Grower Summary

SF157

Improving integrated disease management in strawberry

Annual report, March 2018

Disclaimer

While the Agriculture and Horticulture Development Board seeks to ensure that the information contained within this document is accurate at the time of printing, no warranty is given in respect thereof and, to the maximum extent permitted by law the Agriculture and Horticulture Development Board accepts no liability for loss, damage or injury howsoever caused (including that caused by negligence) or suffered directly or indirectly in relation to information and opinions contained in or omitted from this document.

The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

Use of pesticides

Only officially approved pesticides may be used in the UK. Approvals are normally granted only in relation to individual products and for specified uses. It is an offence to use non-approved products or to use approved products in a manner that does not comply with the statutory conditions of use, except where the crop or situation is the subject of an off-label extension of use.
Before using all pesticides check the approval status and conditions of use.
Read the label before use: use pesticides safely.

Further information

If you would like a copy of the full report, please email the AHDB Horticulture office (hort.info.@ahdb.org.uk), quoting your AHDB Horticulture number, alternatively contact AHDB Horticulture at the address below.

AHDB Horticulture,
AHDB
Stoneleigh Park
Kenilworth
Warwickshire
CV8 2TL

Tel – 0247 669 2051

AHDB Horticulture is a Division of the Agriculture and Horticulture Development Board.

Project title:	**Improving integrated disease management in strawberry**
Project number:	SF 157
Project leader:	Prof Xiangming Xu NIAB EMR
Report:	Annual report, March 2018
Previous report:	Annual report, March 2017
Key staff:	Erika Wedgwood (ADAS) Angela Berrie (NIAB EMR) Rob Saville (NIAB EMR) Avice Hall (UoH) Tom Passey (NIAB EMR)
Location of project:	East Malling; Cambridge; Wisbech
Industry Representative:	Louise Sutherland
Date project commenced:	1 March 2015
Date project completed (or expected completion date):	31 March 2020

GROWER SUMMARY

For ease of reading, this Grower Summary report is split into sections for each of the diseases being worked upon in the project.

Crown rot and red-core caused by *Phytophthora* spp.

Headline

- Research is ongoing to assess if plants treated with fungicides and bio-fungicides before planting have increased tolerance to latent infection by Phytophthora cactorum.

Background and expected deliverables

Adopting a clean propagation system is the first line of defence against crown rot and red-core diseases. This strategy has been working for many years until recent times. Currently, crown rot and red-core can cause significant damage in strawberry even in substrate production. The most likely cause is asymptomatic infection in planting material. Frequent application of fungicides, alleged to have occurred in overseas nurseries, may delay the onset of symptom development until post-transplanting. Subsequent disease spread is likely to occur because of over-irrigation or rain-splash. Alternative products for control of crown rot (both fungicides and biocontrol products) were identified in trials conducted by NIAB EMR as part of the SCEPTRE project. Recent research on Phytophthora spp. has concentrated on detecting the pathogens and seeking products to reduce root rotting. Two AHDB Horticulture projects have just been completed; SF 130 focussed on fungal molecular quantification and an assay was developed that detected Phytophthora rubi, although it was not as sensitive as the Phytophthora fragariae assay (which however detects both pathogens); SF 123 investigated alternative products against P. rubi on raspberry where one novel chemical product gave reduction. Red-core is more difficult to control and currently there is no work on controlling this disease. Note that BBSRC is funding NIAB EMR to manage a five-year project to identify Phytophthora virulence factors against strawberry. More research is required to assist growers to be able to plant disease-free propagation material in order to reduce crop protection product use and crop losses.

The aim of this project on Phytophthora is to quantify the extent of hidden infection in initial planting material and identify treatments to reduce plant losses due to these hidden infections.

Summary of the project and main conclusions in Year 3

Pre-inoculation of plants with arbuscular mycorrhizal fungi (AMF) and/or plant growth promoting rhizobacteria (PGPR) did not reduce infection of strawberry crowns by *P. cactorum*. However, it is not clear whether such treatment would improve plant tolerance to latent pathogen infection, which may enhance fruit production compared to untreated plants. This is to be investigated in a large experiment initiated in year 3 and completed in Year 4. The pathology team at NIAB EMR developed protocols for this large experiment to mimic commercial practice in which infected plants are held in cold store before planting. Plants are inoculated with *P. cactorum* prior to cold storage and those plants without visual symptoms at planting time will be transplanted and treated with a number of products. In addition to plant growth, fruit production will be assessed.

Financial benefits

Potential loss of plants due to P. cactorum could reach 20-30%. In 2016, 90,000 tonnes of strawberries were sold in the UK season with the market valued at £386 million (Data from Kantar). Should 25% of plant losses occur in the UK as a result of crown rot, the volume of fruit sold could be reduced by up to 22,500 tonnes, representing a value of £96 million. Techniques and measures to control P. cactorum could therefore save such potential losses.

Action points for growers

- As this project is still in its infancy, growers should continue their current commercial practice of treating runners with an approved fungicide soon after planting to suppress and control *P. cactorum* and *P. fragariae*.

Strawberry powdery mildew (SPM)

Headlines

- Managed mildew programmes employing predominantly biological control agents provided equal control of powdery mildew to routine fungicide programmes.
- Three products with relatively new approval on protected strawberry provided useful curative and protective action against strawberry powdery mildew.

Background and expected deliverables

Trials in 2015 demonstrated how supplementing a reduced fungicide spray programme with alternative products could effectively control powdery mildew in strawberry, particularly when the level of inoculum is relatively low. Further trials were conducted in 2016 where two biocontrol products, one coded HDC F208 and Ampelomyces quisqualis (AQ10) were combined in control programmes with a plant strengthener (Cultigrow), both with or without a reduced fungicide programme. The mildew risk was much greater in 2016 but the results showed that the biocontrol products were as effective in controlling powdery mildew as the standard fungicide programme, particularly when applied alone in a programme. Having identified effective alternative products, the next step is to combine their use in programmes, incorporating other factors such as disease risk, growth stage and type of fungicide (curative, protectant, antisporulant) in order to develop a decision-based management programme for growers.

Work by the University of Hertfordshire has shown that the use of weekly delivery of silicon through fertigation in strawberries from early in the season can delay the development of powdery mildew. Silicon is known to strengthen plants against abiotic and biotic stress and effects against both pests and diseases are reported in the literature. Work at the University has shown differences in the structure of leaf surface wax after silicon treatment.

In 2017, a trial was set up at NIAB EMR to compare the mildew control achieved in three managed programmes based on biological control agents (BCAs) and alternative chemicals compared to that achieved by a routine fungicide-only programme.

In addition, further work was undertaken in 2017 to assess the efficacy and mode of action of several mildew fungicide products, which are relatively recent approvals on strawberry. The trial included the fungicide products Takumi (cyflufenamid), Luna Sensation (fluopyram + trifloxystrobin) and Talius (proquinazid). These were assessed for both their curative and protectant properties. Two biological control agents (BCAs) including the coded product HDC F208 and AQ10 (Ampelomyces quisqualis) were also assessed for their protectant properties.

Summary of the project and main conclusions in Year 3

In the work to compare routine fungicide programmes with managed programmes, a fully replicated trial took place in a Spanish tunnel at NIAB EMR using an everbearer variety kindly supplied by Berry Gardens Growers. The plants grew in coir bags with a drip irrigation and fertigation system supplied. Treatments for Botrytis were the same for all plots. Similarly, control of aphids and capsids was the same across all plots. Phytoseiulus persimilis (for two-spotted spider mite control) and Neoseiulus cucumeris (for western flower thrips and tarsonemid mite control) were introduced to all plots as necessary throughout the season.

Five treatments were set up to compare powdery mildew control. These included an untreated control, a routine fungicide programme and three managed programmes which employed BCAs as the initial choice of product, but if risk of infection increased, then the programme switched to a fungicide or alternative BCA (AQ10 – which was shown to offer similar control to standard fungicides in the previous year’s work).

The routine fungicide programme and fungicides employed in the managed programmes were drawn from a list of 12 products including Systhane (myclobutanil), Fortress (quinoxyfen), Nimrod (bupirimate), Amistar (azoxystrobin), Karma (potassium bicarbonate), Potassium bicarbonate (commodity product), Luna Sensation (fluopyram/trifloxystrobin), Stroby (kresoxim-methyl), Takumi (cyflufenamid), Kumulus (sulphur), Topas (penconazole) and Talius (proquinazid). Full details are included in the Science Section of the report. The biological control agents included were a coded product HDC F208 + Silwet (Bacillus pumilis) and AQ10 + Silwet (Ampelomyces quisqualis). Other products applied were Cultigrow B204 (flavonoids) and Sirius (silicon).

The managed programmes employed BCAs and fungicides (where risk of infection was high). In one managed programme treatment, Cultigrow was applied monthly from start of growth and in another treatment Sirius (silicon) was applied weekly from the start of growth.

The five treatments are summarised in the table below:

Treatment programmes evaluated at NIAB EMR in 2017

Treatment	Type	Plant protection products	Other
T1	Untreated	-	-
T2	Routine	Fungicides	None
T3	Managed	Fungicides, BCAs,	Cultigrow B204 applied monthly from start of growth
T4	Managed	Fungicides, BCAs,	Sirius applied weekly from start of growth
T5	Managed	Fungicides, BCAs	None

Management decisions on product choice in the managed treatment programmes were based on mildew incidence (monitored weekly), the growth stage of the strawberries and the environmental risk produced by the powdery mildew prediction model which was run using humidity and temperature data collected from data loggers in the tunnels (see table below).

Conditions were very favourable for powdery mildew development throughout the trial, but despite this, the level of mildew on the leaves was very low throughout, even on untreated plots. However, in contrast, levels of mildew on the fruit in untreated plots rose rapidly from 2% on the first pick (28th July) to more than 90% at the sixth pick (21st August). The level of mildew on the routine fungicide plot and all three managed plots remained low throughout the trial on leaves, flowers and fruits. In the managed plots which relied primarily on BCAs, fungicide intervention for mildew was needed only once in early July. The BCA used throughout was the coded product HDC F208, with no obvious reason to switch to AQ10. There was a suggestion that the programmes that included Cultigrow or Sirius had less mildew than the HDC F208 only programme, but this difference was not statistically significant. There were no significant differences in marketable yield between the managed programmes and the routine fungicide programme, but all treated plots had a significantly higher total and marketable yield than the untreated control.

Criteria for powdery mildew management decisions

Item	How determined	Risk	Management options
Disease risk	Determined from input of humidity and temperature from logger in tunnel to disease risk model (see below) and forward weather forecast from internet	More than 4 days with risk above 10% requires action	Product choice – Fungicide (antisporulant or protectant), BCA
Growth stage and rate of growth	Inspections 1-2 times per week	Rapid leaf production, start of flowering/ fruiting indicates increased risk and possible change of product	Spray interval – 7 or 14 days Tunnel ventilation
Mildew monitoring	Inspections 1-2 times per week on youngest leaves on 5 plants per plot. Plants will be selected at random for each inspection	Scored 0-5, where 0 = no mildew	

The trial therefore demonstrated that the use of biological control agents, with or without alternative chemicals, offered good control of powdery mildew in strawberry compared to a routine fungicide only programme. In future, it will be important to explore how this approach for managing powdery mildew can be integrated with control of Botrytis and other fruit rots.

In the trial to assess the efficacy and mode of action of new fungicide products and biological control agents, the three new fungicides (Luna Sensation, Takumi and Talius) displayed useful curative properties. They could prevent young incubating colonies from becoming visible lesions, even up to three days after the strawberry leaves were infected.

All three products also offered protectant activity. Talius reduced the incidence of powdery mildew lesions developing up to 7-10 days after treatment, while Luna Sensation and Takumi could reduce incidence up to 4-7 days after treatment. Of the two biocontrol agents tested for protectant activity, only the coded product HDC F208 reduced mildew development, within 4 days of application.

Financial benefits

Powdery mildew can result in yield losses of between 20-70% of crop potential. In 2016, 90,000 tonnes of strawberries were sold in the UK season with the market valued at £386 million (Data from Kantar). At 20% losses, using these figures, this could contribute to an industry volume of 18,000 tonnes at a value of £77.2 million. Providing effective control can therefore offer enormous financial benefits.

The results of the powdery mildew research in 2017 suggest that managed programmes could result in the reduction in use of traditional fungicide products, which may help to reduce the number of spray applications made whilst also reducing the risk of incurring residues in fruit. The availability of new and improved fungicide products with longer lasting action would have a similar effect.

Action points for growers

- Luna Sensation, Takumi and Talius offer useful new products to improve the control of strawberry powdery mildew when integrated within routine fungicide programmes.
- Managed programmes based on biofungicides with or without Cultigrow or silicon alone are as effective as weekly standard fungicide applications and offer an alternative for strawberry powdery mildew control to growers. However, it is important to ensure early control using this technique.

Fruit rot complex

Headline

- The species of *Pestalotiopsis* present in the UK and found on strawberry is *Pestalotiopsis clavispora*.

Background and expected deliverables

Recent evidence in the UK and New Zealand has shown that Botrytis is not the only pathogen causing fruit rot, and that the importance of B. cinerea in strawberry may have been over-stated because of similar morphological characteristics of Botrytis fungal morphology with two other rotting fungi – Mucor and Rhizopus spp. The relative importance of these three pathogens may vary greatly with time and location. Although the overall direct loss to these pathogens may be relatively small compared with other diseases, the consequence (e.g. rejection of a consignment by retailers) of fruit rot is much more serious.

Projects SF 74 (Defra Horticulture LINK HL0175) and SF 94 (Defra Horticulture LINK HL0191) suggested that in raspberry and strawberry, rapid post-harvest cooling to storage at 2°C is effective in delaying Botrytis development. However, such cooling treatment is not effective against Mucor as it can develop in cold conditions. In Project SF 98, NIAB EMR identified a few fungicides that offer partial control of Mucor. Berry Gardens Growers (BGG) recently funded a PhD project at NIAB EMR on the epidemiology and management of Mucor and Rhizopus rot in strawberry; significant progress has been made in this project but due to commercial confidentiality the findings cannot be disclosed in this report. BGG continues to fund work on the control of fruit rotting at NIAB EMR.

Towards the end of Year 2 of this project, there were increasing reports on the occurrence of a new pathogen (Pestalotiopsis spp.) isolated from the crowns of wilting plants. In addition, this pathogen was shown to cause fruit rot on strawberry in Egypt. In Year 3, the pathology team carried out preliminary work on this new pathogen of strawberry to determine the importance of this disease to the UK industry.

Summary of the project and main conclusions in Year 3

Using a collection of Pestalotiopsis isolates collected from strawberry plants that were not of high health status the pathology team at NIAB EMR molecularly characterised representative isolates to species level which identified Pestalotiopsis clavispora as the species that is present in the UK. A series of pathogenicity tests were developed to: 1) prove if Pestalotiopsis is pathogenic against popular commercial strawberry cultivars and hence can be a primary pathogen and 2) determine how widespread the pathogen is in the UK industry. Using a detached fruit and leaf pathogenicity test, the team demonstrated that all the Pestalotiopsis isolates tested can establish infection and colonise the host tissue. The pathogen was also able to cause a post-harvest rot following inoculation during fruit development. However, it could not be proved that the isolates tested were able to cause a disease in the crown. Plant leaves and crown were inoculated with the Pestalotiopsis spore and mycelium inoculum and despite providing highly favourable conditions, only a background level of disease was recorded. Based on the findings and the literature it can be concluded that Pestalotiopsis is a weak pathogen which is able to infect the plant when it is under other stresses. To determine the presence of this disease in the UK industry, molecular primers are currently being validated for detecting this new pathogen and will be used to determine the incidence of Pestalotiopsis in the DNA samples collected from crown tissue of >2000 nursery strawberry plants in years 1 and 2 of this project.

Financial benefits

- It is too soon to speculate on the financial benefits of this specific work. This will become clearer once it has been demonstrated how widespread the fungus is following the molecular based survey.

Action points for growers

- Current results are insufficient for making any recommendations.

Verticillium wilt

Headline

- Some early trends are developing in a trial to compare three biocontrol methods for Verticillium wilt in soil-grown strawberry.

Background and expected deliverables

Verticillium wilt of strawberry, caused by Verticillium dahliae is a soil borne disease which causes plant wilting and death. Depending upon the population levels of the pathogen in a field soil and the susceptibility of the strawberry variety being grown, plant losses can vary between 5-90%, so very significant yield loss occurs.

In the past, strawberry growers relied on the use of a range of chemical biocides to fumigate soils before planting strawberry crops, to reduce the soil inhabiting V. dahliae populations to a level which would not adversely affect the crop. The availability and approvals for such fumigants have declined over the past 20 years, so growers wishing to grow crops in soil need alternative methods of treating the pathogen.

Previous research has identified and tested a number of alternatives to chemical fumigants including plant derived materials which, when incorporated into soils, create biofumigation. Biofumigation is the suppression of soil-borne pathogens and pests by naturally occurring compounds. Not all materials tested have been sufficiently effective to require development. However, a number have been worthy of further investigation.

Bio-Fence is one such material which is a granular product incorporated into field soils and releases chemicals called isothiocyanates, which are known to reduce V. dahliae inoculum and the viability of its spores. Anaerobic digestate is another material which is organic in nature and may be able to suppress plant pathogens by encouraging the build-up of beneficial microbial populations. The fungicide Serenade ASO which is composed of a strain of the bacterium Bacillus subtilis is another material which has successfully controlled plant pathogens such as white rot sclerotia and is thought to have potential activity against V. dahliae.

These three materials will be assessed in the project in a field trial on a farm in Oxfordshire with an existing population of V. dahliae spores. Their efficacy at controlling the pathogen in the soil will be compared using the moderately susceptible strawberry variety Symphony. This variety was chosen because it is known to become infected and display wilt symptoms whilst still producing fruit, whereas a more susceptible variety would die completely.

Summary of the project and main conclusions in Year 3

The trial was set up in a field soil at Rectory Farm, Stanton St. John, Oxfordshire, by kind permission of Richard Stanley. The soil had previously grown barley and when tested for existing levels of V. dahliae, was shown to have between 2.6 and 5.6 propagules per gram of soil (depending on the area of the trial sampled). The soil was also sampled for nutrition, a base dressing of fertiliser applied, then re-tested. The trial was established within a commercial field-soil strawberry crop, which was grown on raised beds covered with blue polythene mulch. All beds except the trial area were fumigated with chloropicrin before planting. The trial plots received one or two of three alternative soil treatments, with the five treatments in five replicated plots in a Latin Square design. The treatments are summarised in the table below:

Materials applied to plots before and after planting cv. Symphony cold-stored strawberry runners on 6 June 2017 in a Verticillium infested field in Oxfordshire

Code	Product	Ingredients	Rate per ha	Application method
T1	None	N/a		
T2	Anaerobic digestate solids (pasteurised PAS 110)	Chopped maize and vegetable crop waste	50 tonnes	Spread then incorporated up to 150 mm depth then covered
T3	Bio-Fence pellets	*Brassica carinata* meal	2,000 kg	Spread then incorporated up to 150 mm depth, irrigated then covered directly with polythene
T4	Serenade ASO*	*Bacillus subtilis* strain QST 713	10 L in 1,000 L water	Single nozzle directed 40 ml over each plant (0.4 ml concentrate)
T5	Bio-Fence pellets Serenade ASO	*Brassica carinata* *Bacillus subtilis*	2,000 kg 10 L in 1000 L water	As for T3 and T4 combined; pre-planting incorporation of Bio-Fence then plant drench with Serenade ASO

* Applied as an over-plant drench under experimental permit COP 2016/00922. EAMU 0706 of 2013 permits the same 10 L /ha in 1,000 L/ha water as a spray to outdoor strawberries

The soil was formed into raised beds and marked into 7m long plots. Treatments were applied to the central 6m. On 24 May 2017, anaerobic digestate solids were applied to Treatment 2 and incorporated to 150mm by rotavation into the soil. Nutritional analysis of the anaerobic digestate was also carried out. Bio-Fence granules were applied to Treatments 3 and 5 on the same day and also incorporated by rotavation into the soil. Two lines of trickle irrigation were laid on each bed. The Bio-Fence treatments were irrigated on 26 May and all 25 plots were . then covered straight away with blue polythene mulch over the raised beds. Seven days later, all plots were ventilated by making planting holes in the polythene. Five days later, on 6 June 2017, cold stored bare-root Symphony plants were planted. Six days after planting, on 12 June 2017, the 27 plants in Treatments 4 and 5 in the central 6m of each plot were drenched with Serenade ASO through the planting holes in the polythene mulch.

Both plant phytotoxicity and plant establishment were assessed and recorded three times after planting, in June 2017. Numbers of fruits were recorded on each plant prior to the first two picks. In September 2017, the percentage of plants wilted or totally collapsed were recorded. In October, the percentage of plants wilting and total percentage of plants still alive were recorded. Observations on foliage growth were made in January 2018. Fruit yield and berry size are to be recorded in June 2018 both within the 25 trial plots and five plots marked out in an adjacent chloropicrin treated bed.

Results

In one area of the trial, plant establishment was poor, particularly in two adjacent plots. This may have been a result of very hot, dry weather conditions in June 2017 following planting, coupled with stony areas of the field where root contact with the field soil was reduced.

Plants throughout the trial displayed symptoms of leaf scorch, but the incidence of this was greater in those plots treated with Bio-Fence or anaerobic digestate solids. It is possible that the incorporation of these materials into the soil beds, created more of an open structure to the soil, which resulted in more rapid soil drying. It is also possible that during the hot soil conditions which followed planting, more rapid chemical release from these treatments may have resulted in plant scorch, particularly as the chemicals tend to escape through the polythene mulch via the planting holes. It is also possible that the interval of 10 full days between treatment and planting may have been insufficient to allow such chemicals to dissipate, but this timing was chosen to reflect the practice employed in the commercial crop surrounded by the trial which were treated with chloropricrin.

Verticillium wilt often manifests itself following the stress of fruiting, and symptoms of wilting were recorded during plant assessments made during September. The typical symptoms of wilt on one side of the plant coupled with leaf collapse were more apparent by the October assessment, but there were no significant differences between treatments. However, a trend did appear to show that Treatments 3 and 5 which had been treated with Bio-Fence, had a lower proportion of wilting plants (5%) compared with the other treatments (mean 10%). Plants in the anerobic digestate treated plots had fewer fruits at the first pick, but it is possible that fruit formation was delayed until later. Further plant assessments will be made in Spring 2018 by which time winter stress may have increased the incidence of wilting.

These treatments are not expected to eliminate Verticillium in the soil like chloropicrin, but either reduce the level and so reduce infestation severity (in the case of Bio-Fence) or increase the resilience of the plants (in the case of anaerobic digestates or Serenade ASO).

Further assessments in 2018 will determine if the higher ranking incidence of wilting in the untreated and Serenade ASO only treated plots, is a trend that continues.

Financial benefits

Potential loss of plants due to V. dahliae in soil grown crops can vary between 5-90%. In 2016, 90,000 tonnes of strawberries were sold in the UK season with the market valued at £386 million (Data from Kantar). At present, it is estimated that 30% of the UK strawberry crop is grown in field soils, equating to £115 million. Should 25% of plant losses occur in the UK as a result of Verticillium wilt, this would represent lost revenue of £29 million. Techniques and measures to control Verticillium wilt could therefore save such potential losses.

Action points for growers

- Sample soil for Verticillium, allowing at least six weeks for Harris testing results.
- Incorporation of materials that increase soil organic matter should improve soil health.
- Consider the use of bio-fumigants before polythene covering beds.
- After adding organic materials, check if watering should be adjusted.
- When possible, use strawberry varieties with some resistance to Verticillium.