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MANAGING AVOCADO PESTS WITH ROMANCE, INTRIGUE AND WAR – INTEGRATING PHEROMONES, ASSASSINS AND WEAPONS OF MASS DESTRUCTION

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SUMMARY

Avocado growers continually wage war on pests that ravage their crops. For the last 60 years, crop protection tradition fostered by the generally excellent results achieved, has been to use weapons of mass destruction in the form of chemical pesticides to combat the enemy. Issues of chemical resistance development in target species, chemical residues in fruit and the environment, and improving the safety of orchard workers are some of the drivers for the development of alternative pest management strategies. Conservation biological control of some pests using natural populations of assassins, achieved through the use of minimally disruptive pesticides in conjunction with smart tactics that take advantage of specific behavioural characteristics of target species, are being investigated to reduce the overall use of chemicals. For some pests, the molecular messages (semiochemistry) that enable insects to find mates and host plants are being investigated.

KEY WORDS: Avocado pests, pheromones, fruitspotting bugs, parasitoids

INTRODUCTION

The improved management of insect and mite pests of tree crops is an on-going and evolving process. The modern era of pest control was heralded by the discovery and development of organic pesticides in the mid-1900s, and the 'war philosophy' quickly became the focus of control. These new weapons provided humans with a real strategic advantage in their battle with pests and diseases. Insecticides and fungicides generally provided opportunities for increased crop production and quality of produce never before seen nor imagined. As wonderful and beneficial as these compounds have proven to be, history also shows that there have been some negative aspects associated with their use, and that the traditional pest control approach is flawed.

Apart from the many environmental and health issues associated with pesticide usage, the use of insecticides in particular is often counterproductive. Chemicals that kill most pests in an orchard can be very useful, but there will always be some species that escape and require additional sprays when they multiply in the absence of their natural enemies. Moreover, sooner or later resistant pest populations will evolve, requiring a switch to alternative chemicals. Of course it is now universally recognized that an integrated approach to pest management is the most desirable course to steer. Chemical controls will always feature prominently in many systems, but biological controls and clever manipulation of insect communication systems and behaviour hold promise for the development of smarter, effective management systems.

Table 1: Common insect and mite pests of Queensland avocados

Pest	Status	Management
Fruitspotting bugs – two species	Major	Endosulfan, β-cyfluthrin - frequent sprays required throughout season Limit β-cyfluthrin sprays to limit scale and mite problems. Utilize hotspots and trap trees
Ivy leafroller	Minor, but may be a major in some areas – infestations inconsistent	Monitor, pheromone available Spray with tebufenozide Biological -heavily parasitised
Latania scale	Minor, but may be induced by FSB sprays to become a major problem	Methidathion Biopest oil and biological (*Aphytis* spp., lacewings)
Tea red spider mite	Minor – may be induced by FSB sprays	Fenbutatin-oxide Biopest oil and biological (*Stethorus* sp.)
Ectropis looper	Major in some areas	Methomyl Biological (*Apanteles* sp.)
Fruit fly	Minor	Pheromone available (Cuelure) Dimethoate cover sprays Bait sprays -Naturalure®
Red shouldered leaf beetle	Minor -sporadic	Carbaryl, endosulfan Treat individual trees
Thrips	Minor	Endosulfan
Fruit borer	Minor	β-cyfluthrin Pheromone possible, not yet investigated
Various caterpillars (mostly loopers)	Minor	Suppressed by FSB sprays and biological agents

In Queensland, the avocado pest complex would be relatively easy to manage if were not for the fruitspotting bugs. Depending on the location of orchards with respect to district and local vegetation, numerous sprays may be applied each season to prevent excessive damage from these bugs. While insecticide applications remain the frontline defence, research conducted over the last twenty years has attempted to identify specific aspects of the bugs' ecology and behaviour that might be used to assist and improve fruitspotting bug management (Aldrich *et al*., 1993; Waite and Huwer, 1998; Waite *et al.*, 2000; Waite, 2004). Because chemical sprays aimed at fruitspotting bugs dominate the pest management scene in Queensland avocados, the type of chemical applied impacts significantly on the whole orchard ecosystem. An efficient IPM system will control the bugs effectively and suppress less important pests either through the direct effect of the bug sprays, or conservation biological control where most of the natural enemies of pests are able to survive and continue to exert background control. The avocado pest complex with current management options is listed in Table 1.

The development of an IPM system involves the combination and testing of many different approaches for beating the enemy. This includes tricking amenable pests by romancing them through the use of pheromones and other chemicals (collectively known as semiochemicals) that govern their daily lives. These can be used to lure them to traps with the promise of a mate, or to disrupt their love life by releasing enough of the pheromone to confuse them. Using undercover agents, nature's own assassins in the form of predators, parasitoids and diseases we can attempt to maintain a stable, non-economic population of potential pest species. When this subterfuge doesn't work, the real weapons of mass destruction, broad spectrum insecticides, may be invoked. The resultant flare-up of previous minority pest groups that often follows such use might be likened to the terrorist cadres that infiltrate and disrupt supposedly stable nations after military 'successes'!

MATERIALS AND METHODS

Information on the lifestyle preferences and requirements of various avocado pests has been acquired from continuous field and laboratory observations and experiments conducted over many seasons throughout avocado growing districts of Queensland. Common grower practices were monitored to determine the most effective and practical approach to pest management, and how various pests and their natural enemies reacted to certain chemicals.

Most research has been concentrated on fruitspotting bugs. Because they have a wide host range and are more easily observed on some alternative hosts, these have also been used. Behavioural data indicated that immigration of fruitspotting bugs into orchards is often initially manifest as 'hotspots', which are usually adjacent to natural bug habitat or untended orchard trees. Field trials were conducted to investigate this phenomenon and to determine if monitoring could be successfully focused on these areas, and targeted sprays applied to them. The relative susceptibility of avocado cultivars was also investigated by recording bug damage inflicted on the fruit of certain cultivars throughout consecutive seasons.

For the pheromone investigations, laboratory cultures of fruitspotting bugs (both *Amblypelta nitida* and *Amblypelta lutescens*) were utilized by caging males and females separately, collecting volatile compounds emitted by them on activated charcoal, and analysing these samples by GCMS (Gas Chromatograph/Mass Spectrometer) as described by Aldrich *et al.,* 1993. Antennae of female *A.nitida* connected to an electroantennogram device were stimulated by an aeration sample collected from male bugs. This was co-injected into a linked GCMS. Blends of presumed pheromone components were tested in the field using loaded rubber septa that were placed inside a sticky ‘football trap’ hung in host trees.

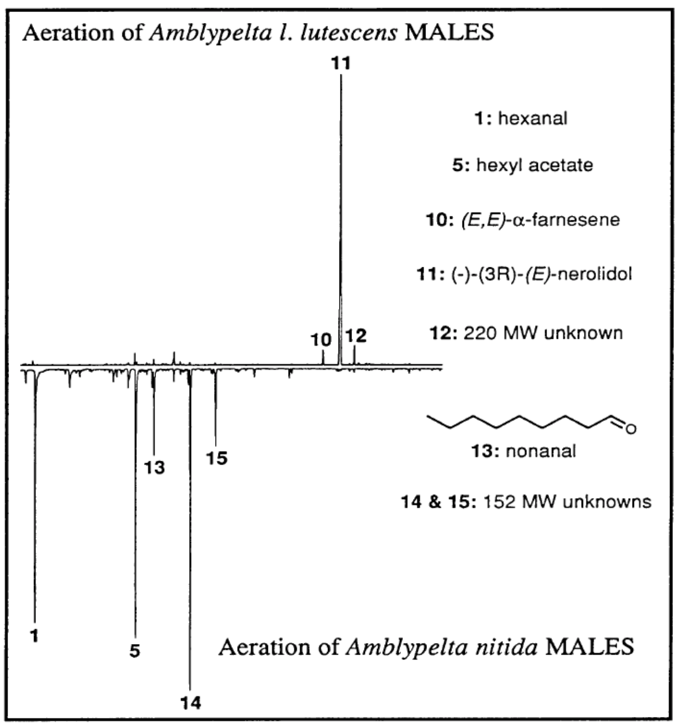
To broaden the semiochemical research, volatile chemicals emitted by green fruit and flowers of some common bug hosts were collected using SPME (Solid Phase Microextraction), and analysed by GCMS.

RESULTS AND DISCUSSION

The romance

Insects relate to their environment and one another through chemical cues. Finding a mate is fundamental to the existence of animal species. Entomologists have long recognised that the process of mate finding represents an opportunity for us to manipulate this if the chemicals that mediate it can be identified. The pheromones of many insects have been elucidated and some are now used in various situations to attract individuals to traps, or to disrupt the mating sequence.

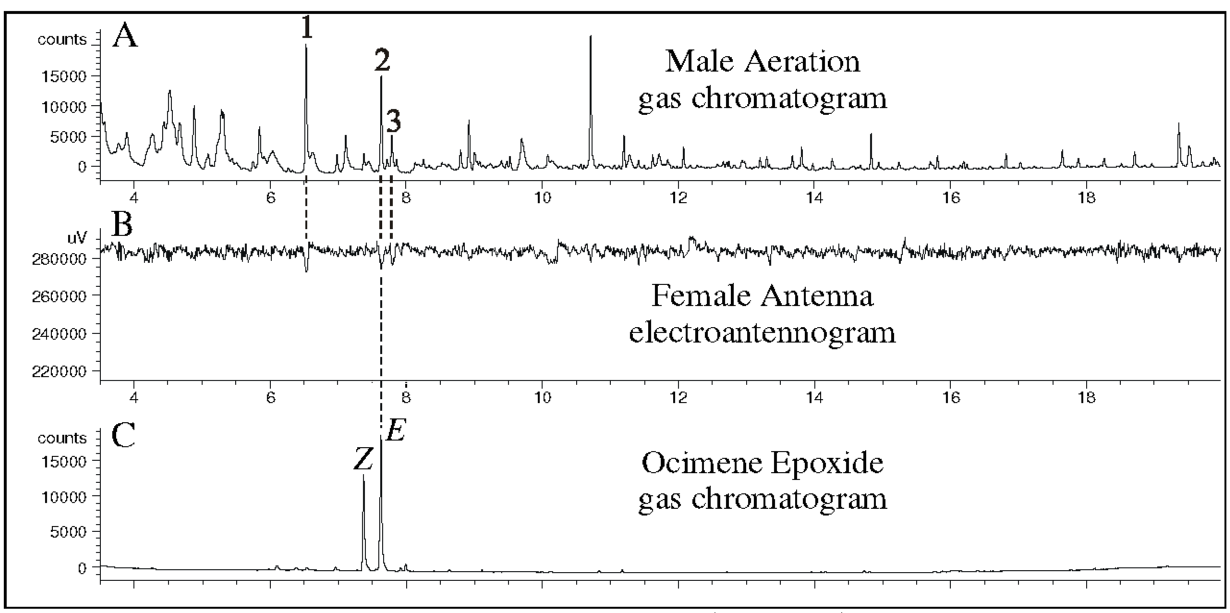
Figure 1: Identification of pheromone components from original fruitspotting bug aerations, 1991 (Aldrich *et al.* 1993).



Most insect pheromone research and application has been associated with the Lepidoptera (moths and butterflies), but other insect groups are receiving increased attention. The pheromones of true bugs such as the fruitspotting bugs seem to be more difficult to come to terms with, but there have been some successes (Aldrich and Cantelo, 2000). The fruitspotting bugs have proven to be especially difficult, since we have found no specific pheromone glands that can be dissected to extract the chemicals from either sex. In true bugs, the males often produce the pheromone. Despite the lack of glands, the aeration technique has allowed us to acquire samples from males of what is presumed to be the pheromone for each *Amblypelta* species. Figure 1 shows our conclusions from the first season's research way back in 1991. For *A. lutescens*, two of the three components were identified, α-farnesene and E-nerolidol. The 220 MW compound remains unknown. For *A. nitida*, only nonanal was initially identified, leaving two unknown compounds. Subsequently Dr Chris Moore, the QDPI&F project organic chemist, determined that one of these compounds was a new chemical, β-ocimene-epoxide (myroxide), which could not be found in the chemical database when the original analyses were carried out in 1991. The other unknown is now considered to be an artifact of the particular sample analysed.

Myroxide is now manufactured by a Swiss perfume company (Firmenich), so that large quantities are available for purchase. When an aeration sample from male *A. nitida* was puffed onto the excised antenna of a female of the same species connected to an electroantennogram device that was linked to a Gas Chromatograph, the antenna reacted to the compounds numbered 1, 2, and 3 in Figure 2. The antennal reaction to compound 2 aligned perfectly with the standard for the E-isomer of ocimene-epoxide (myroxide). The other two reactions noted in the EAG were to nonanal (seen in the original analysis) and decanal (not seen previously).

Figure 2: A. Gas chromatogram for aeration extract of *Amblypelta nitida* males (60m DB-WAXetr; 80°C for 2 minutes to 250°C at 10°C/min, hold 10 minutes). **B**. Electroantennogram detection using *Amblypelta nitida* female antenna**. C**. Gas chromatogram of a synthetic standard of beta-ocimene epoxide ('myroxide', Firmenich Inc. Switzerland).



The three compounds, myroxide, nonanal and decanal, which elicited responses in the female *A. nitida* antenna, were blended and used to coat a rubber septum that was placed inside a football-shaped bug trap hung in a fruiting longan tree at Maroochy Research

Station. Within a couple of hours of its being deployed, a female *A. nitida* had alighted on the trap. While this was a promising outcome, no more individuals arrived. These chemicals are quite volatile, and they may have dissipated within a few hours. Further experiments with varying ratios and concentrations of the components are required. Electroantennogram experiments for *A. lutescens* remain to be carried out. Investigations into whether the suggestion of a good meal as a bonus might sway the amorous tendency of female bugs have commenced. The starting point for this is attempting to identify the volatile chemicals emitted by host fruit.

The ivy leafroller, *Cryptoptila immersana*, can sometimes cause significant damage to Queensland avocados. The female sex pheromone of *C. immersana* was identified by researchers at CSIRO, Canberra (Horak, 1988), and trials conducted on The Sunshine Coast demonstrated that it could be used in traps to monitor moth populations.

The intrigue

The wonderful thing about Nature is that every living thing has its own suite of enemies. These enemies may be numerous or not, debilitating or just a nuisance, large or microscopic. And it's just as well this army of opposition exists to balance everything out! Without interference from us, Nature copes quite well in balancing different animal, plant and insect populations, but of course the result is not always good enough to suit the demands of farmers growing crops in modern mass monocultures. Insect populations living within ecosystems live continuously with the threat of predation and parasitism. Natural enemies infiltrate their host populations, becoming silent killers that gradually reduce host numbers. Without these assassins, suppression of many potential pest problems would be much more difficult. For instance, latania scale, *Hemiberlesia lataniae*, can be found on most avocado trees, but in a well-managed orchard it rarely becomes noticeable. Research revealed that parasitism by several tiny wasps, and predation by lacewings and ladybirds normally keep it in check (Waite, 1988), but under conditions of extreme disruption of these natural enemies the scale will become a problem.

Similarly, tea red spider mite, *Oligonychus coffeae*, can be suppressed by the ladybird, *Stethorus* sp. However endosulfan, even though it is regarded as being relatively safe for use in IPM systems, when applied frequently for fruitspotting bug control, was found to disrupt *Stethorus* populations, allowing the mite to multiply and cause severe bronzing of the foliage. This usually occurs in late summer after numerous spotting bug sprays have been applied.

In 1989 a trial conducted to find a suitable chemical control for the ivy leafroller, *Cryptoptila immersana*, had to be abandoned because of the extensive parasitism of the larvae, which compromised the data for chemical efficacy. From this it is inferred that this pest may also occasionally be a problem which is induced by the use of inappropriate pesticides that disrupt its numerous natural enemies. Fruitspotting bugs too are attacked by a suite of egg parasitoids (Fay and Huwer, 1993; Waite and Petzl, 1997) which have their greatest impact late in the season. This parasitism occurs mostly in breeding areas outside of orchards and impacts too late to reduce the number of bugs migrating into avocado orchards and causing economic damage. Even so, such parasitism is still important from a seasonal point of view as it reduces the number of bugs that over-winter and start the cycle in spring.

The war

The employment of romance and intrigue is effective and desirable when the enemy is susceptible and amenable to such ploys. However, when the opposition is more robust and employs 'hit and run' tactics, a different strategy may be required. This has been found to be the case with fruitspotting bugs, which breed in natural forest and a range of exotic fruit and ornamental plant species from which they continuously migrate into avocado orchards. Some other avocado pests have a different *modus operandi*, and infest orchards through the establishment of discrete populations at certain times in the season. For example, leafroller infestations may arise from the egg-laying activity over several nights of many moths that emerged together, forming a generational cohort. Such pests might often be dealt with for the season with one well-timed spray. On the other hand, in very susceptible locations, fruitspotting bugs demand that growers be on a constant war footing, with repeated 'blanket bombing' of orchards required. The challenge under these circumstances is to conduct a successful war against the bugs, while causing minimal collateral damage to the natural enemies of other pests as described above.

The efficacy and value of numerous chemical weapons used against fruitspotting bugs have been evaluated over the years. Current recommendations regarding the weapons of choice take into account not only efficacy, but also the collateral damage and the risk to farm personnel and the environment. Despite its dubious environmental credentials, endosulfan has been preferred over methidathion and pyrethroids (Table 2), mainly because it has consistently performed satisfactorily without inducing outbreaks of pests such as scales that can be difficult to manage. Despite its continued use over many years there is no evidence of fruitspotting bugs becoming resistant to endosulfan.

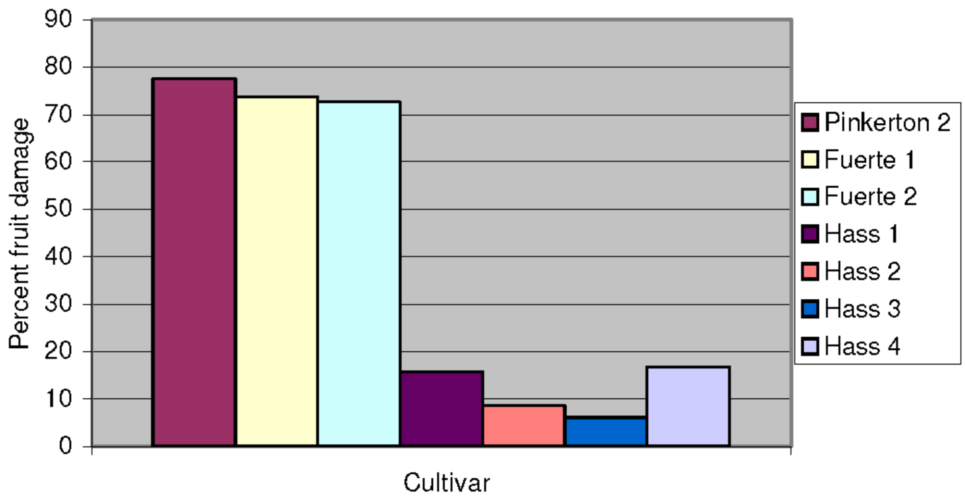
Table 2. Comparison of properties of various weapons of choice for fruitspotting bug control.

Weapon	Collateral damage to beneficials	User safety	Environmental effects	Efficacy vs. FSB
Endosulfan	Minimal	Moderately toxic	Negative on aquatic species	Good - poor residual
Methidathion	Severe	Highly toxic	Disruptive in the orchard	Good - poor residual
Pyrethroids	Severe	Low-moderate toxicity	Disruptive in the orchard	Good – moderate residual

Research into the behaviour of fruitspotting bugs has suggested that orchard-wide deleterious effects of broad spectrum insecticides used for bug control might be moderated by restricting the target area to which they are applied. It was found that the bugs tend to infest orchards via certain pathways, which gradually develop into 'hotspots'.

Once these hotspot areas are identified, an efficient surveillance programme that often may be just a border patrol can be used to detect enemy activity in these areas, and controls applied to the hotspots as activity is detected. This action can be restricted to the areas of insurgency, and because such areas are relatively small in relation to the whole orchard, heavy bombardment with 'guided missiles' and 'smart bombs' that don't disrupt the whole orchard ecosystem, is possible. Hotspot areas can be made more effective by planting them to cultivars such as 'Fuerte', which research has found appears to be especially attractive to fruitspotting bugs (Figure 3) (Waite, 2004). However, the conditions that lead to the development of a strong hotspot will override the apparent non-preference of a cultivar such as 'Hass'.

Figure 3: End of season fruitspotting bug damage on unsprayed tree/cultivar (single trees), Maroochy Research Station 2003-04.



CONCLUSIONS

An understanding of the avocado ecosystem and the lifestyles of the pests that affect the crop is vital for developing effective and sustainable strategies for pest management. While a broad, generalised approach to pest management can be recommended for the crop grown in Queensland, local conditions in each growing locality determine which species are the key pests. In areas where fruitspotting bugs are prevalent the tactics employed to manage them need to be tailored to minimise the fall-out for natural enemies and the environment. Until a pheromone or other attractant that is useful for monitoring fruitspotting the bugs is perfected, the adoption of targeted strategies such as the use of hotspots and trap or decoy trees is recommended.

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