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Location of work:	ADAS Boxworth
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[The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.]

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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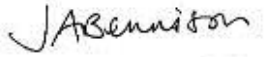

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GROWER SUMMARY

Headline

- Vine weevil adults continue to feed and lay eggs at temperatures as low as 6°C.
- A commercially produced plastic vine weevil trap is a more effective monitoring tool for adults than corrugated cardboard or grooved boards.
- Cuticular hydrocarbons from vine weevil adults may have potential for improving vine weevil monitoring.
- A 'little and often' system for applying reduced rates of entomopathogenic nematodes through the overhead irrigation could offer a more cost-effective strategy for control of vine weevil larvae than using high volume drenches without compromising on efficacy.

Background

Vine weevil is currently the most serious pest of UK hardy nursery stock (HNS). Chemical control of larvae is now difficult due to the withdrawal of the most persistent products for use in growing media and to current EC restrictions on using one of the available neonicotinoid insecticides (imidacloprid) on flowering plants. There is now more grower interest in controlling of weevil adults as well as larvae, and growers need more information on the efficacy and timing of insecticide sprays that are compatible with Integrated Pest Management (IPM) programmes, linked with further knowledge on weevil activity and egg laying behaviour. Growers are under increasing pressures to reduce the use of pesticides, not only to meet retail demands but also to meet the requirements of the EC Sustainable Use Directive (SUD) which states that all growers must use IPM where practical and effective. Many growers of HNS are now adopting biological pest control methods within IPM programmes. Available biological methods for control of vine weevil larvae include entomopathogenic nematodes. In soft fruit production, nematodes for vine weevil control are applied quickly and easily through drip irrigation but most growers of HNS need to apply nematodes using high volume drenches which is labour-intensive and thus expensive.

Objective 1. Improve understanding of the impact of environmental conditions on vine weevil biology and behaviour in order to optimise application of plant protection products

Background

Minimum temperatures (Objective 1.1.1) - Egg laying activity of vine weevil adults appears to cycle between periods of peak egg laying and periods where few or no eggs are laid. The causes of these cycles are not fully understood but are thought to relate to the nitrogen content in the host plant, and to temperature. As vine weevil adults do not enter a true diapause, temperature is important in determining when overwintering adults may start to lay eggs again in the spring and when egg laying finishes in the autumn. A minimum temperature of 12°C has been suggested for egg laying to occur but some other researchers report egg laying at lower temperatures. The aim of this objective is to investigate the minimum temperature for both egg laying and feeding to occur.

Summary

Minimum temperatures (Objective 1.1.1) – Vine weevil adults were placed individually in ventilated Petri dishes lined with damp filter paper and a strawberry leaf disc provided as a source of food. Petri dishes were placed into controlled temperature cabinets set to a constant 6, 9 or 12°C. Leaf area consumed and numbers of eggs laid were recorded. Vine weevil feeding and egg laying was recorded at all temperatures tested, indicating that 12°C is not the minimum temperature for these activities. In additional work in which vine weevil adults were kept at a constant 5°C very little feeding was recorded and few eggs were laid, suggesting that this may be close to the lower threshold for these activities.

Objective 2. Develop practical methods for monitoring adults in order to detect early infestations and inform control methods

Background

Monitoring (Objective 2.1) - Presence of vine weevil adults may be determined either directly or indirectly. Directly monitoring vine weevil adults can be done by simply searching through leaf litter, under pots or other suitable refuges during the day and after dusk by inspecting the crop for adults. Trapping of vine weevil adults reduces the amount of time required to monitor

crops and can be done at a more convenient time of day. Several techniques have been developed but grooved boards and corrugated materials such as cardboard are most widely used by growers. Experimentally, simple plastic crawling insect traps and pitfall traps have also been shown to be effective as vine weevil traps. Although there isn't currently a commercially produced vine weevil trap sold in the UK, a trap is available to monitor this pest in other countries. The aim of this objective is to compare the relative efficacies of the commercially produced vine weevil trap and other monitoring techniques used by growers.

Potential of lures to improve monitoring (Objective 2.2) - Research on attractants for vine weevil adults has until now focussed on the the odours (mainly compounds known as green leaf volatiles, which are produced by most plants when damaged) produced by host plants and weevil frass (insect droppings). Based on this research a patent has been produced for a vine weevil attractant based on plant volatiles. This lure has not, however, been shown to increase trap catches but rather to increase the number of weevils found within a radius of 60 cm of traps. As such there is a need to improve our understanding of the chemical ecology of vine weevil adults in order to improve the efficacy of lures based on volatile compounds. In addition, the lipid layer on the cuticle of the weevils may play a role in communication between vine weevil adults. The lipid layer of the insect cuticle is essential for their survival, preserving the insect from desiccation, cuticle abrasion and infection. However, in many insects, cuticular lipids, in particular the hydrocarbons, have evolved to become part of their communication system acting as short-range/contact pheromones involved in species and sex recognition. Given the aggregation behaviour of vine weevil, it is perhaps surprising that their cuticular lipids have not been studied previously. The aim of this objective is to identify and test the responses to compounds that may improve the efficiency of monitoring for this pest.

Summary

Monitoring (Objective 2.1) – A comparative study testing the efficacy of vine weevil monitoring tools was completed by establishing adult vine weevil populations of known density in large tent cages placed within a ventilated polytunnel. The efficacy of each monitoring tool was assessed by recording the number of weevils found but also how reliably the presence of vine weevil adults was indicated. Results from this experiment indicating the reliability of each monitoring tool are summarised below (Figure 1).

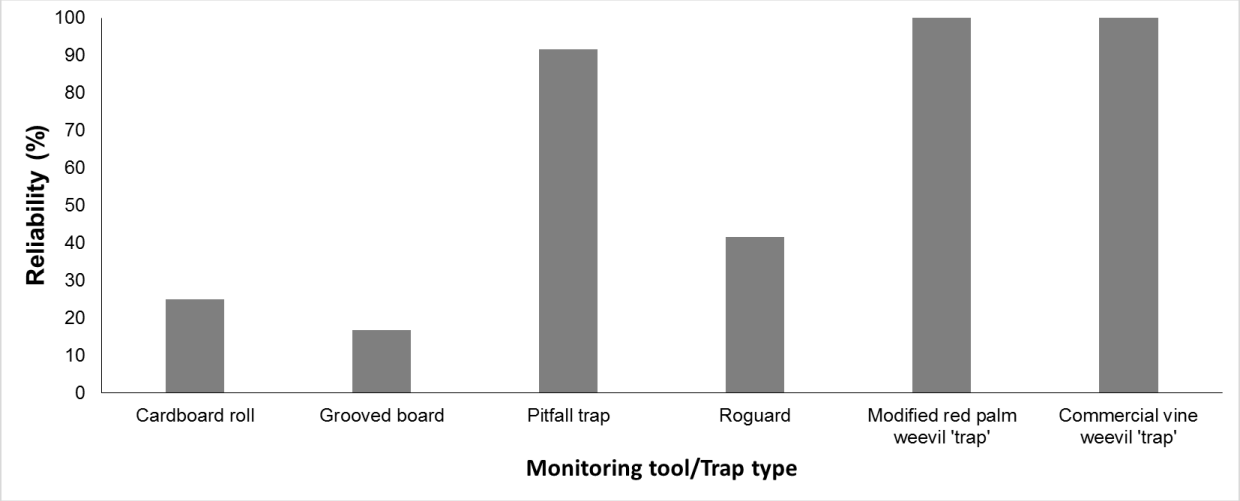

Figure 1. Reliability expressed as a percentage for the number of times out 12 assessments completed in which vine weevil adults were recorded in the monitoring tool/trap type (*n* = 12).

Potential of lures to improve monitoring (Objective 2.2) – Volatile compounds produced by large numbers of vine weevil adults were collected, and over 100 volatile compounds have been tentatively identified. As the weevils used had first been removed from host plant material and starved for 24 hours the majority of volatile compounds identified are unlikely to be associated with the host plant or insect frass.

Cuticular lipids were extracted from vine weevil adults and adults of a non-native species of weevil, *Otiorhynchus lavandus* sub-species *lavandus*, recently recorded on a soft fruit crop in the UK. Cuticular lipids were identified by GC-MS. Analyses of cuticular hydrocarbons from vine weevil adults and the non-native species showed that their compositions are quite consistent and different from each other, providing evidence that they are species-specific and could be used for species recognition. These have potential in use to improve vine weevil monitoring.

Objective 3. Improve best-practice IPM approaches including the use of entomopathogenic nematodes, fungi and IPM-compatible insecticides

Background

Pilot experiment testing little and often nematodes at ADAS Boxworth (Objective 3.1.1) - The method tested a 'little and often' approach for maintaining control of vine weevil larvae through

the season, applying reduced nematode rates through overhead irrigation compared with the standard full rates applied as high volume drenches.

Summary

Steinernema kraussei (Nemasys L) was applied to replicate plots of potted fuchsia plants infested with vine weevil eggs in a research polythene tunnel at ADAS Boxworth. The nematodes were applied at the recommended rate in September and October either as drenches comparable with the industry standard or through the overhead irrigation system, or at reduced rates (20% and 40% of recommended rate) applied through the overhead irrigation system five times between 1 July and 21 October. Water control treatments were applied either as a drench or through the overhead irrigation system.

All the nematode treatments were equally effective in significantly reducing numbers of vine weevil larvae per pot compared with the water controls. Both the reduced rates of nematodes applied as a 'little and often' system through overhead irrigation were as effective as the full rate applied twice as a drench (Figure 2) and could offer a less labour-intensive and more cost-effective application system than using high volume drenches. Further research is planned in 2017 to validate the system on a commercial nursery.

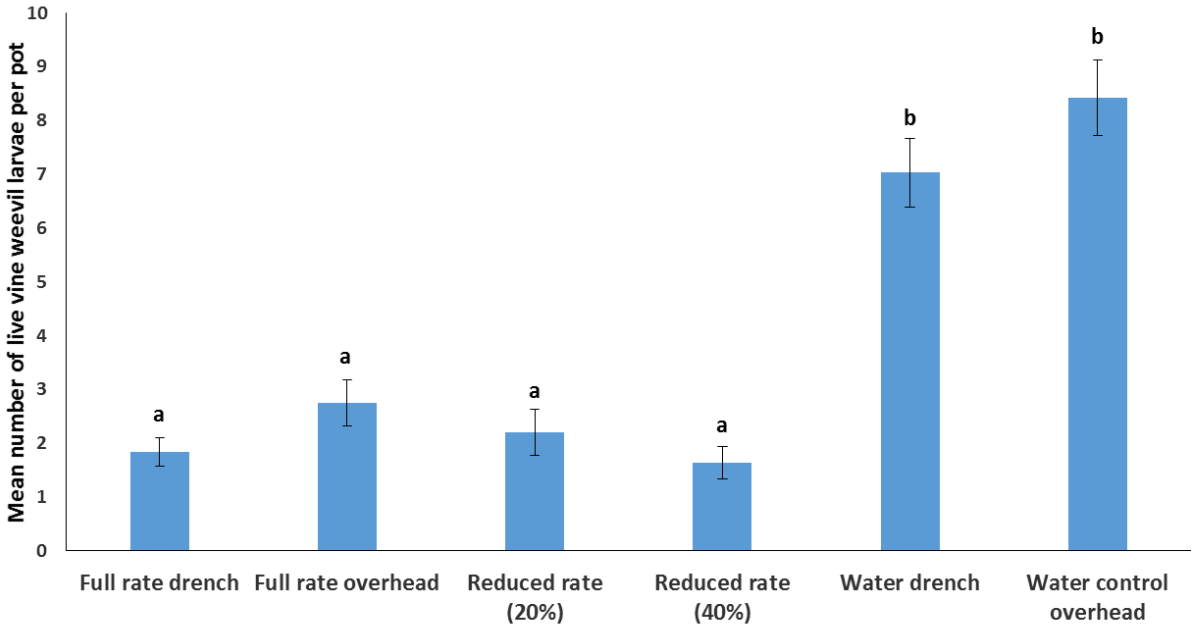

Figure 2 Mean numbers of vine weevil larvae per pot. Means +/- standard error. Bars with different letters significantly different (P<0.01).

Financial Benefits

Various entomopathogenic nematode species and products are available for vine weevil control (see AHDB Horticulture Factsheet 24/16). Many growers choose to use *Heterorhabditis bacteriophora* when growing media temperatures are suitable (minimum 12-14°C depending on product) and *Steinernema kraussei* at lower temperatures (minimum 5°C). It is estimated that it takes five hours labour to apply a high volume drench of nematodes to an area of 1000m^2 with 3L pots but only one hour to apply them through the overhead irrigation. Taking into account the costs of two consecutive drenches of nematodes at recommended rates (one of *H. bacteriophora* and one of *S. kraussei),* it is estimated that applying 40% rates of the same products five times through the overhead irrigation (four applications of *H. bacteriophora* and one application of *S. kraussei*) would be equal to the cost of two full-rate drenches whereas applying 20% rates five times through the overhead irrigation would save 44% of the cost. Cost savings of applying reduced rates of nematodes five times through the overhead irrigation would be greater if growers currently apply three consecutive drenches of nematodes at recommended rates (two of *H. bacteriophora* and one of *S. kraussei*) i.e. a saving of 30% if using 40% rate and 60% if using 20% rate.

Action Points

- Monitoring for vine weevil adults should begin in the spring when temperatures rise above the threshold of 6°C and continue until the autumn/winter when temperatures decline below this threshold once more.
- Consider using plastic plant trays, pitfall traps, plastic crawling insect traps or where available commercial vine weevil traps instead of or as well corrugated cardboard and grooved boards to monitor for the presence of vine weevil adults.
- The ‘little and often’ system of applying entomopathogenic nematodes through the overhead irrigation needs validation on a commercial nursery and on a range of plants with different architectures before it can be recommended for grower uptake.