working Group chair Harriet Duncalfe, to secure EAMUs and emergency approvals to help us gain control of spotted wing drosophila (SWD). They worked in close collaboration with CRD, who have been particularly understanding of the difficulties facing the soft- and stone-fruit industry and who helped us to secure products at a time in the season when growers were most in need. Important examples of products secured in 2017 include the emergency 120-day authorisations for Tracer on plum, cherry and apricot and Exirel on plum, damson and cherry – all for the control of SWD.

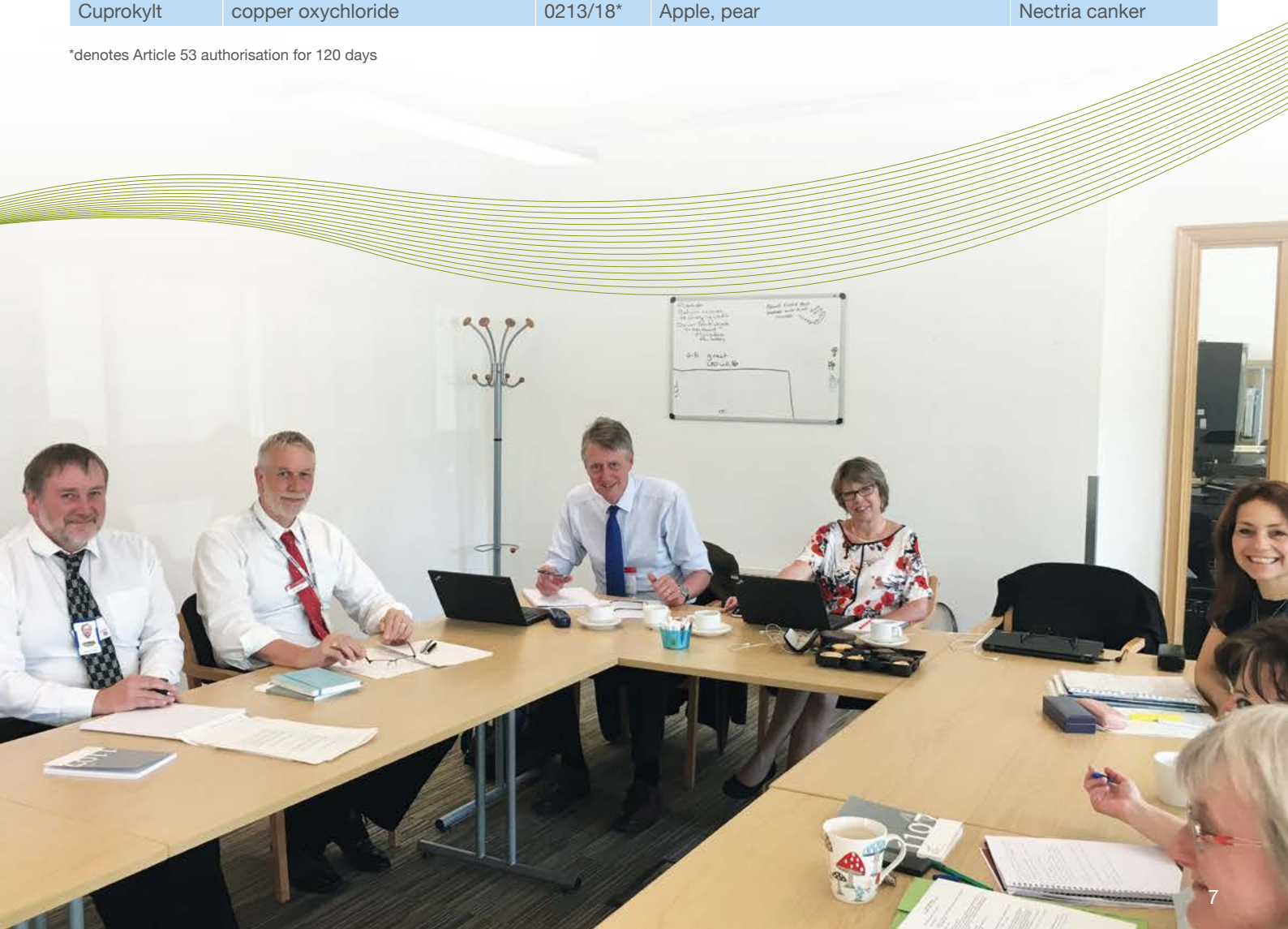
A list of the key products which have been delivered through AHDB activity in 2017 and early 2018 are found in the table opposite. Note that some of these approvals will have lapsed by the time of printing this publication.

"We are greatly indebted to staff at CRD for the help and cooperation we received in securing emergency authorisations for SWD control in 2017 and 2018," said Vivian Powell, AHDB Horticulture Senior Crop Protection Liaison Manager.

Growers and grower groups who have concerns about impending losses of crop protection products should contact the AHDB Horticulture crop protection team at **EAMU@ahdb.org.uk** or email: **comms@ahdb.org.uk**

Product	Active ingredient	EAMU No.	Crops	Target pest/disease
Movento Top	spirotetramat	1017/17*	Apple	Woolly aphid
Gibbs Plus	gibberellins	1152/17	Pear, quince	Plant growth regulator
Tracer	spinosad	1173/17*	Cherry	Spotted wing drosophila
Regalis Plus	prohexadione	1174/17	Outdoor plum	Plant growth regulator
Exirel 10 SE	cyantraniliprole	1134/17*	Cherry	Spotted wing drosophila
Exirel 10 SE	cyantraniliprole	1283/17*	Plum, damson	Spotted wing drosophila
Tracer	spinosad	1228/17*	Apricot	Spotted wing drosophila
Tracer	spinosad	1315/17*	Plum	Spotted wing drosophila
Cuprokylt	copper oxychloride	1469/17*	Plum, apricot, cherry	Bacterial canker
Sercadis	fluxapyroxad	2430/17	Peach, nectarines	Powdery mildew, scab
Flexidor	isoxaben	0011/18	Almond, chestnut, hazelnut, walnut	Broad-leaved weeds
Amylo X	*Bacillus amyloliquefaciens*	0469/18	Tree fruit	Bacterial canker, Monilinia, fireblight, botrytis, powdery mildew
Cuprokylt	copper oxychloride	0669/18*	Organic apple and pear	Scab
Cuprokylt	copper oxychloride	0213/18*	Apple, pear	Nectria canker

*denotes Article 53 authorisation for 120 days



The push and pull of spotted wing drosophila

Since 2013, AHDB has been funding research into the management and control of spotted wing drosophila (SWD) in soft- and stone-fruit crops. The initial project (SF 145) was led by Michelle Fountain at NIAB EMR in association with the James Hutton Institute and this ended in March 2017. It greatly enhanced our knowledge and understanding of how SWD behaves in UK growing conditions and the best management and control options available to growers. However, SWD remains one of the greatest challenges for growers to deal with and further research is needed to continue to develop a suite of measures which growers can employ to maintain control.

The project

The latest project (SF/TF 145a) aims to track the development of pest populations across the UK throughout the calendar year. It will develop and test a 'push-pull' system using repellents and 'attract and kill' strategies. Novel bait sprays will also be investigated, using them in combination with control products to see if they will enhance their efficacy. The opportunity to prolong spray intervals to maximise the effect of control products while reducing the number of applications will be assessed. Later in the project, work will be done to integrate the use of exclusion netting with other control options. The results of all of these lines of research will be compiled in a year-round SWD control strategy for growers.

National monitoring

The entomology teams at NIAB EMR and James Hutton Institute have continued to monitor populations of SWD across the UK with the help and collaboration of Berry Gardens Growers Ltd.

Numbers and activity of SWD increased earlier in the spring (Mar–May) and late summer (Jul–Aug) of 2017 than in previous years. This earlier activity correlated with increases in reported damage to early forced June-bearer strawberries and resultant higher populations caused damage in later cane fruit. The first peak autumn catch was almost a month earlier and catches in the November/December period were almost double the number of the previous highest recording. These peaks coincided with mild weather, and the Nov/Dec peak coincided with an absence of fruit and leaf defoliation in crops and wild areas, a time of year when SWD adults are more attracted to the lures contained within monitoring traps. This monitoring work will continue through the life of the project.

Developing a push-pull system

The aim of this work is to combine the use of repellents and attractants so that the pest can be pushed away from the crop using a repellent and attracted into a trap which would contain a distracting or fatal component.

Early experiments to assess the impact of several repellents, used either alone or in combination in an unsprayed cherry orchard, were disappointing, as no statistically significant results were produced – partly because the numbers of SWD in the cherry orchard were too aggregated early in the season or too high later in the season. It is possible that the plot size was too small to be able to detect repellent effects. However, a blend that was used in the first experiment only resulted in one SWD egg being found in sentinel fruit. Currently, experiments are being set up on a larger scale to test the repellent blend in strawberry crops.

An experimental 'attract and kill' prototype trap is being compared with one in commercial development, with both containing a control component enclosed within the inner surface of the device to minimise human exposure and environmental contamination. Unlike mass traps, the 'attract and kill' device is open-ended and does not become saturated with dead flies, which reduces labour costs. The experimental prototype Falcon tube device used Decis (deltamethrin) as a killing agent and was found to be as effective as the commercial trap in controlling SWD. The device achieved up to 30 per cent kill of SWD within 24 hours in semi-field cage trials.

SF/TF 145a – Development and implementation of season-long control strategies for *Drosophila suzukii* in soft and tree fruit

Term: April 2017 to March 2021

Project leader: Michelle Fountain, NIAB EMR

Industry representative: Marion Regan, Hugh Lowe Farms

Location: NIAB EMR and the James Hutton Institute

The devices with eight holes on the red sections of the tube were more effective than devices with four holes on the clear part of the trap. However, increasing the number of holes on the device from eight to 16 did not increase the efficacy.

Further work was carried out to develop the Cha-Landolt SWD lure into a dry formulation contained within a sachet, which is more practical and easier for growers to use than a liquid equivalent. Such dry lures only require changing every six weeks, compared with every week Experiments were done to optimise the release rates of the different components of the dry lure in the sachet. The optimised lure caught greater numbers of SWD adults than the liquid Cha-Landolt lure or the Dros'Attract lure in some experiments but less in others. The reason for this is not yet clear. Further work is developing a 'Minilure' for use in the Falcon tube 'attract and kill' device which will have a lifetime of six weeks or more.

Bait sprays

Using bait sprays in combination with spray control products should help to attract SWD adults to feed on the spray product, improving the likelihood of control. When compared with a 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.

Commercially available and novel baits were tested for their attractiveness to SWD, their toxicity to SWD when combined with a low dose of control product and their ability to prevent egg laying. In laboratory tests in Petri dishes, baits tested included a suspension of the yeast *Hanseniaspora uvarum* in sugar solution, fermented strawberry juice and Gasser bait. All of these significantly enhanced the efficacy of Tracer (spinosad) when used at 3.3 per cent of the recommended field rate for protected strawberries (at six per cent recommended field rate, 100 per cent mortality was observed in the laboratory). The yeast suspension (combined with a control product) was most effective in killing SWD, but all three were effective in reducing egg laying to a low level. Both the yeast plus sugar solution and the fermented strawberry juice improved the level of SWD mortality when mixed with Tracer, Hallmark (lambda-cyhalothrin) and Exirel (cyantraniliprole). This preliminary work shows good promise for the use of feeding-stimulant baits to improve the mortality and, importantly, reduce egg laying of SWD in crops.

Prolonging spray intervals

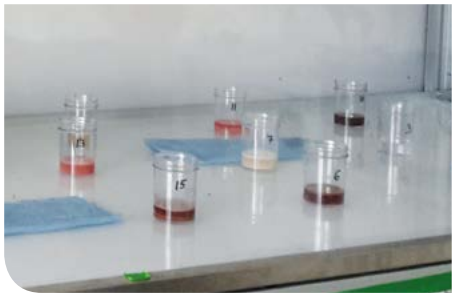
This work aims to determine the length of time that cherry extra-floral nectaries are available to SWD in a cherry orchard and also to investigate the length of time that spray products targeted against SWD in spray programmes are active. This may allow growers to prolong their spray intervals beyond seven to 10 days.

To learn about the attractiveness of floral nectaries, experiments were done on the cherry varieties Penny and Sweetheart (both open crops) by collecting leaves weekly from the trees and exposing them to SWD adults on the floor of a culture cage of SWD. The number of SWD that landed and fed, the time to find the floral nectaries and the length of feeding time over five minutes was recorded. The first 2017 fecund females were found in early April and over 50 per cent were fecund within a week. This coincided with cherry flowering. As the season progressed, the time taken to locate nectaries in the leaves tended to increase but demonstrated that there was a nectar food source available to SWD until after harvest.

In work to investigate spray intervals, trials were done in a commercial crop under replicated tunnels and in a single tunnel at NIAB EMR. Either a weekly or fortnightly spray programme was employed on both sites and fruits and leaves collected weekly, just before the next spray was applied. Fruits were collected from the commercial site and incubated to calculate the numbers of emerging SWD. Laboratory bioassays were performed on the leaves at the NIAB EMR site to test the mortality of SWD that came into contact with the leaves. In the commercial site, there were no differences in the numbers of SWD adults emerging from the fruits between the weekly and fortnightly sprays. In the NIAB EMR site, there was significantly more SWD mortality in the weekly and fortnightly spray programmes compared with the untreated control, but no difference between the two spray programmes. The study demonstrated that fortnightly sprays gave comparable efficacy to weekly sprays in cherry crops.

The most recent factsheet (Factsheet 06/17 Management and control of spotted wing drosophila) provides comprehensive guidance on the research results and management control measures that growers should implement and can be found on the AHDB horticulture website: **horticulture.ahdb.org.uk**

> "Unlike mass traps, the 'attract and kill' device is open-ended and does not become saturated with dead flies, which reduces labour costs"



Predators surviving insecticide sprays

In recent years, with the increase in protected cherry production, two-spotted spider mite has become an increasing problem in cherry crops. Growers have been doing their best to construct spray programmes which encourage an increase in populations of naturally occurring predatory mites to overcome this problem. Some have also introduced predatory mites to gain control. However, with the arrival of spotted wing drosophila (SWD), growers have had to increase their reliance upon traditional control products, given the lack of effective biocontrol measures for SWD. Products used to control SWD have the potential to disrupt IPM and biocontrol programmes for mite pests, so if predatory mites could be found with resistance to products being used to control SWD, then IPM programmes would be unaffected.

The project

This project set out to develop strains of predatory mites which are resistant to products used for SWD control so that they may continue to be used in IPM programmes. The work concentrated on the predatory mites *Amblyseius andersoni* and *Neoseiulus cucumeris* as they are commercially available for control of a range of important pests in soft- and stone-fruit crops and are considered 'native' species for authorisation for any subsequent use on non-glasshouse crops.

Results

Early work exposing *A. andersoni* and *N. cucumeris* to fresh residues of field rates of spinosad (Tracer) showed that this was only moderately harmful to both predators, but exposure to fresh residues of 0.1 times field rate of lambda-cyhalothrin (Hallmark) was highly damaging to both species. It was therefore hoped to develop strains of mites with greater tolerance to spinosad, but it was not possible to rear sufficient numbers of either *A. andersoni* or *N. cucumeris* under laboratory conditions to achieve this.

The work programme was therefore amended to provide growers with more information on the effects of topical applications of lambda-cyhalothrin (Hallmark), cyantraniliprole (Exirel) and spinosad (Tracer) on the survival of *A. andersoni* and *N. cucumeris*.
For *A. andersoni*, the LD50 (dose required to kill 50 per cent of tested individuals) for lambda-cyhalothrin after 48 hours was 0.17 field rate, for cyantraniliprole it was 2.2 times field rate and for spinosad it was 3.6 times field rate.

For *N. cucumeris*, it was not possible to derive an LD50 for lambda-cyhalothrin, but the LD50 after 48 hours for cyantraniliprole was 0.5 times field rate and for spinosad was around field rate.

These results suggest that for both species some predatory mites are likely to survive field rate applications of spinosad and cyantraniliprole. However, growers should guard against relying solely on these products for SWD control as this will significantly increase the risk of the pest developing resistance to them over time.

"Although this project did not succeed in developing predatory mites resistant to SWD control sprays, we have increased our knowledge of the survival rates of certain predators to the most commonly used products," commented Marion Regan, Hugh Lowe Farms.

> "Results suggest that some predatory mites are likely to survive field rate applications of spinosad and cyantraniliprole"

SF 153 – Selection of strains of predatory mites that can survive applications of insecticides required for SWD control

Term: April 2014 to March 2017

Project leader: Jean Fitzgerald, NIAB EMR

Location: NIAB EMR

Controlling SWD via viral pathogens and behavioural patterns

AHDB-funded research into spotted wing drosophila (SWD) has been extensive since the pest arrived in the UK in 2012 and many of the results have been presented in this publication over the years. In addition to the industry-funded project (SF 145), two PhD studentships have been supported by AHDB, investigating alternative and novel topics.

The projects

Bethan Shaw, who had previously worked with Michelle Fountain's entomology group at NIAB EMR focusing on SWD research, is studying a PhD under the joint leadership of University of Southampton and NIAB EMR. The research project is examining the behavioural and physiological rhythms of *Drosophila suzukii*, as determined by its internal circadian clock and environmental cues. It is hoped that this will reveal the times of day when SWD is most active in the crop, allowing growers to time control sprays to coincide with this.

In project CP 142, Nathan Medd is working under the supervision of the University of Edinburgh and NIAB EMR to investigate viruses specific to SWD which might be used for the development of microbe-based biopesticides which would be compatible with all the other IPM programmes already used by soft-fruit growers.

"The industry needs SWD research to follow up every line of enquiry to find a combination of control measures to contain this pest and both of these projects are usefully complementing the industry-funded project SF 145a," explained industry representative Marion Regan from Hugh Lowe Farms.

Results

The circadian rhythm work has already identified that the most active period for the female SWD to lay its eggs is during the daytime when the outside temperature reaches between 25–29.9°C.

During the cropping months, female *D. suzukii* display a preference for egg laying in the warmest part of the day, typically early afternoon. However, when temperatures exceed 30°C, egg laying is greatly reduced. Periods of activity appear to be in the morning and late afternoon, with very little movement or egg laying at night. Bethan Shaw has also been investigating the optimum laboratory parameters, such as social housing and environmental conditions, with the aim of producing a standard laboratory practice.

In the virus work, Nathan Medd has so far discovered seven new RNA viruses unique to SWD, along with a host of other viruses which, although described first in other fly species, regularly infest UK SWD. Techniques have been developed to isolate new viruses to test their pathogenicity and applicability as biological control agents.

> "The circadian rhythm work has already identified the most active period for the female SWD to lay its eggs"

CP 122 - The identification of viral pathogens suitable for the control of *Drosophila suzukii* in the UK

AHDBSTUDENTSHIP

Term: September 2014 to August 2017

Project leaders: Darren Obbard, University of Edinburgh, and Jerry Cross, NIAB EMR

Location: University of Edinburgh and NIAB EMR

CP 142 – Enhancing the control of the soft- and stone-fruit pest *Drosophila suzukii* (spotted wing drosophila) by exploiting its activity patterns in the field

Term: October 2015 to September 2018

Project leaders: Herman Wijnen, University of Southampton, and Michelle Fountain, NIAB EMR

Location: University of Southampton and NIAB EMR

Research into integrated pest management

Project TF 223 focuses on the investigation of control measures for a range of key pests and diseases in tree fruit crops. It has the flexibility to switch to other pressing problems as they arise during the course of the five-year programme.

In the first two years of the project, the research dealt primarily with apple scab, powdery mildew, canker, codling moth, tortrix moth and apple fruit rhynchites weevil. These results were reported in previous Tree Fruit Review magazines and in the annual reports, which can be viewed on the AHDB Horticulture website.

In 2017, the third year of the project, research continued on powdery mildew and canker. However, work began on Monilinia (brown rot) in cherry, Blastobasis moth, apply sawfly and *Anthonomus spilotus* (a weevil in pear). In addition, practical work in commercial orchards was instigated to improve the reliability of natural predation of pests.

A final objective of this project is to implement a surveillance programme for new and emerging pest and disease threats to the UK tree fruit industry. Each of these individual strands of the project are reported in this edition of the Review.

TF 223: Integrated pest management (IPM) of tree fruit pests and diseases

Term: April 2015 to March 2020

Project leader: Robert Saville, NIAB EMR

Entomology leader: Michelle Fountain, NIAB EMR

Project collaborators: ADAS, Natural Resources Institute, Reading University

Industry representatives: Nigel Kitney, Herridges Orchard; Nigel Jenner, Avalon Produce; Jeremy Linsell, Chromesword; Tom Hulme, A.C. Hulme & Sons

Location: NIAB EMR, Kent

Apple sawfly: an elusive pest

Apple sawfly can cause considerable damage to apples, laying its eggs on the receptacles of flowers. The subsequent larvae which hatch out can damage young fruitlets, leading to fruit drop or damage to remaining fruits in the form of ribbon scars, which are visible on the skin and render the fruit unmarketable. The pest has become more common with the loss of the active ingredient chlorpyrifos and it is particularly prevalent in organic orchards where there are no available products to control the pest.

The project

With the loss of broad-spectrum control products which used to eradicate apple sawfly if applied after petal fall, growers now need to be able to target other products directly to coincide with the emergence or appearance of the pest. This project aims to identify the sex pheromone of the pest, which could be used in a monitoring trap to detect the appearance of the sawfly. It could also be used in potential mating disruption studies which might be deployed in future in the production of organically produced apples.

"As an organic apple grower, I am well aware of the risk that apple sawfly poses to my crop. I am hoping that this work will lead to the development of a sex pheromone trap and further mating disruption techniques which will help me to control the pest," said Paul Ward, Mole End Farms Ltd.

Results

Work has begun to collect the pest so that studies can begin to identify the sex pheromone it produces. However, frustratingly, what would appear to be a simple task has proven to be very challenging for the entomologists at NIAB EMR. Apples were collected from an unsprayed orchard at East Malling which were known to contain apple sawfly larvae. These were held in mesh-covered bins to collect emerging adults from the fruits, but none emerged in the first year. More affected fruits were collected in 2017 and have been stored in a range of different temperature regimes, with the hope of facilitating successful emergence, which will allow the collection of volatiles from the adults for pheromone identification.

TF 223: Objective 8 – Apple Sawfly

"Frustratingly, what would appear to be a simple task has proved to be very challenging"

Surveillance of new pests and diseases

This part of Project TF 223 aims to survey new and emerging pest and disease threats to inform the industry of problems which may lead to yield losses in the future. Such intelligence will also help AHDB to shape future research priorities.

Insect pests

Drosophila suzukii (spotted wing drosophila) continues to be surveyed as part of a national monitoring scheme in Project SF/TF 145a. Compared with previous years, numbers were particularly high in 2017 and the population began to rise earlier in the year (April). AHDB notified the industry of population increases throughout the season. Few incidences of crop losses in cherry or plum were reported. Given recent experience of the pest, stone fruit growers have revised their management of their crops and implemented new and improved control programmes.

Summer fruit tortrix moth was detected for the first time in the West Midlands in 2015 and growers are encouraged to monitor for it in the region using pheromone traps alongside codling moth and fruit tree tortrix monitoring traps.

Anthonomus spilotus is a new pest damaging spring flower and leaf buds, which has been found in commercial pear orchards over the past two to three seasons. It was identified in 2017 by NIAB EMR and the National History Museum. Following identification, further work into understanding the life cycle and control options for this pest have been carried out as part of TF 223 (also reported in this review magazine), demonstrating how responsive this funding model can be.

Brown marmorated stink bug (*Halyomorpha halys*) is an invasive pest causing damage to apples and pears. It originates in East Asia but has spread to North America and mainland Europe in recent years. To date, it has not been found in UK orchards, but the entomology team at NIAB EMR is now deploying traps to monitor for its presence in Kent, the most likely location that it will first become established.

Pear shoot sawfly (*Janus compressus*) has been sighted by the Royal Horticultural Society. To our knowledge, this sawfly has not yet been found in any commercial pear orchards.

Diseases

Apple scab is being monitored in an indicator orchard by NIAB EMR as part of a large pan-European project. The same indicator varieties have been planted in 25 European countries, each variety containing different combinations of the known resistance genes of scab. At the UK site, the severity of the scab epidemic on *Malus floribunda*, a malus species from which Vf (a major resistance gene of scab) was derived, was comparable to disease incidence on Gala. This confirms that the local scab population has broken the resistance conferred by Vf which has been observed across Europe over the past 30 years.

Apple rot surveys continue to be carried out by NIAB EMR scientists and in the 2016/17 storage season, the overall average loss was 1.5 per cent, lower than surveys in the recent past. Nectria rot was most prevalent, making up 33 per cent of rots. Brown rot (Monolinia) was second (19.3 per cent), followed by Neofabraea – formerly Gloeosporium (12.4 per cent), Penicillium (11.2 per cent) and Botrytis (9.2 per cent). Phytophthora was only found in a single sample.

Neofabraea kienholzii is a species of Neofabraea (formerly called Gloeosporium) which causes an apple rot in store. This fungus, first recorded in Canada, has been reported for the first time in the UK by NIAB EMR pathologists.

TF 223: Objective 1 – Surveillance

Apple powdery mildew

The work on foliar diseases so far has focused on finding ways to control powdery mildew and scab that would fit into an IPM programme. Season-long control is required in apple orchards to protect shoots and buds from foliar diseases and prevent high levels of the pathogen surviving over winter. Despite such stringent measures, scab and mildew control can break down during the growing season. Effective control is further threatened by a reduction in available actives and a rise in pathogen populations which have reduced sensitivity to the existing fungicides. Mildew epidemics can, in extreme cases, defoliate trees, reducing yield and giving rise to fruit russet. Scab infection not only renders fruit unmarketable, it can lead to cracking, which serves as entry points for rot fungi which subsequently develop in store.

The project

This project aims to develop an integrated programme focused on reducing inoculum, promoting tree health/resistance and evaluating alternative treatments based on physical and biological properties, with the aim of reducing fungicide applications while maintaining acceptable disease control.

Early work assessed the biology of leaf litter degradation and accelerating this process to help to reduce the level of scab which overwinters. Work on powdery mildew has been assessing alternative products to traditional fungicides. Experimental plots in a Gala orchard were established with both high (40–100 per cent mildewed leaves) and low (10–30 per cent mildewed leaves) incidences of secondary mildew. The main plots were sprayed with a standard fungicide programme at 7- or 14-day intervals and, within these plots, nine alternative treatments were evaluated in sub-plots, including Cultigrow CBL, Sporekill, SB Invigorator, Wetcit, Garshield, Mantrac Pro, Trident, 2EY and Vacciplant. These were applied eleven times at 7 to 10-day intervals, apart from CBL (three sprays at monthly intervals) and Mantrac Pro (nine sprays only). The untreated control plots were the 7- or 14-day fungicide-only programmes.

Results

All of the test products significantly reduced mildew, compared with the fungicide-only plots. SB Invigorator was the most consistent in reducing mildew. Wetcit and Trident were the next most consistent products. Vacciplant, Mantrac Pro and CBL were least effective. Although CBL appeared to have little effect at the start of the experiment, by the time the third application was made, CBL-treated plots had a significantly lower mildew incidence than the fungicide-only plots. This suggests that it may have a cumulative effect.

> “All of the test products significantly reduced mildew, compared with the fungicide-only plots”

This powdery mildew work was repeated in 2017 using the best-performing products from the first trial (SB Invigorator, Wetcit, Trident and CBL) and a new product B225, either alone or in combination. Plots treated with CBL in 2016 were retained for a second year to evaluate the cumulative effects of this product. The experimental design from the previous year was repeated, with treatments applied eleven times and at 7 to 10-day intervals, except CBL (three sprays at monthly intervals). B225 was applied monthly or at 7 to 10-day intervals. Overall, all treatments had significantly less mildew that the fungicide-only plots. SB Invigorator was the most consistent in reducing mildew, confirming results from previous years. CBL (2 years), CBL + Wetcit and Wetcit only were almost as effective. CBL (two years) had almost significantly less mildew than plots receiving CBL for the first year, indicating a possible cumulative effect of this product. Trident performed as well as the previous year. In 2016, Trident had caused some leaf spotting and russeted fruit, but this did not occur in 2017, probably due to a change in the wetter included in the formulation.

TF 223: Objective 3 – Foliar diseases

Pear sucker prevention

Previous work by AHDB, as part of Defra Horticulture LINK project HL0194, demonstrated the benefits of enhancing natural populations of earwigs and anthocorids to prey upon pear sucker, and many commercial pear growers have amended their management of pear orchards to harness these natural predators. When establishing new orchards of apples or pears, however, growers create a vacuum which is devoid of flora or fauna and it takes a considerable time to recreate a natural ecosystem which can be deployed for pest- or disease-control purposes.

In work to implement interventions in newly planted orchards, six replicate commercial apple orchards were chosen in 2017 and secured for experimental purposes through help from Caroline Ashdown at Worldwide Fruit. In each orchard, 0.25ha is being treated with ecological enhancement interventions, including the sowing of alleyway seed mixes (yarrow, ox-eye daisy, bird's-foot trefoil, self-heal, red campion and red clover), the provision of earwig refuges and hoverfly attractants. Each treated area will be assessed and compared with an untreated area of the same orchard throughout 2018 and 2019. A wide range of data will be collected, including flower strip establishment, numbers of solitary bee nesting sites, presence of aphids and their predators, presence of apple leaf midge, rust mite and red spider mite and their predators, and activity of earwigs at night.

In the work to improve effective monitoring of predators and pear sucker in pear orchards, NIAB EMR entomologists set up training courses for five commercial pear growers and their agronomists to use a current established template for pear orchard pest/predator assessment, which was developed for staff to implement on farm. The staff are also reporting data regularly to entomologists at NIAB EMR to determine thresholds for control and to contribute to data for a potential model for predator/prey thresholds.

Each grower selected three orchards (high, medium and low pear sucker infested) on each farm and allowed time for a worker to systematically assess the chosen orchards and complete a record sheet each week.

> "It was found to be important to continue monitoring after harvest when there can be a resurgence in egg laying"

In 2016 and 2017, the first-generation peaks of pear sucker occurred between mid-May and early June. On one farm, early-season predators and late-season natural enemies appeared to control pear sucker. In one of its orchards, in some weeks over 80 earwigs were present per 30 branches assessed.

It was found to be important to continue monitoring after harvest when there can be a resurgence in egg laying and nymph hatch, which subsequently damages overwintering buds.

In general, preliminary data is suggesting that where there are at least 10 anthocorids and/or earwigs in 30 tap samples each week, there is good control of pear sucker. Often, earwigs were found where there were more anthocorids. This could be a consequence of crop management being more sympathetic to natural enemies on some sites.

The monitoring will continue in 2018, building up a three-year database of 15 orchards for use in future pest outbreak predictions.

"We have long since known of the benefits of the natural ecosystem for pest control in orchards and I am pleased to see some positive steps being taken to encourage growers to implement our knowledge of this," explained Mike Solomon, Scientific Advisor to the AHDB tree fruit panel.

TF 223: Objective 7 – Improving the reliability of natural predation of pests

Tackling Blastobasis moth with IPM

In the first two years of this project, research into the control of codling and summer fruit tortrix moths employed mating disruption techniques (RAK3+4) and compared them with conventional control methods. The mating disruption was effective at low population densities, but at higher densities some additional sprays were required when monitoring-trap catch thresholds were exceeded. However, in the mating disruption experimental plots, an increase in Blastobasis moth populations were observed. Blastobasis would traditionally be controlled by products targeted at controlling codling and tortrix moths. In the trials, the appearance of Blastobasis moth required the application of products which negated the advantages of using the mating disruption technique.

The project

Should the use of mating disruption for codling and tortrix moths lead to increases in Blastobasis moth, significant damage could occur. Larvae of the moth feed on the surface of apple and pear fruits in mid- and late-summer, often where clusters are touching, cause large, open, scallop-shaped wounds in the flesh, rendering attacked apples unsaleable. Growers currently have no means of identifying whether they have a problem other than the occurrence of damage the previous year, which can be confused with damage caused by other moth pests.

This work aims to develop a pheromone-based monitoring trap for Blastobasis moth so that growers can determine whether they have a problem and can time production applications accordingly.

Results

In the 2017 season, field trapping experiments with three potential pheromone lure blends based on previous work were carried out in Kent, Herefordshire and Northern Ireland. A number of moths were caught by these blends, but the use of DNA barcoding showed that only one was a Blastobasis species. In the Northern Ireland traps, a number of *Rhigognostis incarnatella* were captured in one pheromone blend. This species is related to the diamondback moth, which has a similar pheromone. In 2018, work will focus on obtaining virgin adults of *Blastobasis lacticollela* for pheromone and molecular analysis.

"The recent reappearance of Blastobasis following the use of mating disruption is a warning to growers that this pest could become a bigger problem in future, so I am pleased that NIAB EMR scientists are working to develop improved monitoring techniques," Nigel Kitney, Herridges Orchards.

TF 223 – Objective 6 – Codling and tortrix moths

> "Growers currently have no means of identifying whether they have a problem other than the occurrence of damage the previous year"

Diseases of stone fruit

Brown rot, caused by Monilinia species, is one of the principal diseases causing yield loss in plum and cherry crops in the UK. Total losses are difficult to quantify as infection can occur throughout the season, from blossom time through to harvest and during the storage period. Post-harvest development of brown rot limits the storage potential of plums and cherries. To gain control, growers currently rely heavily on the use of conventional fungicides such as Signum (boscalid + pyraclostrobin) and Switch (cyprodinil + fludioxonil) applied both during blossom and close to harvest.

The project

This project aims to evaluate newly available control products, including plant health promotors, biological control agents and fungicides, which, in combination, could provide a more effective programme for brown rot control. This work on brown rot began in 2017.

Results

The work in 2017 was severely hampered by late frosts. These coincided with the blossom period and early fruitlet development in the cherry orchard chosen for the trial, resulting in reduced yields. Some further damage by spotted wing drosophila to the remaining fruits resulted in further yield reduction and there was insufficient fruit at harvest time to be able to draw any meaningful conclusions. The trials will be repeated in 2018.

TF 223 – Objective 4 – Stone fruit diseases

Weevil worries

In recent seasons, entomologists at NIAB EMR have been made aware of a weevil pest which has become increasingly prevalent in pear orchards in the south-east of England. The weevil was initially thought to be the pear bud weevil (*Anthonomus pyri*), an uncommon species that is known to cause damage to pear, but experience of the damage being found was not consistent with pear bud weevil and suggested that another species was involved.

The project

The purpose of this project was to determine the lifecycle and damage being caused by this pest, improve our understanding of its biology and identify the exact species involved. In addition, the scientists at NIAB EMR set out to determine the efficacy of commonly used crop protection products in UK pear orchards for the control of the weevil. Ideally, this would fit within an IPM system and be compatible with an earwig safe spray programme.

Results

The weevil was confirmed by the Natural History Museum as *Anthonomus spilotus*, which is known to be widely distributed throughout continental Europe. It has one generation per year. Adults overwinter until early March and then begin to feed on developing flower and leaf buds of pear and, less frequently, on medlar or hawthorn. The adult appears to be more active at night.

The adults feed on developing leaf and flower buds, leaving holes and resulting in necrosis. They lay eggs from mid-March until mid-April in the holes they've created and in flower buds. The leaf buds develop irregularly and the flower buds are consumed by the hatching larvae, resulting in a reduction in flower and fruit number. Larvae develop inside the buds into May, at which point the adult numbers and feeding damage are much reduced. Adults emerge in mid-June and diapause until the following spring.

In research into control, it was found that two parasitic wasps present in the UK can parasitise *Anthonomus spilotus*, but these cannot be relied upon to keep weevil numbers below an economic threshold, so the entomology team at NIAB EMR assessed a range of products currently used by pear growers to evaluate their effect at controlling the weevil. Calypso (thiacloprid) was shown to be effective in field studies. In laboratory studies on sprayed A. spilotus adults from UK pear orchards, Calypso and Spruzit (pyrethrins) gave almost 90 per cent kill, while Hallmark (lambda-cyhalothrin), Gazelle (acetamiprid) and Exirel (cyantraniliprole) offered around 50 per cent control of adults. It should be noted that Exirel is not currently approved for use on pear. Steward (indoxacarb) and Coragen (chlorantraniliprole), applied to the adult insects topically, were ineffective. These results came from laboratory-based tests, so cannot be wholly relied upon in commercial orchards. Work in 2018 is examining the commercial consequence of damage by the weevil, with the aim of eventually setting a spray threshold.

An AHDB factsheet for growers, Factsheet 10/18 *Anthonomus spilotus* – a new pest of pears in the spring, has been published to offer comprehensive guidance on the recognition, biology and control of this pest in commercial pear orchards.

"I am pleased that AHDB funds have been used to learn more about this new pest of pears in the UK, as it ensures that we can be vigilant and prepared to deal with it in our own pear orchards," said Nigel Stewart of AC Goatham & Son.

TF 223 – Objective 9 – *Anthonomus spilotus* in pear

> "The damage being found was not consistent with pear bud weevil and suggested that another species was involved"

Apple canker detection and prevention

European apple canker, caused by *Neonectria ditissima*, continues to challenge apple growers, as it can give rise to significant levels of tree death, reduce fruiting wood and causes fruit rot in store, leading to serious yield reductions. It can be particularly prevalent in newly established orchards and it is not uncommon to lose up to 10 per cent of trees per year in the first three years after planting. This incurs additional costs in replacing and replanting trees and reduces yields in the early stages of a new plantation, at a time when growers need quick returns to repay the significant outlay required to establish a new orchard. Tree fruit growers continually cite the disease as the single most important problem they need AHDB research to address.

The project

This project is using a systems approach to tackle the disease from nursery through to tree establishment. The main objectives are to:

- Develop a detection tool
- Evaluate rootstock and interstock combinations for their canker susceptibility
- Evaluate whether biological soil amendments will reduce canker expression; and
- Evaluate novel methods to deliver treatments targeted at canker

Results

Neonectria ditissima can often be latent within nursery trees, but rarely expresses itself, either in the rootstock or the young tree in the nursery. Without better detection methods in stool beds, rootstocks, budwood, graftwood, mother stock or indeed the orchard, this situation will not improve. An initial objective therefore was to develop a detection tool for the presence of the pathogen. A panel of seven antibodies were identified and the antibody with the greatest specificity to *Neonectria ditissima* was chosen, allowing the scientists to develop a diagnostic tool.

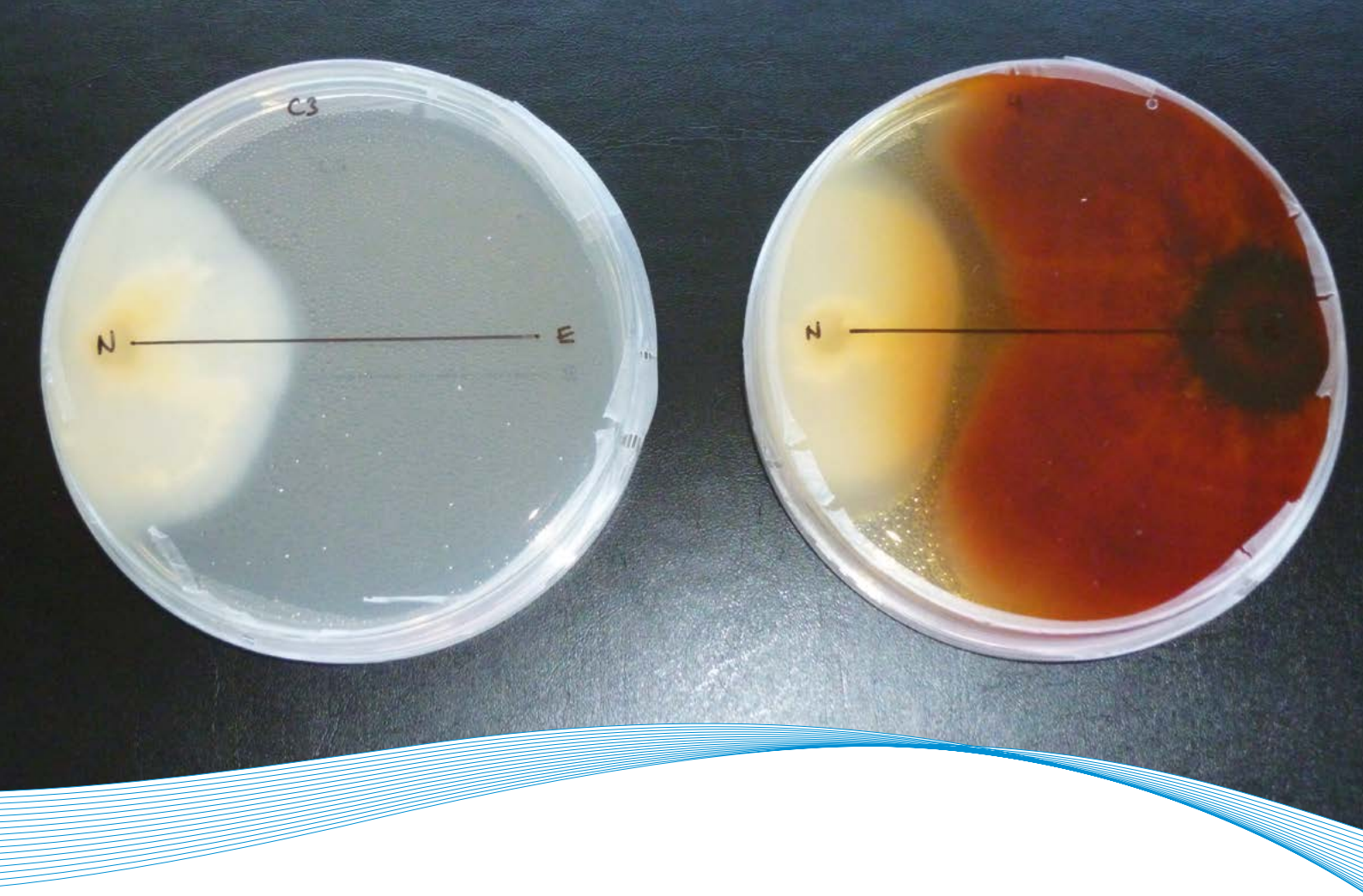
> “Tree fruit growers continually cite the disease as the single most important problem they need AHDB research to address”

This is currently being utilised in a PhD studentship project (CP 161) to increase our understanding of latent non-symptomatic canker infections, with the ultimate goal of developing a sampling strategy to deploy the diagnostic tool in the nursery.

In the work to evaluate rootstock/interstock combinations for their canker susceptibility, along with biological soil amendments to assess if they will reduce canker expression, long-term trials have been established on multiple sites. The rootstock trials are evaluating a panel of rootstocks commonly used today, alongside several advanced selections from the NIAB EMR and Geneva rootstock breeding programmes. The amendment trials are evaluating the effect of arbuscular mycorrhizal fungi (AMF), plant growth promoting rhizobacteria (PGPR), Trichoderma and Biochar in both newly planted orchards and stool beds. These trials are now established, but their long-term nature means that data will need to be collected over the remaining two years before conclusions can be drawn.

In work to evaluate novel methods to deliver canker treatments, two delivery systems have been assessed. A pruning wound protection device (Felco 19 System) allows pruning wounds to be treated as pruning cuts are made. This device compared five different wound treatments with an untreated control. The treatments included Folicur (tebuconazole), Blocade (a physical barrier), T34 (a Trichoderma strain) and combinations of these. Folicur alone and Blocade in addition to Folicur or T34, all reduced infection significantly, compared with the untreated control. A tree injection system (Fertinyect) has also been trialled with a view to eradicating systemic infection within the tree. Products evaluated so far have included conventional plant protection products, defence elicitors and biological-based products, but none have shown sufficient efficacy to recommend this system as part of an integrated programme.

TF 223 – Objective 2 – Canker



Neonectria kept in check from the inside

Endophytes are microbes that live within plant tissues for at least part of their lifecycle without causing noticeable disease. Although widespread, we know very little about them, but researchers believe some can help plants tolerate attacks by pathogens or stresses such as drought; and there is increasing evidence that the plant host's genetics influence its endophytic microbes.

Endophyte populations can also be affected by the presence of pathogens and by crop management practices. NIAB EMR researchers have already found that certain fungal endophytes may help to keep the apple canker pathogen *Neonectria ditissima* in check if it is present in a tree and may be linked with a variety's tolerance to it. The pathogen itself can live in a latent phase for some time after infection without causing symptoms.

The projects

AHDB is a partner (TF 226) in a four-year 'Link' project funded through the Biotechnology and Biological Sciences Research Council and with industry collaborators Adrian Scripps, Avalon Produce, Frank P Matthews, Worldwide Fruit and T&G Global. The project is investigating whether varietal differences in tolerance to neonectria canker are associated with endophytes and, if so, to find out which endophyte species are involved.

Leone Olivieri's AHDB studentship (CP 161) runs alongside TF 226. He is working with pathologists at NIAB EMR and with endophyte experts at Royal Holloway, University of London, to learn more about how *N. ditissima* infects trees and where it develops during its latent phase – and whether it lives in the host as an endophyte before becoming pathogenic. He is also helping to identify the other fungi and bacteria that live as endophytes in apple and how they are affected by the season and by the characteristics of particular apple varieties.

> "The new diagnostic test can detect neonectria in its latent phase"

Four key aims of TF 226 are:

- To identify which endophytes are associated with canker resistance in a selection of existing apple varieties with varying degrees of susceptibility to the disease
- To test the biocontrol properties of endophytes which are in greater abundance in the less canker-susceptible varieties
- To determine whether the host's genetics influence the endophyte community
- To assess what factors in the early stages of orchard establishment influence the endophytes in young trees and whether this in turn affects the appearance of canker symptoms from latent infections

One group of fungal endophytes belonging to the genus *Epicoccum* is already known to be more abundant in some canker-tolerant apple varieties than in some susceptible ones. If the Link project team can show that its abundance in certain apple varieties is actually linked to canker tolerance, they will investigate whether it can be exploited for canker management. They are also working to find out whether a tree's endophyte population is influenced by its genetics and by environmental factors such as soil characteristics, and how the presence of particular endophytes is related to whether or not *N. ditissima*, when present, causes canker symptoms.

Olivieri's studies aim to add to this by confirming whether neonectria establishes as an endophyte prior to switching to a pathogenic phase. Working out what happens at this stage in the pathogen's lifecycle could offer opportunities to develop new diagnostic tools and control strategies.

These projects on endophytes could help breeders searching for canker resistance, by discovering to what extent the plant 'recruits' particular endophyte species. In turn, this will help unravel the multilayered resistance mechanisms that are believed to play a role in this host–pathogen relationship – some aspects of canker resistance may be coincidental with the tree's ability to recruit beneficial endophytes.

Ultimately, both projects will help establish an effective sampling and diagnostic procedure to detect *N. ditissima* in its early stages and bring closer the possibility of harnessing endophytes for biological control.

Results

The Link project team has already tested a small range of apple varieties that differ in their susceptibility to neonectria canker and found that they host different endophyte communities. A wider range of combinations of apple varieties and rootstocks has been planted out at two trial sites and will be sampled over the next 18 months to confirm the initial findings and help identify which endophytes are associated with a degree of resistance to canker.

Meanwhile, some endophytes which were found to be abundant in the more resistant varieties examined in the early stages of the project have been tested in cultures in the laboratory to see how they affect growth of *N. ditissima*. Those which appear to be particularly strong antagonists will be taken forward to field trials in which they will be inoculated into a canker-susceptible apple variety to see if they are able to confer any reduction in susceptibility.

In the studentship project, Leone Olivieri has developed an antibody-based diagnostic tool (ELISA test) which can detect the presence of *N. ditissima* in its latent phase. The test is sensitive enough to pick up the pathogen in bark and sapwood even when other microbiological techniques proved unsuccessful. More work is needed to refine the technique and to find out just how little neonectria needs to be present to get a 'positive' result, but such a test could prove invaluable, for example to screen nursery or planting stocks for the presence of latent canker. "This work is going a long way to developing a useful canker diagnostic, which would be very well received by both growers and nursery producers," said AHDB Horticulture Tree Fruit Panel member Paul Smith.

However, Olivieri is already using the test, backed up with laboratory culture techniques, to learn more about how neonectria infects and spreads, tracking the growth of the fungus from deliberately inoculated leaf scar or pruning wounds. In initial experiments, *N. ditissima* was found in apparently healthy wood underneath the cambium at up to 4cm from a pruning cut.

Meanwhile, he has also started to put together a culture collection of fungal and bacterial endophytes that he has sampled from apple tree tissues. More than 30 isolates have been categorised and stored for further study.

After being identified to genus or species level using molecular methods, they will be tested for their potential as biological control agents.

Several other trials are under way but at too early a stage to yield results. Eventually, the work will underpin the development of practical measures to reduce canker development, particularly in the early stage of orchard establishment, which in turn will lead to reduced secondary infection of branches and fruit due to a reduction in inoculum.

The industry representative for TF 226, Peter Checkley, says the project is already delivering some useful results. "We are seeing information which will help in our long-term quest to find solutions to apple canker," he said.

CP 161 – Understanding endophytes to improve tree health

Term: October 2016 to September 2019

Project leader:
Robert Saville, NIAB EMR

TF 226 – The role of endophytes in affecting symptom development of European apple canker caused by Neonectria ditissima

Term: October 2017 to December 2020

Project leader:
Xiangming Xu, NIAB EMR

CP 141 – The molecular basis of pathogenicity of *Neonectria ditissima*

Term: October 2015 to October 2018

Project leaders: Richard Harrison, NIAB EMR, and Robert Jackson, University of Reading

PhD student: Antonio Gomez Cortecero

Location: NIAB EMR

> “Canker was found to be genetically similar across the world, suggesting that should any resistance be found, it is likely to be effective worldwide”

Understanding *Neonectria ditissima* at a molecular level

AHDB is currently funding a number of projects to improve our understanding of Neonectria ditissima. One of these is a PhD studentship project being done by Antonio Gomez Cortecero under the supervision of Dr Richard Harrison at NIAB EMR and Robert Jackson at the University of Reading. They are investigating the genetics of the pathogen to improve our understanding of potential resistance, which may be deployed in future control strategies.

The project

The causal agent of European canker, *Neonectria ditissima*, has become a globally important plant pathogen of apple over recent years and is causing significant economic losses across all major apple-growing territories globally. Very little is known about this pathogen at a molecular level. This project will provide fundamental insights into the molecular basis of pathogenicity in *N. ditissima*, dissecting components of the pathogen’s genome that modulate the virulence and how these are linked with the host resistance.

“This type of study will inform long-term breeding and the development of resistance strategies to overcome European apple canker,” explained Tony Harding, Worldwide Fruits.

Results

In the early stages of the work, a number of useful discoveries were made. Canker was found to be genetically similar across the world, suggesting that should any resistance be found, it is likely to be effective worldwide.

Identifying the nature of resistance to *N. ditissima* has been challenging in the past. Artificial pathogenicity tests carried out in the laboratory on a range of apple varieties revealed differences in susceptibility responses. These observations were consistent with their performance in the field, ranging from highly susceptible cultivars, like Gala or M9, to resistance in Golden Delicious and even more in the wild apple Malus x robusta 5. Nevertheless, tests in apple seedlings from different crosses revealed that resistance responses to *N. ditissima* are complex and involved multiple resistance genes.

Samples collected from the infected tissue in potted trees of Golden Delicious and M9 were used for the analysis of gene expression during the infection to identify those specific genes important in the resistance of Golden Delicious compared with the M9. The analysis of these samples can be used in the opposite way, identifying pathogenicity genes of *N. ditissima*. During the infection, the pathogen secretes a big repertoire of enzymes to damage the host tissue and secretes small proteins, called effectors, which interact with the host to modulate the defence response and allow the colonisation. Artificial inoculation tests of the highly susceptible rootstock M9 have demonstrated that there are strains of *N. ditissima* that are almost non-pathogenic and others that are pathogenic. These results suggest that not all of the isolates possess the same elements for the infection and these could be gained or lost during the evolution of this pathogen.

This project presents a dual strategy to understand the mechanism underlying apple canker infection and will set the basis for effective resistance breeding that can be durable in the field.

The right start for fruit walls

The scope they offer for mechanisation and reduced labour costs means more and more growers are considering fruit-wall systems when it comes to planting new apple orchards. But the sums only add up if the right kind of planting stock is chosen so that the trees come into fruit as early as possible and continue to produce high yields of top-quality fruit.

Several specialist nurseries are developing tree types designed especially for fruit walls. These include 'grow through trees' and Bibaum trees from Mazzoni nurseries. Other nurseries recommend that using a maiden tree or an eight-month tree at a close planting distance gives better results.

The project

Although several growers in France, Belgium and the Netherlands have already established fruit walls, they selected planting stock to suit their local conditions and their decisions don't necessarily translate to English climates and soil types. In this project we are comparing establishment, growth and yielding patterns of five distinct types of stock in a fruit wall planted at Brogdale Farm, Faversham, Kent in the winter of 2013/14. The tree types are: one-year 5+ branches; one-year unfeathered; two-year-old 'grow through'; standard 'knip'; and twin stem.

Results

The fruit wall was given its first mechanical prune in 2014, at nine new leaves emerged on that season's growth. In the first two years, trees from the two-year-old planting stock yielded most fruit overall, while those planted as one-year unfeathered trees yielded the least.

Total yields for 2016 were variable. Trees planted as one-year unfeathered stock continued to be the lowest yielding per stem because they were the least developed and had less fruiting wood than the other types. Those planted as two-year-old trees were still the highest yielding, but statistical analysis showed they were not significantly better than trees planted as a standard knip or one-year 5+ branches – all three types were by then producing close to the expected 30 tonnes per ha of a conventionally pruned standard knip in its third fruiting year.

> "Class 1 yields have now reached a commercially acceptable level for the trees' age except in the case of the twin-stem type"

In 2017, the fourth fruiting year, the trees from the two-year-old stock again had the highest annual yield and also the highest cumulative yield – significantly so in both cases. Trees planted as twin stems had the lowest yield in 2017 and those planted as one-year unfeathered stock, the lowest cumulative yield. From measurements of tree height and spread, it was calculated that the volume of all five tree types was less compared with the previous year, but all produced greater overall yields, nonetheless, despite suffering frost damage.

Class 1 yields have now reached a commercially acceptable level for the trees' age except in the case of the twin stem, although its yield efficiency is now the highest among all of the different types.

Despite low initial tree costs per ha for the one-year unfeathered trees, and predicted higher returns for twin-stem trees, results in this trial so far suggest that they are the least suitable for growing as a fruit wall because of their slow establishment and lower early yields compared with the others in the trial and to conventionally pruned trees of the same type and age.

"I believe this type of trial is essential for the tree fruit industry, as increasing numbers of growers are establishing fruit-wall systems. I have been following the results of this project with great interest," said Mark Holden of Adrian Scripps.

TF 206 – Comparison of different planting material for fruit-wall orchard systems for apple

Term: December 2012 to March 2019

Project leader: Abi Dalton, FAST

TF 214 – Improving nitrogen use efficiency, sustainability and fruit quality in high-density apple orchards

Term: April 2014 to March 2017

Project leader:
Eleftheria Stavridou, NIAB EMR

Fertigation to meet nitrogen demand

High-density plantings irrigated by fertigation are replacing traditional apple orchards. As well as delivering nitrogen and other nutrients to the trees, a fertigation system can be used to schedule irrigation to meet the trees' water demand, based on monitoring soil moisture deficits in the root zone. It enables growers to cut back on water use but has implications for managing fertiliser application.

The project

The work in TF 214 was aimed at developing fertigation guidelines to help growers match nitrogen application to the crop's demand. High nitrogen rates may result in larger apples and increased seasonal yields but won't necessarily help quality or cumulative yields.

Excess nitrogen in the tree promotes vegetative growth, causing shading within the canopy, with knock-on impacts on flower bud development, fruit set and fruit quality, in terms of lower concentrations of soluble solids, a reduction in firmness, poorer colour and shorter storability.

Over-application also leads to a build-up of nitrogen in the soil where it is vulnerable to leaching. The main apple-producing areas are in nitrate-vulnerable zones and growers need to justify their nitrogen applications in terms of yield and prove they are following good practice.

"With the increased use of high-intensity growing systems for apples, the industry needs new guidelines on the optimum use of nitrogen in these orchards," said the project's industry representative Graham Caspell, farm manager at NIAB EMR.

In the final year of trials, four nitrogen rates were supplied by fertigation (10, 20, 30 and 40g nitrogen in total per tree), with a nil rate for comparison, in a mixed orchard of five-year-old Gala and Braeburn on M9.

> "Yields of Class 1 and Class 2 fruit were unaffected by nitrogen rate across the range of levels tested"

Irrigation was scheduled to an average soil matric potential within the rooting zone of -200kPa and fertiliser injected for a short period at the end of each irrigation. Post-harvest, additional fertigation was applied to increase tree nitrogen reserves and to feed the following year's flowering and fruit set.

Soil nitrogen levels were analysed before the experiment and taken into account when planning the regimes – there were no significant differences across the experimental area.

During the experiment, soil solutions were sampled in the root zone (at 30 or 60cm depth) and nitrate concentrations measured. Nutrient analyses of leaves, fruit and soil were also carried out during the growing season.

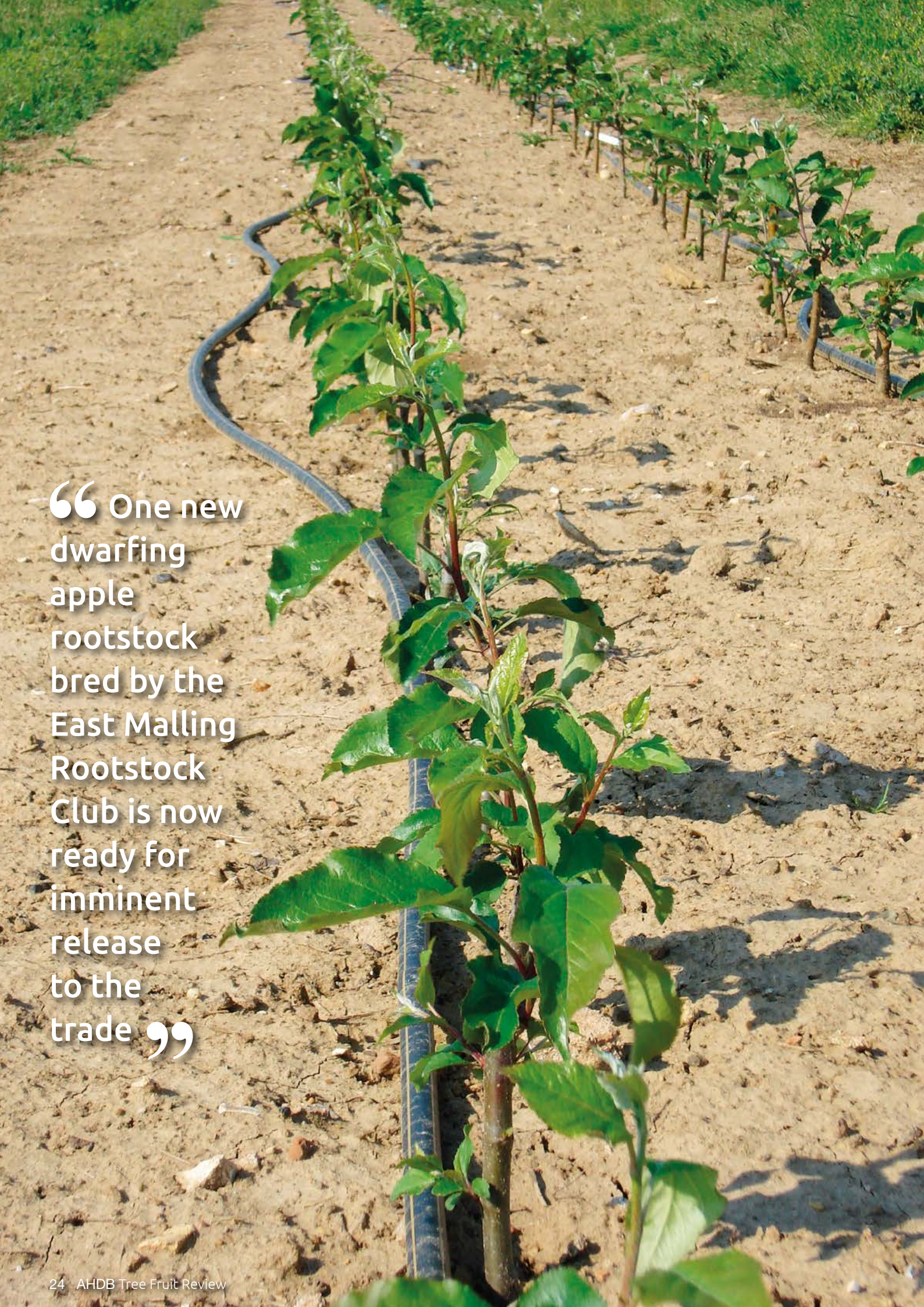
Results

Yields of Class 1 and Class 2 fruit per tree were unaffected by nitrogen rate over the range of levels tested and there were no differences, either, in fruit quality (firmness and Brix levels), indicating that all treatments supplied enough nutrients.

There was a tendency for lower yields where no nitrogen fertiliser was applied, and although this was not statistically significant, applying no nitrogen at all potentially would have cost around £5,000 per ha in lost yields.

Effects on storage and shelf life were checked after three and six months in a controlled-atmosphere store. There were no significant differences in fruit firmness between the fertiliser treatments, for either of the storage durations, which remained above commercial thresholds for both varieties. Fruit firmness after three months ranged from 82.6 to 81.4 Newtons for Braeburn and 72.7 to 70.8 for Gala, and dropped slightly by six months to between 77.4 and 75.4 for Braeburn and 71.8 to 68.6 for Gala.

None of the fertiliser treatments affected internal fruit quality during storage and few disorders were found.



> One new dwarfing apple rootstock bred by the East Malling Rootstock Club is now ready for imminent release to the trade

Rootstocks to secure the next generation of orchards

Reliable pest and disease resistance, combined with good vigour control, are essential ingredients for the new breed of rootstocks the industry needs for the next generation of apple and pear orchards, where financial and environmental sustainability will hinge on lower labour costs and fewer chemical applications.

Apple growers are also looking for rootstocks offering better tolerance to stresses such as soilborne diseases, waterlogging and woolly apple aphid attacks, while maintaining the range of vigour that's already available in the familiar M9 to M116 series. For pear growers, the aim is to replace the current range of quince rootstocks with pyrus types, which, being more closely related, will be more compatible with pear scions and that are better adapted to the range of soil types in UK orchards and more disease-resistant.

Growers are keen, too, that we develop rootstocks that lend precocity while avoiding biennial bearing and which have good anchorage, while specialist fruit stock nurseries require new material to be easy to propagate.

The East Malling Rootstock Club

This is one of the few apple and pear rootstock breeding programmes left in the world. Since 2008, AHDB funding has helped ensure the programme meets the needs of the home industry and that any resulting new rootstock varieties are available to all UK growers. The programme also attracts funding from a range of other sources, including the European arm of the International New Varieties Network.

AHDB funding contributes to the continuing evaluation and field trials of potential new rootstocks from earlier crosses, as well as the ongoing breeding work. It has also helped the team at NIAB EMR to introduce marker-assisted breeding techniques, which use detailed 'genetic maps' to speed up the selection of suitable parent lines to cross and the initial selection of the most promising offspring. The technique has already been used to identify molecular markers linked to resistance to fireblight and woolly apple aphid to preselect apple rootstock seedlings to bud and plant for trials.

Results from other research at NIAB EMR, including some funded through AHDB, such as work on the genetics of replant disease, collar rot and resistance to canker, are being fed into the breeding and selection process.

New rootstocks from overseas breeding programmes are also being trialled for their suitability under UK conditions.

The project team is looking to breed or identify new rootstocks with vigour ranging from dwarfing to 'semi-invigorating' that are also a source of excellent yield efficiency and precocity. In apple, we aim to replace M9 and M26 with selections that have better anchorage and which are more resistant to replant and other soilborne diseases. A rootstock more dwarfing than Quince C is needed for pears, along with a dwarfing pyrus rootstock that's easy to propagate.

Promising selections

Two apple rootstock trials planted in 2010 ended in winter 2017/18. One of these assessed five NIAB EMR rootstocks under conventional orchard management, with Royal Gala and Braeburn as scions. The dwarfing selection R59 has proved to have useful resistance to canker and woolly aphid, along with excellent yield efficiency, and gives the breeding team a useful parent for future crosses. Two other selections are also showing commercial promise and are currently being evaluated in Europe by members of the International New Varieties Network.

The other trial has been testing four semi-dwarfing NIAB EMR selections, but although they initially looked promising, none have turned out to offer any improvement over M116. They are, however, continuing to be assessed in larger trials overseas funded by the International New Varieties Network, in which one selection, R80, is performing well.

NIAB EMR is also hosting a new rootstock trial coordinated by the European Fruit Research Institutes Network, which is evaluating rootstocks at 19 sites from Norway to Spain.

Six of the apple selections in the trial come from the East Malling breeding programme. A similar pear/quince trial is planned for 2019.

Two new apple and pear trials are to be planted in autumn/winter 2018 – the trees' genetics are currently being analysed to ensure trueness-to-type before planting. As well as including new material, the pear trial will assess the best pear rootstocks from the East Malling trial, completed in 2014, and which the International New Varieties Network are also evaluating.

New rootstock release

One new dwarfing apple rootstock bred by the East Malling Rootstock Club is now ready for imminent release to the trade. Though this really promising selection has yet to be named, it is exciting members of the International New Varieties Network, as in trials it has consistently induced a higher productivity index than M9, with up to 20 per cent more vigour. It also has a better tolerance of apple replant disease and fireblight.

Its release has been postponed a couple of times to ensure stool beds are establishing well, not only in Europe but also with partners elsewhere in the world. This should mean it will be easier for the industry to start growing and using it and avoid the delays experienced during the early years of release of M116.

M116 is now the first choice for cider-apple growers as a replacement for MM106, or MM111 in bush orchards, and, according to leading UK fruit stock propagation nursery Frank P Matthews, is selling well to growers thanks to its collar/crown rot resistance. However, it is difficult to propagate and because it took the industry a long time to establish productive stool beds, sales in continental Europe are only now reaching levels that were expected. Better planning for future releases should see them make a much quicker global impact.

"Rootstock breeding does not deliver quick benefits to the industry, but it is vital to maintain a long-term search for new and improved rootstocks which will confer major benefits to production," said Nigel Stewart, AC Goatham & Son.

TF 224: East Malling Rootstock Club
Term: June 2015 to May 2020
Project leader: Feli Fernández, NIAB EMR

Detecting fruit maturity earlier than ever

Apple growers have responded to the increasing popularity of Gala and Braeburn among British buyers by planting intensive orchards. UK Gala production jumped by 50 per cent from 2011 to 2016, while Braeburn was up 45 per cent and together these varieties now account for more than half of all dessert apples grown here.

With these increasing volumes comes a need for longer-term storage to spread the marketing season – the industry estimates that around 30 per cent of the fruit harvested will need to be kept beyond April. But when that long-term stored fruit does go on sale it will need to be as good as that available earlier in the season and able to compete on quality with the first of the southern hemisphere imports.

The project

Recent international research has confirmed that good eating quality, particularly sweetness, is linked to high dry matter content of fruit at harvest, suggesting that consignments going into store with a high dry matter content should retain their quality for longer. However, the underlying basis of this relationship needs to be better understood so that growers can manage it in their production and storage regimes.

One important feature of this project is its use of 'meta-analysis' computing techniques that has allowed the research team to find patterns relating to factors that could influence dry matter content from the large amount of data that's already available in existing published research papers and from other sources. The results are being used to help design orchard trials looking at ways to manipulate dry matter content during production – such as the use of different pruning regimes or reflective mulches to improve light levels in the canopy, or different thinning treatments to manage crop load.

Dry matter is just one influence on the quality of long-term stored apples – picking the fruit at its optimum maturity is also critical. Dry matter content does not change significantly during the ripening process, so the project team is looking at how to determine optimum harvest dates for fruit destined for long-term storage because the current method, where fruit samples are tested with iodine for starch content, doesn't give growers enough time to organise picking before starch levels drop further. A relatively new technique based on measuring chlorophyll fluorescence is being investigated. It doesn't need fruit to be picked and cut open and could give growers an extra week's notice of optimum pick date.

The research in this project concentrates on Gala but much of its findings can also be translated to Braeburn.

Results

Information from research projects covering more than 50 Gala orchards was put through a meta-analysis during the project's first year to find patterns in the data on fruit dry matter content and mineral composition, and leaf and soil mineral composition. The results suggest that fruit with good mineral balance also has better dry matter levels, but the research team is now looking in more detail to pinpoint which elements are the most important in determining dry matter. "Many factors contribute to the optimum dry matter content in fruit and it is important to identify the many small changes in orchard practice that may help to deliver improved fruit quality," said project leader Richard Colgan.

A pruning trial was set up at NIAB EMR to assess the effect of light interception on dry matter levels. It is comparing fruit from tall spindle trees planted in a conventional fruit wall with fruit from trees pruned using the latest 'centrifugal pruning' strategy, developed in France as a means of improving light penetration into the canopy while suppressing extension growth by increasing competition between the laterals. For the trial, existing tall spindle trees in a Gala fruit-wall orchard were converted to centrifugal trees in winter 2016/17. Both tree types were compared with or without a white reflective ground cover laid on the orchard floor.

In 2017, the centrifugal pruned trees intercepted more light than the standard spindle trees – and the combination of centrifugal trees and white reflective mulches produced the highest proportion of Class 1 fruit and the highest proportion of large fruit (over 65mm). The white mulches also led to a more intense red and background yellow fruit skin colour. Fruit on the lower branches of the centrifugal trees matured more quickly than fruit in the upper canopy. There was no difference in dry matter content between fruit from the top and bottom of the canopy in the tall spindle trees, but in the centrifugal trees, dry matter content was higher in the upper-canopy fruit than the lower.

A trial to assess the effect of thinning treatments on dry matter content, harvest maturity, fruit size and eating quality is also underway, at FAST's trials site at Brogdale Farm in Kent. During 2017, the methods compared were bud thinning, mechanical thinning, chemical thinning – Exilis (6-benzyladenine) or Brevis (metamitron) – on May 23, hand thinning (June 3 or 14), late hand-thinning and no thinning.

Class 1 yields were very variable as a result of spring frosts and the research team is still analysing the data. Trees that had not been thinned and trees that had been hand thinned (June 14) or thinned using Brevis produced the highest overall yields, however. Detailed analysis of the data on harvested fruit quality and

dry matter is also still ongoing to find out how they were affected by thinning regime.

Work on using chlorophyll fluorescence meters to monitor fruit maturity and predict harvest readiness is being undertaken with help from commercial crop protection and storage product specialist Landseer.

Chlorophyll fluorescence readings are highest in immature fruit with green skin that's actively photosynthesising and decline as the fruit matures and the skin chlorophyll degrades. To monitor fruit maturity, a baseline reading is taken from fruitlets (at 30–35mm size); experience so far from using the technique suggests that once fluorescence falls to 50 per cent of that level, it indicates the fruit is best picked seven to 10 days later for long-term storage.

Fruit was monitored in five commercial orchards during 2017, comparing chlorophyll fluorescence with the traditional iodine starch test to predict harvest maturity. The study found that chlorophyll fluorescence measurements correlated so well with the iodine test results that they could predict, at least a week in advance, the date at which the iodine test would show a drop in starch to 75 per cent. Such an early indication of harvest maturity would be a great help when organising harvest operations and this monitoring will be repeated in 2018 to confirm the reliability of the measurements.

Grower representative for TF 225, Nigel Jenner of Avalon Produce, says the project is addressing some interesting concepts. "The pruning and thinning trials are improving our understanding of how to maximise dry matter content, while the work on chlorophyll fluorescence should result in growers being able to have more of an advance warning of the optimum time to pick," he said.

TF 225 - Developing practical strategies to improve quality and storability of UK apples

Term: May 2016 - April 2021

Project leader: Mehrdad Mirzaee, Landseer

"Chlorophyll fluorescence measurements correlated so well with the iodine test results that they could predict, at least a week in advance, the date at which the iodine test would show a drop in starch to 75 per cent"

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