Development and commercialisation of pheromone products in New Zealand

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Abstract The sale of pheromone traps, lures and mating disruption products for horticultural insect pest species has grown steadily since the late 1980s, with expanding sales to New Zealand growers from Plant & Food Research (PFR) and its predecessors. New biosecurity incursions led to pheromone identifications for delimitation and pest management of other species. Mating disruption products were developed to target leafrollers, currant clearwing, codling moth and oriental fruit moth. In 2010-11, the activity involved with production of > 30 pheromone products was sold as a business unit by PFR to a New Zealand company. In addition, the first legislative group standard for plant protection products was drawn up to enable future development of straight-chained lepidopteran sex pheromones, under New Zealand's Environmental Protection Authority. The availability of pheromone products to assist with decision support and pest management is now subject to market forces.

Keywords pheromone, trap, mating disruption, group standard.

PHEROMONE IDENTIFICATION FOR TRAPPING AND MATING DISRUPTION

Since the first moth sex pheromone identification by a German Nobel prize winner in 1959, there has been a steady expansion in this research field, with thousands of lepidopteran pheromones identified; these have been summarised into a comprehensive database (El-Sayed 2012). There has also been a major worldwide expansion of pheromone products for Integrated Pest Management (IPM) with extensive use in traps, as well as direct control using mating disruption products (Witzgall et al. 2010). This review briefly summarises the identification and development to commercialisation of moth sex pheromones

in New Zealand, since Wearing & Charles (1978) first reported the use of codling moth traps here, after this pest's sex pheromone was identified in the USA (Roelofs et al. 1971).

Local identifications of sex pheromones for New Zealand in the 1980s primarily focussed on the native tortricid leafrollers that were pests of horticulture and related species (Galbreath et al. 1985; Young et al. 1985; Foster & Roelofs 1987; Foster et al. 1990; Clearwater et al. 1991; Foster & Dugale 1991; Foster et al. 1993). A lack of commercial availability led to the development of pheromone lures and trap products for a range of horticultural pest species and sales from the late 1980s by the then government organisation, the

Department of Scientific and Industrial Research. The demand for pheromone traps continued to rise after the identification of pheromones or sex attractants for pest species native to New Zealand, as well as important cosmopolitan species (Table 1). The supply of traps supported the development of IPM programmes (Suckling et al. 1990; Shaw et al. 1993; Walker et al. 2001; Suckling et al. 2008; Walker et al. 2011). Since then, this activity has grown steadily with sales of traps and lures (Table 1) and mating disruption products developed by a Crown Research Institute

(HortResearch, and more recently Plant & Food Research, PFR), following the Crown Research Institute Act (1992). There were identifications and refinements for a wider range of pest species, some native and some cosmopolitan or invasive (Table 1). Some pheromones have required refinement for application in New Zealand, due to variations in blend between taxa (e.g. Foster et al. 1990). This was the case with the diamondback moth, after it was discovered that lures published elsewhere were relatively ineffective (Suckling et al. 2002). New biosecurity incursions led to

Table 1 Predominant pheromone or sex attractant lure products produced and used in New Zealand for monitoring pest or beneficial moths.

Scientific name	Family	Common name	Reference(s)
<i>Agonopterix ulicitelletta</i>	Oecophoridae	Gorse shoot moth	Suckling et al. 2000
<i>Agrotis ipsilon</i>	Noctuidae	Greasy cutworm	Hill et al. 1979
<i>Chrysodeixis eriosoma</i>	Geometridae	Green looper	Benn et al. 1982
<i>Cnephasia jactatana</i>	Tortricidae	Black lyre moth	Foster et al. 1993
<i>Coscinoptycha improbana</i>	Carposinidae	Guava moth	Gibb et al. 2006
<i>Ctenopseustis herana</i>	Tortricidae	Brownheaded leafroller	Foster & Roelofs 1987
<i>Ctenopseustis obliquana</i>	Tortricidae	Brownheaded leafroller	Young et al. 1985; Foster et al. 1987
<i>Cydia pomonella</i>	Tortricidae	Codling moth	Roelofs et al. 1971
<i>Cydia succedana</i>	Tortricidae	Gorse pod moth	Suckling et al. 1999
<i>Epiphyas postvittana</i>	Tortricidae	Light brown apple moth	Bellas et al. 1983, El-Sayed et al. 2011
<i>Graphania mutans</i>	Noctuidae	Grey-brown cutworm	Fr��rot & Foster 1991
<i>Grapholitha molesta</i>	Tortricidae	Oriental fruit moth	Roelofs et al. 1969
<i>Helicoverpa armigera</i>	Noctuidae	Tomato fruitworm	Rothschild 1978
<i>Heliothis punctiger</i>	Noctuidae	Native budworm	Rothschild 1978
<i>Hetercrossa rubophaga</i>	Carposinidae	Raspberry bud moth	Foster & Thomas 2000
<i>Herpetogramma licorsalisalis</i>	Crambidae	Tropical grass webworm	Gibb et al. 2007
<i>Phthorimaea operculella</i>	Yponomeutidae	Potato tuber moth	Fouda et al. 1975
<i>Planotortrix excessana</i>	Tortricidae	Greenheaded leafroller	Foster et al. 1990
<i>Planotortrix notophaea</i>	Tortricidae	Greenheaded leafroller	Foster et al. 1990
<i>Planotortrix octo</i>	Tortricidae	Greenheaded leafroller	Foster et al. 1990
<i>Plutella xylostella</i>	Plutellidae	Diamondback moth	Tamaki et al. 1977; Suckling et al. 2002
<i>Phthorimaea operculella</i>	Gelichiidae	Potato tuber moth	Roelofs et al. 1975
<i>Prays nephelomina</i>	Yponomeutidae	Citrus flower moth	Gibb et al. 2005
<i>Sceliodon cordalis</i>	Crambidae	Poroporo stem borer	Clearwater et al. 1986
<i>Spodoptera litura</i>	Noctuidae	Tropical armyworm	Tamaki et al. 1976
<i>Symmetrischema tangolias</i>	Gelechiidae	Tomato stem borer	Griepink et al. 1995
<i>Synanthdon tipuliformis</i>	Sesiidae	Currant clearwing	Voerman et al. 1984; Suckling et al. 2005
<i>Uraba lugens</i>	Nolidae	Gum leaf skeletoniser	Gibb et al. 2008

pheromone identifications for delimitation and pest management of guava moth, citrus flower moth, tropical grass webworm and gum leaf skeletoniser (Table 1). Some lures, such as those for fall webworm *Hyphantria cunea* (El-Sayed et al. 2005), were developed for use by the Ministry of Agriculture and Forestry (now Ministry for Primary Industries) for surveillance in New Zealand, and provided to overseas co-operators to assist with the development of a phenology model for this species (Kean & Kumarasinghe 2007).

Mating disruption is an approach that utilises sex pheromones for direct control of insect pests, by reducing mate location and subsequent generations. First trialled against codling moth using hollow fibres in the late 1970s (H. Moffat & C.H. Wearing, personal communication), this technique was then further developed in the 1980s and 1990s targeting lightbrown apple moth, currant clearwing, native leafrollers, codling moth and oriental fruit moth (Suckling and Clearwater 1990; Thomas & Burnip 1991; Suckling & Shaw 1995; McLaren et al. 1998; Lo & Cole 2007; Walker et al. 2011; Suckling et al. 2012). Research revealing promising pest suppression

using mating disruption was also conducted on citrus flower moth (L.E. Jamieson, Plant & Food Research, unpublished data) and guava moth (D.M. Suckling, unpublished data). Until recently, the development of polyethylene tubing dispensers (ISOMATE®) has dominated the New Zealand mating disruption product range (Table 2). Lure and kill systems have been investigated for lightbrown apple moth and codling moth (Suckling & Brockerhoff 1999), but to date only mating disruption products have been sold.

COMMERCIALISATION OF PHEROMONE PRODUCT PRODUCTION

In 2010-11, the pheromone business, with more than 30 products including ISOMATE® products from Japan, was divested by PFR to a New Zealand company, ETech Crop Solutions Ltd. Meanwhile, research into new or innovative products including those targeting multiple species (Walker et al. 2011; Suckling et al. 2012) continues to be developed by PFR, as this aligns with its core purpose. Other companies are also now selling mating disruption products into the New Zealand market for some moth pests (Table 2).

Table 2 Pheromone mating disruption products registered in New Zealand for control of a range of moth pests. Such products can now be covered by the group standard (HSR100628; see Boyd-Wilson et al. (2012) and Anon. (2012)).

Product	Technology	Target species
ISOMATE®-C Plus	Polyethylene tubing	<i>Cydia pomonella</i>
ISOMATE® CC	Polyethylene tubing	<i>C. pomonella</i>
ISOMATE®-CM FLEX	Polyethylene tubing	<i>C. pomonella</i>
CheckMate® CM-XL1000	Membrane	<i>C. pomonella</i>
Halo™ C-S Pheromone Insect Confusion Agent	Polyethylene tubing	<i>C. pomonella</i>
No-Mate CM	Spiral	<i>C. pomonella</i>
ISOMATE®-C TT	Polyethylene tubing	<i>Grapholita molesta</i>
ISOMATE® LBAM Plus	Polyethylene tubing	<i>Epiphyas postvittana</i>
ISOMATE® OFM Rosso	Polyethylene tubing	<i>G. molesta</i>
ISOMATE® CFM	Polyethylene tubing	<i>Prays nephalomima</i>
ISOMATE® Three NZ Leafroller	Polyethylene tubing	<i>E. postvittana</i> , <i>Planotortrix octo</i> , <i>Ctenopseustis obliuana</i>
ISOMATE® 4Play	Polyethylene tubing	Several species of leafrollers, <i>C. pomonella</i>
Isonet Z	Polyethylene tubing	<i>Synanthedon tipuliformis</i>
Puffer CM	Aerosol spray	<i>C. pomonella</i>

Pheromone lure sales by volume have fluctuated over time. After a steep increase over the last few years, sales have stabilised, along with more concentrated lures designed for use with monitoring traps under mating disruption in apple orchards. To some extent the expansion of mating disruption of codling moth was a consequence of regulatory requirements to meet export standards of New Zealand fruit products. This type of product use information has facilitated the adoption of IPM and compliance programmes against particular pests required for export fruit. The original development of the pheromone business by the New Zealand government was in response to a lack of commercial activity by the horticultural sector in this area, but today these products support many millions of dollars of export horticultural products.

Although the pheromone tools were developed from the 1980s onwards, economic use patterns by growers typically took longer to establish. The time for adoption of early IPM programmes in apples and kiwifruit was about 5 years (Suckling et al. 2003), but in a number of cases, pheromone lures have been made available but use patterns remain poorly developed. Today, the presence of several companies actively selling products in the New Zealand market (Table 2) signals the role of pheromone technologies in the market-led adoption of IPM practices. However, for some pest species, the low initial demand for lures or disruption products represents a risk that is sometimes referred to as “the valley of death” between discovery and economic market activity. Up until now, government-funded science providers have been responsible for production of products to enable research and innovation to continue in the pest management field. However, now that pheromone production has been commercialised, supply of low volumes of lures may be at risk, especially for pests of limited geographic range or affecting minor markets. The cost of developing and maintaining some products may be unjustifiable when the size of the potential pheromone market is small. This will potentially be a major issue for the smaller sectors.

FUTURE OUTLOOK

Straight chain lepidopteran sex pheromones are considered to be hazardous substances in New Zealand, and as such require regulation by the Environmental Protection Authority. However, a legislative group standard for straight-chained lepidopteran sex pheromones (Boyd-Wilson et al. 2012) has just been approved by the Environmental Protection Authority. This group standard removes the requirement for individual approval of every species-specific moth pheromone. This means that in the future, mating disruption products such as those in Table 2 would not require individual approvals, reducing upfront development costs. Where data are not available for a particular substance, this group standard makes allowance for data from an appropriate analogue to be provided.

Several internationally-based companies, including Suterra LLC (Bend, Oregon), Scentry Biologicals Inc. (Billings, Montana) and Shin-Etsu Fine Chemicals (Tokyo) are now actively selling moth pheromone products through distributors into New Zealand, and it seems likely that the drivers for more sustainable insect control methods will not reduce in the near future. Rather, demand for such products is likely to continue to increase as fruit and vegetables with reduced residue profiles are increasingly sought by international markets. The group standard for straight-chained lepidopteran sex pheromones should permit the involvement of more pest management companies, use of more products and greater innovation by New Zealand growers, although the small market size will continue to limit development.

The group standard unfortunately does not cover other insect pheromones that are not from Lepidoptera, but may have similar potential for use in IPM. Examples include sex pheromones of mealybugs (Homoptera: Coccidae) (El-Sayed et al. 2010) and apple leaf curling midge (Diptera: Cecidomyiidae) (Cross & Hall 2009). These compounds are likely to be of similar risk profile to the above pheromones, and are active in milligram or microgram quantities, but unfortunately lack the toxicological research data required to demonstrate this to regulatory authorities. This lack of evidence

of safety could prevent the commercial use and uptake of these low-risk materials.

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