Improving knowledge and experience of integrated pest control of soft fruit in Wales to reduce pesticide application and wastage.

Final Report

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GENERAL NOTES

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About EIP-AGRI

The European Innovation Partnership for Agricultural productivity and Sustainability (EIP-AGRI) was launched by the European Commission in 2012. It aims to foster a competitive and sustainable agriculture and forestry sector that "achieves more from less". It contributes to ensuring a steady supply of food, feed and biomaterials, and to the sustainable management of the essential natural resources on which farming and forestry depend, working in harmony with the environment.

EIP Wales

Menter a Busnes delivers the EIP Wales scheme on behalf of the Welsh Government, and has received funding through the Welsh Government Rural Communities – Rural Development Programme 2014-2020, which is funded by the European Agricultural Fund for Rural Development and the Welsh Government.

For Welsh farm and forestry businesses to remain competitive, profitable and resilient, they will need to work on a continuous programme of improving both business and technical practices.

The aim of EIP Wales was to solve common agricultural and forestry problems by bringing people from practical and scientific backgrounds together. It's an opportunity for farmers and foresters to put their ideas into practice by testing new technologies or techniques. Each project that is approved has access of up to £40,000 (incl. VAT) and can run for up to 3 years.

This project sought to trial the use of integrated pest control in protected strawberry production on two soft fruit farms operating different systems in South Wales. Growers were and are keen to move away from conventional pesticides where possible. A range of products were trialled, and growers given guidance by specialists experienced in control species' lifecycles over two growing seasons. Latest industry methods and knowledge were utilised to maximise the potential for effective pest and disease control on their holdings. Outputs were compared against each site's conventional methods. Effective biological control can enable growers to reduce wastage, reduce pesticide application and future proof against further reductions in pesticide availability and it was envisaged that this project would provide guidance and best practise on how to achieve this.

EIP Operational group

The businesses represented in the operational group are:

Organisation	Name	Farm/Location	Role
Springfields Farm	Nick & Pat Bean	Springfields Farm, Manorbier, Tenby SA70 7SL	Lead growers & principal contacts
Scurlage Farm	Tom & Alex Higgs	Scurlage Farm, Scurlage, Swansea SA3 1BA	2nd grower in trial
Biobest	Tim Crittenden	N/a	Actor
Koppert Biological Systems	Jasper Hubert	N/a	Actor

Other members of the project

RSK ADAS Ltd.	Chris Creed	ADAS Horticulture	Horticulture Specialist procured to carry out to work with the farmers
RSK ADAS Ltd	Peter Seymour	ADAS Plant Health Consultant -Entomology	Entomology Specialist procured to carry out to work with the farmers
RSK ADAS Ltd	Guy Johnson	ADAS Horticultural Consultant	Horticulture Specialist procured to carry out to work with the farmers
RSK ADAS Ltd	Aldwyn Clarke	Canolafan Enterprise Park Llanafan Ceredigion SY23 4AY	Senior Scientist procured to carry out crop assessments in 2020
RSK ADAS Ltd	Will John	Henstaff Court Business Centre, Groesfaen, Cardiff CF72 8NG	Innovation Broker

EXECUTIVE SUMMARY

Growers' crops are increasingly vulnerable to damage from mite, aphid and thrips pests due to reducing pesticide efficacy and availability. As the industry tries to move away from pesticide interventions some new challenges face the industry in Wales. Biological pest control has become standard for larger farms supplying into supermarkets, particularly in response to loss of chemical actives and emerging resistance, but these benefits have yet to be realised by some of the fruit growing sites in Wales in an effective way. A range of biological controls (e.g. *Aphidius, Amblyseius, Phytoseiulus* and nematodes) are commercially available and can offer comparable if not greater pest control than chemical methods. Effective biological control can enable growers to reduce wastage, reduce pesticide application and future proof against further reductions in pesticide availability. Biological pest control is also integral to organic production, allowing growers to achieve a market premium on organic fruit. It should also be noted that conventional pest control is not a simple process, as pesticides can be difficult to apply and calibrate and are never 100% effective. Small quantities are not available to suit growers with fewer production facilities and sharing between growers is not permitted. Often large quantities have to be purchased and stored and these may be withdrawn at short notice leaving growers to dispose of expensive pesticides.

Effective biological pest control requires a significant base knowledge of both pest and bio control biology, and how this interacts with the environment and other (e.g., chemical) control methods in a site-specific fashion due to growing habit, cultivars and marketing model. Grower uptake of biological control has been historically hindered by a lack of understanding and knowledge. Few of the smaller farms producing soft fruit in Wales are specialist and most have several other enterprises all competing for depth of knowledge and monitoring.

Long season picking by using several techniques from sequential planting of cold stored plants to use of everbearer varieties in both raspberries and strawberries is a challenge for management. In-depth understanding of both pest and control species' lifecycles is required to ensure sufficient populations of control agents can be established. New biological control agents are being made available commercially, and the regulatory environment is constantly evolving as actives are deregulated or become available through new registrations or short-term Extension of Authorisation for Minor Use (EAMUs) for off-label use. The existing suppliers of biological control often list tables of the relative safety of pesticides on the introduced beneficials, but this is quite complex for growers to use and become familiar with and some interpretation will be key to getting success and confidence going forward. Such understanding is often lacking among smaller producers and this project seeks to take the knowledge of the larger scale producers and transfer it to the smaller growers who sometimes struggle to keep abreast of technological advancements within the industry. This results in an ongoing challenge for growers looking to combine chemical and biological control to implement an effective integrated pest and disease (IPDM) programme.

Best practice recommendations.

- Being fastidious in keeping the crop clean as well as the wider site can go a long way to reducing pest numbers or keeping them low.
- Remove any waste from the plants and dispose of properly far from your crop – pests will leave this waste and go back into the crop!
- A clean and disinfection at the end of the season will go a long way to helping prepare for the new season.

- Regular monitoring is invaluable for effective decision making. Keep a log of common areas you are observing pests, these can be useful for future years at your site.
- Consider the environmental variables, temperature and relative humidity, and their impact on the pest and predator levels and survival. Low temperatures typically mean slower development of pests but also predators.
- Consider using data loggers in tunnels to monitor the conditions and help inform you when the benchmark temperatures for predators have been reached (e.g. 15®C for *Orius*).
- Buying good plant stock is important, pests often arrive on these plants if ordered from a less reputable propagator. These can be expensive initially but save a lot of issues. Sometimes new plants are the primary method for the introduction of new pests onto an otherwise clean site. Make sure to check the new plants for pests and disease immediately.
- Containerised growing media can be replaced, a useful option when compared to soil grown crops. This is useful for 're-setting' pest levels each year to avoid a yearly steady build up especially if you are buying new plants.
- When placing new cropping areas investigate and consider the local environment for pests and where they may come from. Alex and Tom Higgs have had a lot of success from their new tunnels centrally placed in a field where it is harder for pests to come in.
- Cold winters are a useful free way of reducing pest numbers, this is obviously not entirely reliable and so clean up sprays at the start of the season has been seen to be useful in this project.

Future work

This work has primarily focused on the use of biological controls for pest reduction within an integrated pest management (IPM) programme. The use of bio protectants for the treatment of pests, diseases and weeds is similarly challenging and there is a lot of scope for future work to help support the development of these schemes within Wales. Further specialised mentoring and guidance on the recognition of pests and diseases is another area that can be developed further.

CONTENTS

1 INTRODUCTION

1.1 Background and Introduction to the Sites

The two growers in this project represent two different scenarios of soft fruit production but share a common challenge. The Gower PYO (Scurlage) first started fruit production in 2019 in newly established tunnels, having diversified from an arable/livestock concern. Springfields, Manorbier has been a mixed fruit farm for several decades, growing a range of soft fruit for supply into local shops, retail chains and wholesale. The different marketing models, facilities and experiences have caused each business to develop in slightly different ways, but their methods of growing are still broadly representative of the UK soft fruit sector as a whole. A shared challenge of both growers is achieving suitable control of pests. Increasing resistance, reduced availability of pesticide actives and a desire to move away from chemical control has created a need for effective integrated pest management (IPM) control on each site. Effective IPM requires a high level of grower knowledge and understanding – how to recognise pests, what biological controls are available and how best to use them and how to integrate them into an existing pest/disease control programme. Accessing this knowledge can be difficult, and the evolving nature of the approach often can be difficult to keep up to date, especially for smaller scale sites.

1.1.1 Springfields

Springfields is a specialist grower of strawberries, cherries, blueberries and asparagus, located near Tenby. Annual rainfall for the area taken from Manner NPK is 1,086 mm per annum. The project site was located at 50 metres above sea level.

The growers (Nick and Pat Bean) had been using IPDM successfully in their own everbearer strawberry tunnels for many years, typically integrating biological pest control with bio-fungicides from flowering of the crop onwards. They pick from May until November.

They currently use products including *Neoseiulus cucumeris*, *Phytoseiulus persimilis* and *Aphidius colemani* and were looking for ways to improve their existing programmes and expand the IPDM methods used.

They have three fully enclosed polytunnels, with a hedgerow running parallel to one of the tunnels. They typically use loose-substrate troughs which is conventional in the industry.

1.1.2 Scurlage Farm

Scurlage Farm is a mixed farm, situated on the Gower Peninsular. Annual rainfall for the area taken from Manner NPK is 1,148 mm per annum. The project location was at 50 metres above sea level. The PYO tunnels were constructed in 2019 so the growers were new to soft fruit production. This highlighted the need for training and support on this type of enterprise.

The Scurlage site consisted of 12 polytunnels, with plants grown on tabletops in pre-wrapped coir slabs. The focus was on 60-day varieties, commonly referred to as June-bearers. The growers (Alex and Tom Higgs) were comparatively newer to using IPM in their June-bearer strawberries. They were looking for support in adding IPM to their current methods of crop protection as they previously had only used spider mite predators.

2 METHODOLOGY

2.1 Experimental Design

The project was designed to produce a broad range of evidence relating to the implementation and benefits of IPM programmes in strawberry production in Wales. The project planned to trial the establishment of an IPM programme on the two contrasting commercial sites over two seasons. Throughout this period collaboration within the project operational group (comprised of the host growers, project mentor and biopest control industry) was used to provide targeted training to underpin effective IPM implementation alongside the collation of evidence as to its effectiveness. This was achieved through the implementation of four work packages (WPs).

In order to carry out the programmes effectively it was necessary to compare the grower's standard programme with the EIP programme in separate tunnels. Due to commercial interest, and the complexities of pest management in protective cropping, it was not possible to have an untreated tunnel, as it would be unlikely to produce any saleable crop due to pest and disease pressure. Some pests such as western flower thrips (*Frankliniella occidentalis)* are not controlled by any permitted pesticides now due to resistance issues so, an everbearer crop could easily be lost for example. There are very few farms, if any, not practicing some element of IPM nowadays.

2.1.1 WP1: IPM Strategy Planning – Early 2020

Task 1.1

A yearly trial plan was developed with each grower to ensure that the IPM programme was tailored to their needs to maximise the potential impact of the project. Through operational group meetings, an initial IPM strategy was developed for each site for season one, including product applications and a likely schedule of applications. This also identified the nature of training and consultancy support that would be required in WP2.

Candidate biocontrols were selected based upon in-depth knowledge from ADAS technical experts with significant experience with the crops and pest species and procured in line with Welsh Government protocols. Products were selected based on their efficacy at other grower sites along with personal experience and consultation with the biological product suppliers.

Specific use of products at each site was identified based on each host grower's requirements as well as pest presence. IPM is carried out to be preventative rather than curative – therefore, predator introductions were scheduled to develop a stable suppressive community before pest establishment as opposed to reactive applications in response to a particular pest problem. Pest presence can be highly variable so adjustments were sometimes needed. Most products were applied preventatively early in the season, though there were limitations to how early some could be applied e.g. parasitoids cannot go out before frosts end. Higher rates were to be used later depending on product to get a curative effect. Using hotspot treatments of pests with curative rates is more cost effective than applying high rates across a site as these products can sometimes be very expensive. Proposed control methods for pests outside of the project scope were also agreed, ensuring compatibility with the predators that were released for target organisms, as sometimes the predators introduced had a wider target range. It was intended that four pests would be targeted through the developed IPM programme (Table 1) but was extended to include whitefly primarily at the Springfields site. This was because of higher numbers of this pest observed at that site.

Table 1 Strawberry Pests and Candidate Biocontrol's

Target Pest	Photo of pest	Biological control Agent	Description
Two spotted (Red) Spider Mite		*Phytoseiulus persimilis*	Predatory mites released as adults and nymphs from a plastic tube.
Thrips		*Neoseiulus cucumeris* (sometimes referred to as *Amblyseius cucumeris*)	Mites in a sachet with food that feed on 1st stage larvae of some thrips species (principally for Western flower thrips).
		Orius laevigatus	Predator adults or nymphs released from a bottle (will feed on adults and larvae of most thrips species).
Aphids		Parasitoid wasps of a mix of species (*Aphidius colemani, Aphidius ervi, Aphelinus abdominalis, Praon volucre* and *Ephedrus cerasicola*) though sometimes just *Aphidius colemani* is used.	Parasitic wasps as mummies in a bottle that then hatch and fly amongst the crop.
		Chrysoperla carnea	Lacewing larvae, not mobile but effective predators of aphids and also Two spotted spider mite.

Target Pest	Photo of pest	Biological control Agent	Description
Vine Weevil		*Steinernema kraussei*	Nemasys® L targets larval stages of the black vine weevil in soil or container-grown crops.
Whitefly*	No photo available.	Encarsia formosa	Winged parasitoid wasp that parasitizes both the Greenhouse whitefly (*Trialeurodes vaporariorum*) and the Tobacco whitefly (*Bemisia tabaci*).

*This pest was spotted in the trial area at Site 1 in 2021 and though not initially one of the pests proposed to be controlled was added to the monitoring scheme, ADAS approached Biobest for *Encarsia* to control the pest.

A given species of predator may be available from multiple producers, but these often show little difference between suppliers at a species level. Differences may be evident between different products targeted at a given pest, but these are based on different species or combinations of predators, rates and timings. Therefore, product names have been referred to where possible to be as transparent as possible regarding what was used.

Once products were identified, a preliminary application schedule was developed, and potential adjustments of the dosing strategy. This also addressed different approaches to commercial recommendation/products, where available. A full IPM strategy was required on each site, as application of single products in isolation would likely be ineffective. Not only would this be artificial compared with normal practice but would adversely impact results. For example, application of only Phytoseiulus to control spider mite (without any other predators) would have required chemical applications to control other pests such as aphids. Conventional aphid control previously utilised Calypso (a broad-spectrum insecticide, now banned) which could have upwards of a 50% mortality of Phytoseiulus, making stable population control difficult. This pattern of collateral damage is somewhat common with broad spectrum insecticides. Therefore, all biological control agents were to be utilised across each site except for grower tunnels, with considerations needing to be made as to what sprays (if any) would be needed.

Task 1.2: Second Season IPM Strategy Planning- Early 2021

The activities of task 1.1 was repeated at the start of the following season. This included a review of key messages from the 2020 season, allowing for an update of IPM approaches.

Procurement was challenging in 2021 due to the impact that Covid-19 was having on the supply chain. This was corrected in 2021 but temperatures were very low for early introductions of aphid parasitoids which caused delays.

2.2 WP2: Grower mentoring.

2.2.1 Task 2.1 & 2.2: Grower mentoring - 2020 - 2021

Growers received mentoring and advice on a variety of topics over the course of the project:

- **Pest recognition** – ways of identifying common pests, alongside beneficial predators (both introduced and external colonisers). This also covered biology, lifecycles, feeding habits and how this interacted with control options such as overwintering habits.
- **Monitoring methods** – How to monitor specific pests including likely sites of congregation, damage, early warning signs and methods of ongoing monitoring. This was factored into the assessment strategy. This also covered the timings of pest monitoring and how this feeds a reactive IPM strategy, and how unique aspects of different pests could be used to aid monitoring e.g., appearance of natural aphid predators such as lacewing and hoverflies as an early indicator of aphid outbreaks. This should have covered instrument use (lens etc.) and the correct use of monitoring traps alongside key windows of monitoring requirements. However, Covid 19 implications meant that face to face time between ADAS staff and growers was limited and the supply of monitoring traps was disrupted in both years with suppliers unable to give them.
- **Biological Control Options** – Complete coverage of the range of biological control options available, their biology and how this could be manipulated to promote target pest control. Including predator storage/handling and release for maximum impact. This would bridge commercial recommendations with practical experience.
- **IPM Programme Development** – Planning of release schedules, how these could be updated to reflect changes in pest/predator numbers and weather. This addresses integrating necessary conventional (e.g., chemical) control of pest and diseases such as timing of applications and product choice to minimise impacts on predator populations.

The training was provided on an ongoing basis throughout the project, allowing practical advice to be given at key points across the season. Joint training was provided wherever possible to maximise peer learning, and training was carried out with input from the project mentor and biocontrol industry representatives.

The proximity of the two grower sites was meant to help facilitate peer learning and shared training on each other's sites. However, Covid-19 affected this, but it was supported by online communications. This communication was supplemented by factsheets produced by ADAS for the host growers and wider industry to utilise (links at Appendix 1-3).

The training also included the signposting of key resources such as instruction in the use of chemical compatibility databases for example: the Biobest side effect manual https://www.biobestgroup.com/en/side-effect-manual .

2.3 WP 3: IPM Establishment

2.3.1 WP3: IPM Programme Establishment

2020

Table 2 Application schedule of biological controls used in the IPM tunnel at the two sites in 2020.

Biological control Product	Supplier	Rate	Application Dates
Phytoseiulus-System *(Phytoseiulus persimilis)*	Biobest	Rate: 4 mites/plant,	6/5/20, 13/5/20 & 27/5/20
ABS - System *(Neoseiulus cucumeris*)*	Biobest	Rate: 2 sachets per 2m	13/5/20 & 3/6/20
Orius-System *(Orius laevigatus)*	Biobest	Rate: 0.25 adults per plant.	3/6/20
Aphiscout *(Mix of parasitic wasps, Aphidius colemani, Aphidius ervi, Aphelinus abdominalis, Praon volucre, Ephedrus cerasicola.)*	Koppert	Rate: 1.25/m² (Curative rate)	Weeks 19, 20, 21, 22, 23.
Chrysopa *(Chrysoperla carnea)*	Koppert	2-5 per m²	7/5/20 & 13/5/20
Nemasys L *(Steinernema kraussei)*	BASF	1 million nematode/m² applied as a soil drench.	Week beginning 14 September.
Encarsia-System *(Encarsia Formosa)*	Biobest	1 card per 25 linear metres	12/7/20, 28/7/20 and 11/8/20
An additional application of *Amblyline, Aphyline & Phytoline* were made in the week beginning the 13 April by an additional order from Fargro at site 1 in order to get biological controls into the crop as soon as possible due to rising aphid numbers.			

2021

Table 3 Application schedule of biological controls used in the IPM tunnel at the two sites in 2021.

Biological control Product	**Supplier**	**Rate**	**Application Dates (Calendar Weeks)**	**Target pest**
Phytoseiulus-System *(Phytoseiulus persimilis)*	Biobest	Rate: 4 mites/plant,	Wk. 20, Week 22, Week 24**	Two spotted mites
ABS - System *(Neoseiulus cucumeris*)*	Biobest	Rate: 2 sachets per 2m	Wk. 20, Week 22	Thrips
Orius-System *(Orius laevigatus)*	Biobest	Rate: 0.25 adults per plant.	Week 22, Week 24** (Site 1 only)	Thrips aphids etc large predator
Aphiscout *(Mix of parasitic wasps, Aphidius colemani, Aphidius ervi, Aphelinus abdominalis, Praon volucre, Ephedrus cerasicola.)*	Koppert	Rate: 1.25/m² (Curative rate)	Weeks 16 -20	Aphids,
Chrysopa *(Chrysoperla carnea)*	Koppert	2-5 per m^2	Week 18, Week 19 Week 28	Aphids all
Encarsia-System *(Encarsia Formosa)*	Biobest	1 card per 2m (normally 1 card per 25 linear metres)	Week 31***	Whitefly

**Neoseiulus cucumeris was only applied at Site 1, Site 2 was reported by the grower to not have a problem with Western flower thrips (the primary prey of Neoseiulus cucumeris) and so was not applied there.*

*** An extra application than planned to continue protection against pests seen by monitoring.*

****No planned applications were made initially for this pest as it is not common, however numbers started to rise. The application rate was higher than the normally as whitefly were becoming difficult to control*

2.3.2 Monitoring & assessments

A monitoring schedule with ADAS staff was identified to support implementation of the IPM programme, alongside a calendar of consultancy visits by Chris Creed for the season. Pest numbers at the start of the season were likely to be negligible so it was anticipated that the onset of regular monitoring would begin around April/May and would continue until the season end in late September or early October. This was to tie in with the bulk of pest presence in a season which is most common at higher temperatures. The everbearer crop at Springfields had a longer harvest period than this and was not fully covered due to funding limitations. Pest numbers rose quicker in April than initially anticipated so in 2021 this was changed, but introductions were limited by late frosts that would have harmed beneficial introductions if made earlier.

Commercial monitoring traps were unavailable for the majority of pests targeted by this trial, so pest monitoring was carried out as counts per plant or as percentage damage observed on plants for pests such as thrips and mites. Growers were trained in monitoring methods as part of WP2, training included leaf and flower examination, examples of damage and typical locations of pest incidence. Pest monitoring would then occur on a weekly basis led by the grower, with monthly support and additional situational training through monthly site visits by the ADAS staff.

2.3.3 Grower inputs to the trial tunnels

2020

Table 4 Biological control and bioprotectants products applied for pest and disease control as well as any conventional pesticides applied at Springfields, Site 1.

Date	Product	Target pest/disease	Also applied to the IPM tunnel?
08/03/20	Paraat	*Phytophthora*	Y
26/03/20	Calypso	Aphids	Y
01/04/20	Abamectin	Thrips and mites	Y
10/04/20	Flipper, Topas & Teldor	Aphids, Powdery mildew & botrytis	Y
15/04/20	*Phytoseiulus persimilis*	Spider mites	N
17/04/20	*Aphidius colemani*	Aphids	N
19/04/20	AQ10, Serenade Aso	Powdery mildew	Y
29/04/20	*Neoseiulus cucumeris* & Amylox	Thrips and Powdery mildew	N
29/04/20	Majestik	Mites	Just to IPM tunnel
30/04/20	*Chyrsoperla carnea*	Aphids	N
06/05/20	*Phytoseiulus persimilis*	Spider mites	N
12/05/20	AQ10, Serenade Aso	Powdery mildew	Y
13/05/20	*Phytoseiulus persimilis*	Spider mites	N
22/05/20	Amylox, *Pretect*	Powdery mildew	Y
21/05/20	*Chyrsoperla carnea*	Aphids	N
27/05/20	*Neoseiulus cucumeris*	Thrips	N
28/05/20	AQ10, Serenade Aso	Powdery mildew	Y
02/06/20	Potassium bicarbonate	Powdery mildew	Y
03/06/20	*Neoseiulus cucumeris*	Thrips	N

Table 5 Biological control and bioprotectants products applied for pest and disease control as well as any conventional pesticides applied at Site 2.

Date	**Product**	**Target pest/disease**	**Also applied to the IPM tunnel?**
29/01/20	Batavia	All pests	Yes
11/04/20	Amistar	Powdery mildew	Yes
25/04/20	Switch	Botrytis	Yes
12/05/20	Teldor	Botrytis	Yes
25/05/20	Charm	Powdery mildew & botrytis	Yes
06/06/20	Luna sensation	Powdery mildew & botrytis	Yes
22/06/20	Charm	Powdery mildew & botrytis	Yes
09/07/20	Luna sensation	Powdery mildew & botrytis	Yes

2021

Table 6 Grower inputs at Springfields, site 1.

Date	Product	Target pest/disease	Also applied to the IPM tunnel?
06/03/21	Paraat	*Phytophthora*	Y
14/03/21	Floramite, Hallmark, Amistar & Switch	Mites, caterpillar aphids, Powdery mildew, Botrytis	Y
29/03/21	Topas, Teldor, Flipper	Powdery mildew, botrytis & aphids	Y
11/04/21	Scala, Amistar, Flipper	Powdery mildew, botrytis & aphids	Y
15/04/21	Aphiline, Phytoline	Aphids	N
19/04/21	Signum, Topas	Powdery mildew, botrytis & aphids	Y
29/04/21	AQ10, Serenade ASO, Silwet	Powdery mildew	Y
29/04/21	Phytoline	Spider mites	Y (as part of schedule)
03/05/21	*Amblyseius Cucumeris* sachets	Thrips	Y (as part of schedule)
	Aphiline	Aphids	N
06/05/21	Aphiline	Aphids	N
07/05/21	*Amblyseius Cucumeris* sachets	Thrips	Y (as part of schedule)
09/05/21	Amylo X	Powdery mildew	Y
17/05/21	Amylo X	Powdery mildew	Y
19/05/21	Chrysoline, Phytoline	Aphids & thrips	N
	Amblyseius Cucumeris sachets		N
24/05/21	Sonata, Boteckter	Botrytis	Y
02/06/21	Serenade, AQ10	Powdery mildew	Y
12/06/21	Amylo X	Powdery mildew	Y
23/06/21	Sonata, Botecker	Botrytis	Y
02/07/21	Serenado Aso, AQ10	Powdery mildew	Y
12/07/21	Amylox protect	Powdery mildew	Y
26/07/21	Sonata, Botecker	Botrytis	Y
30/07/21	Orius	Thrips & other pests	N
03/08/21	Phytoline	Spider mites	N
20/08/21	Romeo	Powdery mildew & botrytis	Y
27/08/21	Amylo X	Powdery mildew	Y
06/09/21	Sonata, Bodector	Botrytis	Y
17/09/21	Serenado Aso, AQ10	Powdery mildew	Y
27/09/21	Amylo X	Powdery mildew	Y
10/10/21	Serenade aso	Powdery mildew	Y

Table 7 Grower inputs at Scurlage, site 2.

Date	Product	Target pest/disease	Also applied to the IPM tunnel?
14/04/21	Switch	Botrytis	Yes
06/05/21	Amistar	Botrytis & Powdery mildew	Yes
18/05/21	Signum	Botrytis & Powdery mildew	Yes
03/06/21	Charm	Botrytis & Powdery mildew	Yes
14/06/21	Luna sensation	Botrytis & Powdery mildew	Yes
19/07/21	Charm	Botrytis & Powdery mildew	Yes

3 WP4: IPM REVIEW- RESULTS

3.1 Results 2020

Due to Covid–19, ADAS scientific staff were not allowed to visit the grower sites initially. An assessment schedule was devised for the growers to monitor the crops and send data through to ADAS consultants throughout this period. As growers are often very busy the assessments were designed to minimise the impact on the growers but still enough to collect a robust data set for comparison.

Ideally assessments were to take place every two weeks but monthly was also suitable (plants were obviously checked daily). This was successful at Site 1 (Springfields). Site 2 (Scurlage) was unable to send through data sets, however they did virtual crop walks by using a mobile phone video that was sent to ADAS for crop monitoring and programme development. Both methods of assessment and data capture worked equally well, and no data were missed.

Eight to ten strawberry plants per tunnel were selected, each plant had four leaves, four flowers and four strawberry fruits checked for the pests in Table 1. After the 25 June 2020 ADAS were able to access the sites and visited monthly. Assessments finished on the 25 August at Site 1 and the 15 July 2020 at Site 2. Site 2 was then re-visited on the 04 August, however the polytunnel skin had been removed and crop left to dry out so no recordings were made.

3.1.1 Site 1 – Springfields

Site 1 performed an early spray of Calypso (26/03/20 -Thiacloprid) and Flipper (10/04/20 – Fatty acids) (**Error! Reference source not found.**) to reduce initial pest numbers continuing from last season. Risk of pest pressure is higher when keeping overwintering crops, as done so at this site, as pests have longer to establish a foundation as well as an earlier chance to build up.

Aphid numbers at Site 1 were initially higher in the IPM programme than in the grower programme (the grower tunnel is the owners' normal practice, the IPM tunnel is the trial. It was not possible to have an untreated control tunnel on the farms due to the levels of infestation and spread this would have created) in the early months of the season. The higher numbers are very likely to be due to the higher temperatures that occurred which boosted the aphid numbers. The growers at Site 1 were able to react faster and started treatments earlier allowing for a swifter control in the control tunnel. Numbers peaked on the 20 May 2020 at a mean of 7.5 aphids per leaf assessed compared to the 0.13 in the grower programme (Table 8). Aphid specimens were confirmed as the potato aphid *Macrosiphum euphorbiae.* Parasitoids were applied heavily (one cylinder containing 250 mummies was the minimum size available) from early May in both the grower tunnel and the IPM tunnel, along with lacewing applications as a curative measure in both, as it was impractical to have a complete untreated control for this pest. The main difference in usage was that the IPM tunnel used a species mix which is effective against a wider range of aphid species. *Aphidius colemani* which was used in the control tunnel at Site 1, though effective against the cotton aphid (*A. gossypii*) and the peach potato aphid (*Myzus persicae)* is less effective against the potato aphid. A different species of parasitoid is recommended *(Aphidius ervi)* to deal with them. It can often take time to identify aphids to species and to apply the correct parasitoid species, hence why the species mix of parasitoids is recommended. Many mummified aphids in the IPM tunnel were spotted in late May and all through June showing the parasitoid wasp were having an impact on aphid numbers. The grower added to this control by removing infected runners of particularly infested plants in April. Between these actions numbers were much lower on the 04 June 2020 and barely seen at all from the 18 June 2020.

Low levels of adult vine weevil damage was seen in the IPM tunnel during July and early August before the nematode applications were made mid-September (Table 8). Overall though damage from vine weevil adults was low. The main risk to crop from vine weevil comes from the larvae which consume the roots and can cause plant death in the autumn, no plant death or damage due to vine weevil larvae was observed at any of the visits. The nematode applications should have controlled the larvae in the root zone to help avoid plant death. Unfortunately, there is no physical way to monitor the larval numbers without removing the plants and checking the root zone, which is a destructive assessment and beyond the remit of this monitoring. The monitoring continued into the next season (2021) to show how the nematodes achieved control of the larvae, demonstrated by less adults present.

Mean numbers of thrips peaked in June 2020 (Table 8), laboratory identifications found these to be a species called the Rubus thrips (*Thrips major*). This species largely does not breed in the crop to the same level as Western Flower Thrips and so *Neioseiulus cucumeris* which feeds on larvae, would have had less of an impact on its numbers. As a result, *Orius* that feed on adults of *T. major* were introduced to control thrips in the IPM tunnel.

The observation of whitefly in the crop which were low in number and observed on other plants than those monitored led to the introduction of *Encarsia*. From the grower notes it was able to reduce the whitefly levels.

Table 8 Results from Site 1, Springfields. Aphid numbers, Two spotted spider mite (TSSM), vine weevil damage are mean per leaf assessed. Mean number of thrips and mean % thrips bronzing are per flower and per fruit respectively.

DATE OF ASSESSMENT	TREATMENT	MEAN APHID NUMBERS	MEAN TSSM DMG	MEAN % VINE WEEVIL DMG	MEAN NO. THRIPS	AVERAGE OF % THRIPS BRONZING
22.04.20	IPM Programme	0.35	0.00	0.00	N/a*	N/a*
	Grower Programme	0.00	0.00	0.00	N/a*	N/a*
06.05.20	IPM Programme	4.38	0.00	0.00	0.00	0.00
	Grower Programme	0.00	0.00	0.00	0.00	0.00
20.05.20	IPM Programme	7.50	0.00	0.00	0.00	0.00
	Grower Programme	0.13	0.00	0.00	0.00	0.00
04.06.20	IPM Programme	1.01	0.00	0.00	0.94	0.00
	Grower Programme	0.00	0.00	0.00	0.45	0.00
18.06.20	IPM Programme	0.08	0.00	0.00	0.95	0.00
	Grower Programme	0.00	0.00	0.00	0.38	0.00
14.07.20	IPM Programme	0.00	0.00	0.31	0.38	0.00
	Grower Programme	0.00	0.00	0.00	0.22	0.00
04.08.20	IPM Programme	0.00	0.00	0.78	0.38	0.00
	Grower Programme	0.00	0.00	0.00	0.24	0.00
25.08.20	IPM Programme	0.00	0.00	0.00	0.09	0.16
	Grower Programme	0.00	0.00	0.00	0.03	0.00

***no thrips data from this period as there were no flowers or fruit.**

Yields from the two tunnels at Site 1 are shown in Table 9. The two tunnels have a different cladding which can impact yield, but the total yields are relatively similar and equates to approximately 45 t/ha. The IPM tunnel had a cladding that reduced daytime temperature whereas the grower tunnel had a standard 5-year polythene. The fact that the yields are similar is a positive sign given the difference in pest pressure and the different cladding on the external skin.

Table 9 Yields (kg) from the Grower and IPM tunnels at Site 1 (Springfields).

	GROWER TUNNEL	IPM PROGRAMME
MAY	157	130
JUNE	126	76
JULY	631	519
AUGUST	558	652
SEPTEMBER	221	168
OCTOBER	71	100
TOTAL KG	1764	1645

3.1.2 Site 2 – Scurlage

At site 2, only two assessments were made as soon as Covid restrictions lifted and ended when the cropping of the June-bearers ended at the end of July 2020. An assessment attempt was made at the start of August, but the cropping had finished. Numbers of all pests were very low in both the IPM tunnel and the grower tunnel with very small numbers of aphids observed (in the grower programme) and no two-spotted spider mite damage observed. No vine weevil damage was seen in the crop during the two assessments. Low levels of thrips were seen, their abundance was patchy however numbers were so low and so not presented (<0.4 thrips per flower) and with minimal damage to the fruit. From the comments made by the grower, videos send to ADAS and the two site visits the IPM tunnel fared well compared to the grower control. Risk is lower for June-bearer crops due to their shorter cropping especially for western flower thrips, hence why no *N. cucumeris* were applied there.

3.2 Results 2021

With the continuation of Covid 19 site access was limited but ADAS staff were able to start visits earlier than in 2020. Pest pressure in general was higher in 2021 than 2020 in both control and treatment tunnels. Aphids were seen in higher numbers, thrips were also seen in much higher numbers at Site 1 than in the previous year, causing crop damage and being observed more regularly. No vine weevil damage was observed at either site. A small amount of Two spotted spider mite (TSSM) damage was observed and it was noted that TSSM was more prevalent in other cropping areas at site 1, highlighting that it was still a pest issue.

Due to the higher pest numbers an individual breakdown is presented for each pest at each site for 2021.

Assessments were carried out by Guy Johnson monthly, beginning April 2021 at each site and these continued until September 2021.

3.2.1 Site 1 – Springfields

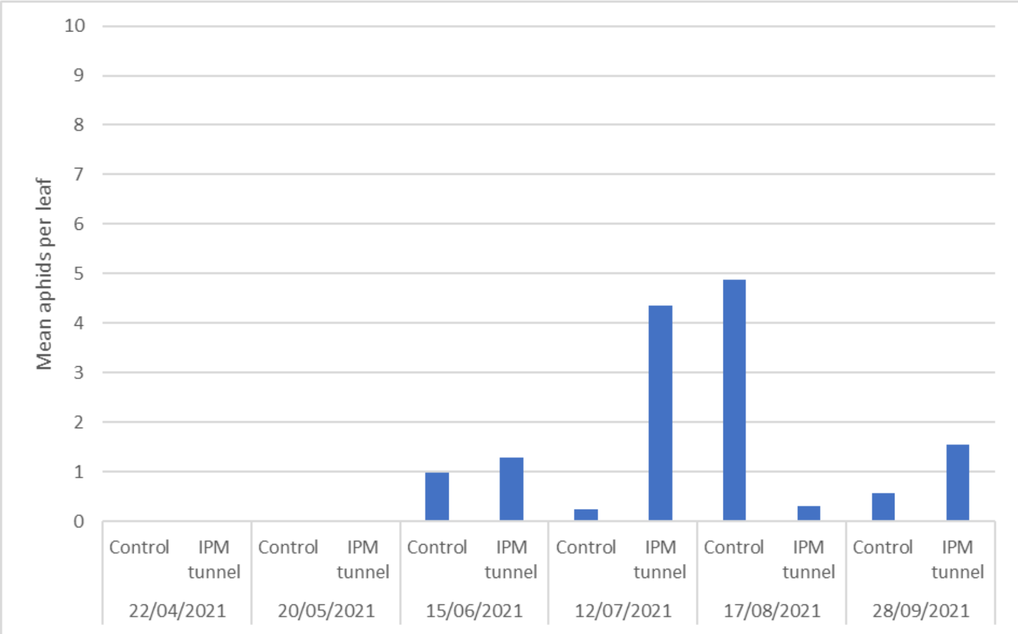

Figure 1 Mean aphids per leaf at Springfields site 1, 2021. ***Note the higher scale than the following pests.***

At the start of the trial (22 April 2021) there were no aphids present in either tunnel (Figure 1). Aphids were first recorded in small numbers on the 20 May (0.04 per leaf) in the treatment tunnel but not in the control tunnel. A mean of 0.99 aphids per leaf in the control tunnel was observed compared to 1.3 in the IPM tunnel. On 12 July a spike of 4.35 aphids per leaf were seen in the IPM tunnel but no rise was observed in the control tunnel. This was then mirrored in the following month of August with the control tunnel receiving a spike of 4.875 which was the highest recorded in the trial. Numbers dropped in September for the final assessment with a mean of 0.57 in the control tunnel and 1.54 in the IPM tunnel.

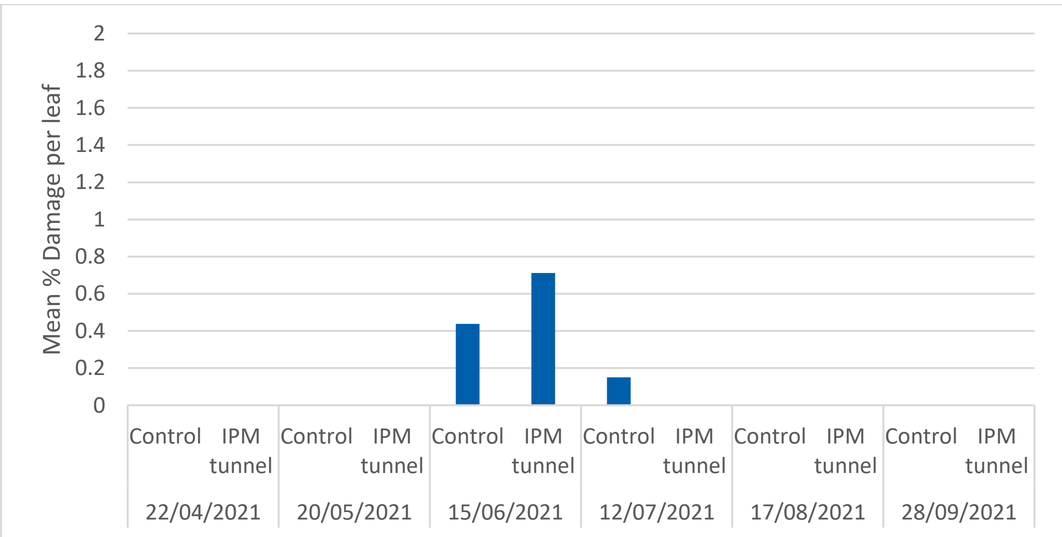

Figure 2 Mean TSSM per leaf at Springfields site 1, 2021.

Overall TSSM damage was low at the site with only a small level of damage being observed in the control tunnel in June and July and in the IPM tunnel in August (Figure 2).

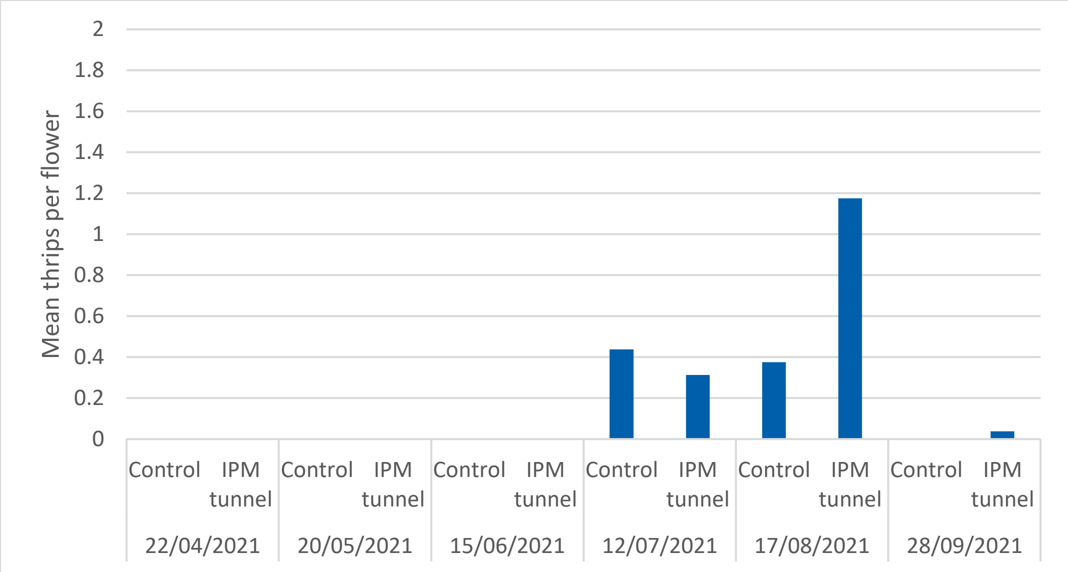

Figure 3 Mean thrips per flower at Springfields site 1, 2021.

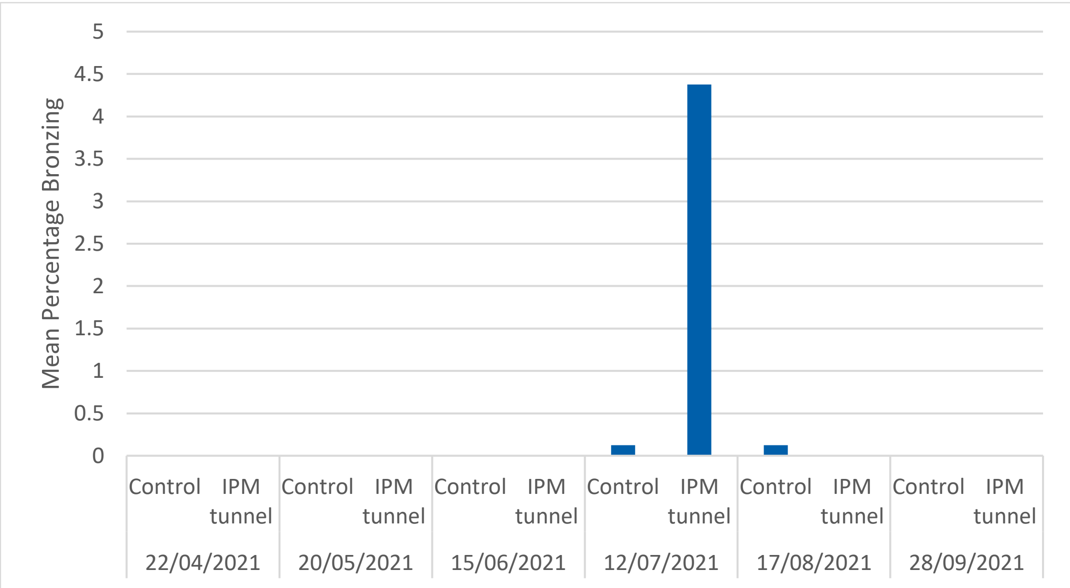

Figure 4 Mean % fruit bronzing at Springfields site 1, 2021.

Thrips showed a short sharp peak of abundance at Springfield's that resulted in fruit damage (Figure 3). They appeared in July with lower mean levels of 0.43 in the control tunnel and 0.31 in the IPM tunnels per flower. There was associated thrips bronzing with these levels and a mean level of 4.35% but this damage was localised with some fruit demonstrating up to 100% bronzing but others untouched (Figure 4). Thrips identified from the flowers taken were *T. major* (Rubus thrips) and *T. fuscipennis* (Rose thrips).

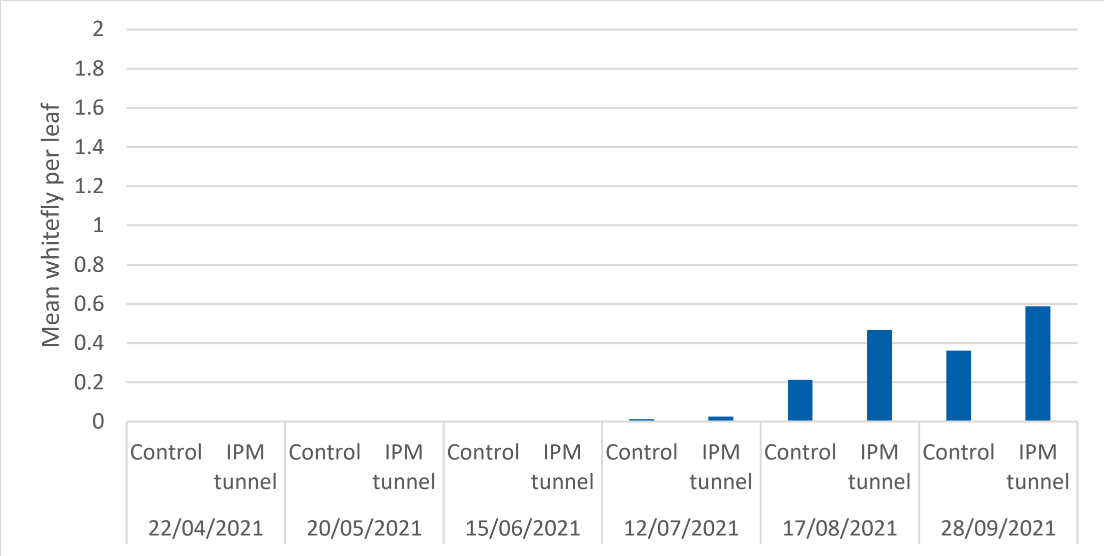

Figure 5 Mean whitefly per leaf at Springfields site 1, 2021.

Whitefly levels were low at the start of the trial (Figure 5), with a steady increase over the course of the trial from July. Numbers were generally higher in the IPM tunnel than in the control tunnel. The highest numbers recorded were a mean 0.59 per leaf in September 2021.

Yield – Site 1-Springfields

Table 10 Yields (kg) from the two tunnels 2021.

	GROWER TUNNEL	IPM PROGRAMME
MAY	52	38
JUNE	100	115
JULY	322	281
AUGUST	97	120
SEPTEMBER/OCTOBER	143	124
TOTAL KG	714kg	678kg
MEAN	891g/ plant	848g/ plant

3.2.2 Site 2 – Scurlage

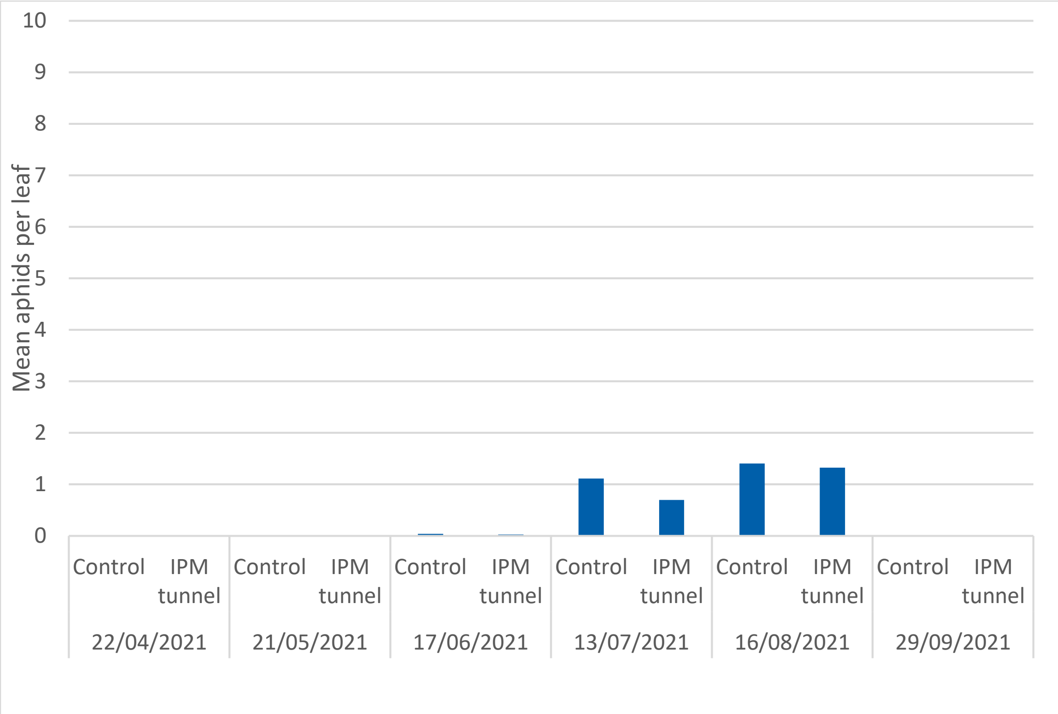

Figure 6 Mean aphids per leaf at Scurlage site 2, 2021. (*Note: higher scale than the following pests).*

Aphid numbers were generally low at the Scurlage site 2, only seeing a mean of approximately 1 aphid per leaf (Figure 6). They were only seen in July and August. The treatment tunnels had marginally lower overall aphid levels.

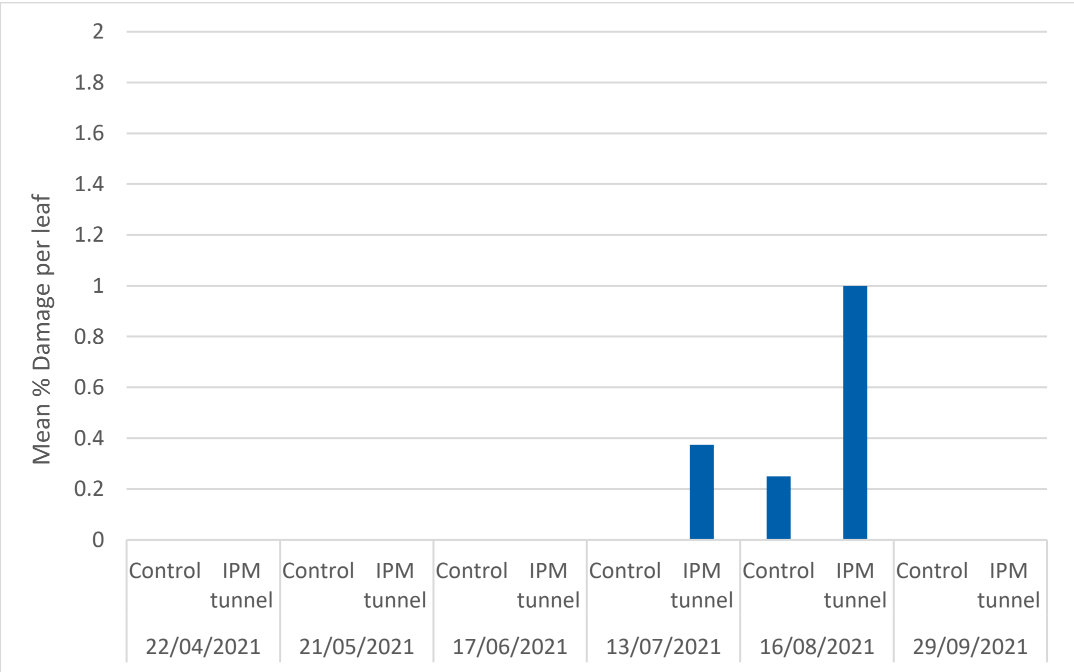

Figure 7 Mean TSSM per leaf at Scurlage site 2, 2021.

Overall TSSM damage was low, with a very small level of damage observed in the IPM tunnel in July and August, and in the grower tunnel in August only (Figure 7).

Thrips were not observed at the Scurlage site 2. A small amount of thrips related bronzing (mean 0.5) was noticed in the grower (control) tunnel on 13 July, however this was isolated to that tunnel and no thrips were seen in the flowers at any sample date.

Whitefly abundances were also very low at Scurlage, and only seen a small number of times in July and August in the IPM tunnel.

Cost benefit analysis

Understanding the direct costs involved with IPM and comparing to conventional pesticides can be very challenging as the costs vary from site to site and depend on the product choice. On larger scales discounts can be offered reducing costs, some growers do not need contractors meaning that they have no extra labour costs so the variation between sites can be considerable. What is more appropriate is to consider broad cost considerations for conventional chemistry and biological controls for smaller growers.

Prices of conventional pesticides vary. Spirotetramat has a label for use in strawberry for aphids and is approximately £130 per litre with 1L covering a hectare of crop. If multiple sprays are needed it becomes expensive. Often these come in pack sizes of many hectares and may be withdrawn leaving the grower stranded with expensive outdated material plus storage difficulties. Pesticides are withdrawn for a number of reasons (legislative or they may no longer be economic to produce). Withdrawals can be at short notice, although most have a use up period specified. This is a common problem for growers as they are unable to share pesticides with neighbours, yet do not always need large quantities themselves. The shelf life of a chemical is a further consideration, as it is often not feasible for it to be entirely used within the product's timeframe.

Other important considerations include conventional chemistry needing a pesticide store, handling facilities, proper PPE and important safety considerations that must be followed for the operators (and often in small holdings the owners themselves) safety. This is in addition to the general health and safety implications of using pesticides and many growers would favour the idea of keeping their use to a minimum.

Biologicals however go out fresh and straight into the crop without wastage, they cannot be stored long-term (there are some exceptions). Grower feedback has stated that applications of biologicals are often quicker than spraying with a pesticide.

Nick and Pat observed that they pay around 40p per kilo of fruit for their biological controls (fruit can retail for £7.00/kg). They do not have a comparison for pesticides. In their grower tunnel they produced 714kg of fruit, representing an input of approximately £285. They are very active with preventative biologicals and so the need for more expensive curatives is reduced.

There is therefore a favour towards IPM for small scale fruit producers, from economic and logistical reasons.

3.3 Environmental data

3.3.1 Weather data 2020

Site 1 – Springfields

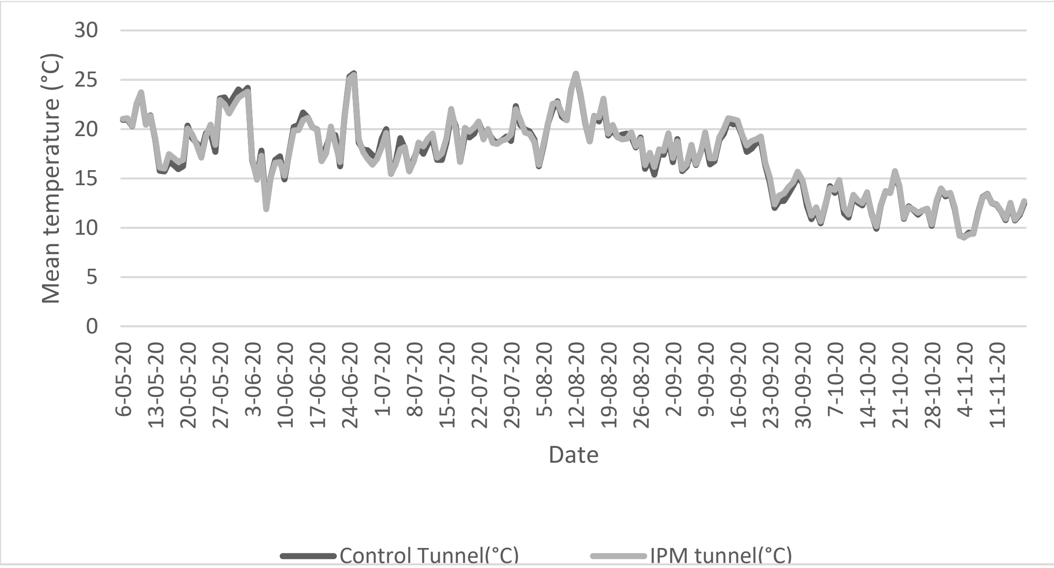

Figure 8 Mean temperature (°C) in the grower and IPM tunnels at site 1 in 2020.

Mean temperatures in the two tunnels were roughly consistent throughout the trial period. The highest temperatures noted was on the 24 June (25.4°C) and 12 August (25.6°C). The lowest temperature was on the 4 November (9.0°C) (Figure 8).

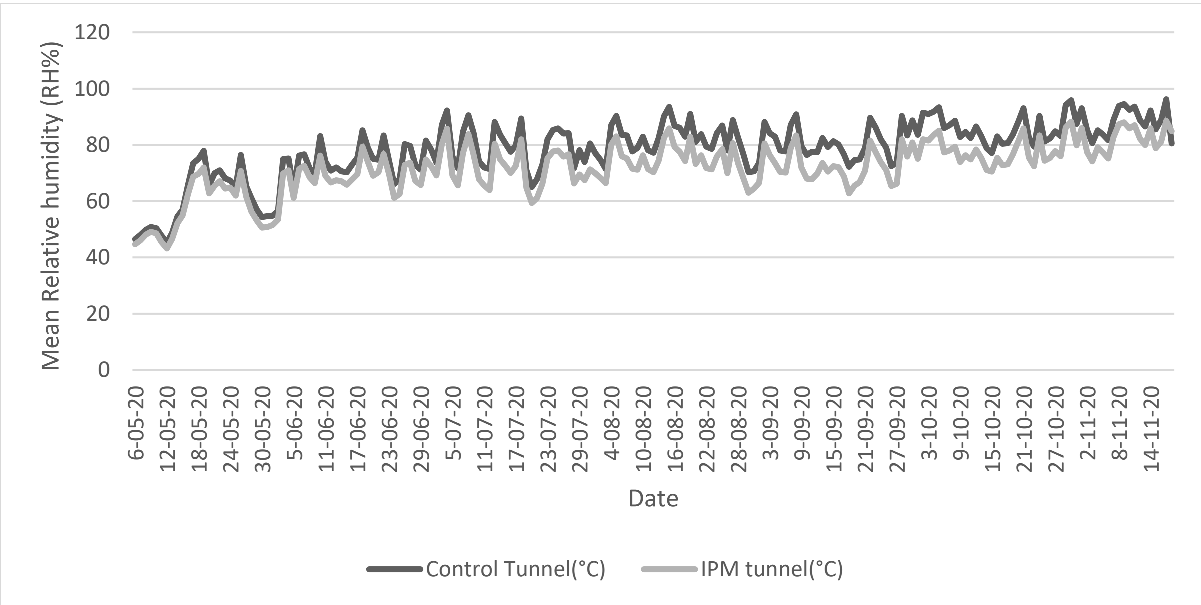

Figure 9 Mean Humidity (%RH) in the grower and IPM tunnels in 2020 at Site 1.

Mean humidity was roughly consistent between the two tunnels with the grower tunnel typically showing slightly higher levels of humidity than the counterpart IPM tunnel (Figure 9). The highest level of humidity was observed on the 17 November at 96% RH in the grower tunnel. The lowest observed was 43.18% RH in the IPM tunnel on 31 May.

Site 2 – Scurlage

Unfortunately, the two data loggers that were placed at site 2 rusted through and could not be downloaded. Water may have got within the housings and damaged them. This has not happened in previous trials. Data loggers were setup differently the following year to avoid this being repeated.

3.3.2 Weather data 2021

Site 1 – Springfields

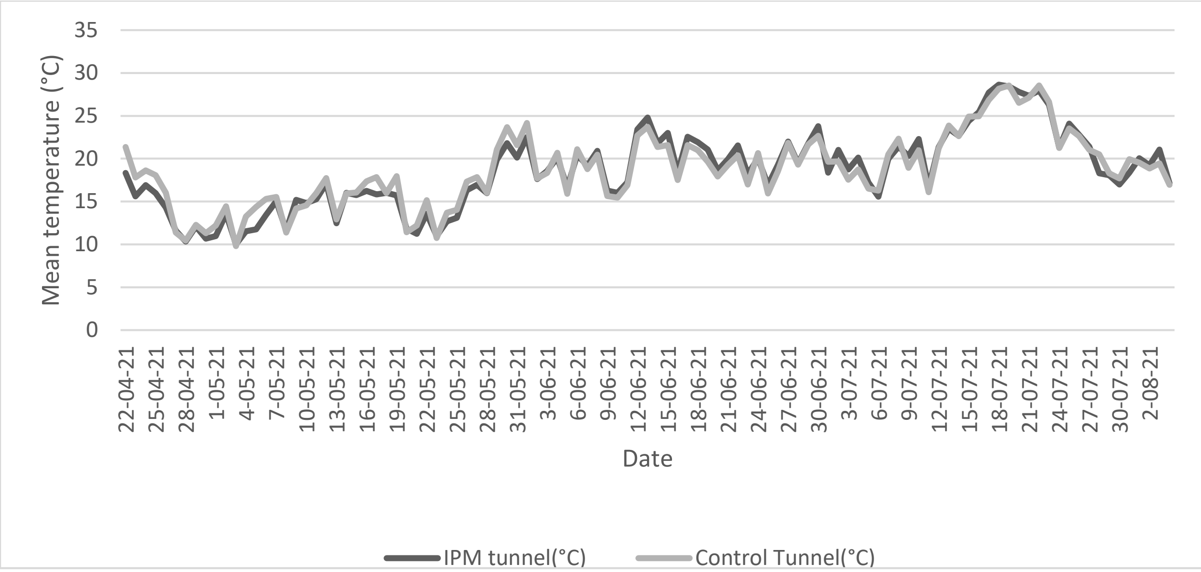

Figure 10 Mean temperature (°C) in the grower and IPM tunnels at site 1 in 2021.

Mean temperatures were largely consistent between the two tunnels in 2021, the lowest recorded mean temperature was on the 30 April (6.6°C) and the highest was on the 19 July (28.5°C) (Figure 10).

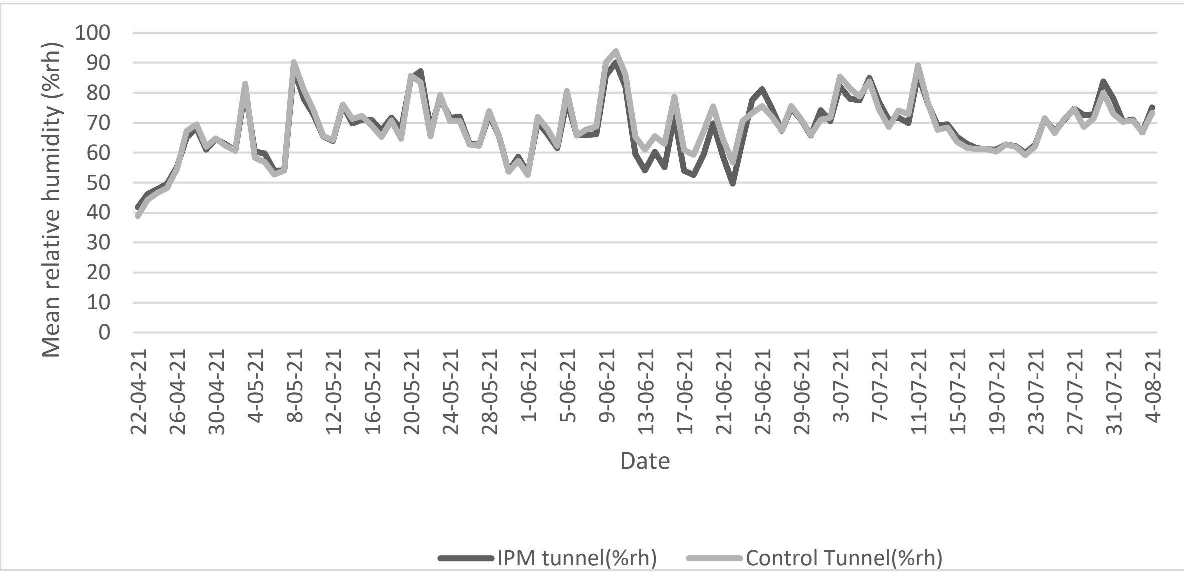

Figure 11 Mean Humidity (RH%) in the grower and IPM tunnels at site 1 in 2021.

Mean humidity at site 2 was also largely consistent, the lowest mean humidity was recorded at the start of the trial at 38.3% on 22 April. The highest recorded was 93.8% on 10 June (Figure 11).

Site 2 - Scurlage

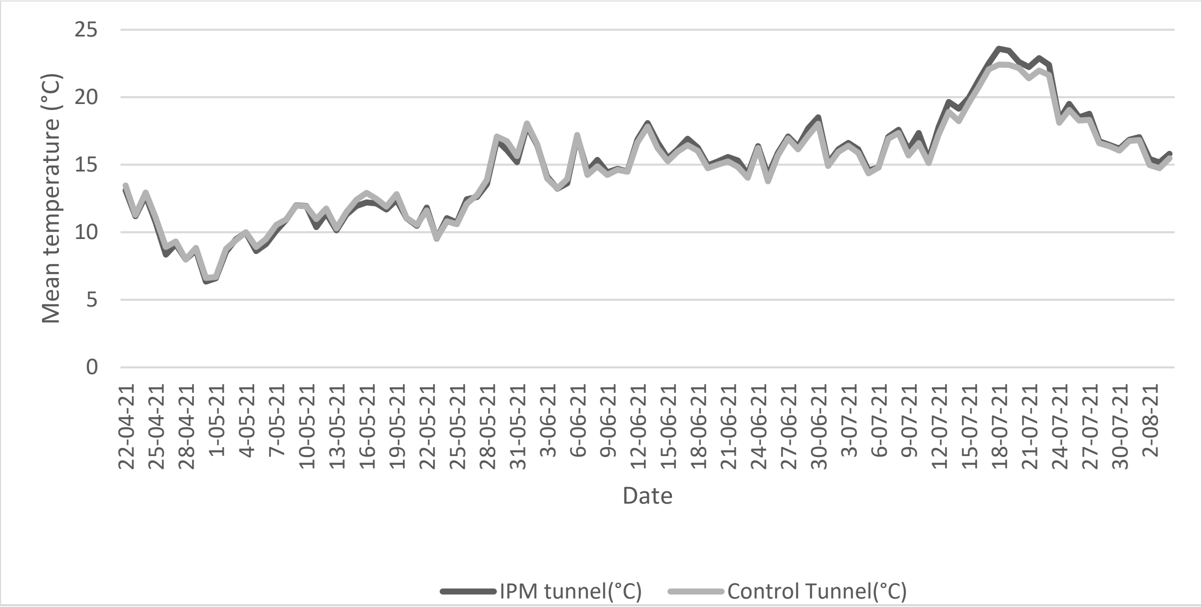

Figure 12 Mean temperature (°C) in the grower and IPM tunnels at site 2 in 2021.

Mean temperatures were largely consistent between the two tunnels in 2021, the lowest recorded mean temperature was on the 30 April (6.6°C) and the highest was on the 19 July (23.4°C) (Figure 12).

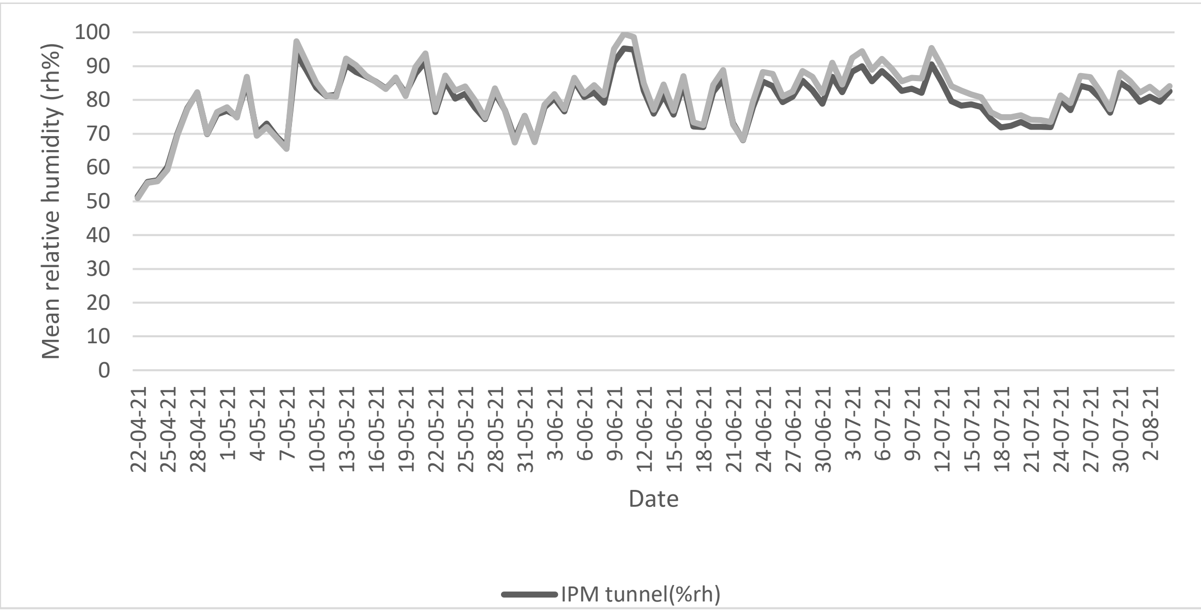

Figure 13 Mean Humidity (%rh) in the grower and IPM tunnels at site 2 in 2021.

Mean humidity at site 2 was also largely consistent, the lowest mean humidity was recorded at the start of the trial at 50% on 22 April. The highest recorded was 99.5% on 10 June (Figure 13).

4 DISCUSSION

4.1 ADAS Discussion

4.1.1 Summary – Year 1 2020

It was a difficult year for several reasons, COVID 19 made availability of biological controls limited as they're mostly imported from Europe, leading to early delays. High temperatures early in the year also led to a spike in pests early in the season before IPDM would normally be deployed in the region. This primarily consisted of aphids at Site 1 that developed quickly in the high temperatures. Ideally if the higher temperatures could be predicted aphid protection would have started earlier in the season to match this. This was identified as a key change required in the second year of the trial. Parasitoid wasps are a preventative biological control and are best applied early with lacewing applied as a curative measure. The applications of biological controls combined with runner removal were able to get the aphid numbers under control and comparable with the standard grower programmes.

Low levels of vine weevil damage were seen in the IPM tunnel during July and early August at site 1 before the nematode applications were made. No vine weevil damage was observed at Site 2.

Low numbers of thrips were seen through the trial at both sites, so it appears that the preventative *Neoseiulus cucumeris* combined with *Orius* protected the tunnels well.

At Site 1 the yields from the two tunnels were similar, though not directly comparable due to different claddings it is reassuring that they have yielded very similarly despite the issues with aphids in the early season.

Site 2 had low numbers of pests overall and it appears that the pest pressure overall was low. It is likely that this is due to a combination of the Batavia spray early in the year, combined with less pests present due to the shorter growing season of the June-bearers compared to the everbearers.

Overall, the aim of this trial was to demonstrate that biological controls could operate comparably to standard grower programmes. Though it had a difficult start, the IPDM strategy was able to control pests to a similar level as the grower programmes after there was a period of time for establishment. The grower programmes were also able to keep numbers of pests low through the season and avoided a build-up which was positive.

Next steps that were identified for 2021

- 2021 grower trials – programmes would be set up earlier to get protection in as early as reasonably possible and avoid an aphid build up like the previous year. Bioprotectants (such as flipper, a bioprotectant aphid killer that must be applied immediately when the pest is seen as it will not control a large infestation) to be used initially if needed.
- Determine whether any bioprotectants (in this instance, biological fungicides) could be used for disease control as part of the project.
- Aim to cover a longer period of monitoring by combining ADAS and grower assessments.
- Incorporate monitoring for SWD (Spotted Wing Drosophilla) into the monitoring scheme.
- Carry out a cost analysis comparing the grower programmes and biological controls.
- Tweak the applications of biological controls at Site 1 to reflect what was seen in year one.
- Ensure a better data coverage at Site 2, to monitor the crop on a site using more conventional methods and to refine the applications of biological controls there.
- Continuation of grower training.

4.1.2 Summary- Year 2, 2021

Overall, despite higher levels of pests at both sites compared to the previous year the pest levels were kept at a controllable level and from the feedback from growers had little overall impact on the yield and production of the strawberry crop. The IPM programmes established at both sites operated well, and although in places pest levels got higher in the treatment tunnels the beneficials were able to reduce them again and bring them down to acceptable levels. Nick and Pat summarised in an email ''the important consideration that IPM does not mean eradication of pests, just reducing to manageable levels'' and that is what has happened at the two sites.

At Springfields the IPM programme in the grower tunnel performed well, as did the IPM programme in the trial tunnel which had slightly different timings and products. Springfields had higher pest pressure than Scurlage, especially of aphids and thrips. Other grower sites in the UK struggled heavily with both aphids and thrips, this was not an isolated incidence.

The aphids arrived early in the year and established well which led to larger colonies developing. Parasitoid activity was hampered by the cold weather but their use was supplemented with Lacewing larvae which is useful as a hotspot control. Between the two, aphid levels were reduced again. Lacewing larvae also feed on other pests so their inclusion benefits in reducing other pests as well.

Thrips damage is not uncommon at the time of year we observed as some migratory species enter the crop and cause damage. These species are not believed to be affected by *A. cucumeris* mites (as the mites only eat larvae) which is why it was critical to also introduce Orius predators to deal with the adults. Orius also eat other pests as well as thrips such as capsids so their introduction in general is very helpful. Thrips damage starts to be seen at around a threshold of 1 thrips per flower and provides a useful measure of when to consider introductions. Frequent monitoring in flowers can help catch numbers increasing.

A general noticeable pattern is that the IPM tunnel at Springfields seemed to get pests earlier than the control, this was noticed in 2020 and noticed again by Guy Johnson in 2021. Guy noted that there was a hedgerow that ran perpendicular to the tunnel which, although it could be a host for beneficial insect predators, it could also be the early source of pests. This is not uncommon in cropping environments for this to happen with pests entering from one area and then moving to others. This may help explain times where numbers were higher initially in the IPM tunnel before the beneficial insects were able to get them under control.

These localised variations are important for growers to realise with their cropping area as the patterns can exist year to year. Localised variations are quite common with early stages of pest development. These patterns can then be anticipated and can be used to modify future programmes. It is important to look at the conditions each year and adjust and to not follow a set pattern that does not account for temperature or living conditions for the biological controls. By adjusting to the conditions, growers can save money by not making unnecessary introductions or ones that are set to fail and must be repeated. For example, within these trial years, spring came very early in 2020 and caught us out, however in 2021 spring was late and predators had been put out when conditions were too cold.

Overall pest pressure was lower at Scurlage, this is not uncommon with June-bearer crops as there is a shorter flowering window. However, this does mean that any impact in the shorter timeframe can have a larger financial impact. So, it is good to see that the IPM route managed to keep pest levels low and avoid large scale crop damage.

Another noticeable difference between the sites was the environmental data, typically Springfields was warmer than Scurlage. Likely due to the fully enclosed tunnels which Springfields used. We lacked this data from 2020 due to the loss of the data loggers at Scurlage. This can be useful to allow for earlier introductions of predators, however it can also allow for faster reproduction of pests that use the higher temperatures. It should also be noted that too high temperatures (around 25- 30C) can start to impair/ kill some biological controls. Humidity can also impact egg laying by predators if too low, but too high and disease levels can occur. This is why a number of biological controls have recommended temperature ranges.

Most importantly the growers were satisfied with how the programme went and the associated cost.

Observations from 2021

- Programmes and monitoring started earlier; however, it would have been good to start even earlier again with earlier applications of parasitoid wasps for aphids. This was limited by frosts that were later in the year than normal, which would have killed the wasps. This highlights the need for following an integrated approach rather than following a calendar for introductions. Often a grower would choose conventional chemistry if aphids were spotted very early. Other pests did not arrive until later in the year and so were not affected by the cold weather.
- Unfortunately, we were unable as hoped to investigate the use of fungicidal bioprotectants due to the budget constraints.
- Unfortunately, limitations on getting traps again limited the ability to start trapping for Spotted Wing Drosophila (SWD). Additionally, there is currently no commercial form of biological control for the control of SWD and if detected it would need applications of chemical insecticide.
- We were able to monitor Site 2 Scurlage for a longer period this year within the June-bearer season.
- We were able to continue grower mentoring, a video was produced to discuss the effects of the mentoring and the trial.

4.2 Grower discussion points/ Comments

4.2.1 Springfields (Site 1) – Nick and Pat Bean – notes taken from the growers

2020 Season: Conventional pesticides were used until 19/4 (except Majestik on 29/4). All those, with exception of Topas, are known to have harmful effects on some predators. All spray rounds were the same in both treatments and were generally carried out early or late, avoiding high light or periods of low humidity. Old, damaged and diseased leaves, fruit and trusses were removed at each picking (3 x weekly).

No pest problems occurred except the early incidence of aphid in T3 and whitefly in late July/August in both tunnels, thought to originate in pinks in a third tunnel.

The predator programme seemed to work well but this year (2021) we intend to use the combination of parasitic wasps for the later introductions rather than straight Chyrsoperla Carnea, and we will also monitor the crops for whitefly and introduce Encarsia sachets earlier if necessary.

Powdery mildew is quite difficult to manage. If there is a break-down of control too early that threatens the fruit we would revert to conventional fungicides towards the end of the season.

Regarding 2021, as of 3/2/21 we will not be able to apply Calypso (due to its withdrawal from the market) and are reluctant to substitute Hallmark (conventional pesticide). We would prefer to rely on Flipper and Botaniguard (both bioprotectants) early and to pile in with early introduction of aphid-predators rather than invest in another conventional pesticide. Also we must substitute Amistar (conventional fungicide) for Fortress (bioprotectants, herbicide), and include Signum or Scala (both bioprotectants) rather than latish Teldor (conventional fungicide). By September we were running out of options for mildew/botrytis control and have decided to include a third combination of bioprotectants, namely Sonata (MAPP 19161) & Botector (MAPP 19443) to alternate with those already used (subject to availability). Also, we are looking at an elicitor Fytosave (18433) (which is designed to improve natural plant defence mechanisms).

I think last year amply demonstrated the usefulness of the programme. Perhaps the ADAS treatments could be more innovative this year, the only real difference last year was timing and the inclusion of Orius. Maybe look at lower cost options and definitely some input on the appropriate fungicide strategy would be welcome.

2021 Season: Key points from Nick and Pat are that IPM is less compromising than multi-use of chemicals and improves our sustainability. Pesticides require PPE, expensive frost free storage and go out of date or are withdrawn giving disposal issues.

IPM has been shown to be cost effective at Springfields, but there is a need to adapt to specialized training, regular monitoring and improved general husbandry and hygiene in the crop. Pitfalls include inadequate crop hygiene during set-up, incorrect timing of introductions and incorrect matching of predator and pest species. A lack of knowledge when identifying species of pests was identified.

Best practice should include regular monitoring and keeping of records to illustrate local seasonal patterns of pest activity. Future projects could include comparing conventional pesticides with biopesticides, and extend into other fruit crops.

No harvest intervals on IPM (i.e. the crop can be harvested and sold for consumption during treatments) is better for direct retailers and this is also a plus point for marketing produce.

4.2.2 Scurlage farm (Site 2)– Alex and Tom Higgs.

2020

"I was very impressed with the biological controls we used last year and will definitely use the parasitic wasps and *Phytoseiulus* again in all tunnels and the wasps in the raspberries for aphids (I think it was a bad year for aphids in all crops last year but the wasps certainly kept the aphids at bay).

We used the nematodes for vine weevil in the strawberry crops kept for next year as a precaution and I was very pleased how cheap they were.

Tom and I were impressed by the biological controls and definitely had a build-up of aphids in the later tunnels, not in trial, when we forgot to order wasps.

It is important to compare the prices of biologicals against standard sprays as this would encourage more to use them. Biologicals are surprisingly good value, easy to administer and of course much more 'organic'.

In conclusion IPM seems to be very useful in our crops. It helps that we do not have everbearers and we only over winter half the strawberries, as trouble does not have an opportunity to build up.

I think it would be good to repeat this year again next year. We found the biologicals very good this year, but you never know year to year. Hopefully will be able to meet next year. If we intend to continue the trials, we should sort things out well before spring starts."

2021

"We got used to the IPM and it was easier than spraying and more effective. The only pest problem we had in 2021 was aphid in raspberry that came in and multiplied rapidly when the crop was being harvested. This was not part of the trial area. We will continue to use IPM going forward and we are confident in getting commercial control."

4.3 Overall summary and action points.

WP1 – Strategy planning

- Growers should monitor their sites regularly (ideally daily) to inform their decision-making processes. The more information they have the greater the speed that they can react and the greater confidence in what they are introducing will be.
- Regular monitoring is the key to success. Crops have to be walked regularly to scout for pests, check feed levels and dripper failure. Some time spent each day gives the best results and other farm activities may need to be delegated to free up the appropriate time.
- Growers should be willing to adapt their strategies based on the evolving situation. Following a calendar approach can lead to higher pests or excess introductions that are not needed. Yearly changes to weather can greatly change what you can introduce (e.g frost hamper parasitoids).
- Consider sending samples for identification periodically to understand what species are present on your sites. Some biologicals are species specific (e.g. *Aphidius colemani* is an effective parasitoid more for Myzus spp. and Cotton aphid than others) so knowing what pests are in your crop can save you a lot of money. This helps the grower build their identification skills.
- If growers have specific pests then consider using 'precision monitoring' with small sticky traps to look at what pests are in the crop and use them to warn yourselves of when pests are incoming. Be mindful that these can catch beneficials so use sparingly and in certain situations.
    - Consider the colour of the traps carefully as they will catch different pests (more info typically available from the suppliers)
    - You can supplement the colour with the aggregation pheromones of certain pests if there are specific pests you are concerned about e.g. there is a Western flower thrips (WFT) pheromone). Pheromone monitoring is not available for every pest.

WP2- Grower mentoring

- Grower mentoring was successful despite covid conditions. It led to a rise in online meetings and digital communication between groups.
- New fruit growers would need specialist advice, especially for biological controls, having a specialist, like Chris, around is invaluable for getting these programmes set up.
- The growers have been able to use these approaches and transfer them to other crops using the transferable knowledge.
- Many growers require some training in crop walking and interpretation of findings.
- Many growers may require additional support with correct identification of pests in order to determine what is in their crops.
- Peer learning amongst farms has been a factor in Wales especially as pan Wales communication via Zoom has been adopted in the pandemic.

WP3- IPM Establishment

- Preventative applications of predators are typically far more successful and cheaper than needing to make curative applications. When pest levels reach high levels, it can take longer to get them reduced by the introductions of predators which needs to be considered when planning.

- Climatic variations in Wales was found to be a major factor for timing of introductions for many pests including aphid and spider mites
- Temperature and relative humidity are important factors for pest levels and predators, higher temperatures can speed development, but too high temperatures (roughly above 25®C) can start impacting biological controls. Similarly, low temperatures can slow feeding or breeding of biologicals (e.g *Orius* needs 15®C in order to feed properly). Therefore, it is important to consider the predators introduced and their needs to ensure success.
- Humidity can also impact egg laying by predators if is too low, but too high and disease levels can occur.

WP 4- IPM review

- IPM programmes with beneficials can be completed cost effectively within both Everbearer and June-bearer strawberry crops. Especially when placed preventatively.
- IPM is not necessarily about pest eradication, its focus is more on reducing pests to an acceptable level.
- New entrant farms are often small scale and the purchase of pesticides is a factor. Often these come in pack sizes of many hectares and may be withdrawn leaving the grower stranded with expensive outdated material plus storage difficulties
- Not using pesticides is a useful marketing message to direct retail farms.
- Biologicals do not require PPE and the regulations involved with chemical pesticides. This is another useful factor for smaller units.
- Biologicals do not have any harvest intervals, like conventional pesticides do. Harvest intervals are hard to implement on direct retail farms, so use of biologicals is a benefit.
- A focus on biologicals and either no or reduced pesticides is a good marketing plus. The public is becoming more conscious and aware of the use of pesticides so their reduction will be seen positively.
- No restrictions on staff (or members of the public) re-entry after treatments of biologicals whereas there are restrictions with a lot of conventional chemistry, especially insecticides.
- Some biological controls have been noticed to overwinter by Nick and Pat, this is useful for the new year to provide some early protection. This may be due to the mild winters that they can have in their area.

Best practice recommendations.

- Being fastidious in keeping the crop clean as well as the wider site can go a long way to reducing pest numbers or keeping them low.
- Remove any waste from the plants and dispose of properly far from your crop – pests will leave this waste and go back into the crop!
- A clean and disinfection at the end of the season will go a long way to helping prepare for the new season.
- Regular monitoring is invaluable for effective decision making. Keep a log of the common areas where pests are observed, these can be useful for future years at your site.
- Consider the environmental variables, temperature and relative humidity and their impact on the pest and predator levels and survival. Low temperatures typically mean slower development of pests but also predators.

- Consider using data loggers in tunnels to monitor the conditions and help inform you when the benchmark temperatures for predators have been reached (e.g. 15®C for *Orius*).
- Buying good plant stock can be important, pests often arrive on these plants if ordered from a less reputable propagator. These can be expensive initially but save a lot of issues. Sometimes new plants are the primary method for the introduction of new pests onto an otherwise clean site. Make sure to check the new plants when they arrive and before you plant them.
- Containerised growing media can be replaced, a useful trait when compared to soil grown crops. This is useful for 're-setting' pest levels each year to avoid a yearly steady build up especially if you are buying new plants.
- When placing new cropping areas investigate and consider the local environment for pests and where they may come from. Alex and Tom have had a lot of success from their new tunnels centrally placed in a field where it's harder for pests to come in.
- Cold winters are a useful free way of reducing pest numbers, this is obviously not entirely reliable and so clean up sprays at the start of the season has been seen to be useful in this project.

Future work

This work has primarily focused on the use of biological controls for pest reduction within an IPM programme. The use of bio protectants for the treatment of pests, diseases and weeds is similarly challenging and there is a lot of scope for future work to help support the development of these schemes within Wales. Further specialised mentoring and guidance on the recognition of pests and diseases is another area that can be developed further.

4.4 Acknowledgments

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