Bio-Protection

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The New Zealand Institute for Plant & Food Research Limited

New approaches to thrips pest management using semiochemicals

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New approaches to thrips pest management using semiochemicals

1. Introduction
2. Semiochemicals
3. Lure Discovery
4. Behavioural Response
5. Variable Efficacy
6. **Pest Management**

Thrips as research focus

- Thrips are important pests
  - » cultivated plants (agriculture, horticulture, forestry)
  - » causing direct damage and virus transmission
- Difficult to control
  - » Attributes: polyphagy, vagility, rapid reproduction, cryptic behaviour and insecticide resistance
- Strong interest in alternative/additional control methods
  - » incl. semiochemicals (pheromes/allelochemicals)

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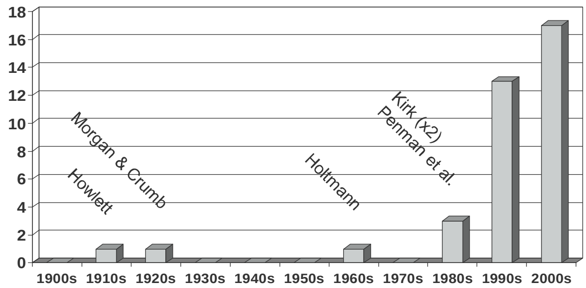
Thrips lures: historical

Publications on thrips attractants/lures



Source: Koschier 2008. Nat. Prod. Comm. 3

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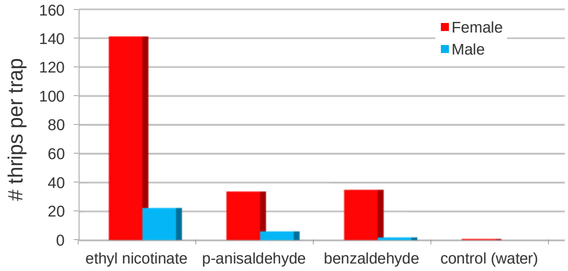
Thrips lures: historical

Response of NZ Flower Thrips (summer)



Source: Teulon 1988

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New Zealand flower thrips on grape flowers

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Semiochemcials
chemicals that mediate interactions between organisms

Allelochemicals
chemicals that are significant to individuals of a species different from the source species

Pheromones

Allomones — *favorable to the emitter but not the receiver*

Kairomones — *favorable to the receiver but not the emitter*

Synomones — *favorable to both emitter and receiver*

Alarm
Sex
Aggregation

Synomones
•**Sender - host plant benefit:** pollination
•**Receiver - thrips benefit:** pollen, nectar, oviposition sites

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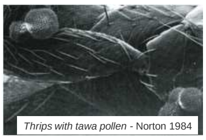
Thrips and flowers

- **Receiver:** Thrips are found in flowers in very large numbers
  - » Habitat for eggs, larvae and adults
- **Sender:** Thrips pollinate plant species
  - » Crop and natural systems
  - » Pollination syndrome - Thripophily: medium size flowers, white to yellow, with or without nector, small to medium size pollen, shelter, scented
- **Synomone:** Floral odour important component of thrips attraction to flowers
  - » Indicated in many lab bioassays


NZFT on *Hoheria*

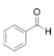
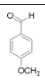
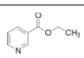
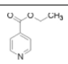

NZFT on *Gardinia*


Thrips with tawa pollen - Norton 1984

Thrips allelochemicals

- Very common compounds in flower odours (e.g. benzaldehyde) - true allelochemicals
- Uncommon or undetectable compounds
  - » True allelochemicals - Current technology unable to detect compounds but may be found to be more common with time.
  - » Allelochemical mimics - Don't exist in nature. Have similar structure to true allelochemicals and bind to their olfactory receptors to elicit a similar response

Thrips allelochemicals

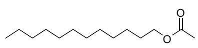
Allelochemical lures [and mimics]	Structure	Natural source	Trap increase [*Thrips tabaci*]
Benzaldehyde		flowers of: kiwifruit, safflower, carnation, strawberry, cotton, apple, alfalfa, elderberry, clover	x 4.0
p-anisaldehyde		flowers of: strawberry, elderberry	x 4.0
Ethyl nicotinate		star fruit (fruit) jasmine (flower)	x 4.2
Ethyl iso-nicotinate		currently unknown	x 30.8

Teulon et al. 2007. J Agric Food Chem 55

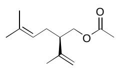
Thrips pheromones

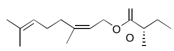
Western flower thrips:

- ➢ Alarm pheromone [Teerling et al. 1993]


Dodecyl acetate

- ➢ Aggregation pheromones [Hamilton et al. 2005]


Lavandulyl acetate


Neryl 2-methylbutanoate

Thrips palmi:

- ➢ Aggregation pheromones (similar to WFT) [Kirk & Hamilton 2009]

Commercial products

Aggregation pheromone

LUREM-TR

Allelochemical

NZ Research Focus

Our focus
- » Allelochemicals (kairomones or synomones) or their mimics as lures or attractants
- » Application in thrips pest management

In comparison with pheromones
- » Allelochemicals can be very powerful
  - » NZ flower thrips / ethyl nicotinate >100x
  - » *Thrips hawaiiensis* / methyl anthranilate >800x
- » Attract more than one species of thrips
- » Attract both males and females

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NZ Research Focus

Thrips species
- ➢ NZ flower thrips (NZFT): NZ endemic, polyphagous, non-virus vector
- ➢ Western flower thrips (WFT): cosmopolitan, polyphagous, virus vector
- ➢ Onion thrips (OT): cosmopolitan, polyphagous, virus vector

NZFT

Greenhouse crops
- ➢ Pest species: Western flower thrips, onion thrips
- ➢ History of adoption of new innovations
- ➢ Range of pest management tools already exist

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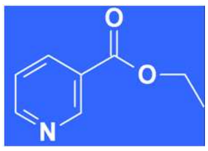

The discovery of new and stronger lures or attractants would be a significant development for thrips pest management

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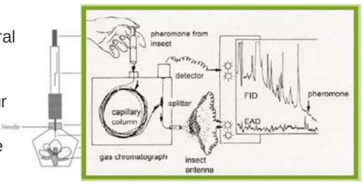
Lure Discovery

- Head space collection of floral odours
- GC-MS: identification of compounds in floral odour
- EAG: neural responses of insects tested against the range of floral odours



Electrophysiological responses do not indicate attraction or repellency
Still need to be tested in other bioassays

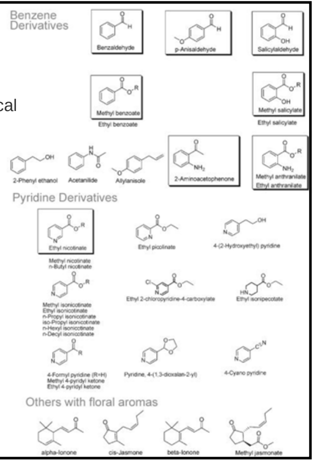
http://www.chemosensory.com/chemosense/chemosense-Sept04.pdf accessed Oct. 2010

Lure Discovery

Screened a range of potential chemical lures derived from compounds:

Similar structure to known thrips attractants:
- » Benzene compounds (≈13) (e.g. benzaldehyde)
- » Pyridine compounds (≈18) (e.g. ethyl nicotinate)

Similar aromas to known thrips attractants (≈4)
(e.g. cis-jasmone)



Teulon et al. 2007. J Agric & Food Chem

Lure Discovery

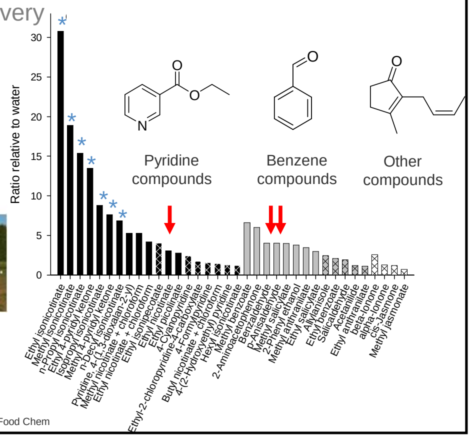
Western flower thrips / Y tube olfactometer

	% thrips to walk up odour-laden arm		
Compound	Undiluted	1%	0.001%
P-anisaldehyde	**46.7 (ns)**	**73.3**	**52.0 (ns)**
Ethyl nicotinate	**54.7**	**66.7**	**50.7 (ns)**
Ethyl isonicotinate	**84**	**69.3**	**60**
Methyl isonicotinate	**73.3**	**70.7**	**73.3**
nPi	**78.7**	**61.3**	**ns at 0.01%**
E4	**76.0**	**68.0**	**ns at 0.01%**
Ii	**60.0**	**66.7**	**ns at 0.01%**
Methyl-4-pyridyl ketone	**62.7**	**77.3**	**77.3**
Ep	**70.7**	**57.3**	**ns at 0.01%**
Ethyl-2-chloropyridine-4-carboxylate	**86.7**	**88.0**	**73.3**
F	**20.0**	**14.7**	**66.7**
HP	**78.7**	**58.7**	**ns at 0.1%**

Davidson et al. 2008. J Agric & Food Chem

Lure Discovery

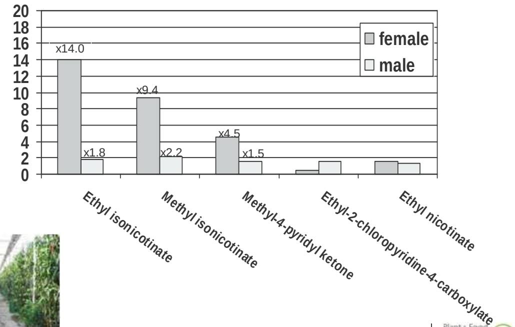
Onion thrips / field bioassay



Teulon et al. 2007. J Agric & Food Chem

Lure Discovery

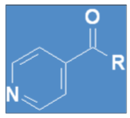
Western flower thrips / greenhouse bioassay



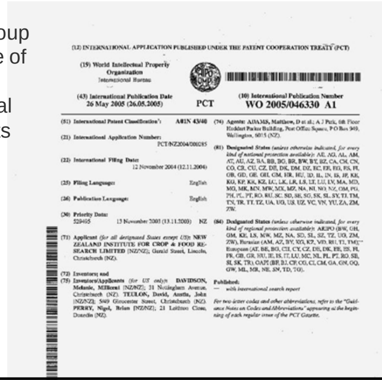
Davidson et al. 2007. NZ Plant Prot 60: 56

Lure Discovery

Patented chemical group which includes some of the strongest known attractants for several important thrips pests



4-Pyridyl carbonyl



Lure Discovery

Lure and its active ingredient(s) have shown activity against nine different thrips species:

Thrips species	Country
Frankliniella occidentalis	Various
Frankliniella schultzei	Kenya
Hydatothrips adolfifriderici	Kenya
Megalurothrips sjostedti	Kenya
Thrips coloratus	Japan
Thrips imaginis	Australia
Thrips major	Netherlands
Thrips obscuratus	New Zealand
Thrips tabaci	various

Nielsen et al. 2010

Lure Discovery

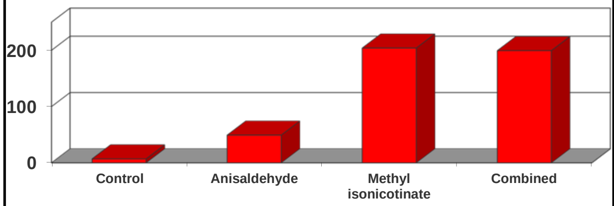
Compound class	Examples	Total reported from flowers	Total reported for thrips
Aliphatics		528	
Benzenoids & phenylpropanoids	benzaldehyde *p*-anisaldehyde	324	17
C5-branched chain compounds		93	
Terpenes	*(E)-β*-farnesene *β*-myrcene	555	7
N-containing compounds	ethyl nicotinate ethyl isonicotinate	61	16
S-containing compounds		41	
Misc. cyclic compounds		112	
Others	lactic acid	-	5
Total		1719	45

Source: Knudsen et al. 2006 Koschier 2008.

Lure Discovery: Mixtures

Target species: Onions thrips

Mixture was no better than best single odour



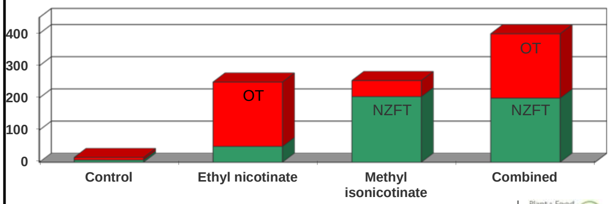
Teulon et al. 2007. NZ Plant Prot 60: 61

Lure Discovery: Mixtures

Target species: NZ flower thrips, onion thrips

Mixture of both odours combines to give similar catch of both species

Useful for the development of generic lures for more than one species



Wogin et al. 2010. Can Ent. 142: 75.

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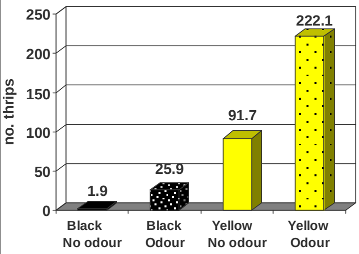
Attractant or Arrestant?

Behavioural Response

- Understanding the underlying behavioural responses of thrips to odour (and colour) will greatly enhance the development of these cues for thrips pest management
- Behavioural response of thrips to odour is probably quite different from larger insects because of their inability to fly upwind (impeded at >0.22 m/s)
- Most experiments measure the end response (e.g. # of thrips in trap) rather than how they got there: an arrestant or attractant can give the same result
- Different methods provide different information: e.g. Y-tube olfactometers only measure the response of walking thrips which may be different from flying thrips

Behavioural Response

Western flower thrips / greenhouse bioassay
- black and yellow water traps
- with and without anisaldehyde



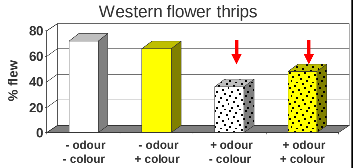
Colour vs odour interaction
- Odour doesn't work well by itself

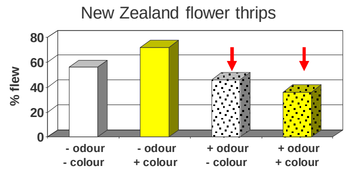
Size of visual component is important (Kirk 1987)
- The larger visual trap the smaller the effect of odour

Teulon et al. 1999. Entomol. Exp. et Appl. 93

Behavioural Response

Wind tunnel bioassays
[± odour cue, ± colour cue]



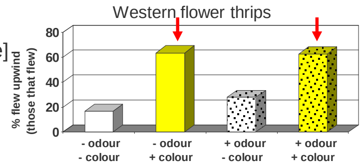


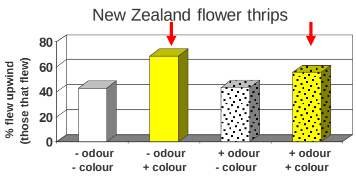
Flight take-off
- Odour reduced the % that flew
- No response to colour

Teulon et al. 1999. Entomol. Exp. et Appl. 93
Berry et al. 2006. NZJCHS 34: 121.

Behavioural Response

Wind tunnel bioassays
[± odour cue, ± colour cue]





Upwind flight
- Colour increased % that flew upwind
- No response to odour

Teulon et al. 1999. Entomol. Exp. et Appl. 93: 9.
Berry et al. 2006. NZJCHS 34: 121.

Behavioural Response - Summary

- Interaction between colour and odour
- Walking thrips response to odour: positive
- Walking thrips response to colour: unknown?
- Flying thrips response to odour: reduced OR increased take-off
- Flying thrips response to colour: positive directional flight

The 'van Tol' hypothesis interpreted by Teulon
'Odour dominated visual arrestment'
- » Flying thrips are arrested by visual cue
  - » probably assisted by odour
- » Weak flight control results in overshooting target
- » After landing thrips undergo short upwind flights or hops induced by odour to cue

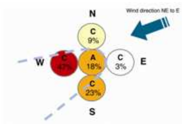


Figure 1 Proportion of female *Thrips tabaci* caught in the four outside control plates (C) (sprayed with water) surrounding the central sticky plate (A) (sprayed with ethyl *iso*-nicotinate)(n = 4). Dotted lines refer to likely odour plume of the attractant.

van Tol et al. 2007. Entomol. Exp. et Appl. 122

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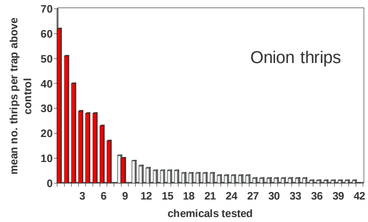
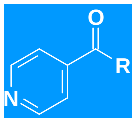
Variable Efficacy: Species / Flying

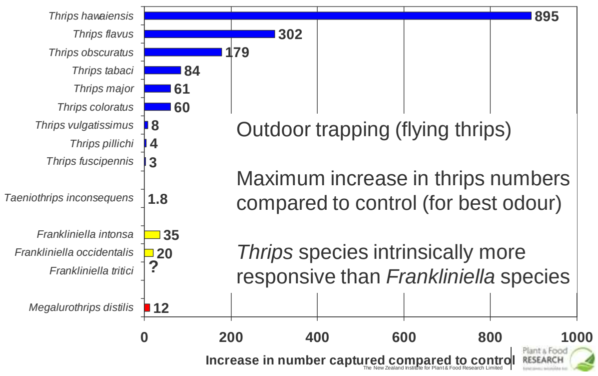
- Thrips species respond to different chemicals to different degrees
- Understanding specific responses can lead to the development of
  - » species-specific lures
  - » effective mixtures



Red bars.
Patented compounds



Variable Efficacy: Genus / Flying



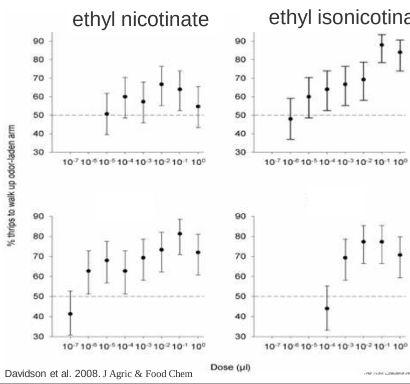
Outdoor trapping (flying thrips)

Maximum increase in thrips numbers compared to control (for best odour)

Thrips species intrinsically more responsive than *Frankliniella* species

Variable Efficacy: Genus / Walking

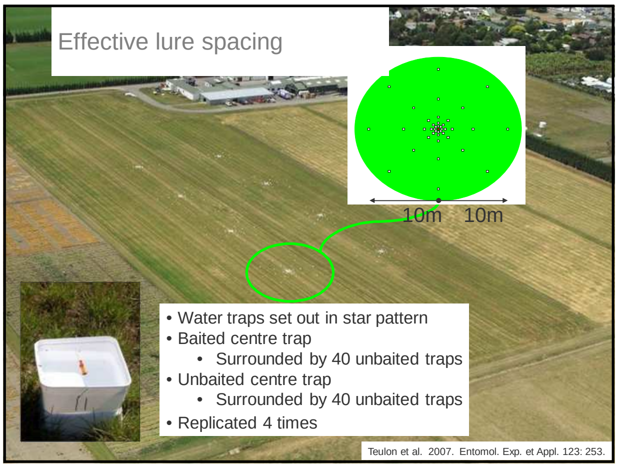
Walking response

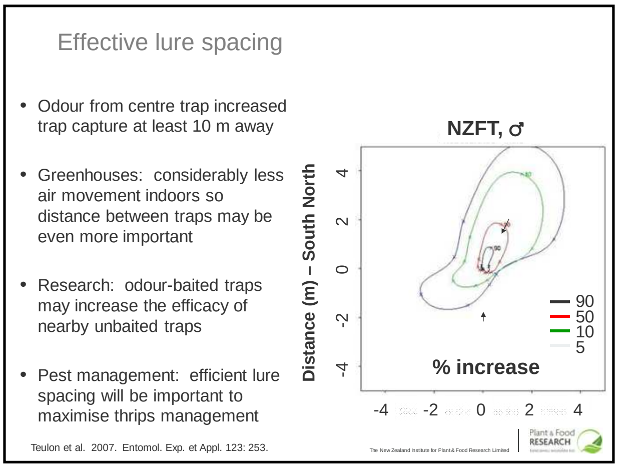


Frankliniella occidentalis

Thrips obscuratus

Davidson et al. 2008. J Agric & Food Chem


Effective lure spacing
10m 10m
• Water traps set out in star pattern
• Baited centre trap
• Surrounded by 40 unbaited traps
• Unbaited centre trap
• Surrounded by 40 unbaited traps
• Replicated 4 times
Teulon et al. 2007. Entomol. Exp. et Appl. 123: 253.


Effective lure spacing
• Odour from centre trap increased trap capture at least 10 m away
• Greenhouses: considerably less air movement indoors so distance between traps may be even more important
• Research: odour-baited traps may increase the efficacy of nearby unbaited traps
• Pest management: efficient lure spacing will be important to maximise thrips management
NZFT, ♂
Distance (m) – South North
4
2
0
-2
-4
-4 -2 0 2 4
90
50
10
5
% increase
Teulon et al. 2007. Entomol. Exp. et Appl. 123: 253.
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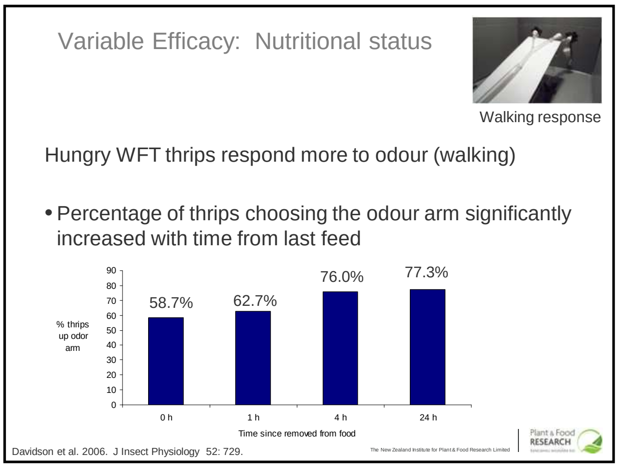
Variable Efficacy: Nutritional status
Walking response
Hungry WFT thrips respond more to odour (walking)
• Percentage of thrips choosing the odour arm significantly increased with time from last feed
% thrips up odor arm
58.7%
62.7%
76.0%
77.3%
0 h
1 h
4 h
24 h
Time since removed from food
Davidson et al. 2006. J Insect Physiology 52: 729.
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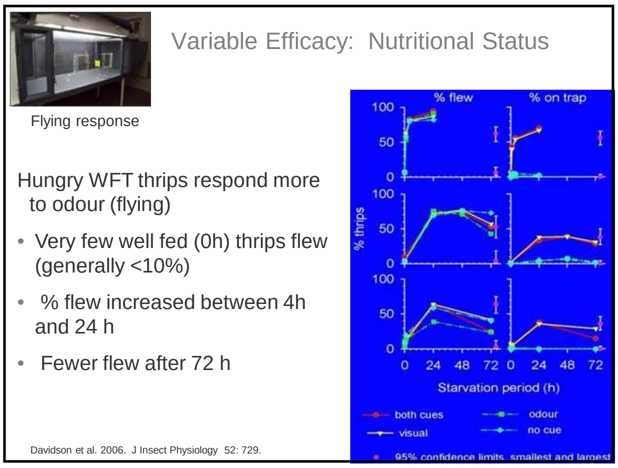
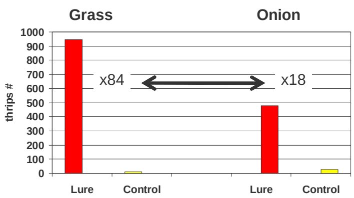

Variable Efficacy: Nutritional Status
Flying response
Hungry WFT thrips respond more to odour (flying)
• Very few well fed (0h) thrips flew (generally <10%)
• % flew increased between 4h and 24 h
• Fewer flew after 72 h
% flew
% on trap
% thrips
Starvation period (h)
both cues
odour
visual
no cue
Davidson et al. 2006. J Insect Physiology 52: 729.

Variable Efficacy: Host Plant Odour Masking

Onion thrips – ethyl isonicotinate
Grass field vs onion crop

- Thrips lure is more effective in non-host (grass) compared to host (onion)



Davidson et al. 2009. J Econ Ent 102

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We have the building blocks
Now lets make them work to manage thrips/viruses

Pest management

- Improved monitoring and mass trapping
  - Greenhouse crops
  - Intensive field crops
- Mass trapping
- Utilising "push-pull" strategies
- Lure & infect, lure & kill, lure & devour
- Surveillance for plant biosecurity
- Post-harvest dis-infestation (e.g. onion bulbs)
- Other biological control applications?

Pest management

Improved monitoring (NZ species)	NZ, Netherlands, Australia, Kenya, Canada
Improved monitoring (non-NZ species)	Australia, Kenya, Japan, Korea
Mass trapping	NZ, Australia, France
Lure and infect	Kenya
Trap cropping	Canada
Chemokinesis-increased movement (increase insecticide effectiveness)	Netherlands / New Zealand

Pest Management - Improved Trapping

Improved monitoring and mass trapping

- Coloured sticky boards, used extensively for monitoring thrips
- Addition of chemicals lures/attractants to coloured traps may;
  - » Improve effectiveness of coloured traps
  - » Lead to earlier and more accurate detection
  - » Presence/absence at low densities for biosecurity incursions
- Semiochemicals for mass trapping not yet a well established practice
  - » Integrated with other mortality factors e.g. biocontrol agents

Pest Management - Improved monitoring

Thrips allelochemical lures

- Greenhouse ornamentals
  - » wisteria, ceanothus, roses, gerbera, philodendron
- Greenhouse vegetables
  - » sweet pepper, aubergine
- Outdoor vegetables
  - » onions, cabbage, leek, beans
- Outdoor fruit
  - » citrus, strawberries, nectarines
- Demonstrated in a range of different countries from Oceania, Europe, North & South America & Africa

Pest Management - Mass trapping

France

- Western flower thrips
- In combination with thrips predator
- Trap density: 1 to 5 per 100 m^2

Victoria, Australia

- Western flower thrips
- Early season when lure is most effective (lower temperatures)
- Trap density: 1 per 100 m^2

Mass trapping has not been verified under experimental conditions

Pest Management - Trap cropping (biocontrol)

- Patches of early maturing susceptible cultivars
- Attractant to lure thrips and their natural enemies
- Additional natural enemies added to patches
- Provide a focus for natural enemies to move into crop

- (*E*)-β-farnesene to enhance the pull of the trap plant for *F. occidentalis* (Bennison *et al.* 2001)

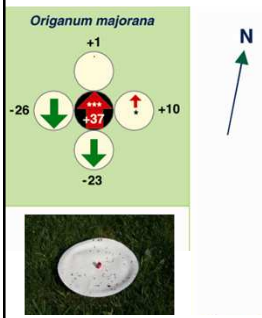
Pest Management - Trap cropping (biocontrol)

Trap scent	*Thrips. hawaiiensis*	*Thrips coloratus*	*Ceranisus menes*
Methyl anthranilate	1523.0	22.0	25.3
Control	1.7	0	0.3

Lure brings thrips and biocontrol agent to same location

Murai et al. 2000

Pest Management - Attractants and repellents (Push-Pull)



Control: plate with attractant surrounded by 4 plates without repellent
Treatment: plate with attractant surrounded by 4 plates with repellent

Plate sprayed with plant essential oil.

Plate sprayed with ethyl *iso*-nicotinate.

Relative increase (%) of *T. tabaci* compared to the control.

Relative decrease (%) of *T. tabaci* compared to the control.

van Tol et al. 2007. Entomol. Exp. et Appl. 122

Pest Management - Lure & kill (lure & infect)

- Allelochemicals used to lure thrips to a place to be killed
  - » Killed by biocontrol agents or insecticides
  - » Killed immediately (predators) or later (pathogens)
- 'Lure (Lure®) and infect' (*Beauveria bassiana*)
  - » No apparent improvement of *F. occidentalis* control (Ludwig & Oetting 2002)

These approaches have not become established practice but all show potential with appropriate chemical lure

New approaches to thrips pest management using semiochemicals

THEORY

- Research on thrips semiochemicals (both pheromones & allelochemicals) lures is still at a rudimentary stage.
- Additional research will help greatly in the development of lures for thrips pest management

PRACTICE.

- The main semiochemical-based pest management approaches are: improved monitoring, but there is huge potential in other areas such mass trapping, lure and kill (etc)

The way forward?

- The discovery of new and stronger lures or attractants would be a significant development for thrips pest management
- Understanding the underlying behavioural responses of thrips to odour (and colour) will greatly enhance the development of these cues for thrips pest management
- Understanding why we are getting such variable results (is now a key issue (what role do intrinsic such as migrating thrips , extrinsic factors such as temperature humidity play
- Development of new products such as mass trapping, lure and kill, lure and infect, trap cropping

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