SCEPTREPLUS

Final Review Report

Trial code:	SP 38
Title:	Control of raspberry cane midge and blackberry leaf midge.
Crop	Raspberry is the main focus of this review. Other crops that this information will apply to include other cane fruit, particularly blackberry and loganberry.
Target	The raspberry cane midge (*Resseliella theobaldi*) (RCM) and blackberry leaf midge (*Dasineura plicatrix*) (BLM)
Lead researcher:	Dr. Charles Whitfield
Organisation:	NIAB East Malling Research
Period:	Start: June 2018 Duration: 7 months
Report date:	20th May 2019
Report author:	Charles Whitfield
ORETO Number: (certificate should be attached)	N/A

I the undersigned, hereby declare that the work was performed according to the procedures herein described and that this report is an accurate and faithful record of the results obtained

……21/05/2019….
Date

Charles Whitfield
Authors signature

Review Summary

Introduction

The raspberry cane midge (*Resseliellia theobaldi*) (RCM) and blackberry leaf midge (*Dasineura plicatrix*) (BLM) can be major constraints to UK raspberry production. RCM damages raspberry canes which can lead to secondary pathogen outbreaks (midge blight). BLM damages the tips of primocane growth, causing poor growth and branching of the primocane. This makes the canes more difficult to train, more prone to low temperature winter damage and can lower the photosynthetic capacity of the plant and resulting yield the following season. Flower development is damaged causing a direct reduction in fruit production. Previously growers controlled these pests with chlorpyrifos-based products, but since authorisation for its use was revoked in 2016 these pests have become an increasing problem. Alternative control strategies are urgently required to assist the UK raspberry industry. A number of currently available active ingredients in the UK can adversely affect the biological control of mites, therefore ideally IPM compatible products are required.

This document reviews the current and potential new control strategies for UK raspberry growers. A number of stakeholders including growers, agronomists, and Plant Protection Product manufacturers and suppliers were interviewed to provide current industry practices in the UK and The Netherlands. Industry reports, scientific publications and commercial sources were reviewed for current and potential control strategies used in and outside the UK. The aim of this review is to identify conventional and novel chemistry and other control strategies (biological products) which are compatible with an IPM programme, and could be used in the UK.

Summary

The key findings of this review are:

Cultural control

- The use of nylon fabric sheeting (Mypex) to cover the ground of the growing area may hugely decrease incidences of RCM and BLM. Both species pupate in the soil (or sometimes in leaf/plant debris on the ground). Laying nylon mesh sheeting over the ground of the growing area, blocks emergence of adults and also stops any larvae from pupating in the soil, leaving them exposed to desiccation or predation. The larvae are also known to pupate in plant debris on the ground. The nylon fabric sheeting is an easier surface to brush, aiding removal of plant debris, which improves crop hygiene. The sheeting should be of sufficient quality with a fine weave allowing water to pass through but not the larvae or emerging adults. Nylon cloth of 100 gsm has also been used effectively. The cloth should cover the entire growing area and be placed and pegged down with overlapping sheets before the polytunnel supports are put into the ground.

Biological control

- Effective biological control options are currently limited.

Bioinsecticides

- Spinosad is used to control blueberry gall midge (*D. oxycoccana*) in the USA, and may provide control of midges in raspberry production in the UK. Met52 products may kill larval stages of the pest. A new liquid formulation of Met52 will be available soon allowing easier and more controlled application of the product. Previous work testing applications of liquid Met52 was inconclusive.

Conventional insecticides

- The number of conventional insecticides available for control of midges in raspberry production is low. Currently in the UK, Decis, Calypso, and Hallmark (outdoor only) are the main products being used by growers. However, their future availability is uncertain beyond 2021 (Calypso) and 2022 (Decis). Previous AHDB-funded trials and grower experience indicate that these are, at best, of only limited efficacy and the Hallmark and Decis are disruptive to IPM. Dutch growers use spirotetramat (Batavia, Movento) to control midges in raspberry and other fruit crops but this is not approved in the UK. Currently the most effective IPM-compatible products available are the use of pheromone baited monitoring traps to ensure that insecticide applications are applied at the correct time for maximum impact on the adult life stages halting oviposition of the next generation. It was suggested that the key to successful control for the season is to reduce the first generation adult population as much as possible using correctly-timed sprays.

Next Steps

Table 1: summary list of suggested active ingredients or products to test for IPM-compatible control of midge species in raspberry production.

Type	Active ingredient	Comments
Bioinsecticide	Spinosad	Shown to provide effective control of midge species in soft fruit outside of UK.
Bioinsecticide	*Bacillus subtilis*	Registered for use in UK raspberry as a fungicide. Shown to provide effective control of midge species in raspberry outside of UK.
Bioinsecticide	Azadirachtin A	Not registered for use in raspberry. Shown to provide effective control of midge species in soft fruit outside of UK.
Insecticide	Cyantraniliprole	Not registered for use in raspberry. Shown to provide effective control of midge species in soft fruit outside of UK.
Insecticide	Spirotetramat	Not registered for use in UK raspberry. Shown to provide effective control of raspberry cane midge in raspberry outside of UK. Concerns over application on flowering crops.

Insecticide	Novaluron	Insect growth regulator. Currently unlikely to get approval for use in the EU. Used elsewhere as part of IPM programmes in soft fruit production.
Cultural	Nylon fabric sheeting	Anecdotal evidence suggests that with careful and thorough use it can provide complete control of midge species. Installation cost and disruption may be an issue.

- For **cultural control strategies**, the most promising approach appears to be the use of **nylon fabric sheeting** (e.g. Mypex) to halt adult emergence from the soil and successful larval pupation. The initial cost of investment is high, and an economic study on the installation of nylon sheets could be of use to growers. Combined with netting to exclude adult midges and other pests (e.g. SWD), this approach may dramatically reduce the growers' need for insecticides. However, netting may alter the climate conditions within polytunnels and the effects on both pest and disease incidence should be assessed in trials.

- For **bioinsecticides**, azadirachtin A (not approved for use in raspberry), spinosad, spinetoram, *Bacillus subtilis*, and Met52 may provide control of the midge species. A new liquid formulation of Met52 OD will be available soon, and this product may provide control of larval stages both on the plant and also on or within the soil – however liquid formulations of Met52 have been trialled before with limited success. Future trials should ascertain the effectiveness and best approach for applying **spinosad, spinetoram,** and ***B subtilis***. In addition, **azadirachtin A (NeemAzal)** could be assessed although this product is not registered for use on raspberry.

- **Insecticides** which the AHDB may also consider testing in the SCEPTREplus programme include novaluron (Rimon 10 EC), cyantraniliprole (Exirel), and spirotetramat (Batavia, Movento), should approval of these products for use on raspberry in the UK be possible. Spirotetramat is known to be effective for control of midge pests in other fruit crops (apple, pear, blackcurrant), controlling larvae in galls, but the parent company Bayer have not to date supported its use in crops such as raspberry which do not have a clearly-defined, limited flowering period. However, use of this active substance is approved on raspberry in The Netherlands and requires further consideration.

- Trials with other IPM-compatible options such as attractants and repellents should be considered. However, because these compounds and application methods are still at the development stage, these approaches will require longer-term research.

Take home message(s)

- Consider investing in nylon ground sheeting, particularly if preparing an area for new polytunnels.

- Use pheromone traps to monitor adult midge populations and apply insecticides once thresholds have been reached. The most important generation to control is the first of the season. Adults are much easier to hit with sprays than the larval stages which are protected under bark or by leaf galls. Timing is key.

- To reduce the damage from RCM, growers should select raspberry varieties that exhibit a lower propensity to split.

Review

Introduction

The raspberry cane midge (*Resseliellia theobaldi*) (RCM) and blackberry leaf midge (*Dasineura plicatrix*) (BLM) can be major constraints to UK raspberry production. RCM damages raspberry canes which can lead to secondary pathogen outbreaks (cane blight). BLM damages the growing shoot tips causing poor growth and lowering the photosynthetic capacity of the plant and thus yield. Flower development is damaged causing a direct reduction in fruit production. Previously growers controlled these pests with chlorpyrifos-based products, but since authorisation for its use was revoked in 2016 these pests have become an increasing problem. Alternative control strategies are urgently required to maintain the UK raspberry industry. Currently-available active ingredients in the UK can damage the biological control of mites, therefore, ideally, IPM-compatible products are required.

This document reviews the current and potential new control strategies for UK raspberry growers. A number of stakeholders including growers, agronomists, and Plant Protection Product manufacturers and suppliers were interviewed to describe current industry practices in the UK and The Netherlands. Industry reports, scientific publications, and commercial sources were reviewed for current and potential control strategies used in and outside the UK. The aim of this review is to identify conventional and novel chemistry and other control strategies (biological products) which are compatible with an IPM programme, and could be used in the UK.

Target Description and Life-cycle

Adult midges are short-lived, and generally only survive a few days. Adult emergence and oviposition are temperature-dependent; the aspect-orientation of raspberry plantations may influence emergence and oviposition dates.

Resseliella theobaldi, raspberry cane midge (RCM)

Adults are 1.4 – 2.1 mm long with a dark reddish-brown abdomen and long delicate legs (Alford, 2007). Females are slightly larger than males. The males' antennae are beaded and characteristically curled back (Figure 1) (Nilsson, 2008).

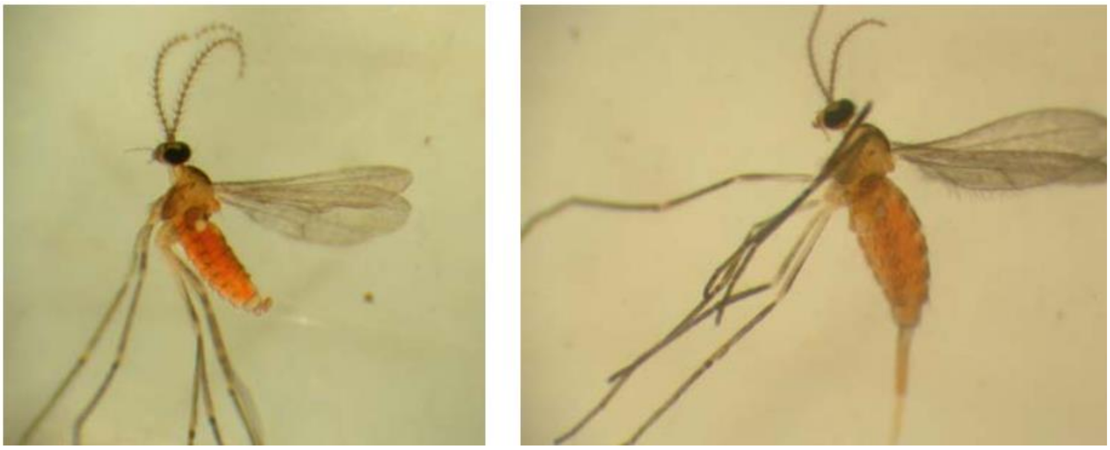

Figure 1: Left: a male raspberry cane midge with long beaded antennae and clasper visible at the tip of the abdomen. Right: a female raspberry cane midge with shorter antennae than the male and an ovipositor visible at the end of the abdomen (Nilsson, 2008).

The eggs are 0.94 x 0.33 mm in size and are shiny and translucent in appearance. Larvae grow up to 3.5 mm in length, starting out colourless but becoming salmon pink or yellowish as they develop. The larval spatula are bi-lobed. The pupae are 1.3 – 2.0 mm long with a dark reddish-brown colour. First generation of adults is reported to emerge in early May, but this is dependent on spring temperatures. Gravid females search for natural splits or wounds in the lower parts of the primocanes into which they oviposit. Eggs hatch approximately 1 week later. The larvae feed on the periderm layer under the bark of the primocanes for up to one month (Buczacki and Harris, 1998), and after three instars the larvae drop to the ground. The larvae burrow into the soil or other debris to pupate.

For the RCM, pheromone trapping has indicated emergence of adults from the soil occurs in the evening (Nilsson, 2008). Males emerge first and mating and oviposition usually occur within 24 hours of female emergence (Pitcher and Webb, 1952).

Dasineura plicatrix, blackberry leaf midge (BLM)

Adults are 1.5 - 2.0 mm long and brown or yellowy in colour. The abdomen of the female is noticeably paler. Eggs are very small, fusiform, and whitish. Larva are up to 2.5 mm long with a creamy colour and have a bi-lobed spatula (Alford, 2007).

The species has three overlapping generations per year in the UK, with growers reporting first generation adults on monitoring traps in late March or early April. This contradicts the information in Alford (2007), which reports adults as appearing in May or June and is likely to be referring to the second generation.

Females lay eggs in unopened leaves, and the larvae feed on the growing leaves. After about three weeks the larvae reach the third instar and drop to the ground to bury themselves 30 mm in the soil to pupate. Studies have shown that the pupae can be found in soil close to the edge of plastic sheeting around the crop, and also in amongst plant debris on top of the sheeting (Bennison, 2011). The pupal stage also lasts for about 3 weeks, after which the adults emerge. The final generation of larvae form cocoons in the soil in which they diapause until pupation and then emergence in the spring.

Symptoms and Identification

Resseliella theobaldi, raspberry cane midge (RCM)

The RCM damages raspberry canes in two ways. Direct damage from larval feeding on the periderm tissues beneath the bark, and secondary pathogen infection and damage as a result of the larval feeding. Pathogens taking advantage of the midge larvae colonising and feeding on the plant tissues include *Fusarium* spp., *Alternaria* spp., *Phoma* spp., and *Leptosphaeria coniothyrium* (Tanaskovic and Milenković, 2012). The midge-pathogen complex is collectively referred to as 'Midge Blight'.

Symptoms of Midge Blight are either seen as brown lesions on the stems where the midges are feeding, or brown lesions spreading upwards or downwards along the canes. The infested and infected canes can grow poorly, snap off, or die.
Identification of larva can be done by inspecting split canes for the presence of lesions and larvae. Identification of the adults is best done using pheromone lures and sticky traps as part of pest monitoring programmes.

Dasineura plicatrix, blackberry leaf midge (BLM)

The BLM is a leaf-galling midge. Gravid females lay eggs in newly-formed or unopened leaves. Larval feeding causes the leaves to be creased, pleated, or curled; the growing shoot tip may be damaged, halting flowering and consequently directly damaging fruit production. BLM-infested leaves can be unrolled and larvae may be visible inside the curls. Identification of the adults is best done using pheromone lures and sticky traps as part of pest monitoring programmes.

Cultural Control and Management

Physical barriers

Physical barriers may provide excellent control for RCM and BLM. Both species pupate in the soil (or sometimes in leaf/plant debris on the ground), and laying mesh sheeting over the surface of the growing area can stop larvae pupating in the soil, leaving them exposed to desiccation or predation. In addition the sheeting is an easier surface to brush to remove plant debris, improving crop hygiene. The sheeting should be of sufficient quality with a fine weave, allowing water to pass through, but not the larvae or emerging adults. Nylon cloth of 100 gsm has been used effectively. The cloth should cover the entire growing area, and be placed and pegged down with overlapping sheets before the polytunnel supports are put into the ground. Gall midges are able to vault several centimetres (Roubos, 2009 and references therein), so covering the rows only and not the alleys is likely to be only partially effective.

Crop hygiene
The BLM damages the growing shoots of the plant, disrupting the plant's production of inflorescences, which consequently has a large impact on fruit production. As it unlikely that infested shoots will produce any fruit, agronomists may advise growers to pinch out the infested shoots to remove the BLM larvae.

Removing plant debris from the floor of the growing area may reduce the survival of pupae to eclosion. Widespread use of ground sheets over the crop area would make sweeping up and removing plant debris easier.

Insect Development Models

The midge species have short adult life-spans' and oviposition is thought to occur within a few days post-emergence. Insect development models for the midge species focuses on prediction of the time of oviposition by the overwintered populations. The prediction models predict dates for oviposition of the first (overwintered) generation, and can assist with improved timing of pheromone monitoring and spraying.

For RCM a prediction model for oviposition which incorporates direction of slope and soil temperature data has been created by (Gordon et al., 1989). Oviposition is predicted to start once 339 degree days above 4 °C are recorded from the 1st March. If the area is on a slope, the model includes adjustments for the predicted date of oviposition based on the aspect of the slope. For south facing slopes the predicted date is advanced by 5.2 days, and delayed by 6.3 days for north facing slopes.

ADAS investigated the use of the prediction model for RCM as a prediction model for BLM. They found that the BLM emerges after around 280 degree days above a base soil temperature of 4 °C (Bennison, 2011).

Monitoring

The most commonly used method used for monitoring the two midge species are sticky traps baited with the species specific sex pheromone.

Pheromone trapping
The sex pheromones for both RCM and BLM have been identified (Hall et al., 2009, Hall et al., 2012) and commercialised. Used with traps the sex pheromones are deployed to provide growers with a means of monitoring pest population levels. Once catch thresholds are reached growers should apply insecticides to control the adult midges, ideally before they have the chance to mate and oviposit. Many growers successfully use this technique to correctly time their insecticide applications, particularly for the first generation of the season. Adequate control of the first generation is paramount as it greatly reduces the pest pressure later in the season when sprays may damage biocontrol agents for other pests (e.g. spider mite).

Natural Predators and Biological Substances

Currently there are few other options for biological substances known to be capable of controlling midge pests in raspberry production as highlighted by Dr. Roma Gwynn's gap analysis (Gwynn, 2009). Compounds that are available are shown in Table 2, with effects on midges noted if known.

Research has been done on the following compounds/organisms.

<u>Beauveria bassiana</u>

In AHDB project SF 102, Naturalis-L (*Beauveria bassiana*) was found to be ineffective at reducing the development of pupae in the soil (laboratory experiment), and applications of Naturalis-L onto the crop did not reduce the number of infested leaf tips (field experiment) (Bennison, 2011).

<u>Predatory mites</u>

Laboratory experiments showed that the predatory mites *Neoseiulus cucumeris* and *Amblyseius andersoni* fed on the eggs and larvae of BLM. Field trials indicated that *A. andersoni* did not reduce infestation by the midge (possibly due to poor establishment), but *N. cucumeris* did.
Further laboratory experiments showed that *Macrocheles robustulus* and *Hypoaspis aculeifer* did not significantly reduce the emergence of midge adults from pupae in the soil (Bennison, 2011).

<u>Orius sp.</u>

Field observations and laboratory experiments showed that *O. laevigatus* will feed on BLM larvae (Bennison, 2011). Subsequent field experiments assessing establishment of *O. laevigatus* and predation on midge larvae in the field could not confirm that the predator had established on the blackberry crop, and that it was not providing any pest control (Bennison, 2011).
Anecdotally, an agronomist has described using anthocorids to control midges as "boom and bust", i.e. they will feed on the pest but the pest population recovers when the anthocorids move on.

<u>Nematodes</u>

Nematode species *Heterorhabditis bacteriophora*, *Steinernema carpocapsoe* and *S. feltiae* have been tested in the laboratory and found to be ineffective against BLM (Wenneker, 2008). Laboratory studies found drenching coir with *S. kraussei* (Nemasys® L) controlled midge larvae, but when tested in the field with a soil-grown raspberry crop, no effect on midge infestation was observed. This may be due to insufficient moisture in the soil, limiting the nematodes' movement and survival, or applying the drench too late. An investigation into applying nematodes via irrigation systems (the 'little and often' approach) to control vine weevil showed that this method of application may work (Wedgewood, 2017) and there is the potential that this method could work for controlling midge larvae in pots.

Azadirachtin A

Azadirachtin A (NeemAzal®) has been shown to significantly reduce the number of RCM larvae (67-82% reduction compared to control) in raspberry splits (Mohamedova, 2017) in field trials in Bulgaria. The concentration of NeemAzal was 0.2% applied at 0.1 L/m^2.

Bacillus subtilis

B. subtilis applied to a raspberry crop reduced RCM larvae (75-81% reduction compared to control) in raspberry splits (Mohamedova, 2017) in field trials in Bulgaria. The concentration of *B. subtilis* was 10^8 CFU with 20 ml applied at a rate of 0.1 L/m^2.

Lacewings

An agronomist in the UK reported that management of midges with lacewing larvae had been tried, but that the lacewings did not appear to establish and no control was evident.

Semio-chemical based control

Semio-chemicals

Attract and Kill formulations have been assessed for control of RCM and BLM (Cross, 2016). The research investigated combining raspberry cane splitting volatiles with insecticide (pyrethroid) and also sex pheromone with insecticide in a Natural Product Matrix (NPM) (Bayer CropScience). Whilst the pheromone-insecticide NPM formulations were effective at attracting and killing male midges in the laboratory, results from the field trials suggested more work is required to find the optimal dispersal density of the NPM deposits. The raspberry cane splitting volatiles did not appear to be sufficiently attractive to female midges. These pheromone based attract and kill and mating disruption treatments could be effective for RCM but a commercial product was not developed for commercial reasons. Such approaches for BLM, even if effective, would be uneconomic because of the high cost of synthesis of the BLM sex pheromone.

Predator attracting and repellent semio-chemicals

Previous work (unpublished) done at NIAB EMR has shown that specific volatile organic compounds (VOCs) significantly reduce numbers of *Dasineura pyri* (pear leaf midge) when applied as prototype sprayable formulations. Although the cause of the reduction in midge numbers was not established, it is suspected that the VOCs are attracting and arresting predators such hoverflies whose larvae are then feeding on the midge larvae, and/or acting as repellents to the adult midges reducing oviposition. The effects were also found for many other pests, and the product may be effective for controlling RCM and BLM. Previous research by van Tol et al. (2007), found that *Resseliella oculiperda* (red bud borer) was repelled from ovipositing onto grafts bound with budding strips impregnated with lavender oil and other VOCs.

Table 2: The list of currently available biological products for protected raspberry crops in the UK.

Products	Active substance	Max individual dose	Total dose	Crop	Method of application	Crop stage	Final Use Date	Known effects on midges
Biocure, Bruco, Clayton Expel, Dipel DF	*Bacillus thuringiensis* var. kurstaki	0.75 kg/ha	8 applications	Raspberry (protected)	Ground spray	Field application	23 March 2020	Minimal effect in other midge species
Mycotal	*Lecanicillium muscarium* strain Ve6			Raspberry (protected) (permanent protection with full enclosure)	Ground spray	Field application	Off Label 31 October 2021	Unknown. Unlikely to be effective
Met52 Granular Bioinsecticide, Lycomax	*Metarhizium anisopliae*	0.5 kg/m3		Raspberry (protected)	Granular (incorporated)	Before planting or production	31 October 2021	Possible active against larvae [1]
Met52 OD	*Metarhizium anisopliae*			Soft fruit (protected) (nursery fruit trees)	Ground spray	Field application	31 October 2021	Liquid formulation may be effective against soil life stages. [2]
Tracer 480 SC	Spinosad	200 ml/ha (protected) 250 ml/ha (outdoor)	3 applications (protected) 2 applications (outdoor)	Raspberry	Ground spray	Field application	Off Label 31 October 2021	Reasonable control shown [3]

Botanigard WP, Naturalis-L	*Beauveria bassiana* GHA	0.75 kg/ha (protected) 0.6 kg/ha (outdoor)	12 applications (protected) 5 applications (outdoor)	Soft fruit (protected) (nursery fruit trees, permanent protection with full enclosure)	Ground spray	Field application	31 October 2021	Ineffective [4]
Serenade ASO	*Bacillus subtilis*	10 L/ha	20 applications 1 application (outdoor)	Raspberry, protected and outdoor	Spray	Field application	EAMU Feb 2020	Registered for use as fungicide. May have activity against RCM [5]

1: See report HNS PO 199 (Jones, 2017). Findings indicate Met52 (granular formulation) may have effect (not statistically significant) on the agapanthus gall midge (*Enigmadiplosis agapanthi*) larvae in the soil. Further investigation is required.
2: A Fargro Senior Technical Officer confirmed that Met52 OD (liquid formulation) will be available soon (possibly 2019).
3: (Mohamedova, 2017)
4: Previous AHDB reports show Botanigard is ineffective, probably due to the pests being hidden either in splits or leaf galls.
5: (Mohamedova, 2017)

No additional biological products which are available outside the UK were identified.

Conventional Insecticides

There are a number of conventional insecticides which are registered for use in protected and outdoor raspberry production in the UK (listed in Table 3). The predominate insecticides used to control the midge species in the UK are Decis (deltamethrin), Hallmark (lambda-cyhalothrin), and Calypso (thiacloprid). However, in the EU, approval for deltamethrin expires on 31/10/2019, approval for thiacloprid expires on 30/04/2020, whilst lambda-cyhalothrin is approved until 31/03/2023. The date for expiry of approval for these substances is longer in the UK (see Table 3 for details), however, there is an obvious need to find alternative control measures in the short to medium term.

Products used outside of UK that may be suitable PPPs are shown in Table 4. The most IPM compatible of these is Rimon (novaluron) which is used in the USA. It is an insect growth regulator and considered to have low risk to the environment and non-targets as it only affects larval stages and has no effect on adults. However, whilst the product was previously registered for use in four EU countries, the manufacturer withdrew its application for approval in 2012 and it is no longer available within the EU including the UK. Sivanto Prime (flupyradifurone) may be suitable for UK raspberry production, but it is not yet registered for use in the UK, and only has limited approval in the EU (for use on hops and lettuce in eight countries).

Movento (spirotetramat) is widely used in The Netherlands to control midges in raspberry. It has approval until 2024 in the EU. It is registered for use in the UK, but not yet on cane fruit (due to the extended flowering period).

Table 3: List of insecticide products available for protected and outdoor raspberry crops in the UK.

Products	Active Substance	Max individual dose	Total dose	Registration expiry in UK	Comments	Known effects on midge spp.
Apollo 50 SC	clofentezine	0.4 l/ha	1 application	30/06/2021	Outdoor raspberry only	Unknown
Calypso	thiacloprid	250 ml/ha	750 ml/ha	31/10/2021	12 month harvest interval for outdoor crops	Known to be effective, but careful timing is required
Clayton Abba, Dynamec	abamectin	0.5 l/ha	1 application	31/12/2021	No sprays between 1st Nov and end Feb.	Effective against *Dasineura rhodophaga* (rose midge) [1] Effective against *D. tetensii* (blackcurrent leaf midge) [2]
Decis, Bandu	deltamethrin	0.5 l/ha	1.5 l/ha	30/04/2022	No handheld	Known to be effective
Hallmark with Zeon Tech.	Lambda-cyhalothrin	0.075 l/ha	0.150 l/ha		Outdoor raspberry only	Known to be effective
Masai	tebufenpyrad	0.375 kg/ha	1 application	30/06/2019	Outdoor raspberry only	Off target, but will kill midges
Plenum WG,	pymetrozine	0.4 kg/ha	3 applications	31/12/2020		12 month harvest interval.

Chess WG						Found to be ineffective against galling midges
Pyrethrum 5 EC	pyrethrins	4 ml/l		31/05/2020		No evidence
Spruzit	pyrethrins	variable		31/12/2021		No evidence
Steward	indoxacarb	170 g/ha	2 applications	30/04/2021		No evidence
Gazelle	acetamiprid 20 w/w	0.5 kg/ha	2 applications		12 month harvest interval	Likely to control midge species

1: Elmhirst (2006).
2. Cross and Saunders (2009)

Table 4: Alternative products used outside of UK on raspberry and other soft fruit

Products	Active Substance	Max individual dose (a.i.)	Total dose	Restrictions	Target pest	Country	Comments
Assail 30 SG	acetamiprid	0.095 kg/ha	0.56 kg/ha	PHI = 1	D. oxycoccana (blueberry gall midge)	USA	Effective against *D. oxycoccana*
Mospilan SG	acetamiprid	0.25 kg/ha	0.5 kg/ha	Outdoor raspberry only	R. theobaldi	Germany	

Delegate WG, Radiant SC	Spinetoram	0.05 kg/ha	3 applications	PHI = 1	Choristoneura rosaceana (oblique banded leaf roller)	USA	Effective against *D. oxycoccana*
Diazinon 50W	diazinon	2.2 kg/ha	5.6 kg/ha	PHI = 7	various	USA	Likely to be effective against midges
Exirel	cyantraniliprole	0.15 kg/ha	0.45 kg/ha	PHI = 3	various	USA	Effective against midges in bushberry crops and other soft fruit (not raspberry)
Imidan	phosmet	1.2 kg/ha	5.6 kg/ha	PHI = 3	various	USA	Registered for use against a range of pests in bush fruit, tree fruit, stone fruit,
Rimon 0.83EC	novaluron	0.88 l/ha product	2.6 l/ha product		various	USA	Insect growth regulator. Considered low risk to environment and non-targets. IPM compatible.
Movento	spirotetramat	365 ml/ha product	1.095 ml/ha product	PHI = 3	Aphids	The Netherlands Canada	Post bloom only.
Multiple brands	malathion	1.4 kg/ha		PHI = 1	*D. oxycoccan*	USA	

Sivento Prime	flupyradifurone	100 g/mCH[1]		PHI = 3	Aphids, flies (maggots)	EU	Possible reports of phytotoxicity in raspberry (not confirmed)

1: grams of active ingredient per meter canopy high

Current Overseas Control Practices and Opportunities for Application in the UK

In the USA neither *D. plicatrix* nor *R. theobaldi* are present, however, blueberry production suffers from the blueberry gall midge (*D. oxycoccana*), which poses similar control problems to the two midge pests in the UK. In the USA OMRI (Organic Materials Review Institute) certified production appears to reply on spinosad (Entrust) for control of the blueberry gall midge (*D. oxycoccana*). Organic raspberry production in the USA relies on various rates of azadirachtin (neem), pyrethrins, and spinosad, and also garlic juice based products.

Raspberry growers in Canada and The Netherlands use spirotetramat (Movento). In The Netherlands this product is used specifically to control *D. plicatrix* and *R. theobaldi*, however agronomists reported that it is difficult to achieve control of *R. theobaldi* due to it being protected behind bark.

Other EU counties use Calypso, however it has been noted that elsewhere in Europe raspberry varieties are grown that have bark which peels less and therefore has a degree of resistance to the RCM (Vétek et al., 2006).
Sivanto Prime (Flupyradifurone) should kill midge larvae, and appears to be licenced for use in raspberry according to Bayer, but there is limited information available on its use. Recommended application rate of 100 g mCH (grams active ingredient/ canopy height). A Dutch agronomist commented that the product may cause damage to leaves and therefore is not used.
The Dutch do use Movento and say it works well to control BLM, but is not so good for control of RCM as it is difficult to hit the target behind the bark.

Survey of growers, agronomists and Plant Protective Products companies

A series of interviews with some key stakeholders in raspberry production was completed. See Appendix A for the list of questions that were asked. The results of these interviews are summarised in Table 5 and Table 6. Due to the time and budgets limits of this review a small number of stakeholders were contacted, including growers and agronomists in the UK, a Dutch agronomist, and an international Plant Protection Products company and a supplier.

One of the UK growers interviewed had spoken extremely positively about the use of Mypex (nylon fabric sheets) and netting which solved a serious midge problem the farm had been experiencing. The grower reported that since installing the ground sheets and netting midges were now almost completely absent from the crop. The netting also protects against SWD. Although the sheeting and netting required a high initial investment the grower felt it had been worth it. To be effective it was reported that the whole growing area had to be covered with Mypex (100 gsm grade) overlapping sheets to ensure no gaps. In addition, by netting both ends of tunnels the grower had found SWD could be controlled and gave an example of trapping numbers from last year, e.g 27,000 SWD trapped outside, but only 8 caught inside.

A Dutch agronomist was interviewed and commented that Sivanto Prime (flupyradifurone) could control midges, but he said there had been evidence of raspberry leaves exhibiting phytotoxicity and it is no longer used. The product label for Sivanto Prime indicates it can be used on raspberry to control aphids and maggots with no mention of phytotoxicity. It is registered for use in EU but not yet in the UK.

Table 5: Priority constraints and concerns for raspberry production stakeholders

Participants	Raspberry var.	Priority production constraints	Priority concerns
Growers	Maravilla	• SWD (August onwards) • Mites • BLM (March onwards) • Whitefly (glasshouse) • Mildew • Aphids	• Registration loss of PPPs (especially insecticides and acarcides) • Resistance to pesticides • SWD control • Cladosporium control
Agronomists (UK)		• Cane quality • SWD (2nd half of season) • BLM (1st half of season) • Spider mite • aphids	• Incompatibility between control of SWD and midges and control of aphids and mites. • Midge population peaks all overlap because of continuous cropping and protected crops. • If BLM left uncontrolled, continued damage to growing tips can stop crop from flowering (70% crop loss possible). Especially risky for primocanes grown and cropped in same year. • Loss of thiacloprid. • Reliance on pyrethroids (Decis and Hallmark) increases risk of resistance. Both IRAC 3A. • Use of Decis to control midges limits its use for control of SWD.
Agronomist (The Netherlands)	Kwanza Glen Ample Enrosadira	• SWD • RCM • BLM • Mites	• Lack of IPM options for midge control.

Table 6: Conventional and IPM compatible control strategies and associated comments.

Participants	Conventional control for midges	IPM compatible	Negative issues for implementation	Causes	Positive aspects of implementation	Causes

		control for midges				
Growers	• Decis (deltamethrin) • Calypso (thiacloprid) • None required	• Pheromone traps. • Mypex ground sheets and netting.	• Balancing conventional pesticide applications with bio-control for mites. • BLM control difficult. • SWD.	• Control for SWD and midges damages bio-control populations • Larvae protected in leaf curls. Need to target adults.	• Midges no longer a problem • Midge blight not seen.	• Maravilla splits less, primocane cropping reduces RCM damage. • Careful monitoring and spray timing BLM is controllable. • Mypex sheeting provides almost total control of midges. Allows for easier crop hygiene (sweeping away debris).
Agronomists (UK)	• Hallmark (λ-cyhalothrin • Decis • Calypso • Pyrethrum	• No biological controls work. • Pheromone trap monitoring.	• Lack of biological control options. • Spraying needs to timed so it does minimal impact on biocontrol for mites.	• Loss of chlorpyrifos.	• RCM and blight not an issue. • RCM usually not a problem anymore.	• RCM mostly controlled by sprays for other pests. • Polytunnel/glass production reduces blight risks. • Current controls are working for both midge species.
Agronomist (The Netherlands)	• Decis • Movento	• BIO1020 - *M. anisopliae* var F52 (as soil application) (Met52).	• Floricane more susceptible to RCM. • RCM hard to control. • RCM and BLM are much worse in soil grown crops. • Decis does not work so well for RCM.	• Too much growth and bark comes loose. • RCM protected by bark.	• Movento works well for BLM. • BLM always present but not always a problem.	• Decis and/or Movento directed to lower parts of plant. Possibly contributes to control of larval stages looking to pupate.

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