SCEPTREPLUS

Final Review Report

Trial code:	SP 23
Title:	**'Pot worm' *Lyprauta* spp. research exchange at Wageningen University and Research, The Nethlerlands**
Crop	Phalaenopsis (Orchid)
Target	'Pot worm' *Lyprauta* spp.
Lead researcher:	Jude Bennison
Organisation:	ADAS
Start date and duration	1 July 2019
Report date:	21 April 2020
Report author:	Elysia Bartel
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

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Date Authors signature

Review visit Summary

- **Introduction**

  The 'pot worm', identified as the larvae of three species of flies in the family Keroplatidae, causes root tip damage to Phalaenopsis orchids on Dutch nurseries and at least one of these species is causing damage on a UK nursery. This report summarises the research that has been led by Wageningen University and Research (WUR) in the Netherlands into the biology and control of pot worms. Options for reducing the damage caused by pot worms have been explored. Methods tested for reducing the number of pot worms focus on cultural and biological control.

- **Summary**

  Elysia Bartel and Jude Bennison (ADAS) and two growers from a UK commercial nursery growing orchids visited Marjolein Kruidhof at Bleiswijk research station in July 2019 to discuss pot worm biology and control. Researchers at Bleiswijk, one of the experimental stations of WUR have confirmed that omnivorous pot worm larvae are responsible for the feeding damage seen on orchid roots. Although primarily predatory, feeding on other invertebrates e.g. sciarid fly larvae in the growing media, the larvae supplement their diet with carbohydrates by feeding on the root tips. This mixed diet improves larval development but is not necessary for survival – e.g. pot worms can be reared with only prey mites as food. Adult females, which resemble large mosquitos or small crane flies, are attracted to bark and coir substrates equally but a higher percentage of coir can reduce the number of air gaps and inhibit movement of the pot worm larvae. Rearing pot worms for experiments is labour intensive and not always successful since larvae develop at different rates and the adults only live for a maximum of one week. A survey of natural predators on Dutch nurseries identified earwigs and predatory beetles as potential predators of pot worm. Earwigs were shown to reduce number of pot worm larvae either by predation or indirectly reducing the availability of prey for pot worm larvae. The beetle *Dalotia* (*Atheta*) *coriara* was observed to eat pot worm eggs but not larvae. The naturally-occurring specialist parasitic wasp *Megastylus woelki* can control pot worm effectively but a culture could not be established at WUR. The hunter fly, *Coenesia attenuata* has been released at a Dutch nursery but provides ineffective control and is not commercially available. Evidence has shown that pot worm larvae can ingest the bacterium

Bacillus thuringiensis subsp. *israelensis* (Bti) but the gastrointestinal tract of the larvae is too acidic for Bti to be effective. Commercially available entomopathogenic fungi (epf) tested at WUR did not have an effect on pot worm larvae, although a naturally occurring epf was able to provide some control at a high concentration. Entomopathogenic nematodes have been used with some success in research conditions when formulated in capsules baited with starch, but these are prone to drying out on the dry growing media. Slug pellets containing metaldehyde did not negatively affect pot worm larvae, but larval development sped up, due to feeding on the starch contained in the pellets.

- **Next Steps**

Further study is required to better understand the biology of pot worms, in particular, to establish the circumstances in which the larvae feed on orchid roots and why this might be necessary. For example, the carbohydrates acquired from the roots could be necessary for production of the acidic webbing produced by larvae, in which they move and catch prey. Research is needed on cultural methods to deter adult females from laying eggs in the substrate, such as determining the ideal growing medium or using a pot topper. Push-pull strategies could be tested using a repellent to push pot worm adults away from the bark, toward light traps or natural enemies. Additionally, a systemic acquired resistance (SAR) based attractant, could be tested to see whether it draws more natural enemies into the crop. Further tests could reveal the potential for control by predators such as earwigs, and hunter fly larvae. Further improvement on the rearing of pot worms could provide potential for commercial rearing of the specialised parasitoid and entomopathogenic fungus.

- **Take home message(s)**

- Using a substrate with a higher percentage of coir or fine bark to increase the pH and reduce the air filled porosity might inhibit web production by pot worm larvae.
- Distracting pot worm larvae with alternative sources of carbohydrate, such as molasses might help to reduce root damage.
- The commercially available predator *D. coriara* did not provide sufficient direct or indirect control in laboratory tests, but might perform better in a different

growing medium with a higher moisture content than bark e.g. coir used in the plugs that young plants are supplied in.

- Releasing the predatory mite *Macrocheles robustulus* can reduce the availability of prey mites in the growing media but might also increase the numbers of springtails, which benefit from fungi growing on the carrier and are also prey for potworm larvae. Predatory mites can predate pot worm larvae directly but provide insufficient control.
- Nematodes can parasitise pot worm larvae in the laboratory and might be commercially effective when used on damp plugs with the young plants or as part of a potential lure and kill strategy in capsules.
- It is possible that a 'push-pull' strategy for adult pot worm management might be possible to develop, based on a repellent ('push') and an attractive lure ('pull').
- The most effective biological control agent is a naturally-occurring parasitoid wasp, *Megastylus woelki*, which is not commercially available. It is important to conserve the species, if found on the nursery.
- Orchid variety choice can be an important factor as slower-growing varieties are more susceptible to pot worm.

Review visit

Introduction

The so-called 'pot worm' has become an economically important pest in the cultivation of Phalaenopsis orchids in Europe. This report summarises the research that has been led by Wageningen University and Research (WUR) in the Netherlands into the biology and control of pot worms. Control methods focus on reducing the number of pot worms and reducing the severity of damage caused. Pot worms are the larvae of flies in the Keroplatidae family, distinct from 'real' potworms, Enchytraidae which are saprophytic. Pot worm larvae are primarily predatory, attacking other organisms e.g. sciarid fly larvae that live in the orchid substrate. However, the pot worms are omnivorous and can damage the root tips of orchids of the genus Phalaenopsis and of the "Cambria" hybrid orchids (Chandler and Pijnakker, 2009). This feeding is particularly damaging to Phalaenopsis because these orchids have few roots. One single pot worm larva in a pot can cause economic damage by slowing plant growth and reducing the number of flower spikes produced. The cost of this damage is significant since the value of a two spike orchid can be 50% - 75% more than a one spike orchid, which may be sold at a loss. To compensate, growers must keep the plants at 28°C, under artificial light for longer in spring and autumn when the energy costs are high. This report builds on the ADAS review completed for the SCEPTREplus project (Bennison & Brown, 2018). The information in this report was shared during a visit by Elysia Bartel and Jude Bennison of ADAS and UK orchid growers, Howard Braime and Malcolm Gregory of Double H nurseries, to Bleiswijk research station of Wageningen University and Research (WUR) in July 2019 **(Figure 1)** and published in a publically available report by Kruidhof *et al.* (2018).

Figure 1 Elysia Bartel, Howard Braime, Marjolein Kruidhof and Malcolm Gregory at Bleiswijk research station, July 2019.

Target Description and Life-cycle

Three species of flies in the Keroplatidae family of South or Central American, Neotropical origin, known as 'pot worms' have become a pest in Dutch orchid nurseries: *Lyprauta cambria* (Chandler), *Lyprauta chacoensis* (Edwards) and *Proceroplatus trinidadensis* (Lane) (Chandler and Pijnakker, 2009). In the UK *L. cambria* has also been identified as a pest on Phalaenopsis orchids at Double H Nurseries Ltd. where, as with most Dutch nurseries growing this crop, the problem with pot worm is in the 12cm pots. The adult pot worms resemble large mosquitos or small crane flies. The larvae are longer and thinner than sciarid fly larvae, transparent, greyish-white with a reddish-brown head (Koppert, 2020). The pupae are white to yellow and found embedded in webbing. It is suspected that the pot worms arrived in Europe on plant material from the neotropics rather than in substrate, since bark, coir and sphagnum are treated by steaming, drying or irradiation, prior to transport (Humala *et al*., 2017). The pot worm larvae produce an acidic web of tubes along which they can move very quickly. The larvae spin diffuse nets, containing droplets of oxalic acid secreted from labial glands, which they use as a springboard to ambush prey (Humala *et al.*, 2017; Pijnakker and Ramakers, 2010). This webbing becomes a 'highway' allowing the larvae to hardly touch the bark. Larvae are sensitive to disturbance, researchers at WUR could not find larvae after they had been disturbed, possibly because disturbance dislodges larvae from the webbing and renders them vulnerable to predation. The larvae eat mites, sciarid larvae, springtails and other substrate-dwelling organisms. A study at WUR confirmed that the larvae of *L. cambria* supplement their predatory diet with carbohydrates, by tracing ingestion of starch from slug pellets into the gastrointestinal tract of the larvae. It was observed that *L. cambria* larval development was improved on a mixed diet of prey and starch compared with a single food source. *Lyprauta cambria* eggs develop in five to six days at 28°C. Larval development depends on the food source and takes three to four weeks, after which the larvae pupate over three days. The winged adults emerge from the pupae and live for three days on average, up to a maximum of seven days, in order to mate. The adults are nocturnal, flying mainly in the evening and at night. In a survey of pest pressure at a Dutch nursery the majority of pots containing pot worm, contained only one larva, but three or more larvae were found in some pots. Pot worm larvae are thought to be typically solitary and can be cannibalistic (Anthura and IMAC, 2016).

Symptoms and Identification

Symptoms of pot worm damage include circular pits on the root tips, and retarded growth, due to a reduction in water and nutrient uptake from the roots. There can also be excessive production of new root tips and a tendency toward more vegetative growth with fewer flower spikes as energy is redirected toward the roots (Humala *et al*., 2017; Bennison and Brown, 2018). Pot worm damage peaks seasonally, in February, March and Autumn, this tends to be when the climate is more variable with changing light levels, which causes plant stress (Braime, personal communication). The pest also tends to be more of a problem on slow-growing varieties that are slower to dry out after irrigation, as it thrives in moist conditions (Braime, personal communication). The eggs of *L. cambria* are black and spherical. Larvae can be identified by their webs; the web of *L. cambria* has more branches than that of *P. trinadadensis*, which has distinctive thickenings in the web threads. Adults are identified by their wing pattern. *Lyprauta cambria* is the most commonly found species of 'pot worm' in Dutch cultivation and has also been confirmed in the UK (Bennison & Brown, 2018). Adults of *L. cambria* are identified by dark shading on the apical part of the wings and dark brown veins **(Figure 2)**. *Lyprauta chacoensis* has faint or absent wing markings and is less commonly found than *L. cambria* in Dutch cultivation. *Proceroplatus trinidadensis* has several, variable dark wing markings but is rare in Dutch nurseries (Chandler and Pijnakker, 2009).

A) B)

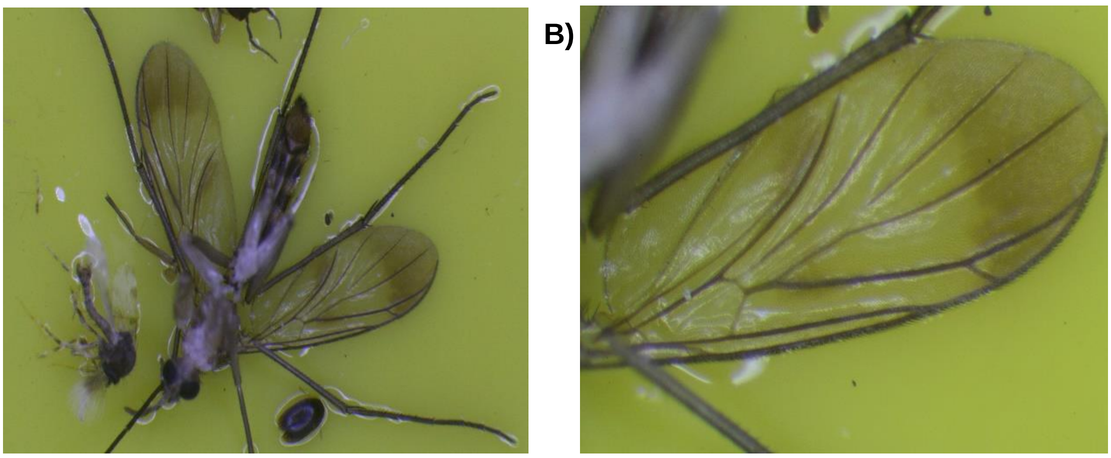

Figure 2 *Lyprauta cambria* adult (A), identified by wing pattern and venation (B), caught on a sticky trap in a light trap at Double H nurseries Ltd, UK.

Cultural Control and Management

Pot worm larvae predate some other root damaging pests, such a sciarid flies. It has been questioned whether pot worm larvae are secondary to sciarid fly damage and whether their presence, where root damage existed, was due to their predation of these other pests. Kruidhof *et al.* (2018) have proven that the larvae of *L. cambria* cause feeding damage to root tips. In a controlled experiment plants were rigorously checked for root condition prior to introducing pot worm and compared with a control in which pot worm was not introduced. The plants containing pot worms suffered from root tip damage. However, pot worms can be reared without access to plants, which shows that feeding on the roots is not necessary for survival. Therefore if the pot worms can be discouraged from feeding on the roots of the plants the damage might be managed in this way.

Researchers at Wageningen tested the hypothesis that *L. cambria* larvae are attracted to root tips for the sugars produced as root exudates. An experiment was designed to test whether root damage could be reduced by distracting larvae from root tips with an alternative source of starch or sugar in the substrate. Molasses, molasses + 1% Silwet Gold and slug pellets were added as different distraction food sources for pot worm and compared with a control. The results showed that there were fewer damaged plants when molasses were added to the substrate compared with the control, although the difference was not statistically significant. The slug pellets started to grow mould during the trial, which would make them unsuitable for commercial use if added to the surface of the growing media. In addition, slug pellets led to faster pot worm population growth as they provided a food source for the larvae (see Insecticides section).

Pot worm is more of a problem in moister substrates, therefore keeping the substrate as dry as possible during the first ten weeks of production helps to reduce problems (Bennison & Brown, 2018). Choice and irrigation management of growing media are important factors in pot worm control and this was discussed between the researchers and growers present at the meeting. There needs to be a careful balance between keeping the substrate dry for pot worm management yet giving enough irrigation for as rapid as possible plant growth.

Adult pot worm are attracted to bark and prefer to lay eggs on a damp surface. Larvae create their acidic webs in the air filled spaces in the bark to move easily. A finer bark or a higher percentage of coir can reduce the air filled porosity in the substrate mix and adding coir will also raise the pH of the media, inhibiting the creation of these webs, helping to control pot worm. Adding charcoal to the growing media might also inhibit pot worm, since an increase in pot worm incidence was observed after charcoal was removed from the substrate mix at Double H (Braime, personal communication). A trial at WUR was conducted on the egg laying preference of *L. cambria,* but there was no significant preference for bark or coir. Following observations that more *L. cambria* adults were caught by light traps above six week old plants than in younger plants, an experiment was designed to test whether pot worm adults are attracted to bark of a certain age. Results showed that females preferred to lay eggs in older bark kept damp with Oasis® in rearing containers, which contained more prey mites compared with new bark (without prey mites) and a negligible quantity of eggs were laid on the Oasis® alone. In an experiment at Double H nurseries plants were netted from the top or bottom or both the top and the bottom, to determine where the females were getting into the pots to lay eggs. The conclusion was that they were accessing the tops of the pots, although netting the top and the bottom provided better control against pot worm. However this method of control was not cost effective, in order to prevent inhibition of pot drainage (Braime, personal communication). Adults are attracted to bark or coir and need to burrow in the top of the substrate to lay eggs, therefore limiting access to the substrate can deter egg laying.

Culturing for Experiments

In order to carry out experiments on pot worm, sufficient numbers of larvae need to be reared in the laboratory. *Lyprauta cambria* larvae can be cannibalistic and must be reared in separate chambers from each other (Anthura and IMAC, 2016). A rearing method was developed at WUR. The rearing chambers contain bark as a substrate, fixed to a block of pre-soaked Oasis® on the wall of a clear plastic pot, covered with a lid and breathable insect-proof mesh-covered opening **(Figure 3)**. The chambers are designed to maintain a high relative humidity for the larvae, which are fed with factitious prey, Astigmatid mites (as used for rearing predatory mites). As the pot worm larvae start to pupate, the lids are removed to reduce humidity and the chambers are dried with vermiculite and tissue. The adults are allowed to emerge, mate and lay eggs on new pieces of bark. Rearing pot worms is very labour intensive and not always successful. The adults live on average for three days, up to a maximum of seven days, so many larvae need to be reared in order to produce adults of synchronised age.

Figure 3 Chamber for culturing a single potworm larvae. Bark is attached to oasis on the wall of the pot, covered by a breathable mesh and lid with an opening.

Natural Predators and commercial Biological Control Agents

A survey of Phalaenopsis nurseries was conducted at WUR, using light traps and substrate assessment to identify prey and potential predators of pot worm. Species from the following groups were identified: Sciarid flies (*Bradysia* spp.), gall midges (Cecidomyiidae), non-biting midges (Chironomidae), moth flies (Psychodidae), fruit flies (Drosophillidae), house flies (Muscidae), blowflies (Calliphoridae), springtails (Collembola), moss mites (Oribata), real pot worms (Enchytraidae), rove beetles (Staphylinidae) and earwigs (Dermaptera).

Earwigs were identified in the survey of natural predators and have been identified as a potential predator of pot worm larvae. The European earwig, *Forficula auricularia*, is encouraged in apple and pear orchards as a generalist predator of several pest species, such as aphids (Orpet *et al*., 2019). A laboratory test at WUR was conducted which found fewer pot worm larvae in pots where third nymphal stage earwigs were also released than in control pots without earwigs. Prey mites were released as a food source for *L. cambria* in the experiment*.* It is not clear whether this was a direct result of predation by the earwigs or competition for the prey mites. Earwigs are omnivorous and can cause damage to some plants. However, an experiment showed that earwigs do not damage Phalaenopsis, therefore they might be encouraged as natural predators of pot worm.

Since predatory beetles were also found in the light traps and in the orchid substrate, the commercially available, generalist predatory beetle *Dalotia coriara* (formerly known as *Atheta coriara*) was released with pot worm in a laboratory experiment at WUR. Both the larvae and adults of *D. coriara* are predatory. The results showed that *D.*

coriaria would eat the eggs of *L. cambria* but did not attack the larvae. Predation was tested with both 1-2 week old and 2-3 week old pot worm larvae. It is possible that *D. coriara* was unable to predate the larvae because of their oxalic acid secretions (Pijnakker and Ramakers, 2010; Pijnakker and Leman, 2013).

Limited success with *D. coriara* prompted work on indirect biological control at WUR, i.e. by reducing available prey for the pot worm larvae. The predatory mites *Macrocheles robustulus* and *Stratiolaelaps scimitus* can feed on young *L. cambria* larvae, but do not provide sufficient control (Pijnakker and Leman, 2013; Bennison and Brown, 2018). These predators were used to test indirect control of pot worm by reducing availability of pot worm prey in the substrate at WUR. Pot worm prey that occur in large numbers in bark substrate include springtails and prey mites in the suborder Prostigmata of the 'sucking', true mite order - Trombidiformes. *Dalotia coriaria* and *M. robustulus* were added weekly in an experiment to reduce numbers of springtails and Prostigmatid mites. *Dalotia coriaria* did not reduce the availability of springtails but *M. robustulus* reduced the number of Prostigmatid mites. From this experiment it was not possible to conclude whether reducing the availability of Prostigmatid mites would negatively impact pot worm larvae. The addition of *M. robustulus* with a carrier led to an increase in the number of springtails, which were possibly feeding on fungi that grew on the carrier. This might increase the availability of food for *L. cambria* larvae. *Dalotia coriaria* could only establish in low numbers in the bark substrate, possibly because it was too dry for good population growth (Bennison, 2010).

A new, naturally-occurring parasitic wasp species *Megastylus woelki* was discovered at a Dutch Phalaenopsis nursery, described by Humala *et al.* (2017). The female parasitic wasp lays an egg in a pot worm larva and the parasitoid larva hatching from the egg feeds on the pot worm larva and kills it. The pot worm larva does not die immediately, but the pupa turns brown and a parasitic wasp emerges instead of an adult pot worm. *Megastylus woelki* was observed to control the three main pot worm species in Dutch orchid cultivation. However, *M. woelki* is a specialist and will not parasitise any other fly species, therefore the population on the nursery where it occurred died out after all the pot worms had been parasitised. The parasitoid is thus able to eradicate a pot worm population. Researchers at WUR could not establish a culture of *Megastylus woelki* since it requires pot worm larvae to reproduce, which are also difficult to culture in a laboratory. *Megastylus woelki* was observed on a second Dutch orchid nursery but a large proportion were caught by spider webs, alongside pot worm adults. In the light trap survey, other smaller species of parasitic wasp were identified, but these are thought to be unlikely to parasitise pot worm larvae.

The generalist predatory hunter fly *Coenosia attenuata* naturally occurs in Dutch and UK glasshouses, particularly where IPM is being used, and can play an important role in controlling pest adults such as shore flies, whitefly, leaf miners and other fly species. *Coenosia attenuata* has been observed to catch and prey on *L. cambria* adults and can be reared on sciarid flies. However there is a risk of introducing sciarid flies with *C. attenuata* and the predator is not currently commercially available A commercial orchid grower on a large Dutch nursery released *C. attenuata* from WUR for pot worm control but found that they were ineffective because *C. attenuata* hunts during the day and pot worm adults fly at night.

Microorganisms have also been investigated for the control of pot worm at WUR. *Bacillus thuringiensis israeliensis* (Bti) is a soil bacterium which produces toxic proteins and a commercial product (Gnatrol) is now approved for use against sciarid fly on protected ornamentals in the UK. In an experiment at WUR, Bti (Culinex®) was added to coloured starch, since Bti must be ingested by the target pest to be effective. The coloured starch could be found in the gastrointestinal tract of the pot worm larvae, confirming that they had ingested the Bti. However, even a high dose of Culinex® did not affect the survival of pot worm larvae. The toxic proteins produced by Bti are more soluble in a high pH gastrointestinal tract. The pH of *L. cambria* larvae was tested and found to be around pH 5. It is likely that Bti did not affect pot worm larvae because the pH of their gastrointestinal tract is too low. The low pH could be due to the production of oxalic acid for webbing (Kruidhof, personal communication).

Four entomopathogenic fungi were tested for activity against *L. cambria* larvae at WUR: *Lecanicilium muscarium* (Mycotal), *Metarhizum anisopliae* (Bio 1020) and *Beauveria bassiana (*both Botanigard and a WUR isolate). There was no observed effect on the survival of *L. cambria* larvae compared with the control. In another experiment a natural entomopathogenic fungus, which was found on a pot worm larva, was bulked up and applied at 30 times the recommended concentration for Mycotal. This experiment led to fewer larvae surviving to become adults, compared with a control.

Entomopathogenic nematodes have previously been tested at WUR for activity against pot worms with success in laboratory conditions. However they have not been used with success on nurseries, probably due to the nematodes not being able to move or persist in the dry growing media and to them being easily flushed out of the bark substrate. In addition, Phalaenopsis production temperatures are often too high for nematodes. A small scale experiment was conducted at WUR with nematodes formulated in alginate capsules. Starch was also put in the capsules as a lure for pot worm larvae and there was some successful infection by nematodes. However on a larger scale there were issues with the capsules drying out at the top of the bark and application of the capsules to the centre of the pot is difficult in a growing product.

Insecticides

Previous research at WUR tested the efficacy of a range of chemical pesticides and biopesticides but none were effective (Pijnakker & Leman, 2013; Bennison & Brown, 2018). More recently, the efficacy of slug pellets containing metaldehyde was tested on *L. cambria*. The results showed that metaldehyde pellets did not negatively affect *L. cambria*, instead they benefitted pot worm population growth as the development time from larva to pupa was reduced.

Further Research

Biology

The tests carried out at WUR have been conducted on *L. cambria*. Further work is needed to establish whether the other species of pot worm are similarly affected and whether they are responsible for the same damage on Phalaenopsis. Greater clarification as to why pot worm larvae feed on roots could help to inform control strategies. For example, the starch may be needed to produce the acidic webbing. Stressed plants are more likely to suffer from pot worm damage, future research could investigate a link between orchid stress, root exudate production and pot worm damage. Further work on distraction with alternative food sources could also be useful, since the results from WUR were promising but not statistically significant. If successful, these alternative food sources could be used to deter pot worm from causing damage, enabling it to exist as a potentially useful predator. Alternatively, the substitute food could be used as part of the lure and kill strategy with nematodes, which could be an effective means of control if appropriately adapted to the nursery environment.

Cultural control

Further investigation is needed on the attraction of pot worm females to bark for egg laying. Pot toppers could provide a potential deterrent by masking the properties of the substrate that the females are attracted to. Any pot topper would need to be compatible with orchid cultivation and allow the aerial roots to grow. Methods to remove larvae from their webs could also be investigated, for example by vibrations to dislodge the larvae or addition of lime to neutralise the oxalic acid. Further work could investigate the effect of adding charcoal to growing media on the activity of pot worm larvae. Blue LED traps are used by UK and Dutch growers to monitor and reduce adult pot worm populations at a recommended rate of one lamp per 150m^2 (Anthura and IMAC, 2016; Bennison and Brown, 2018). Mass trapping of pot worm with these traps might be more effective and economically viable in combination with a lure. A potential lure could be 1-octen-3-ol, used for mosquitos (Bennison and Brown, 2018).

Biological control

PrediPal is an attractant product by Russell IPM, which could provide a new tool for pot worm control. It is designed to attract natural enemies into a crop before the pest population becomes damaging and may also act as a repellent to some pests. PrediPal consists of a signal molecule for systemic acquired resistance (SAR). Insect attack leads to SAR, a state of enhanced defense in plants (Wei *et al.*, 2005). When SAR has been induced some plants release herbivore-induced plant volatiles (HIPVs), which predators and parasitoids are attracted to, in order to aid location of their prey or hosts (Gurr and Kvedras, 2010). PrediPal is available in a controlled release polymeric dispenser and is reported to attract predators and parasitoids such as: ladybirds, hoverflies, lacewings, parasitic wasps and anthocorids. It is unlikely that SAR will have a repellent effect on pot worm adults, since it is the substrate rather than the plants that the females are attracted to for egg-laying (Marjolein Kruidhof, personal communication). As pot worm larvae are predatory it is even possible that pot worm adults will be attracted to HIPVs. Therefore, further investigation is needed into the effect of SAR on pot worm and other products which could be used as part of a 'push-pull' strategy. For example, the attractant Attracker, by Koppert, could be tested for use in luring pot worm larvae away from their webs.

The larvae of *C. attenuata* are predatory and could be worthwhile investigating as predators of pot worm. There is scope for further work on predators for pot worm. Spiders have been observed catching pot worm adults and the parasitoid *M. woelki*. Although not commercially available, methods for encouraging the spider population for control of pot worm could be investigated. It could also be beneficial to confirm whether earwigs will eat pot worm larvae and whether *D. coriara* may perform better in a different growing medium, such as that used for Phalaenopsis plugs, which are kept damper and could be better for *D. coriara* or nematodes.

Any methods for improving the culturing technique for pot worm would be beneficial for research and for potential culturing of *M. woelki*. Establishing whether the parasitoid is present in the UK or in other orchid nurseries in Europe may also help to identify its origin for commercial rearing. The naturally occurring entomopathogenic fungus could also be investigated for commercial feasibility.

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