Winter 1-25-2023

2023 Update Mtg Jan 25: Resistance Management Review

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Pesticide Resistance Management in CRANBERRY

by Katie Ghantous and Marty Sylvia

with input from
Hilary Sandler and Laura McDermott

January 25, 2023

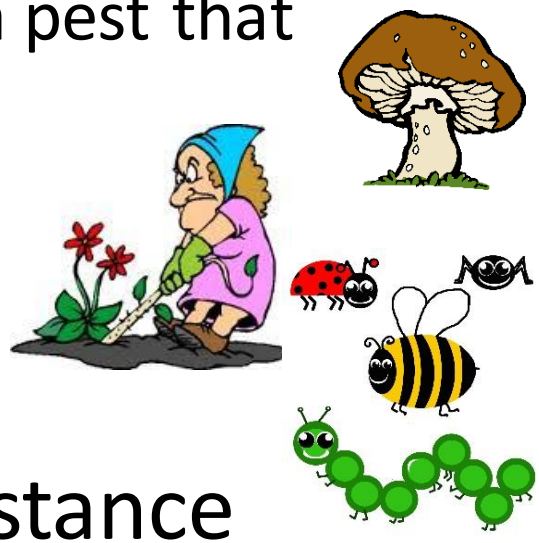
With special thanks to:

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

NE-SARE Professional Development Program
ENE15-140-29994

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.

Pesticide use "selects" for resistance

- Kills those *without* the gene to protect
- Those *with* the gene don't die
  - Are "Selected" for by killing off other types

What is Pesticide Resistance?

Pests with protective gene pass on resistance to their offspring

Pest population has increasing numbers of resistant individuals

Over time, population as a whole is more resistant to the pesticide

Goal of RM

- **Delaying** development of resistance, **not** managing resistant pest biotypes once detected
- Practice good stewardship of the tools we have

Why is Managing Resistance Important?

Pesticide resistance is increasing!

- Currently:
  - +500 insect and mite species
  - +260 weed species
  - 150 plant diseases
  - 10 rodent species

All pesticides are at risk for resistance!

Herbicides
Herbicide Resistance Action Committee (HRAC)
http://www.hracglobal.com

Fungicides
Fungicide Resistance Action Committee (FRAC)
http://www.frac.info

Insecticides
Insecticide Resistance Action Committee (IRAC)
http://www.irac-online.org

International groups founded by the agrochemical industry for a cooperative approach to resistance management. Sources for info and education materials.

Mode of action (MoA)

The chemical structure of a pesticide defines:

- **Target site** - “where” - physical location within an organism where chemical acts
- **Mode of action** - “how” - action of a chemical at target site

Pesticide Groups

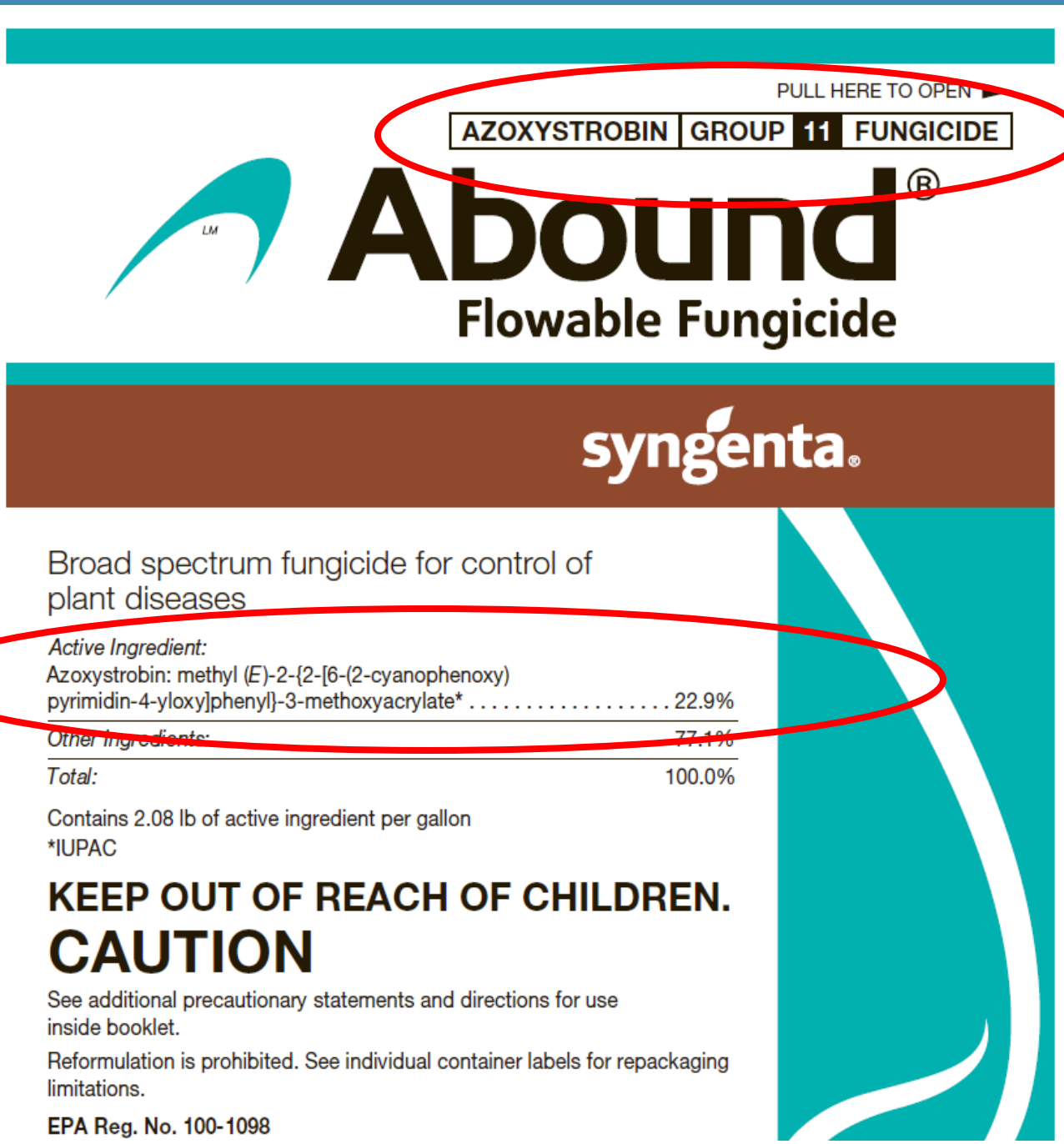
Resistance Action Committees have assigned each pesticide a **Group Number**

- Group number based on target site / MoA
- Pesticides in a group share similar characteristics and risk cross-resistance
- Group number is clearly marked on most labels
- Help make resistance management decisions (plan rotations)
- No relationship across types (HRAC 1 not related to IRAC 1)

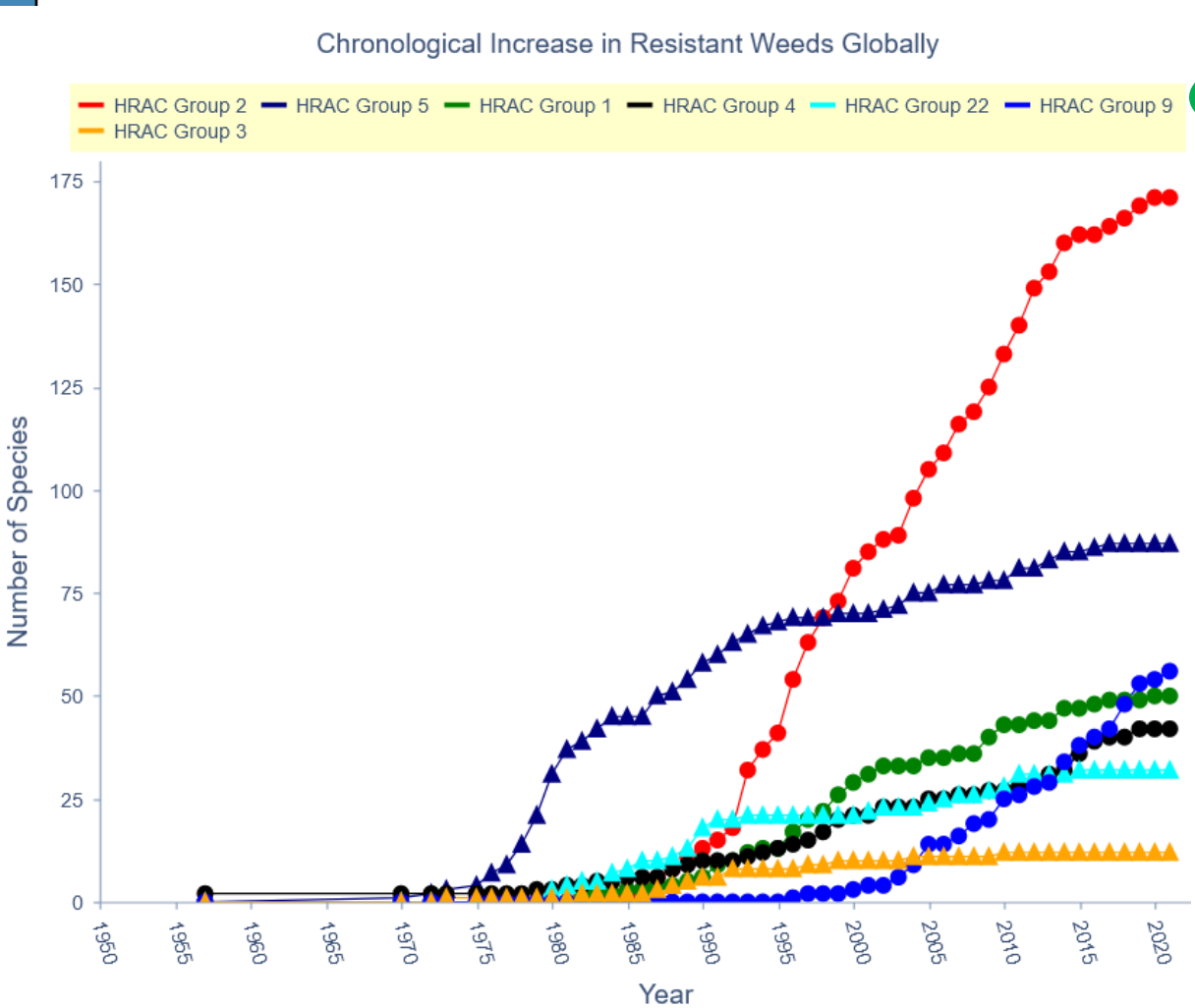
Clethodim - Select, Intensity, IntensityOne, Arrow, Shadow, etc

Sethoxydim – Poast

- Different a.i., but still SAME GROUP


PULL HERE TO OPEN
AZOXYSTROBIN GROUP 11 FUNGICIDE
Abound®
Flowable Fungicide
syngenta®
Broad spectrum fungicide for control of plant diseases
Active Ingredient:
Azoxystrobin: methyl (E)-2-{2-[6-(2-cyanophenoxy) pyrimidin-4-yloxy]phenyl}-3-methoxyacrylate* 22.9%
Other Ingredients: 77.1%
Total: 100.0%
Contains 2.08 lb of active ingredient per gallon
*IUPAC
KEEP OUT OF REACH OF CHILDREN.
CAUTION
See additional precautionary statements and directions for use inside booklet.
Reformulation is prohibited. See individual container labels for repackaging limitations.
EPA Reg. No. 100-1098

Herbicides



WSSA/HRAC GROUP	TRADE NAME	ACTIVE INGREDIENT	MODE OF ACT
1	Select Intensity Poast	clethodim sethoxydim	Inhibition of acety carboxylase (AC
4	Quinstar 2,4-D, Weedar 64 Stinger, Spur	quinclorac 2,4-D clopyralid	Action like indole acid (synthetic au
5	Simazine	simazine	Inhibition of phot at photosystem II
9	Roundup	glyphosate	Inhibition of EPS
12	Evital	norflurazon	Bleaching: Inhib carotenoid biosyn the phytoene desa (PDS)
14	Zeus	sulfentrazone	Inhibition of Protoporphyrinog (PPO)
27	Callisto, Explorer, and others	mesotrione	Bleaching: Inhib hydroxyphenyl-py dioxygenase (4-H
29	Casoron	dichlobenil	Inhibition of cell (cellulose) synthe
0	Devrinol	napropramide	Unknown

Herbicides

Most weeds take a year or more to reproduce
BUT Most resistance shows up in annual plants

Fig 1. Lifecycle Duration for All Resistant Weed Species in the Database

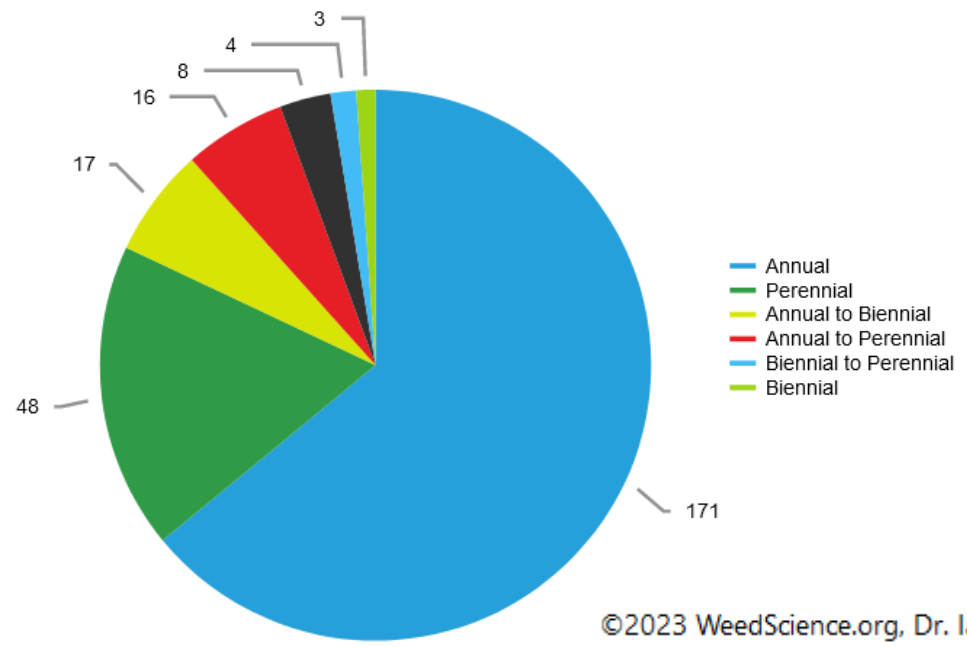
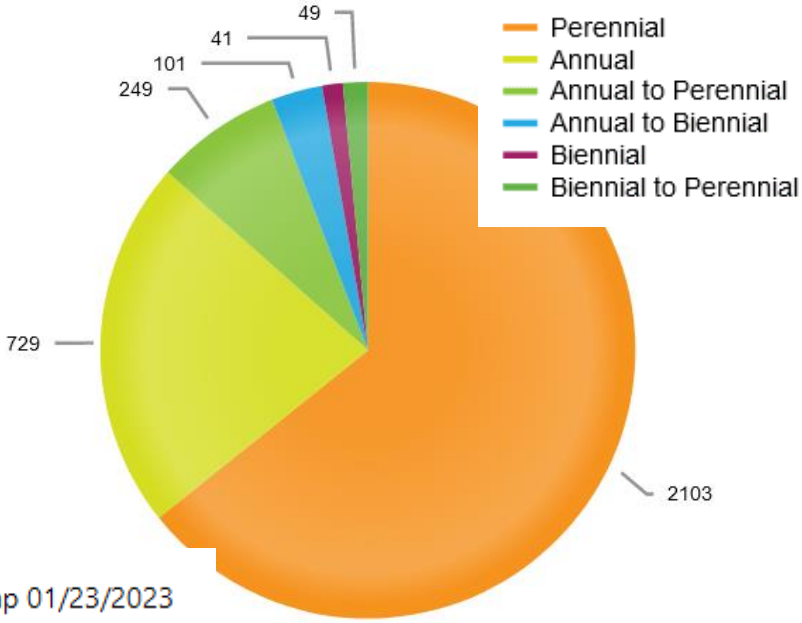


Fig 2. Lifecycle Duration for 3,372 Known Weed Species



Fungicides

Fungi reproduce quickly!

- Many generations in a short time
- Can grow exponentially – doubling in hours
- Many chances for pesticide resistance mutations to spread

Fungicides

A single gene mutation in a fungus can overcome the toxic effects of a single-site fungicide!

To minimize the risk of single-site fungicides, apply them in combinations (example 3+11)

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 AFrame	azoxystrobin	C3: cytochrome bc1 at Qo site	QoI-fungicides	methoxy-acrylates	High Risk (Single site fungicide)
	Aftershock, Evito	fluoxastrobin		Strobilurins	dihydro-dioxazines	
3 + 11	Quadris Top	azoxystrobin + difenoconazole	C3 + G1	QoI- + DMI-fungicides	methoxy-acrylates + triazoles	High/ Medium Risk
3	Indar Proline	fenbuconazole prothioconazole	G1: c14-demethylase in sterol biosynthesis	DMI-fungicides (DeMethylation Inhibitors)	triazoles	Medium Risk (Single site fungicide)
19	OSO Ph-D	Polyoxin D zinc salt	H4: chitin synthase	polyoxins	peptidyl pyrimidine nucleoside	Medium Risk
33	Aliette Legion	fosetyl-Al aluminum-tris	Unknown	phosphonates	ethyl phosphonates	Low Risk Multi-site fungicide
	Alude, Confine Fosphite, Fungi-Phite, K-Phite, Oxiphos, Phiticide, Phostrol, ProPhyt, Rampart, Reliant, Reveille	phosphorous acids and salts				
M1	Badge, Champ, Kocide, Mastercop, Nordox, NuCop	copper (salts)	M1: Multi-site contact activity	inorganic	inorganic	Low Risk Multi-site fungicide
M3	Ferbam	ferbam	M3: Multi-site contact activity	dithiocarbamates	dithiocarbamates	Low Risk Multi-site fungicide
	Dithane, Manzate, Penncozeb, Roper	mancozebs		EBDC's (Ethylene bis dithio carbamate)		
M5	Bravo, Chloronil, Echo Equus, Initiate	chlorothalonil	M5: Multi-site contact activity	chloronitriles	chloronitriles	Low Risk Multi-site fungicide

Consult the label for RM info

RESISTANCE MANAGEMENT

GROUP	11	FUNGICIDE

Abound (azoxystrobin) is a Group 11 fungicide. The mode of action for Abound is the inhibition of the QoI (quinone outside) site within the electron transport system [Group 11]. Fungal pathogens can develop resistance to products with the same mode of action when used repeatedly. Because resistance development cannot be predicted, use of this product should conform to resistance management strategies established for the crop and use area. Consult your local or State agricultural authorities for resistance management strategies that are complementary to those in this label. Resistance management strategies may include alternating and/or tank-mixing with products having different modes of action or limiting the total number of applications per season. Syngenta encourages responsible resistance management to ensure effective long-term control of the fungal diseases on this label.

Follow the crop specific resistance management recommendations in the directions for use.

If no resistance recommendation on number of applications is specified in the directions for use, follow the recommendations in the table below.

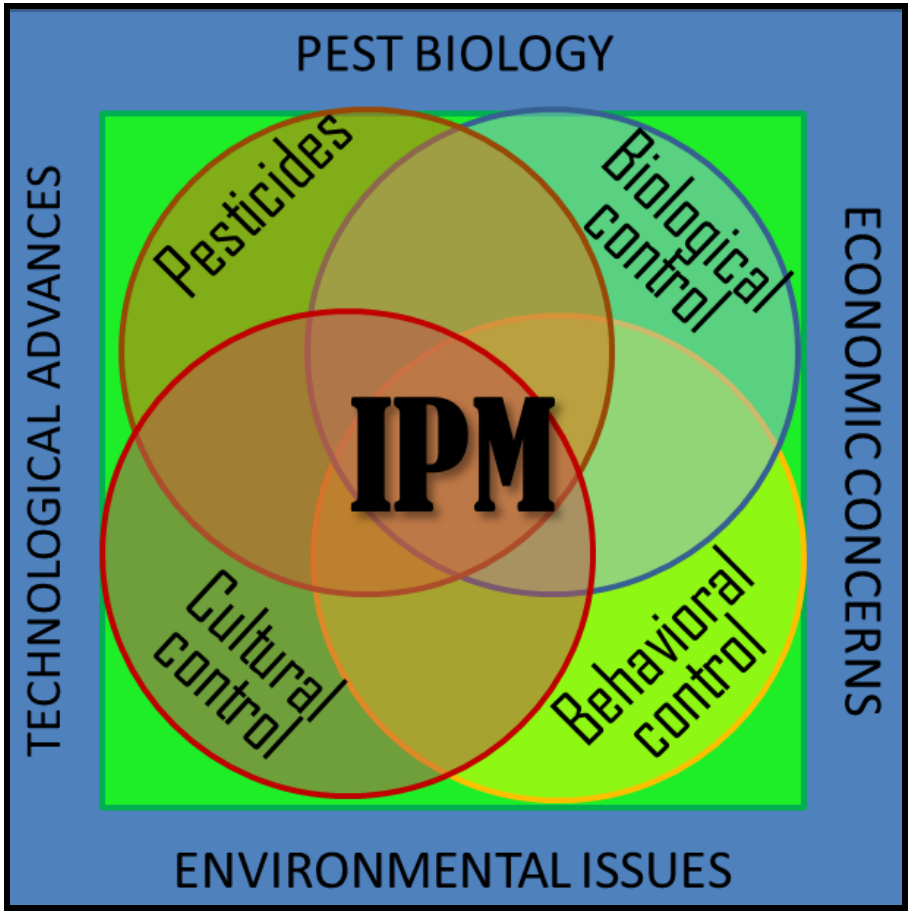
If planned total number of fungicide applications per crop is:	1	2	3	4	5	6	7	8	9	10	11	12
Recommended Solo QoI fungicide sprays	1	1	2	2	2	2	2	3	3	3	3	4
Recommended QoI fungicide sprays in												

Applications must be timed correctly

- Target the most vulnerable life stage of the pest
- Use spray rates and application intervals recommended by the manufacturer and in compliance with local agricultural extension regulations.
  - A high rate can take out pests that might be somewhat resistant, but using a rate too low may allow them to survive

✓ Do not rely on pesticides alone

Integrate different controls!



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

Chart Book is best place to see FRAC groupings

These are the broad spectrums – but all are under MRL clouds
Best options for fruit rot but limited use

FRAC GROUP	TRADE NAME	COMMON NAME	MODE OF ACTION	GROUP NAME	CHEMICAL GROUP	Resistance Development Risk
M1	**Badge, Champ, Kocide, Mastercop, Nordox, NuCop**	copper (salts)	**M1**: Multi-site contact activity	inorganic	inorganic	Low Risk Multi-site fungicide
M3	**Ferbam**	ferbam	**M3**: Multi-site contact activity	dithiocarbamates	dithiocarbamates	Low Risk Multi-site fungicide
	Dithane, Manzate, Penncozeb, Roper	mancozebs		EBDC's (Ethylene bis dithio carbamate)		
M5	**Bravo, Chloronil, Echo Equus, Initiate**	chlorothalonil	**M5**: Multi-site contact activity	chloronitriles	chloronitriles	Low Risk Multi-site fungicide

Chart Book is best place to see FRAC groupings

These are the broad spectrums – but all are under MRL clouds
Best options for fruit rot but limited use
Watch out for other formulations, same chemistry

Copper Count
Cuprofix
Kentan
Top Cop

Koveral

FRAC GROUP	TRADE NAME	COMMON NAME	MODE OF ACTION	GROUP NAME	CHEMICAL GROUP	Resistance Development Risk
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	Dithane, Manzate, Penncozeb, Roper	mancozebs				
M5	**Bravo, Chloronil, Echo Equus, Initiate**	chlorothalonil	**M5**: Multi-site contact activity	chloronitriles	chloronitriles	Low Risk Multi-site fungicide

Chart Book is best place to see FRAC groupings

These are the NOT broad spectrums – **Narrow-spectrum fungicides**!
They are effective against only a few usually closely related pathogens.
These usually have single-site activity and are often systemic.

FRAC GROUP	TRADE NAME	COMMON NAME	MODE OF ACTION	GROUP NAME	CHEMICAL GROUP	Resistance Development Risk
11	**Abound** **AFrame**	azoxystrobin	**C3**: cytochrome bc1 at Qo site	QoI-fungicides	methoxy-acrylates	**High Risk** (Single site fungicide)
	Aftershock, **Evito**	fluoxastrobin		Strobilurins	dihydro-dioxazines	
3 + 11	**Quadris Top**	azoxystrobin + difenoconazole	**C3 + G1**	QoI- + DMI-fungicides	methoxy-acrylates + triazoles	**High/ Medium Risk**
3	**Indar**	fenbuconazole	**G1**: c14-demethylase in sterol biosynthesis	DMI-fungicides	triazoles	**Medium Risk** (Single site fungicide)
	Proline	prothioconazole		(DeMethylation Inhibitors)		

Chart Book has best resistance management section for fruit rot planning

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	Proline	prothioconazole				

4 new fungicides in the pipeline

- 2 new compounds coming down the pike in *FRAC Group 7*
- Different than anything we have
- One older and in other crops (IR-4 2021)
- One newer and maybe more broad spectrum!! (IR-4 2022)

Chart Book has resistance mngmt section

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	Proline	prothioconazole				

- Another ***FRAC Group 3*** is pending submission to EPA (IR-4 2019)
- And best of all, a mix with ***FRAC Group 9 + 12*** (IR-4 2018) that was submitted to EPA May 2022 and should have a label for 2024 season!!

Fungicide Resistance Risk

DMI FRAC Code 3
Indar Proline

chloronitriles FRAC Code M5
Bravo (and many others)

Fungicide resistance is a very real and serious threat!

QoI FRAC Code 11
Abound Evito

polyoxins FRAC Code 19
Tavano

Ferbam

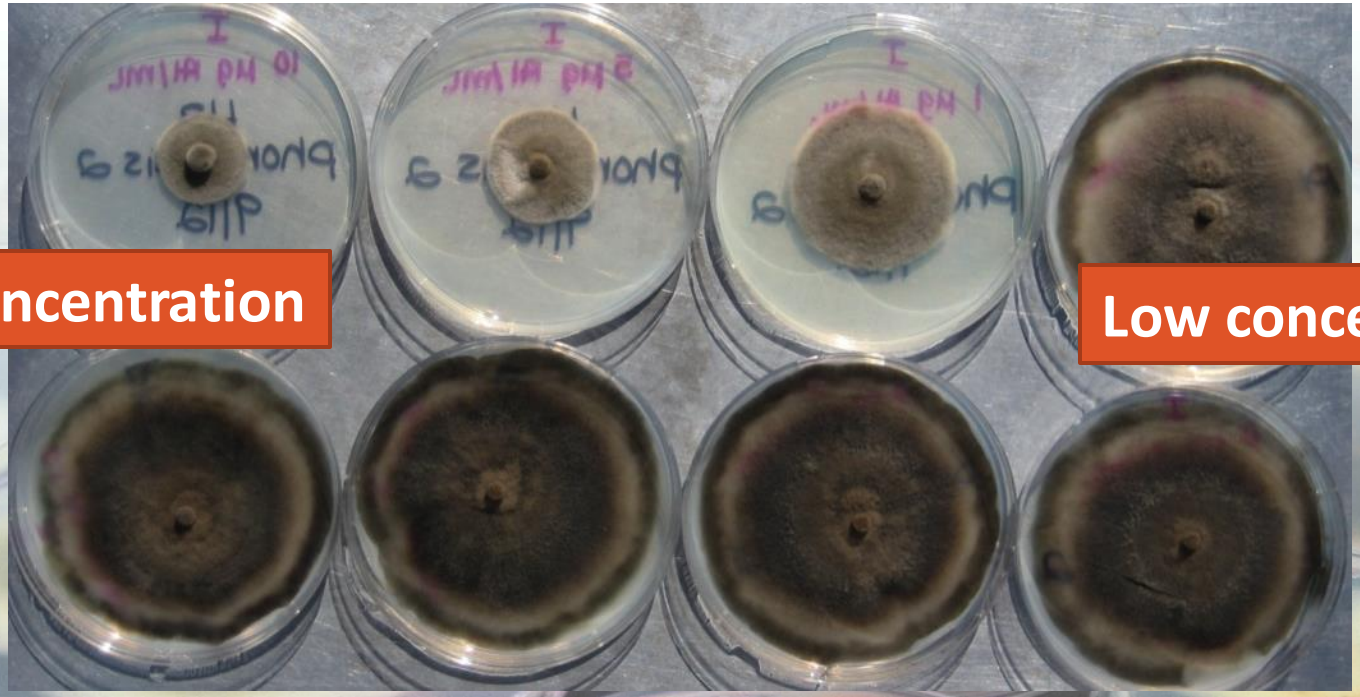
High risk

Medium risk

Low risk

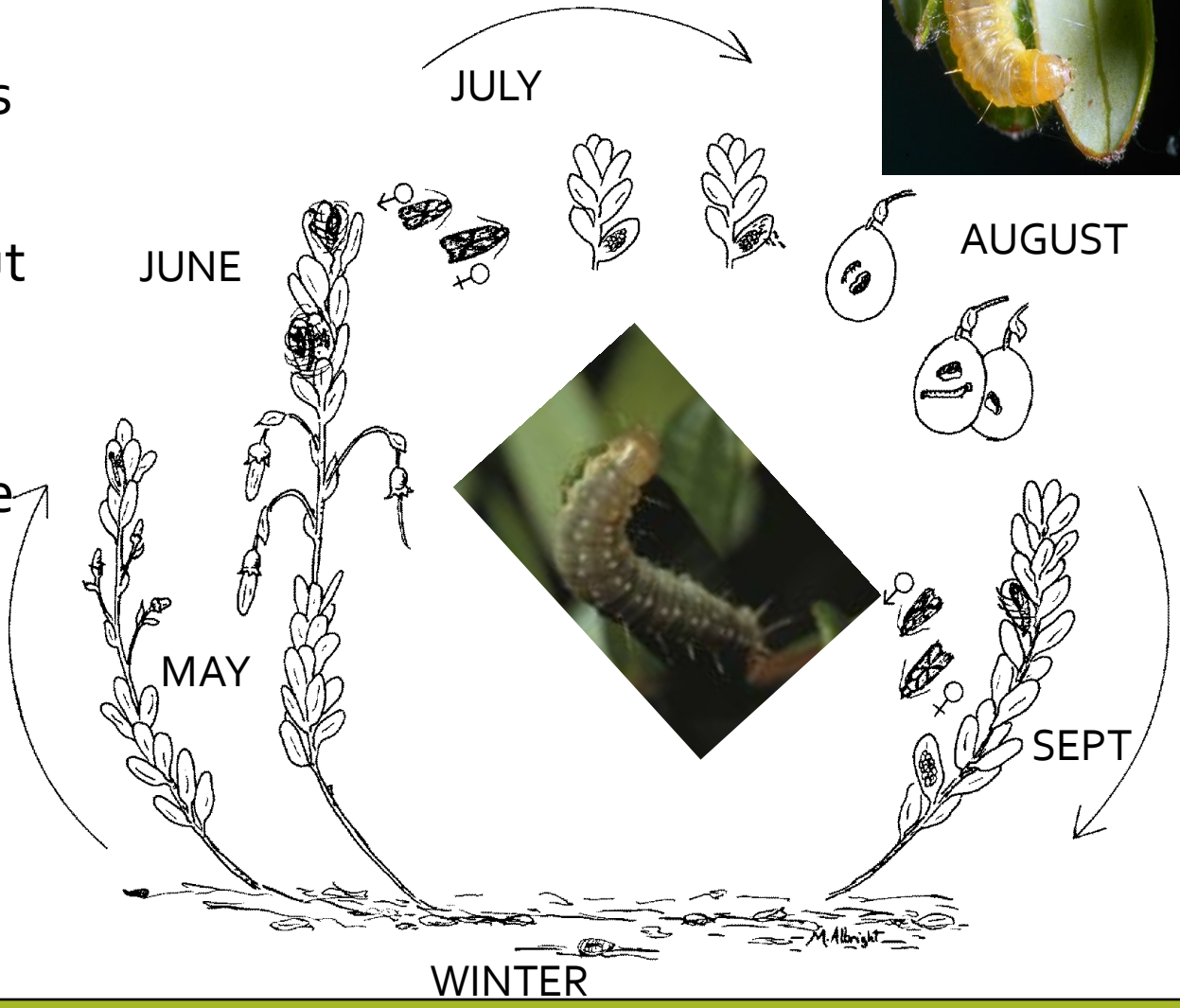
In vitro assays by Frank Caruso in 2012

- 2 different locations in MA
- Reduced sensitivity to Indar and Abound
- 4 fruit rot pathogens
- High to low concentrations of fungicide
- Cross-resistance (Indar & Proline & difenconazole)
  - Same FRAC group



Sparganothis fruitworm developed resistance to organophosphates

- Began ca. 20 years ago in Carver area
- Spread throughout industry
- Lorsban, Orthene no longer effective
- Resistance is no joke



SPAG Spring Spray Options

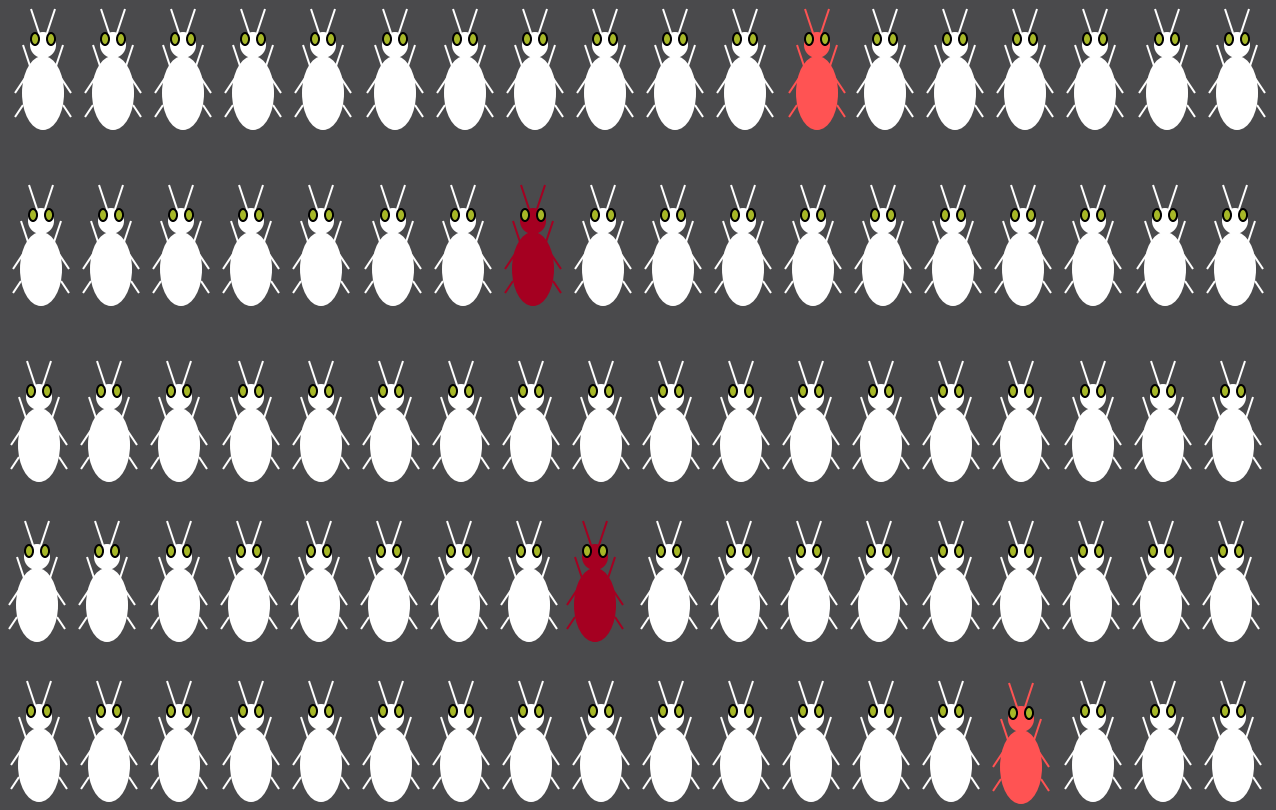
- Altacor
- Assail
- Avaunt
- **Intrepid**, Confirm
  - **Troubadour** Helena
  - **Turnstyle** UPI
- **Delegate**
- ~~Diazinon~~
- ~~Imidan~~
- ~~Lorsban~~
- ~~Orthene~~
- ~~Sevin~~

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!

Natural pest population

- Some bugs have genes that make them less sensitive to a pesticide



Pesticide application

- The bugs that are susceptible die

Pesticide application

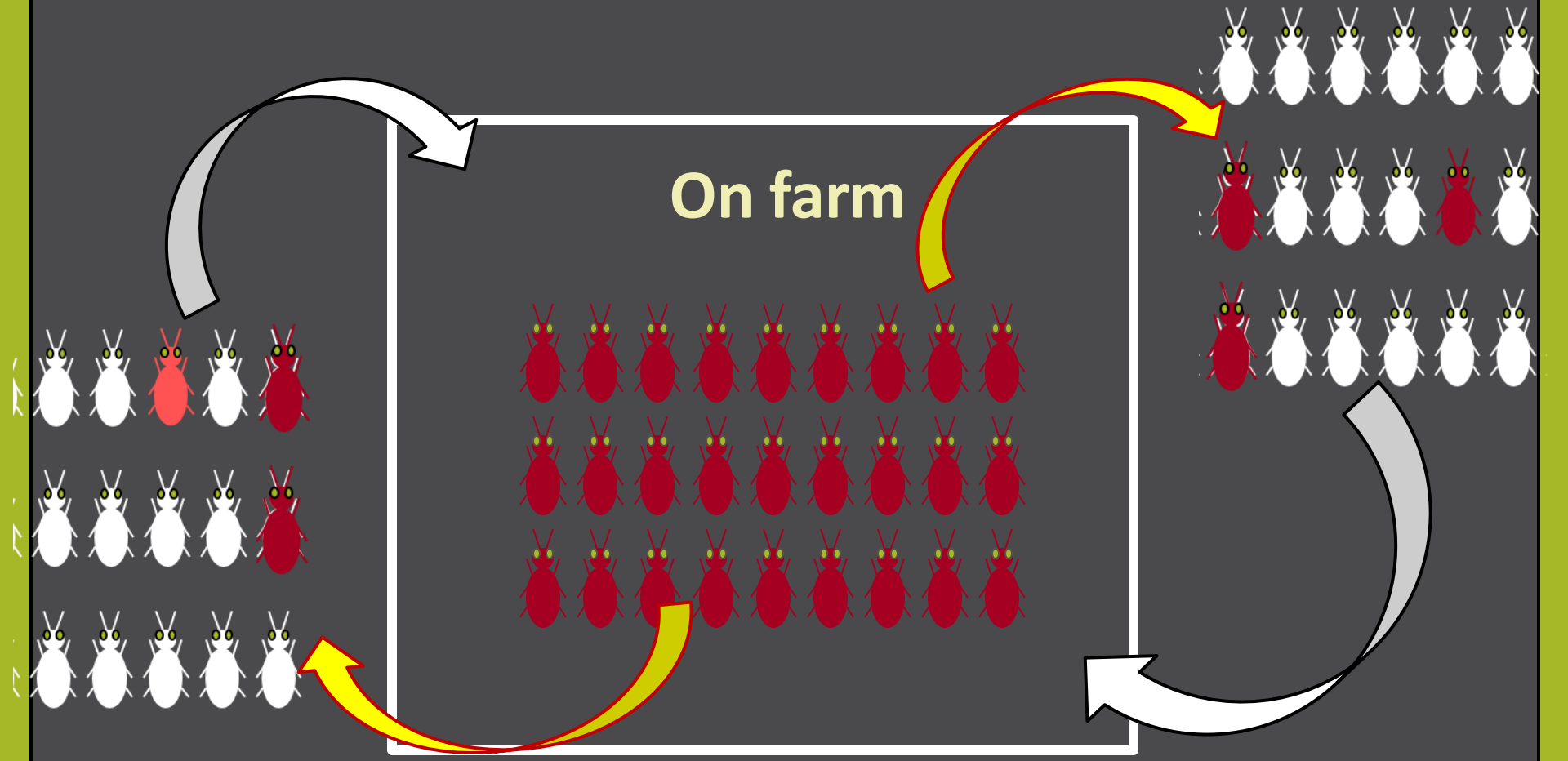
- The bugs that have naturally occurring genes that make them less sensitive to a pesticide survive…

After pesticide application

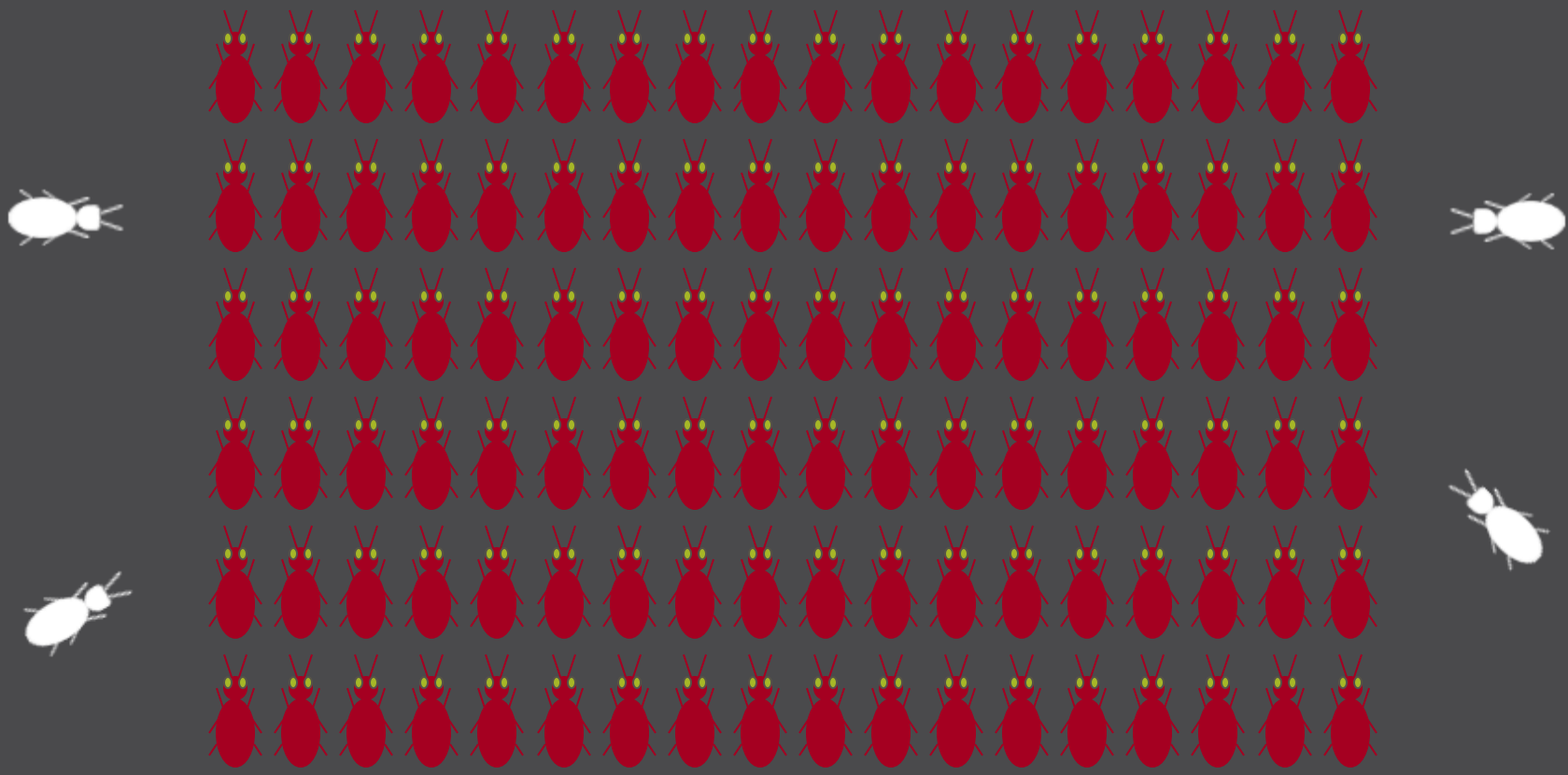
- We have applied selection pressure.
- The bugs with genes that make them less sensitive to a pesticide **reproduce**.
- The offspring have the genes that make them less sensitive to the pesticide.
- The new population is more resistant than a natural population.

- Eventually, the population is mostly made up of resistant individuals.
- Under permanent selection pressure, resistant insects outnumber susceptible ones and the insecticide is no longer effective.

Resistance takes time to develop!



- Outside population brings in susceptible gene.
- But it takes a long time to change.



Cranberry Weevil

Resistant to organophosphates by 2000

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

Resistant in 2015

- **Avaunt**, *indoxacarb*

Resistant to neonicotinoids 2020

- **Actara**, *thiamethoxam*
- ~~**Belay**, *clothianidin*~~

Resistant to pyrethroids in ?? 2026

- **Fanfare**, *bifenthrin*

Resistant to newest compound in ?? 2030

- New mode of action, ***

Weevil Bioassays "Indoxacarb Susceptibility Testing"

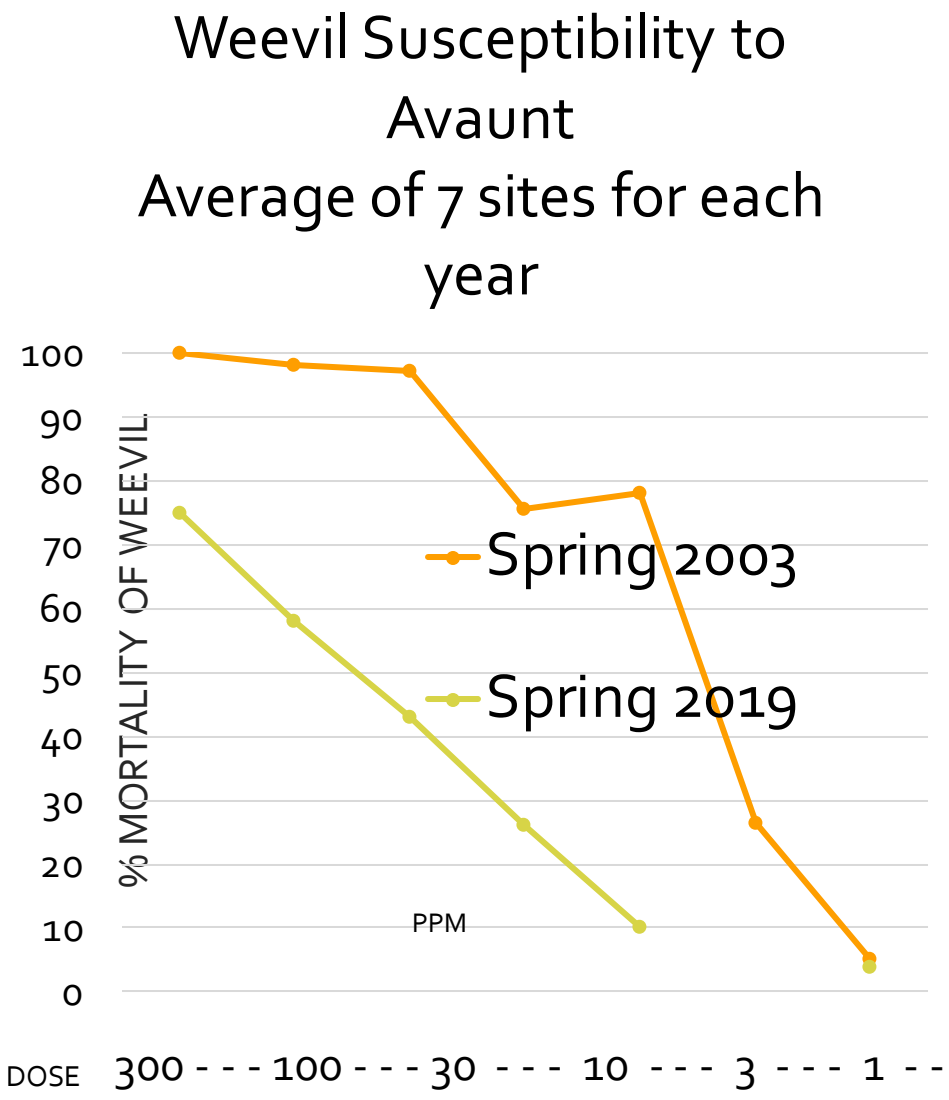
- FMC supplied plastic trays and serial dilutions of Avaunt
- 1 weevil, 24-36 replicates
- Collected from 7 different bogs
- End of May
- Allowed to feed on treated foliage
  - (3 uprights)
- 0-300 ppm Avaunt dips (concentrations)

Assess mortality after 3 days (72 hours)

% Mortality
Cranberry Weevil
Avaunt Bioassay

	2003	2019
Dose	SPRING	SPRING
PPM	Spring 2003	Spring 2019
300	100%	75%
100	98%	58%
30	97%	43%
10	76%	26%
3	78%	10%
1	26%	
0	5%	4%

Chemigation rate??



Insecticide Mode of Action Classification:

Diversity is a key to successful resistance management

IRAC
INSECTICIDE RESISTANCE ACTION COMMITTEE

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.

Group 4 Acetylcholine receptor agonists / antagonists

The Chloronicotinyls act as agonists at acetylcholine post-synaptic nicotinic ACh receptor (nAChR). This leads to neuronal overstimulation and hyperactivity.

Group 5 Acetylcholine receptor modulators

Spinosyns act at the nAChR interfering with normal functioning.

Group 3 Sodium channel modulators

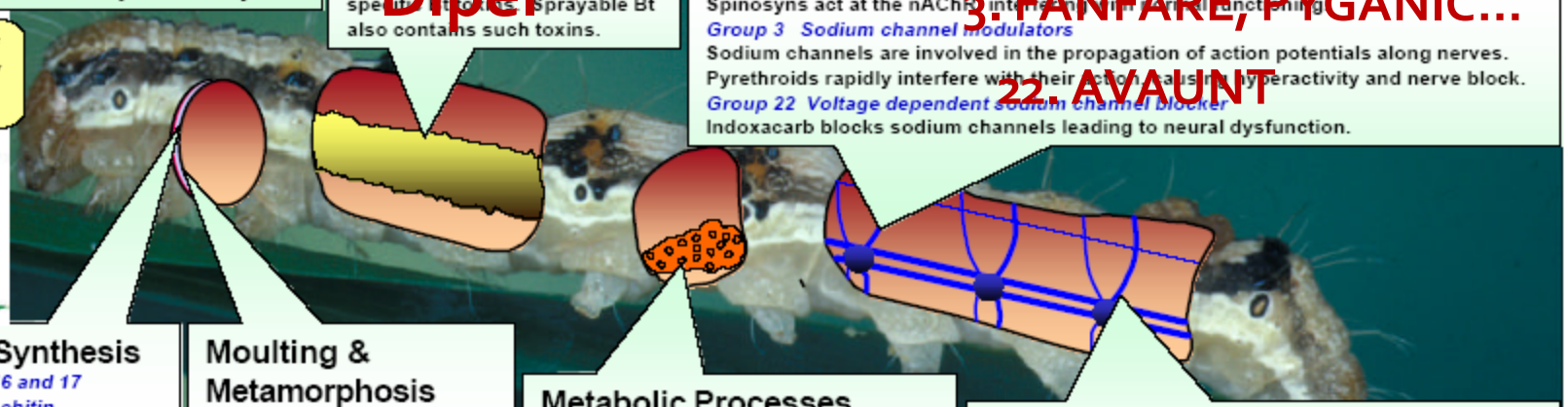
Sodium channels are involved in the propagation of action potentials along nerves. Pyrethroids rapidly interfere with their action causing hyperactivity and nerve block.

Group 22 Voltage dependent sodium channel blocker

Indoxacarb blocks sodium channels leading to neural dysfunction.

1. DIAZ, LORSBAN, SEVIN…
4. ACTARA, BELAY, ADMIRE, AS
3. FANFARE, PYGANIC…
22. AVAUNT

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.

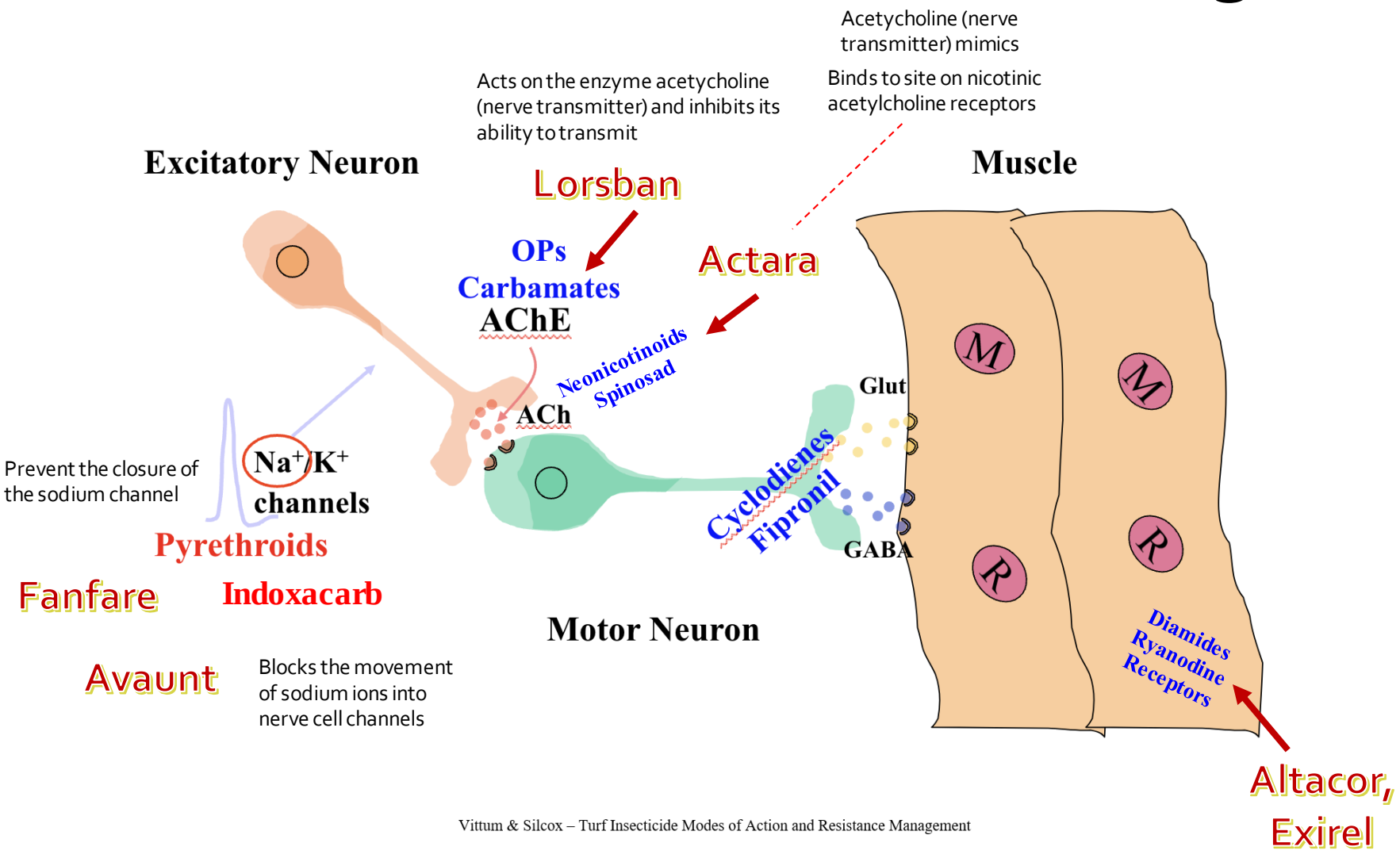
Group 2 GABA-gated chloride channel antagonists

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.

Insecticide Neuromuscular Targets



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Resistant to newest compound in ?? 2030

- New mode of action, ***

GABA receptor antagonists is a neurotransmitter, or chemical messenger, in the brain. New chemistry can control pests that have developed resistance to many other insecticide modes of action, such as pyrethroids and neonicotinoids

Questions?

Polls?