Chemical Control of Spider Mites

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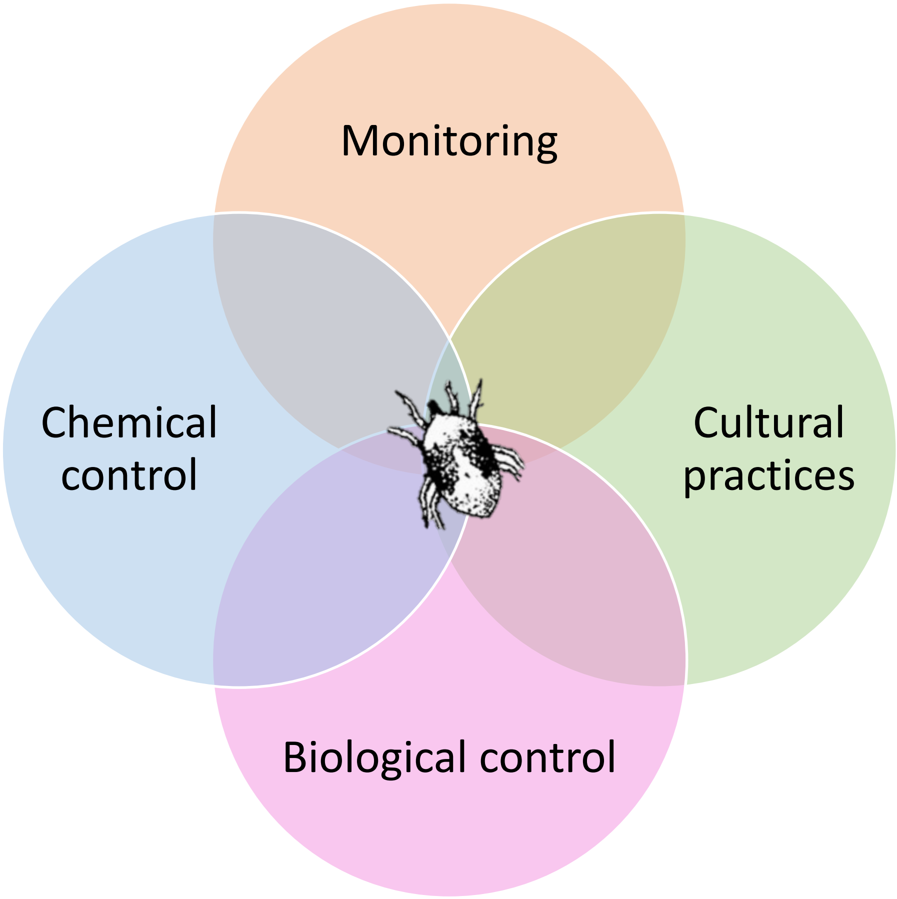
Photo: Jan van Arkel / University of Amsterdam

Integrated Mite Management (IMM)

- Monitoring
- Chemical control
- Biological control
- Cultural practices



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Acaricide Mode of Action Classification:
A key to effective acaricide resistance management

Insecticide Resistance Action Committee

www.irac-online.org

Introduction

IRAC promotes the use of a Mode of Action (MoA) classification of insecticides and acaricides as the basis for effective and sustainable resistance management. Acaricides are allocated to specific groups based on their target site. Reviewed and re-issued periodically, the IRAC MoA classification list provides farmers, growers, advisors, extension staff, consultants and crop protection professionals with a guide to the selection of acaricides and insecticides in resistance management programs. Effective Resistance management of this type preserves the utility and diversity of available acaricides. A selection of relevant MoA groups is shown below.

Effective IRM strategies: Sequences or alternations of MoA

All effective pesticide resistance management strategies seek to minimise the selection of resistance to any one type of pesticide. In practice, alternations, sequences or rotations of compounds from different MoA groups provide sustainable and effective resistance management for acarine pests. This ensures that selection from compounds in the same MoA group is minimised, and resistance is less likely to evolve.

MoA w → MoA x → MoA y → MoA z → MoA w → MoA x

Sequence of acaricides through season

Applications are often arranged into MoA spray windows or blocks that are defined by the stage of crop development and the biology of the pest species of concern. Local expert advice should always be followed with regard to spray windows and timings. Several sprays may be possible within each spray window but it is generally essential to ensure that successive generations of the pest are not treated with compounds from the same MoA group. Metabolic resistance mechanisms may give cross-resistance between MoA groups, and where this is known to occur, the above advice must be modified accordingly. IRAC also provides general recommendations for resistance management tactics regarding specific MoA groups.

Nerve and Muscle Targets

Several current acaricides act on nerve and muscle targets. Acaricides that act on individual targets in this system are generally fast acting.

***Group 1* Acetylcholinesterase (AChE) inhibitors**
Inhibit AChE, causing hyperexcitation. AChE is the enzyme that terminates the action of the excitatory neurotransmitter acetylcholine at nerve synapses.
1A Carbamates (e.g. Methomyl), *1B* Organophosphates (e.g. Pirimiphos-methyl).

***Group 2* GABA-gated chloride channel antagonists**
Block the GABA-activated chloride channel, causing hyperexcitation and convulsions. GABA is the major inhibitory neurotransmitter in insects.
2A Cyclodiene Organochlorines (e.g. Endosulfan).

***Group 3* Sodium channel modulators**
Keep sodium channels open, causing hyperexcitation and, in some cases, nerve block. Sodium channels are involved in the propagation of action potentials along nerve axons.
3A Pyrethroids, Pyrethrins (e.g. Bifenthrin, Halfenprox).

***Group 6* Glutamate-gated chloride channel (GluCl) allosteric modulators**
Allosterically activate glutamate-gated chloride channels, causing paralysis. Glutamate is an important inhibitory neurotransmitter in insects.
Avermectins, Milbemycins (e.g. Abamectin, Milbemectin).

***Group 19* Octopamine receptor agonists**
Activate octopamine receptors, leading to hyperexcitation. Octopamine is the insect equivalent of adrenaline, the fight-or-flight neurohormone.
Formamidines (e.g. Amitraz)

***Group 32* Nicotinic acetylcholine receptor (nAChR) allosteric modulators, Site II**
Allosterically activate nAChRs (at site II), causing hyperexcitation of the nervous system. Acetylcholine is the major excitatory neurotransmitter in the insect central nervous system.
GS-omega/kappa HXTX-Hv1a Peptide

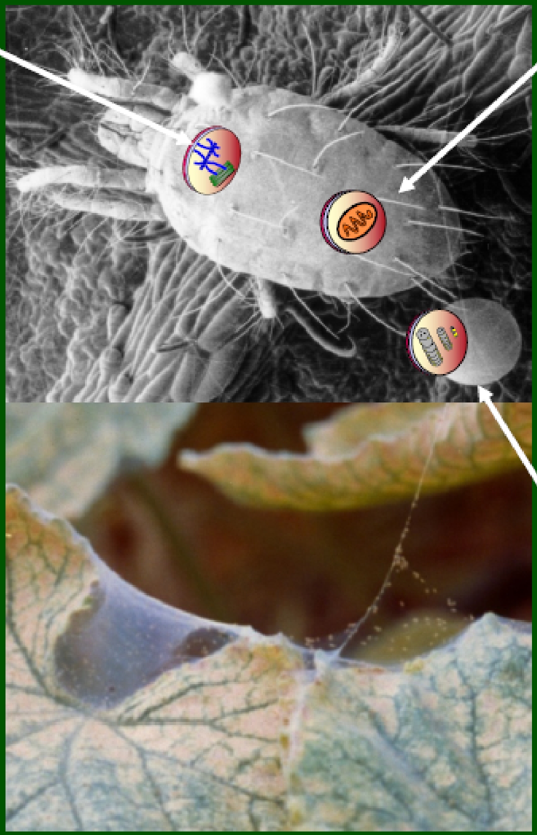
Acaricides for which the mode of action is unknown

These compounds are not classified because there is not sufficient information available on their mode of action.

Benzoximate, Bromopropylate, Chinomethionat, Dicofol.

Targeted Physiology: Rotations for resistance management should be based only on the numbered mode of action groups.

Nerve & Muscle | Growth & Development | Respiration | Midgut | Unknown or Non-specific



Respiration Targets

The mitochondrial respiration process produces ATP, which energizes all vital cellular processes. In mitochondria, an electron transport chain uses the energy released by oxidation to drive ATP synthesis. Several acaricides are known to interfere with mitochondrial respiration by the inhibition of electron transport and/or oxidative phosphorylation, and are generally fast to medium-fast acting.

***Group 12* Inhibitors of mitochondrial ATP synthase**
Inhibit the enzyme that synthesizes ATP.
12A Diafenthiuron, *12B* Organotin miticides (e.g. Azocyclotin, Fenbutatin oxide), *12C* Propargite.

***Group 13* Uncouplers of oxidative phosphorylation via disruption of the proton gradient**
Protonophores that short-circuit the mitochondrial proton gradient so that ATP can not be synthesized.
Pyrroles (Chlorfenapyr), Dinitrophenols (DNOC) and Sulfonamides (Sulfluramid).

***Group 20* Mitochondrial complex III electron transport inhibitors**
Inhibit electron transport complex III, preventing the utilization of energy by cells.
20B Acequinocyl, *20C* Fluacrypyrim, *20D* Bifenazate.

***Group 21* Mitochondrial complex I electron transport inhibitors**
Inhibit electron transport complex I, preventing the utilization of energy by cells.
21A METI acaricides (e.g. Fenazaquin, Pyridaben, Tebufenpyrad).

***Group 25* Mitochondrial complex II electron transport inhibitors**
Inhibit electron transport complex II, preventing the utilization of energy by cells.
25A beta-Ketonitriles (Cyenopyrafen, Cyflumetofen), *25B* Carboxanilides (Pyflubumide).

Growth and Development Targets

Insect and mite growth regulators act by mimicking growth hormones, by directly affecting cuticle formation, or lipid biosynthesis. Acarcides that act on this system are usually slow acting. The target proteins are not always known.

***Group 10* Mite growth inhibitors affecting CHS1**
Incompletely defined mode of action leading to growth inhibition.
10A Clofentezine, Hexythiazox, *10B* Etoxazole.

***Group 15* Inhibitors of chitin biosynthesis affecting CHS1**
Incompletely defined mode of action leading to inhibition of chitin biosynthesis.
Benzoylureas (e.g. Flucycloxuron, Flufenoxuron).

***Group 23* Inhibitors of acetyl CoA carboxylase**
Inhibit acetyl coenzyme A carboxylase, part of the first step in lipid biosynthesis.
Tetronic & Tetramic acid derivatives (e.g. Spirodiclofen).

Designed & produced by IRAC Mode of Action Team, January 2019, Poster Ver 4. Based on MoA Classification Ver. 9.1
For further information visit the IRAC website: www.irac-online.org Photograph and SEM courtesy of Syngenta

CropLife

Problems when Implementing Chemical Control in the Wrong Manner

- Resistance
- Hormoligosis
- Non-target effects

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Pesticide Resistance

"A change in the sensitivity of a pest population to a pesticide, resulting in the failure of a correct application of the pesticide to control the pest"

It develops when the same pesticide or similar ones with the same mode of action are used over and over again

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Pesticide Resistance

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Resistance in Two-spotted Spider Mite

- **588** resistance cases to **96** active ingredients, worldwide!
- In the USA→ **63** cases to **31** active ingredients
- The USA cases do not include FL reports

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Article

First report of acaricide resistance in *Tetranychus urticae* (Acari: Tetranychidae) from south Florida[1]

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Resistance in Two-spotted Spider Mite – S. FL

Active Ingredient	Product	Hibiscus	Croton	Resistance
abamectin	Timectin	9.64-fold	19.28-fold	High
pyridaben	Sanmite	12.34-fold	34.08-fold	High
cyflumetofen	Sultan	1.88-fold	2.39-fold	Low

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Why Is Pesticide Resistance a Problem?

1. Because chemical control products are not efficacious anymore

2. Leads to:
    - mite outbreaks
    - increased management costs

How is Pesticide Resistance Induced?

- By applying the same product repeatedly
- Or by applying different products with active ingredients of the same mode of action

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How Can It Be Resolved?

- In some cases, it cannot be 100% resolved
- Rotation of products with different modes of action
- IPM

Pesticide Hormoligosis

"The phenomenon in which sublethal quantities of stress agents such as **chemicals**, antibiotics, hormones, temperature, radiation, and minor wounds are stimulatory to an organism by providing increased efficiency to develop new or better systems to cope in a suboptimum environment"

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Pesticide Hormoligosis - Examples

- European red mite (*Panonychus ulmi*) exposed to low concentrations of cypermethrin, deltamethrin, spirodiclofen+abamectin, imidacloprid, thiacloprid (Saritas and Ay 2016)
- *Tetranychus turkestani* citronellol (Mohammadi et al. 2016)

Photo: IRAC

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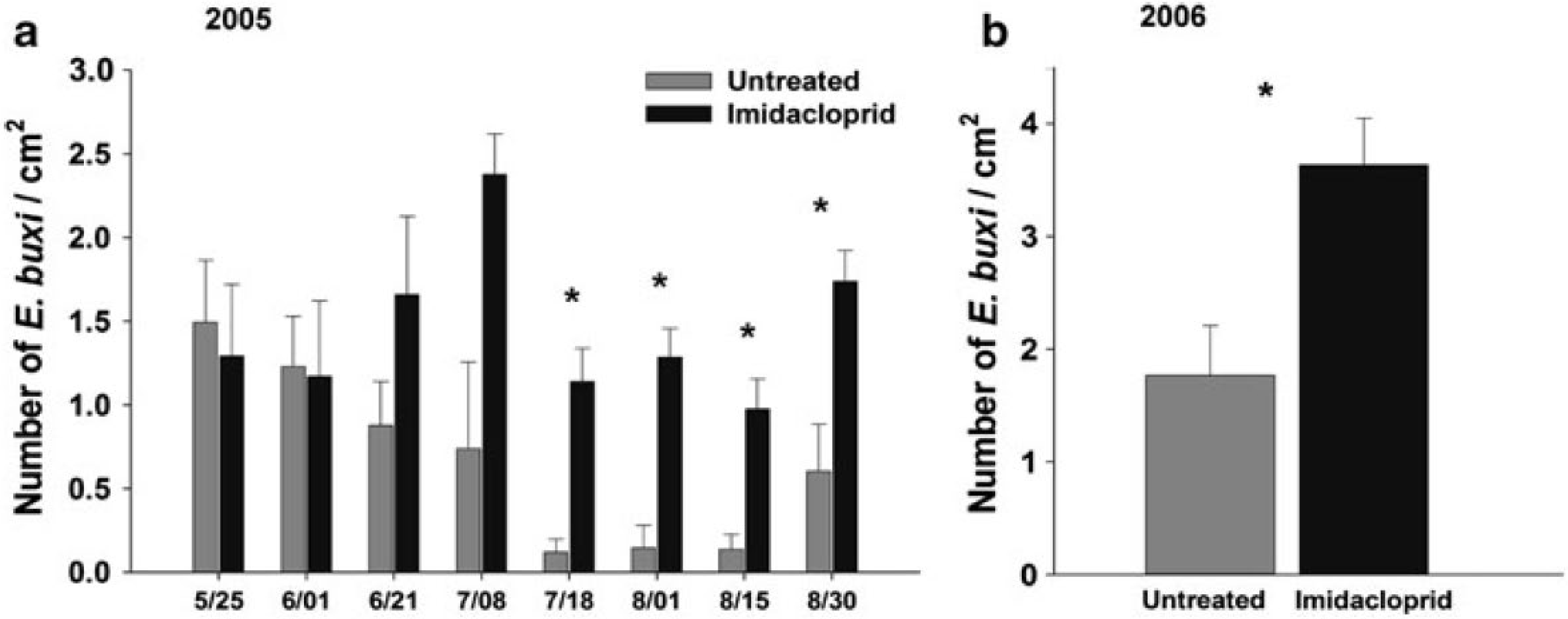
Pesticide Hormoligosis - Examples

Boxwood mite (*Eurytetranychus buxi*) exposed to imidacloprid (Marathon) (Szczepaniec and Raupp 2013)



Pesticide Hormoligosis - Examples

TSSM exposed to **clofentezine** (Marcic 2003), **imidacloprid** (Sclar et al 1998; James and Price 2002), **thiamethoxam**, **thiacloprid**, **acetamiprid** (Barati and Hejazi 2015), **deltamethrin** (Balci and Ay 2023)

Table 2 Life table parameters (mean ± SE) of *Tetranychus urticae* after spray treatment and drench application

Parameters	Method	Control	Thiamethoxam	Thiacloprid	Acetamiprid
R_0 (females/female/generation)	L	$37.51 \pm 4.59^{B,b}$	$47.87 \pm 5.24^{B,ab}$	$52.62 \pm 4.57^{B,a}$	$47.12 \pm 7.57^{B,ab}$
	D	$58.24 \pm 5.10^{A,d}$	$88.44 \pm 5.81^{A,a}$	$73.48 \pm 8.88^{A,c}$	$74.66 \pm 7.09^{A,b}$
r_m (females/female/day)	L	$0.269 \pm 0.004^{B,c}$	$0.307 \pm 0.006^{A,b}$	$0.309 \pm 0.004^{B,ab}$	$0.324 \pm 0.006^{B,a}$
	D	$0.286 \pm 0.004^{A,c}$	$0.315 \pm 0.004^{A,b}$	$0.321 \pm 0.004^{A,b}$	$0.488 \pm 0.14^{A,a}$
λ (females/female/day)	L	$1.308 \pm 0.006^{B,c}$	$1.360 \pm 0.008^{A,b}$	$1.363 \pm 0.005^{B,b}$	$1.383 \pm 0.008^{B,a}$
	D	$1.331 \pm 0.005^{A,c}$	$1.370 \pm 0.005^{A,b}$	$1.379 \pm 0.006^{A,b}$	$1.629 \pm 0.22^{A,a}$
T (days)	L	$13.49 \pm 0.29^{B,a}$	$12.58 \pm 0.20^{B,ab}$	$12.80 \pm 0.27^{B,a}$	$11.91 \pm 0.46^{A,b}$
	D	$14.18 \pm 0.18^{A,a}$	$14.22 \pm 0.18^{A,a}$	$13.34 \pm 0.25^{A,b}$	$8.86 \pm 2.76^{B,c}$
DT (days)	L	$2.57 \pm 0.04^{A,a}$	$2.25 \pm 0.04^{A,b}$	$2.23 \pm 0.03^{A,b}$	$2.13 \pm 0.04^{A,b}$
	D	$2.41 \pm 0.03^{B,a}$	$2.19 \pm 0.03^{A,b}$	$2.15 \pm 0.03^{B,c}$	$1.42 \pm 0.46^{B,d}$

R_0: net reproductive rate; r_m: intrinsic rate of population increase; λ: finite rate of population increase; *T*: generation time; DT: doubling time

L: leaf spray; D: drench application

Means within each column belonging to each parameter followed by the same capital letter are not significantly different ($P > 0.05$; independent sample *t* test)

Means within each row followed by the same small letter are not significantly different ($P > 0.01$; Duncan's multiple range test)

Why Is Pesticide Hormoligosis a Problem?

1. Because it stimulates the mites to lay more eggs

2. Leads to:
   - mite outbreaks
   - increased management costs

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How is Pesticide Hormoligosis Induced?

- By not applying the appropriate label rates

- By poor coverage of plant canopy when applying a pesticide

Pesticide Non-target Effects

Effects of the applied pesticide on organisms other than the target pest

- Direct
- Indirect

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Why Are Pesticide Non-target Effects a Problem?

1. Because they reduce natural enemy populations and contaminate the environment

2. Lead to:
   - mite outbreaks
   - honeybee collapse
   - pollution
   - increased management costs

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When Do I Apply Acaricides?

Limited information on action thresholds for spider mites on ornamentals (and crops in general)!

Depends on various factors:

- Pest density
- Crop
- Season
- Finances

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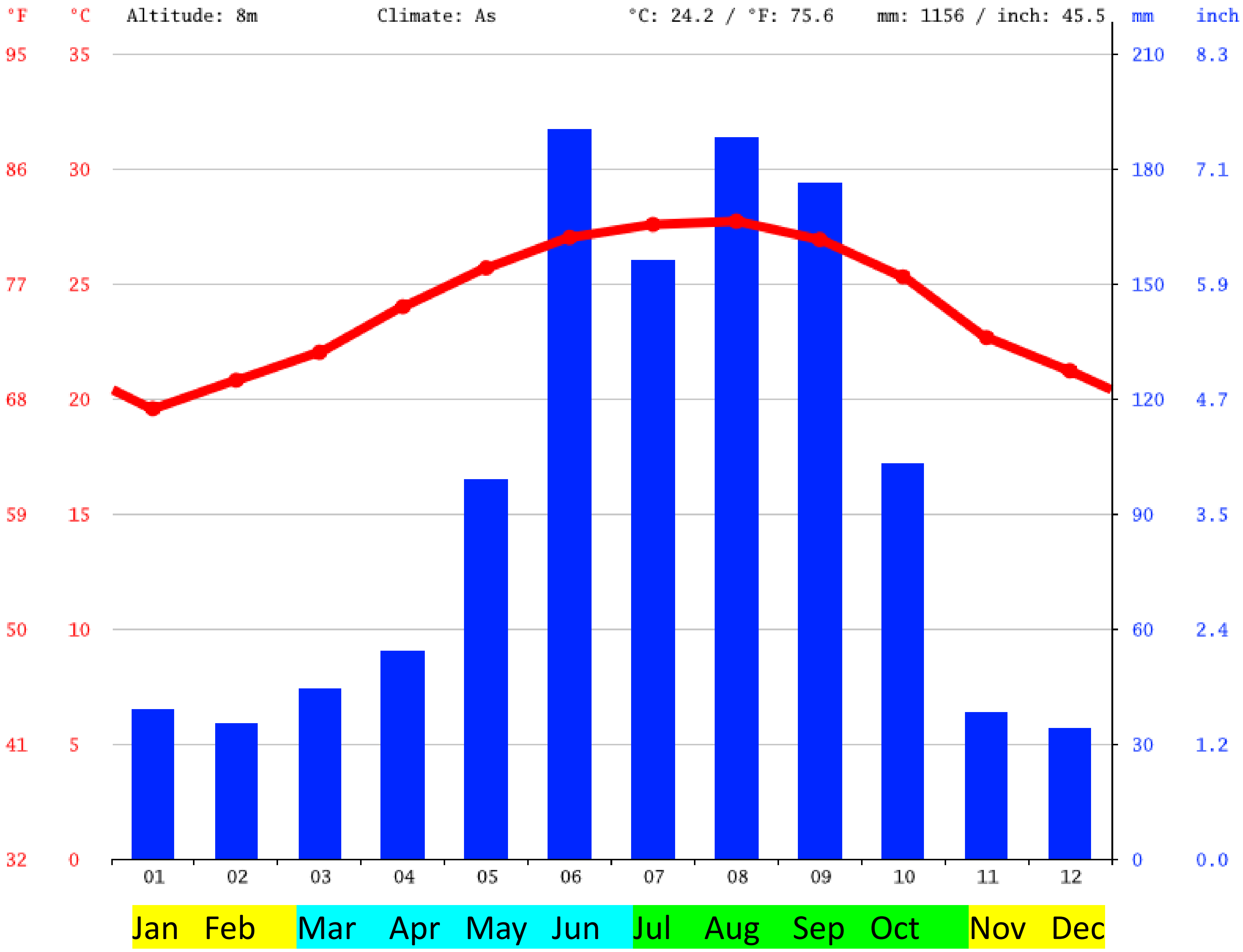
Spider Mite Season in South Florida

Peak population

Moderate population

Low population



https://en.climate-data.org/north-america/united-states-of-america/florida/homestead-1632/#temperature-graph

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When Do I Apply Acaricides?

Monitor and count how many mites per leaf you have

Action thresholds on **ivy geraniums**:

7 mites/ leaf on plants greater than 5 weeks in production or

2 mites/ leaf on plants less than 5 weeks in production

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Info: J. Nechols & K. Williams (Kansas State Univ. Research & Ext.)

When Do I Apply Acaricides?

Action thresholds on **anthurium**:

≥ 6% of flower bracts or spathes damaged (Hara et al., 1990)

Action thresholds on **roses**:

≥ 5 mites/leaflet (Dreistadt 2001)

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What Acaricides Should/Can I Apply?

- Several active ingredients available
- Some have insecticidal and acaricidal properties
- Factors to consider before selecting an acaricide:
  - Mite species and life stages
  - Contact vs translaminar activity
  - Compatibility with biological control

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Nicotinic Acetylcholine Receptor (nAChR) Allosteric Modulators –Site I #5

- 5 Spinosyns
  - Spinosad → spider mites

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Glutamate-gated Chloride Channel (GluCl) Allosteric Modulators #6

- 6 Avermectins
  - Abamectin → spider, flat, broad and gall mites
    - Effective against adults and immature mites
    - Translaminar but not systemic

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Mite Growth Inhibitors Affecting CHS1 #10

- 10A Clofentezine, Hexythiazox
  - Clofentezine, Hexythiazox→ spider mites
  - Does not kill adults but kills eggs and eggs from treated females
  - Suggest not to mix with synthetic pyrethroids

- 10B Etoxazole
  - Etoxazole → spider mites
  - Immature mites are most susceptible, ovicide; adult mites not controlled
  - Translaminar
  - Relatively soft on beneficials

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Inhibitors of Mitochondrial ATP Synthase #12

- 12B Organotin miticides
  - Fenbutatin oxide→ spider mites
  - Restricted use; Danger

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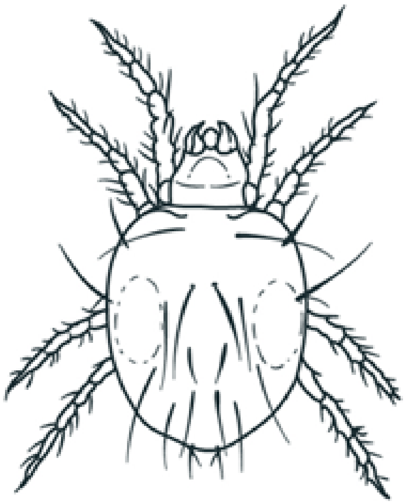
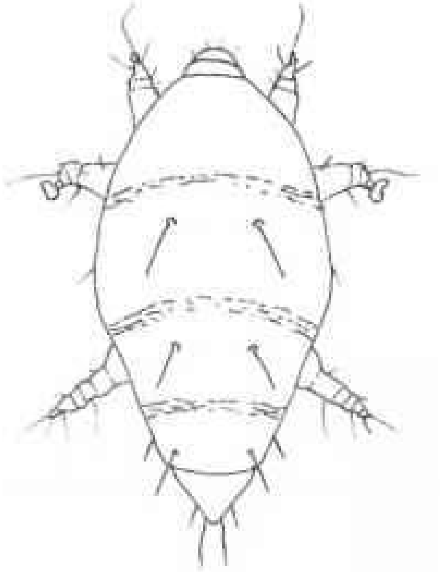
Uncouplers of Oxidative Phosphorylation via Disruption of the Proton Gradient #13

- 13 Pyrroles
  - Chlorfenapyr→ spider, broad and gall mites
  - Greenhouse





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Mitochondrial Complex III Electron Transport Inhibitors –Qo Site #20

- 20B Acequinocyl
  - Acequinocyl→ spider mites

- 20D Bifenazate
  - Bifenazate → spider mites
  - Compatible with predatory mites
  - Effective on adults and immature mites; some ovicidal activity

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Mitochondrial Complex I Electron Transport Inhibitors #21

- 21A METI acaricides and insecticides
  - Fenazaquin, Tolfenpyrad→ spider mites
  - Fenazaquin → highly toxic to bees
  - Fenpyroximate→ spider, broad and gall mites
  - Pyridaben→ spider and broad mites

Inhibitors of Acetyl CoA Carboxylase #23

- 23 Tetronic and Tetramic acid derivatives
  - Spiromesifen, Spirotetramat → spider, flat, broad and gall mites

- Spiromesifen:
  - Translaminar
  - All mite stages including eggs but slightly less active against adults
  - Slightly harmful to predatory mites but non-toxic to honeybees and ladybeetles

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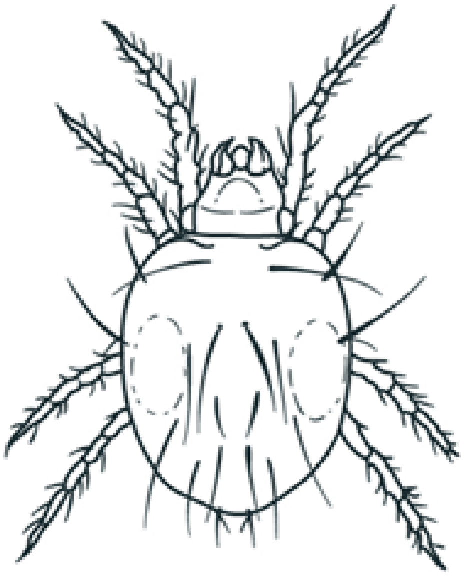
Mitochondrial Complex II Electron Transport Inhibitors #25

- 25A Beta-ketonitrile derivatives
  - Cyflumetofen→ spider mites



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Unknown and Unclassified

- Unknown: Azadirachtin, Sulfur
- Unclassified: Horticultural oils, Insecticidal Soaps, Neem oil
- Present little risk for resistance
- Good coverage is necessary
- Some plant sensitivity
- Do not use during drought

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Adjuvants

"A substance that is added to a pesticide product or pesticide spray mixture to enhance the pesticide's performance and/ or the physical properties of the spray mixture"

Choose the right adjuvant:

- Read the pesticide label!
- Use only adjuvants that are labeled for agricultural or horticultural use
- Adjuvants may not always be necessary

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Examples of Adjuvants

- surfactants (reduce surface tension)
- spreader and stickers (reduce surface tension and stick to a target's surface)
- crop oils (suffocate, break chitin layers)
- thickeners (reduce drift of sprays)
- anti-foaming materials (control or reduce the formation of foam in the tank)
- buffering agents (stabilize the pH at a relatively constant level)

Efficacy Trials on Mandevilla

Treatment	Active Ingredient	IRAC Group Number	Rate
Floramite	Bifenazate	20D	8 fl oz/ acr
Floramite	Bifenazate	20D	22 fl oz/ acr
Eschaton	Etoxazole	10 B	16 fl oz/ acr
Floramite + Eschaton	Bifenazate + Etoxazole	20D + 10B	22 fl oz/ acr + 16 fl oz/ acr
Sultan	Cyflumetofen	25	13.7 fl oz/ acr
Water	NA	NA	NA

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An adjuvant was added to all treatments, except for water

Efficacy Trials on Mandevilla

- Greenhouse experiments (77 ± 2 °F, 70 ± 10% RH)
- 150 adult TSSM were released 2 wks prior to treatment application
- Spray to run-off
- Sample 3, 7, 14, 21 and 28 d post treatment application
- N = 4/treatment

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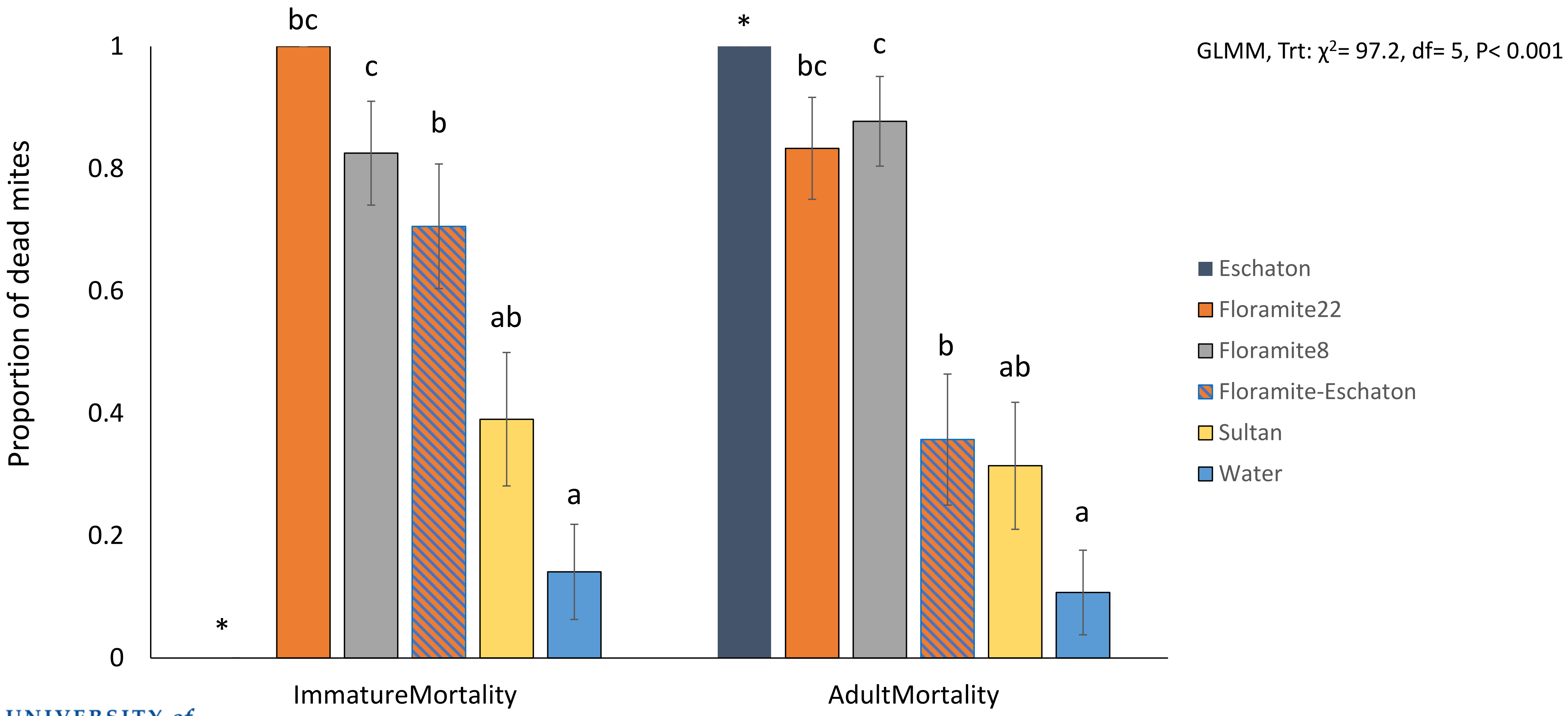
Efficacy Trials on Mandevilla



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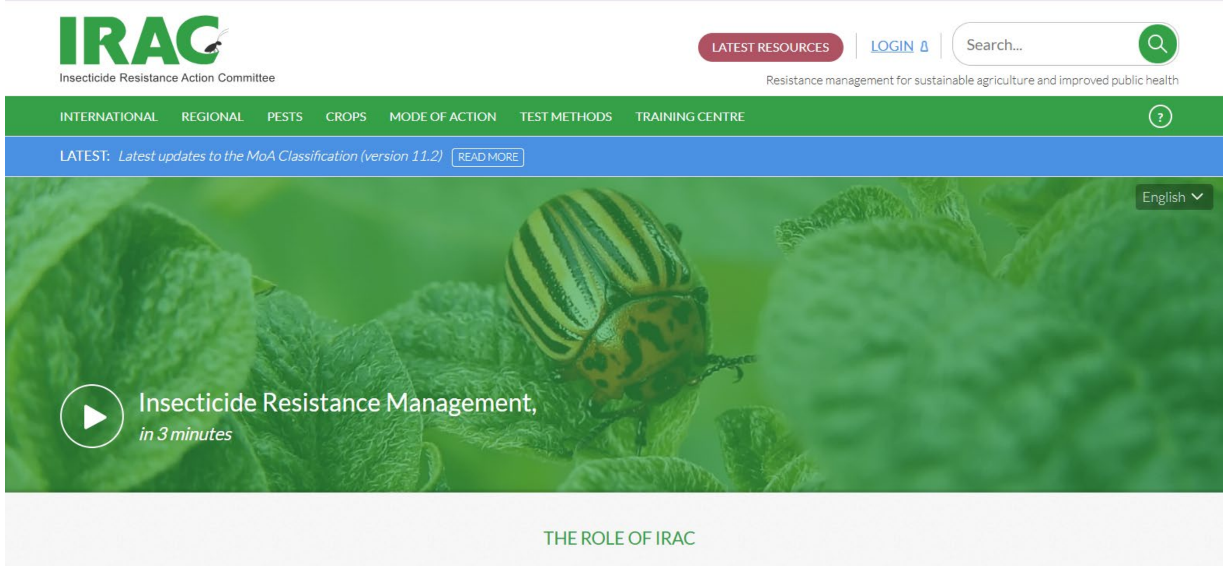
How Do I Apply Acaricides Against Spider Mites?

- By hand!
- Target the under side of the leaves
- Make sure you fully cover the plant canopy

Things to Consider When Applying Acaricides - Recap

- Target species and its life stage
- Appropriate acaricide
- Rate
- Application method
- Rotation
- Adjuvant
- Compatibility with biological control



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Spider Mites

Spider mites are persistent pests of numerous specialty ornamental crops, such as hibiscus, palms, viburnum, orchids, marigold, dracaena, and roses. These pests cause a significant reduction in marketable product quality and yield. Heavy infestations may also cause leaf drop and, ultimately, the death of entire plants.

Resources

· Twospotted Spider Mite, Tetranychus urticae http://edis.ifas.ufl.edu/pdffiles/IN/IN30700.pdf

· Clover Mite Bryobia praetiosa https://edis.ifas.ufl.edu/in776

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Thank you!

Special thanks to Victor Gonzalez!

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