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2018 Pesticide Safety - Pesticide Resistance Management in Cranberry

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Pesticide Resistance Management in CRANBERRY

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with input from
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With special thanks to:

- Dr. Margaret McGrath, Cornell University
- Dr. Andrei Alyokhin, University of Maine
- Dr. Richard Bonanno, University of Massachusetts

NORTHEAST SARE Sustainable Agriculture Research & Education

NE-SARE Professional Development Program
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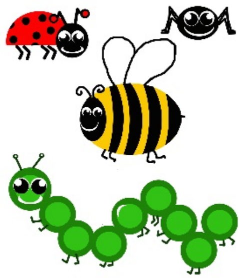
What is Pesticide Resistance?

Inheritable (genetic) characteristic of a pest that makes it less sensitive to a pesticide

- Can occur in **all** types of pests
  - weeds, insects, fungi, etc.



- Pest is able to survive pesticide exposure that would kill those without the genes

What is Pesticide Resistance?

- Genes naturally occur in pest population
  - Not mutations caused by chemical

- Pesticide use “selects” for resistance
  - Kills susceptible individuals - those *without* the gene to protect them die
  - Those with the gene don’t die, and are “Selected” for by killing off other types

What is Pesticide Resistance?

- Pests *with* gene live, reproduce, and pass on the genes for resistance to their offspring
- The pest population has increasing numbers of resistant individuals
- Over time, population as a whole is more resistant to the pesticide

Why is Managing Resistance Important?

- All types of pesticides are at risk for resistance!
- Pesticide resistance is increasing

Mode of action (MoA)

The chemical structure of a pesticide defines:

- **Target site** - the "where" - physical location within an organism where the pesticide acts
- **Mode of action** - the "how" - action of a pesticide at its target site.

Pesticide Groups

- Each pesticide has been assigned a **Group Number** to help growers make resistance management decisions
- Pesticides in a group share similar characteristics and risk cross-resistance
- Group number is clearly marked on most labels

Herbicides - HRAC and WSSA groups

HRAC (letters) and WSSA (Weed Science Society of America, #'s) codes, differ slightly but very similar

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HRAC Group	Site of Action	Chemical Family	Active Ingredient	WSSA Group
A	Inhibition of acetyl CoA carboxylase (ACCase)	Aryloxyphenoxy-propionate 'FOPs'	clodinafop-propargyl cyhalofop-butyl diclofop-methyl fenoxaprop-P-ethyl fluazifop-P-butyl haloxyfop-R-methyl propaquizafop quizalofop-P-ethyl	**1**
		Cyclohexanedione 'DIMs'	alloxydim butroxydim clethodim cycloxydim *profoxydim* sethoxydim *tepraloxydim* tralkoxydim	
		Phenylpyrazoline 'DEN'	pinoxaden	
B	Inhibition of acetolactate synthase ALS (acetohydroxyacid synthase AHAS)	Sulfonylurea	amidosulfuron azimsulfuron bensulfuron-methyl chlorimuron-ethyl	**2**

Consult the label for RM info

In addition to group numbers, many labels have specific info or instructions regarding RM

RESISTANCE MANAGEMENT

Select Max Herbicide *with Inside Technology* is a Group 1 herbicide. Any weed population may contain or develop plants naturally resistant to *Select Max* Herbicide *with Inside Technology* and other Group 1 herbicides. Weed species with acquired resistance to Group 1 may eventually dominate the weed population if Group 1 herbicides are used repeatedly in the same field or in successive years as the primary method of control for targeted species. This may result in partial or total loss of control of those species by *Select Max* Herbicide *with Inside Technology* or other Group 1 herbicides. Repeated use of *Select Max* Herbicide *with Inside Technology* (or similar postemergence grass herbicide with the same mode of action) may lead to the selection of naturally occurring biotypes that are resistant to these products in some grass species.

If poor performance occurs and cannot be attributed to adverse weather or application conditions, a resistant biotype may be present. This is most likely to occur in fields where other control strategies such as crop rotation, mechanical removal and other classes of herbicides are not used from year to year.

To delay herbicide resistance consider:

- Avoiding the consecutive use of *Select Max* Herbicide *with Inside Technology* or other target site of action Group 1 herbicides that have similar target site of action, on the same weed species.
- Using tank mixtures or premixes with herbicides

Consult the Cranberry Chart book!

6 RESISTANCE MANAGEMENT

Fungicide Resistance Action Committee (FRAC) Grouping for cranberry fungicides

FRAC GROUP	TRADE NAME	COMMON NAME	MODE OF ACTION	GROUP NAME	CHEMICAL GROUP	Resistance Development Risk
4	**Metastar** **Ridomil** **Ultra Flourish**	mefenoxam metalaxyl	**A1**: RNA polymerase I	PA – fungicides (PhenylAmides)	acylalanines	**High Risk**
11	**Abound**	azoxystrobin	**C3**: cytochrome bc1 at Qo site	QoI-fungicides	methoxy-acrylates	**High Risk**
	Aftershock **Evito**	fluoxastrobin		Strobilurins	dihydro-dioxazines	
3	**Indar** **Proline**	fenbuconazole prothioconazole	**G1**: c14-demethylase in sterol biosynthesis	DMI-fungicides (DeMethylation Inhibitors)	triazoles	**Medium Risk**
19	**OSO** **Ph-D**	polyoxin	**H4**: chitin synthase	polyoxins	peptidyl pyrimidine nucleoside	**Medium Risk**
	Aliette	fosetyl-Al			ethyl	

Resistance to sites of action used in cranberry

Site of action (examples)	Resistant weed species
HPPD inhibitor (mesotrione)	2
LCFA inhibitor (napropramide)	5
Cellulose inhibitor (dichlobenil)	3
Carotenoid biosynthesis (norflurazon)	6
ACCase (clethodim, sethoxydim)	48
Synthetic auxin (2,4-D, clopyralid)	36
EPSP synthase (glyphosate)	41

Slide courtesy of Jed Colquhoun, University of Wisconsin-Madison

Should cranberry growers be concerned about herbicide resistance?

- We rely on just a few herbicides for weed control
- New herbicide options are few and far between
- The rate range is broad for several herbicides, allowing for sub-lethal doses
- We can't rotate crops and cultural practices are limited
- Many perennials in cranberry are prolific seed producers, such as goldenrod

Slide courtesy of Jed Colquhoun, University of Wisconsin-Madison

So, what can we do about it?

- Monitor for weeds that escape control
- Eliminate survivors
  - We have more tools for managing weeds!
- Rotate herbicide within and across growing seasons
- Guard against contaminated inputs that can spread resistant weeds
- If you suspect resistance, get assistance immediately!

Challenges to Managing Resistance

- Products with resistance risk for one pest are also used for others
  - Pesticides don’t work only on target!
    - Delegate for BHFW…may expose Spag too!

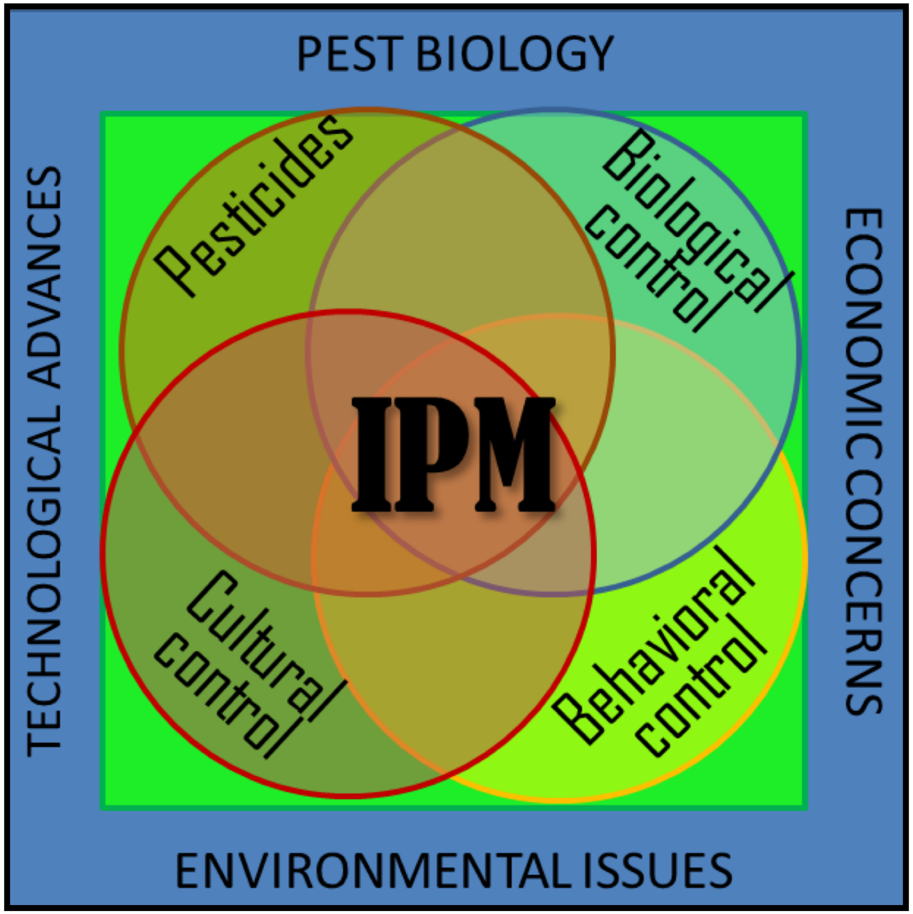
Challenges to Managing Resistance

- Not always something to rotate to, even if you try!

- Not many cranberry herbicides
  - i.e. clethodim and sethoydim for grasses

✓ Do not rely on pesticides alone

Integrate different controls!



- synthetic pesticides
- biological pesticides
- beneficial insects (predators/parasites)
- cultural practices
- chemical attractants/deterrents

IRAC

Insecticide Mode of Action Classification

Insecticide Resistance Action Committee **www.irac-online.org**

CropLife International

Introduction

Insecticide Resistance Action Committee [IRAC] promotes the use of a Mode of Action (MoA) classification of insecticides as the basis for effective and sustainable insecticide resistance management (IRM). Insecticides 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 insecticides or acaricides in IRM programs. Effective IRM of this type preserves the utility and diversity of available insecticides and acaricides.

Nerve & Muscle Targets

Group 1 Acetylcholinesterase (AChE) inhibitors
1A: Carbamates (e.g. Thiodicarb)
1B: Organophosphates (e.g. Chlorpyrifos)

DIAZ, LORSBAN, SEVIN…

Group 2 GABA-gated chloride channel blockers
2A: Cyclodiene Organochlorines (e.g. Endosulfan)
2B: Phenylpyrazoles (e.g. Fipronil)

Group 3 Sodium channel modulators
3A: Pyrethrins, Pyrethroids (e.g. Cypermethrin)
3B: DDT, Methoxychlor

PYGANIC

Group 4 Nicotinic acetylcholine receptor (nAChR) competitive modulators
4A: Neonicotinoids (e.g. Imidacloprid, Thiamethoxam)
4B: Nicotine
4C: Sulfoximines (e.g. Sulfoxaflor)
4D: Butenolides (e.g. Flupyradifurone)

ACTARA, ADMIRE, ASSAIL…

Group 5 Nicotinic acetylcholine receptor (nAChR) allosteric modulators
5: Spinosyns (e.g. Spinosad, Spinetoram)

DELEGATE, SPINTOR, ENTRUST…

Group 6 Glutamate-gated chloride channel (GluCl) allosteric modulators
6: Avermectins, Milbemycins (e.g. Abamectin, Emamectin benzoate)

Group 9 Chordotonal organ TRPV channel modulators
9B: Pyridine azomethine derivatives (e.g. Pymetrozine, Pyrfluquinazon)

Group 14 Nicotinic acetylcholine receptor (nAChR) channel blockers
14: Nereistoxin analogs (e.g. Cartap hydrochloride)

Group 19 Octopamine receptor agonists
19: Amitraz

Group 22 Voltage-dependent sodium channel blockers
22A: Oxadiazines (e.g. Indoxacarb)
22B: Semicarbazones (e.g. Metaflumizone)

AVAUNT

Group 28 Ryanodine receptor modulators
28: Diamides (e.g. Chlorantraniliprole, Cyantraniliprole, Flubendiamide)

ALTACOR

Group 29 Chordotonal organ modulators – undefined target site
29: Flonicamid

Midgut Targets

Group 11 Microbial disruptors of insect midgut membranes
11A: *Bacillus thuringiensis*
11B: *Bacillus sphaericus*

BT-Dipel

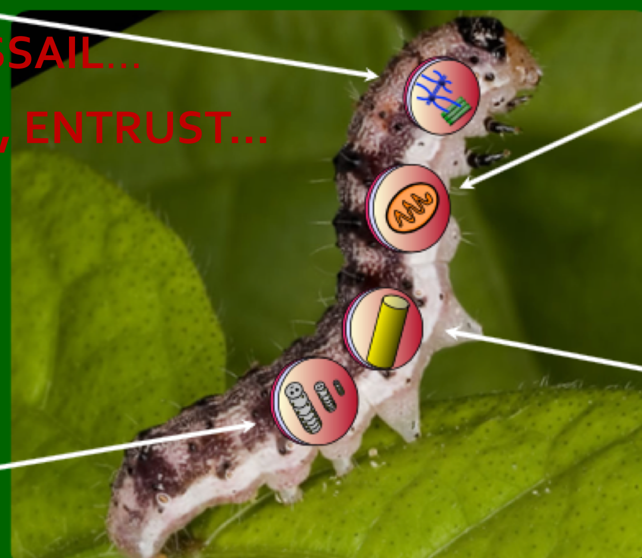
Effective IRM strategies: MoA Sequences & alternations

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

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, e.g. neonicotinoids (Group 4A).

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

Sequence of insecticides through season



Color Scheme Notes:

The color scheme used here associates modes of action into broad categories based on the physiological functions affected, as an aid to understanding symptomology, speed of action and other properties of the insecticides, and not for any resistance management purpose. **Rotations for resistance management should be based only on the numbered mode of action groups.** The cross-resistance potential between sub-groups is higher than that between different groups, so rotation between sub-groups should only be used where effective registered insecticides from other MoA groups are unavailable.

Respiration targets

Group 12 Inhibitors of mitochondrial ATP synthesis
12A: Diafenthiuron
12B: Organotin miticides (e.g. Cyhexatin)
12C: Propargite
12D: Tetradifon

Group 13 Uncouplers of oxidative phosphorylation via disruption of the proton gradient
13: Pyrroles (e.g. Chlorfenapyr), Dinitrophenols, (e.g.DNOC), Sulfuramid

Group 20 Mitochondrial complex III electron transport inhibitors
20A: Hydramethylnon
20B: Acequinocyl
20C: Fluacrypyrim
20D: Bifenazate

Group 21 Mitochondrial complex I electron transport inhibitors
21A: METI acaricides & insecticides (e.g. Pyridaben)
21B: Rotenone (Derris)

Group 24 Mitochondrial complex IV electron transport inhibitors
24A: Phosphides (e.g. Phosphine)
24B: Cyanides (e.g. Sodium cyanide)

Group 25 Mitochondrial complex II electron transport inhibitors
25A: *Beta*-ketonitrile derivatives (e.g. Cyenopyrafen, Cyflumetofen)
25B: Carboxanilides, (e.g. Pyflubumide)

Growth & Development targets

Group 7 Juvenile hormone mimics
7A: Juvenile hormone analogues (e.g. Methoprene)
7B: Fenoxycarb
7C: Pyriproxyfen

KNACK or ESTEEM

Group 10 Mite growth inhibitors
10A: Clofentezine, Diflovidazin, Hexythiazox
10B: Etoxazole

Group 15 Inhibitors of chitin biosynthesis, Type 0
15: Benzoylureas (e.g. Flufenoxuron, Novaluron)

RIMON

Group 16 Inhibitors of chitin biosynthesis, type 1
16: Buprofezin

Group 17 Moulting disruptors, Dipteran
17: Cyromazine

Group 18 Ecdysone receptor agonists
18: Diacylhydrazines (e.g. Methoxyfenozide, Tebufenozide)

CONFIRM, INTREPID

Group 23 Inhibitors of acetyl CoA carboxylase
23: Tetronic & Tetramic acid derivatives (e.g. Spirodiclofen)

MOVENTO

Miscellaneous non-specific (multi-site) inhibitors

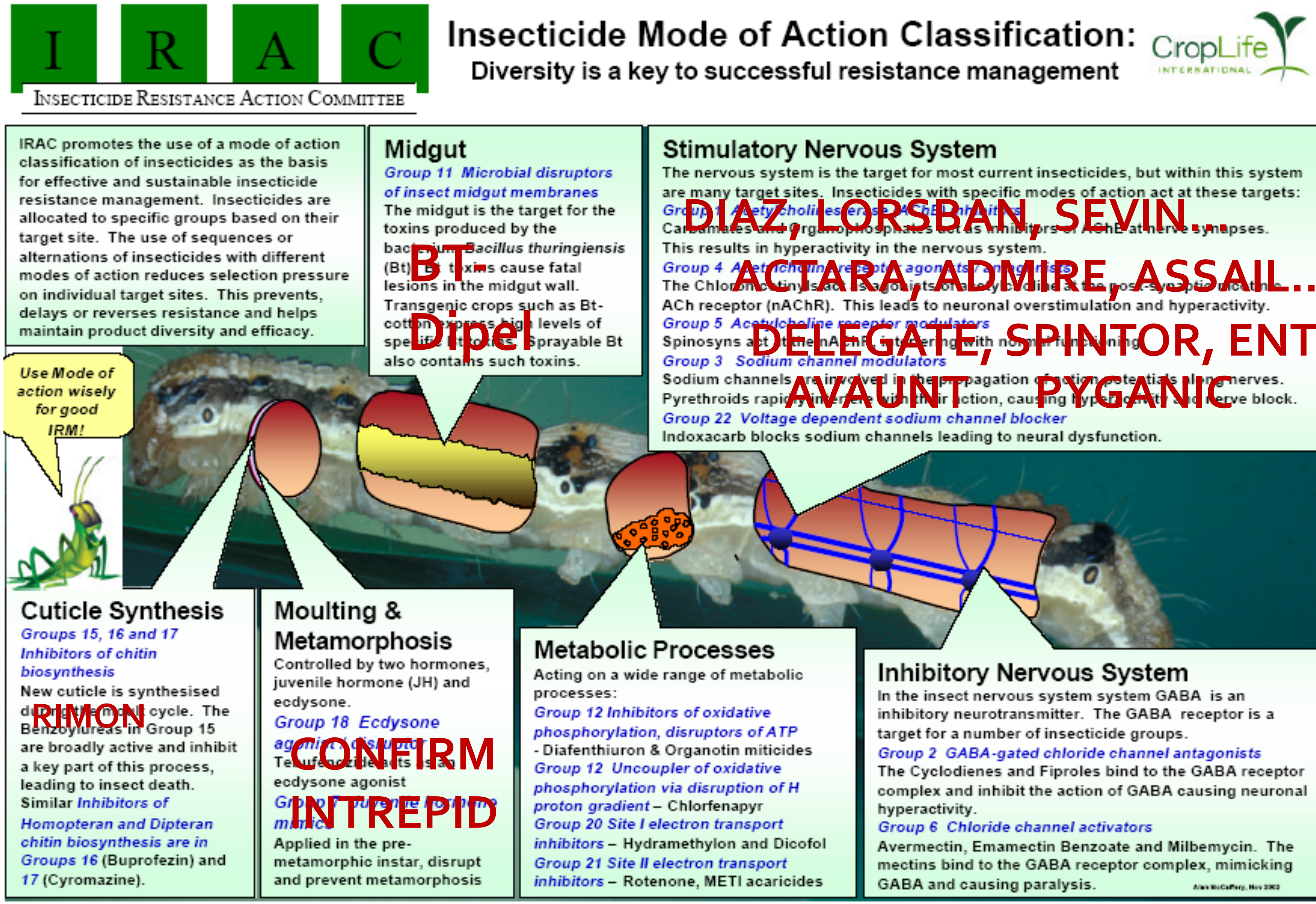
Group 8 8A: Alkyl halides, 8B: Chloropicrin, 8C: Fluorides, 8D: Borates, 8E: Tartar emetic, 8F: Methyl isothiocyanate generators

MoA Sequences & alternations – Exceptions

IRAC recommends alternations, sequences or rotations of compounds from different MoA groups to provide a sustainable and effective approach to IRM. Three groups (8, 13 and UN) are exempt from the recommendations as they do not contain compounds acting at a common target site

Unknown

Group UN Compounds of unknown or uncertain mode of action (e.g. Azadiractin, Benzoximate, Bromopropylate, Chinomethionat, Dicofol, Lime sulfur, Pyridalyl, Sulfur)

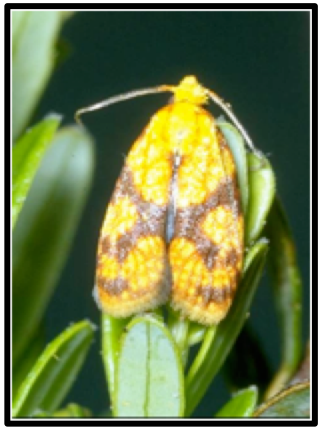


IRAC
INSECTICIDE RESISTANCE ACTION COMMITTEE
Insecticide Mode of Action Classification:
Diversity is a key to successful resistance management
CropLife INTERNATIONAL
IRAC promotes the use of a mode of action classification of insecticides as the basis for effective and sustainable insecticide resistance management. Insecticides are allocated to specific groups based on their target site. The use of sequences or alternations of insecticides with different modes of action reduces selection pressure on individual target sites. This prevents, delays or reverses resistance and helps maintain product diversity and efficacy.
Midgut
Group 11 Microbial disruptors of insect midgut membranes
The midgut is the target for the toxins produced by the bacterium Bacillus thuringiensis (Bt). Bt toxins cause fatal lesions in the midgut wall. Transgenic crops such as Bt-cotton express high levels of specific Bt toxins. Sprayable Bt also contains such toxins.
BT- Dipel
Stimulatory Nervous System
The nervous system is the target for most current insecticides, but within this system are many target sites. Insecticides with specific modes of action act at these targets:
Group 1 Acetylcholinesterase (AChE) inhibitors
Carbamates and Organophosphates act as inhibitors of AChE at nerve synapses. This results in hyperactivity in the nervous system.
DIAZ, LORSBAN, SEVIN…
Group 4 Acetylcholine receptor agonists / antagonists
The Chloronicotinyls act as agonists or antagonists at the post-synaptic nicotinic ACh receptor (nAChR). This leads to neuronal overstimulation and hyperactivity.
ACTARA, ADMIRE, ASSAIL…
Group 5 Acetylcholine receptor modulators
Spinosyns act at the nAChR, interfering with normal functioning.
DELEGATE, SPINTOR, ENTRUS
Group 3 Sodium channel modulators
Sodium channels are involved in the propagation of action potentials along nerves. Pyrethroids rapidly interfere with their action, causing hyperactivity and nerve block.
Group 22 Voltage dependent sodium channel blocker
Indoxacarb blocks sodium channels leading to neural dysfunction.
AVAUNT PYGANIC
Use Mode of action wisely for good IRM!
Cuticle Synthesis
Groups 15, 16 and 17 Inhibitors of chitin biosynthesis
New cuticle is synthesised during the moult cycle. The Benzoylureas in Group 15 are broadly active and inhibit a key part of this process, leading to insect death. Similar Inhibitors of Homopteran and Dipteran chitin biosynthesis are in Groups 16 (Buprofezin) and 17 (Cyromazine).
RIMON
Moulting & Metamorphosis
Controlled by two hormones, juvenile hormone (JH) and ecdysone.
Group 18 Ecdysone agonist / disruptor
Tebufenozide acts as an ecdysone agonist
Group 7 Juvenile hormone mimics
Applied in the pre-metamorphic instar, disrupt and prevent metamorphosis
CONFIRM
INTREPID
Metabolic Processes
Acting on a wide range of metabolic processes:
Group 12 Inhibitors of oxidative phosphorylation, disruptors of ATP
- Diafenthiuron & Organotin miticides
Group 12 Uncoupler of oxidative phosphorylation via disruption of H proton gradient – Chlorfenapyr
Group 20 Site I electron transport inhibitors – Hydramethylon and Dicofol
Group 21 Site II electron transport inhibitors – Rotenone, METI acaricides
Inhibitory Nervous System
In the insect nervous system system GABA is an inhibitory neurotransmitter. The GABA receptor is a target for a number of insecticide groups.
Group 2 GABA-gated chloride channel antagonists
The Cyclodienes and Fiproles bind to the GABA receptor complex and inhibit the action of GABA causing neuronal hyperactivity.
Group 6 Chloride channel activators
Avermectin, Emamectin Benzoate and Milbemycin. The mectins bind to the GABA receptor complex, mimicking GABA and causing paralysis.

We have seen this in cranberry already….

Weevil

- Resistant to organophosphates
- Worried developing resistance to Avaunt



Spag

- Resistant to organophosphates
- May be developing to Delegate

Good news....

photos by C. Armstrong

<u>BHF – Blackheaded fireworm</u>

- Not likely to develop resistance

<u>CFW – Cranberry Fruitworm</u>

- Not likely to develop resistance

Cranberry Weevil

- Avaunt 2007 SPRING

  Indoxacarb

- Actara 2005 SPRING OR SUMMER

  Thiamethoxam

  neonicotinoid, high bee toxicity

  Zone II Restricted

- Belay 2010 SUMMER

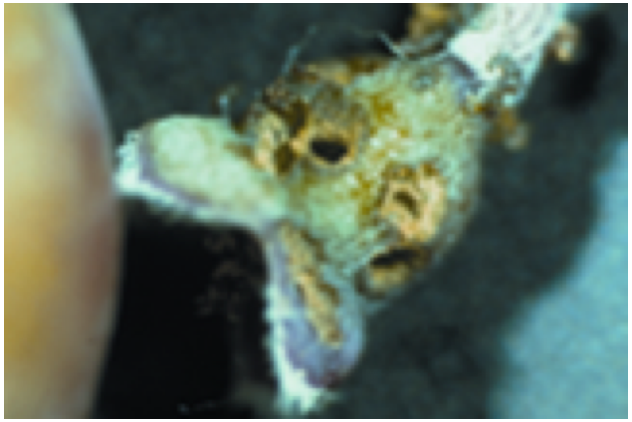
  Clothianidin

  neonicotinoid, high bee toxicity

Resistant to organophosphates in 2000

- Lorsban
- Guthion
- Parathion
- Diazinon
- Imidan
- Orthene
- Sevin

Avaunt (indoxacarb)



Spring population	Summer population
Superb! weevil control! May have to retreat as more weevil come in from woods	**NOT EFFECTIVE** **Do not use Avaunt** **New generation can metabolize the pesticide**

Cranberry Weevil

- Avaunt 2007 SPRING
  Indoxacarb

- Actara 2005 SPRING OR SUMMER
  Thiamethoxam
  neonicotinoid, high bee toxicity
  Zone II Restricted

- Belay 2010 SUMMER
  Clothianidin
  neonicotinoid, high bee toxicity

Resistant to organophosphates in 2000

- Lorsban
- Guthion
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- Imidan
- Orthene
- Sevin

Cranberry Weevil

- **Avaunt** 2007 SPRING
  Indoxacarb

Dupont X FMC

- **Actara** 2005 SPRING-SUMMER
  Thiamethoxam
  neonicotinoid, high bee toxicity
  Zone II Restricted

Syngenta

Resistant to organophosphates in 2000

- Lorsban
- Guthion
- Parathion
- Imidan
- Orthene
- Sevin

X

Resistance trials likely this year!

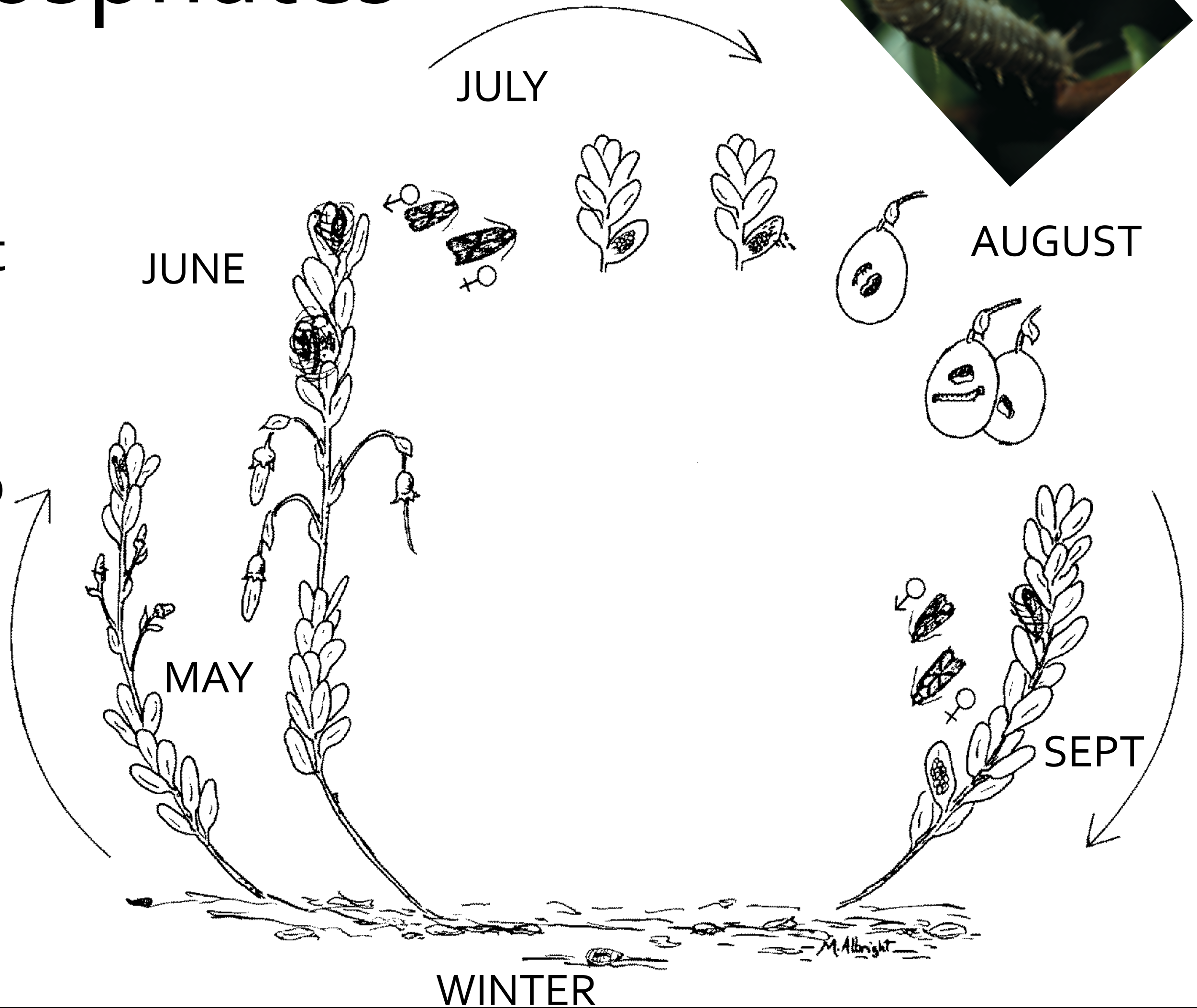
Clothianidin

Sparganothis fruitworm

Comes in different styles— the wriggler

Sparganothis resistance to organophosphates

- Began ca. 20 years ago in Carver area
- Spread throughout industry
- Lorsban, Imidan, Orthene, Sevin no longer effective on most populations



SPAG Spring Spray Options

- Altacor
- Assail
- Avaunt
- **Intrepid**, Confirm
  - Invertid (Loveland)
- **Delegate**
- ~~Diazinon~~
- ~~Imidan~~
- ~~Lorsban~~
- ~~Orthene~~
- ~~Sevin~~

Resistance

- Best management approach is to focus on the spring
- Summer populations much harder to monitor and manage
- Delegate and Intrepid best (only) choices for spring management
- Med-large larvae – Delegate?
- Some growers have better luck with Intrepid even on larger larvae!

SPAG Spring Spray Options

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- ~~Lor[illegible]~~
- ~~[illegible]ene~~
- ~~Sevin~~

Resistance

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So if you are <u>only</u> using Delegate for Sparganothis, you are part of the problem!!

Fungicide Resistance Risk

DMI
FRAC Code 3

Indar
Proline

QoI
FRAC Code 11

Abound
Evito

polyoxins
FRAC Code 19

OSO, Ph-D

chloronitriles
FRAC Code M5

Bravo (and many others)

FRAC Code M3

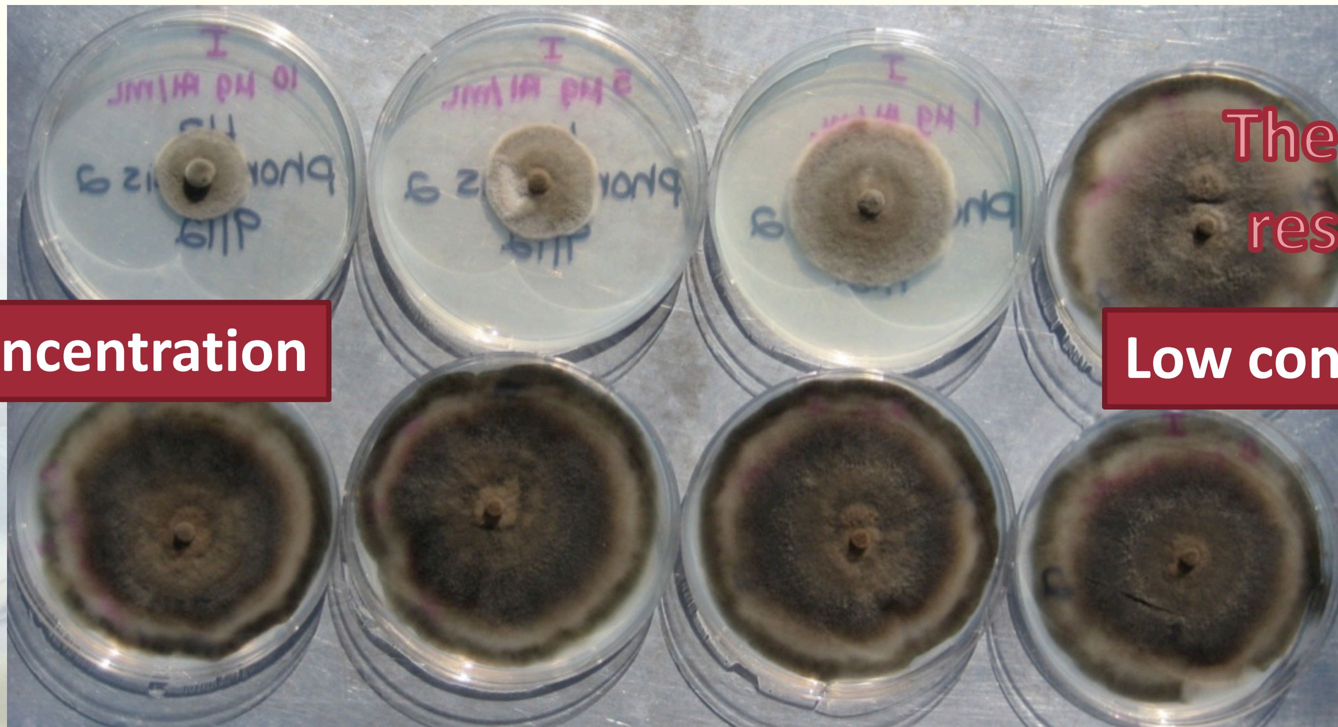
Mancozeb
Ferbam

High risk
Medium risk
Low risk

Fungicide resistance is a very real and serious threat!

In vitro assays by F. Caruso in 2012

- **2 different locations in MA,** 4 fruit rot pathogens
- **High to low concentrations of fungicide**
- Reduced sensitivity to Indar and Abound
- Cross-resistance (Indar & Proline & new one coming)
    - all in same FRAC group



FUNGICIDES - Alternate, rotate, or sequence different pesticide MoA classes

Use FRAC, IRAC, and HRAC when choosing chemicals!

- Do not rely on product names
- Do not rely on active ingredients
  - Many different products and active ingredients can be in the same group!

11	Abound Aftershock Evito	azoxystrobin fluoxastrobin	C3: cytochrome bc1 at Qo site	QoI-fungicides Strobilurins	methoxy-acrylates dihydro-dioxazines	High Risk
3	Indar Proline	fenbuconazole mysteryconazole prothioconazole	G1: c14-demethylase in sterol biosynthesis	DMI-fungicides (DeMethylation Inhibitors)	triazoles	Medium Risk
19	OSO Ph-D	polyoxin	H4: chitin synthase	polyoxins	peptidyl pyrimidine nucleoside	Medium Risk

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Depend on chart book RM section

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FRUIT ROT MANAGEMENT

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19	**OSO** **Ph-D**	Polyoxin D zinc salt	**H4**: chitin synthase	polyoxins	peptidyl pyrimidine nucleoside	**Medium Risk**
M1	**Champ** **Kocide**	copper (salts)	**M1**: Multi-site contact activity	inorganic	inorganic	Low Risk
M3	**Ferbam** **Manzate** **Dithane** **Penncozeb**	ferbam mancozebs	**M3**: Multi-site contact activity	dithiocarbamates EBDC's (Ethylene bis dithio carbamate)	dithiocarbamates	Low Risk
M5	**Bravo** **Chloronil** **Echo** **Equus** **Initiate**	chlorothalonil	**M5**: Multi-site contact activity	chloronitriles	chloronitriles	Low Risk

Mix together

Broad Spectrum

FRUIT ROT MANAGEMENT

11	Abound	azoxystrobin	C3: cytochrome bc1 at Qo site	QoI-fungicides	methoxy-acrylates	High Risk
	Aftershock Evito	fluoxastrobin		Strobilurins	dihydro-dioxazines	
3	Indar Proline	fenbuconazole mysteryconazole prothioconazole	G1: c14-demethylase in sterol biosynthesis	DMI-fungici (DeMethylat	triazoles	Medium
19	OSO Ph-D	Polyoxin D zinc salt	H4: chitin synthase	polyoxins		
M1	Champ Kocide	copper (salts)	M1: Multi-site contact activity	inorganic		
M3	Ferbam	ferbam	M3: Multi-site contact activity	dithiocarbam		
	Manzate Dithane Penncozeb	mancozebs		EBDC's (Ethylene bis dithio carbamate)		
M5	Bravo Chloronil Echo Equus Initiate	chlorothalonil	M5: Multi-site contact activity	chloronitriles	chloronitriles	Low Risk

Mix together

and Rotate

Broad Spectrum

Questions?