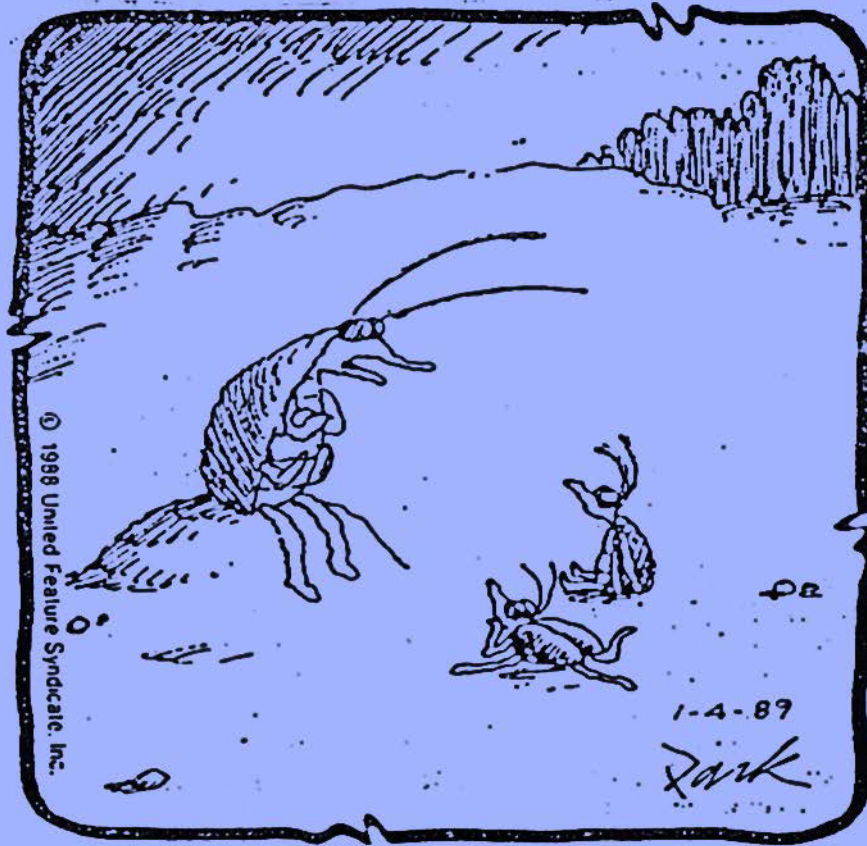


# INSECTICIDE RESISTANCE



“You kids won’t believe this, but  
insecticides *used to be*  
dangerous”

# Outline

- What is resistance?
- Selection pressure
- Understanding insecticides
- Current state of insecticide resistance
- Factors contributing to resistance
- Resistance versus other causes for failure
- Managing resistance

# Insecticide Resistance Action Committee

- IRAC has developed a mode of action classification scheme for insecticides and acaricides
- Purpose is to provide a guide to selection of insecticides and acaricides in an effective and sustainable IRM program
- IRAC-ONLINE.ORG



# Resistance

A heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species.

Insecticide Resistance Action Committee



# Resistance

In other words...

Overuse of an insecticide leads to it not being able to kill the target pest.



# Impact of Resistance

- Overall agricultural productivity
  - Increased pesticide use
  - Increased damage
- Economic / Environmental impact
  - Increased pesticide use
  - Increased use of non-renewable resources
  - Increased acreage
- Pest management flexibility
  - Loss of pesticide
  - Constraint on new pesticides

# Impact of Resistance

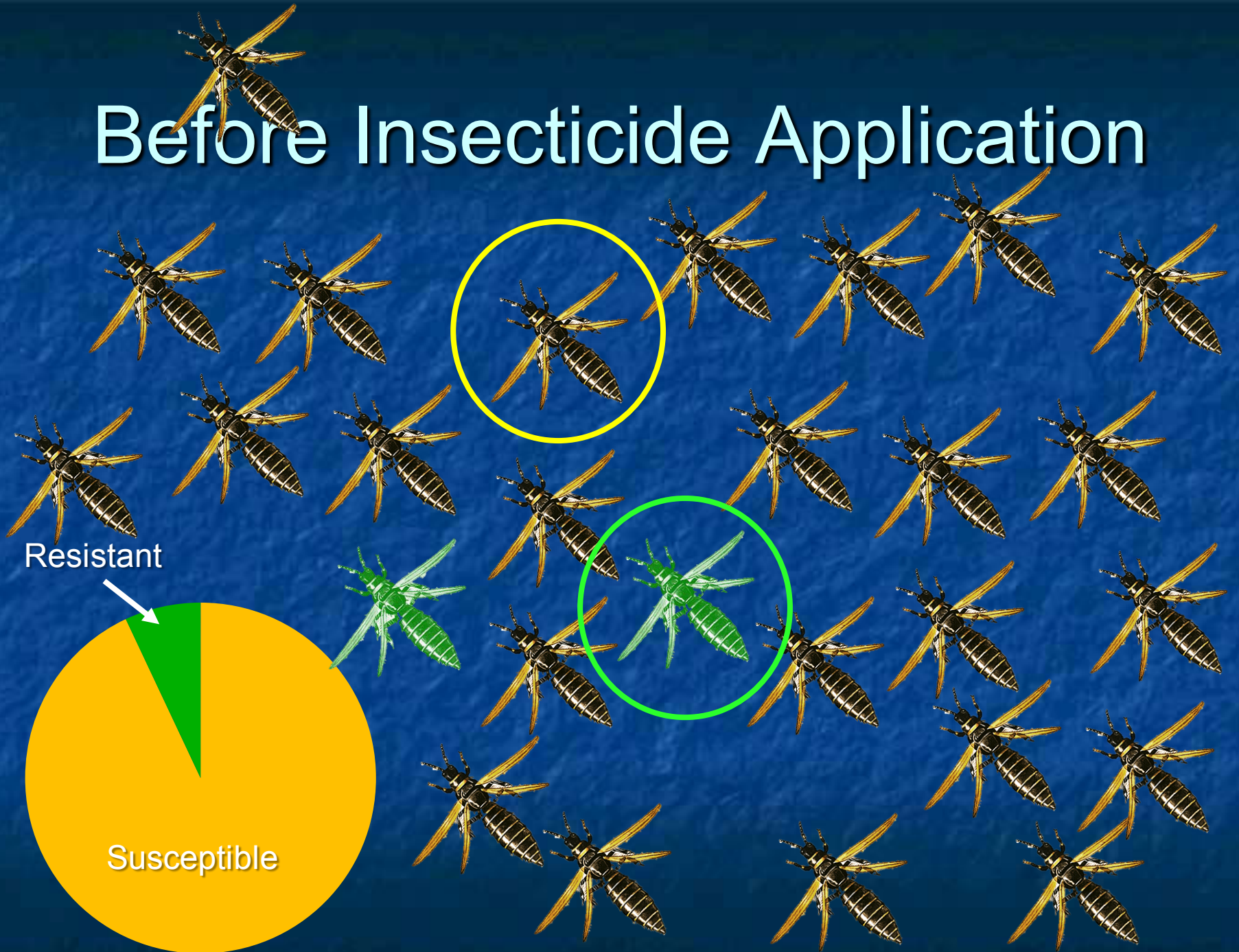


# Resistance

- The insecticide does not create resistant individuals
- Everybody is an individual
- Some individuals will be naturally resistant



# Before Insecticide Application

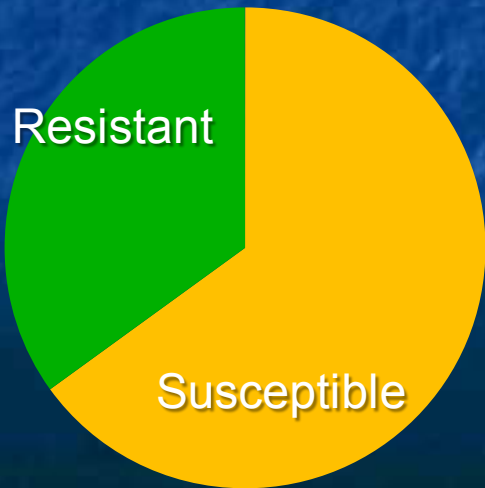


# After One Insecticide Application



80% of Susceptibles Killed  
0% of Resistants Killed

# The Next Generation

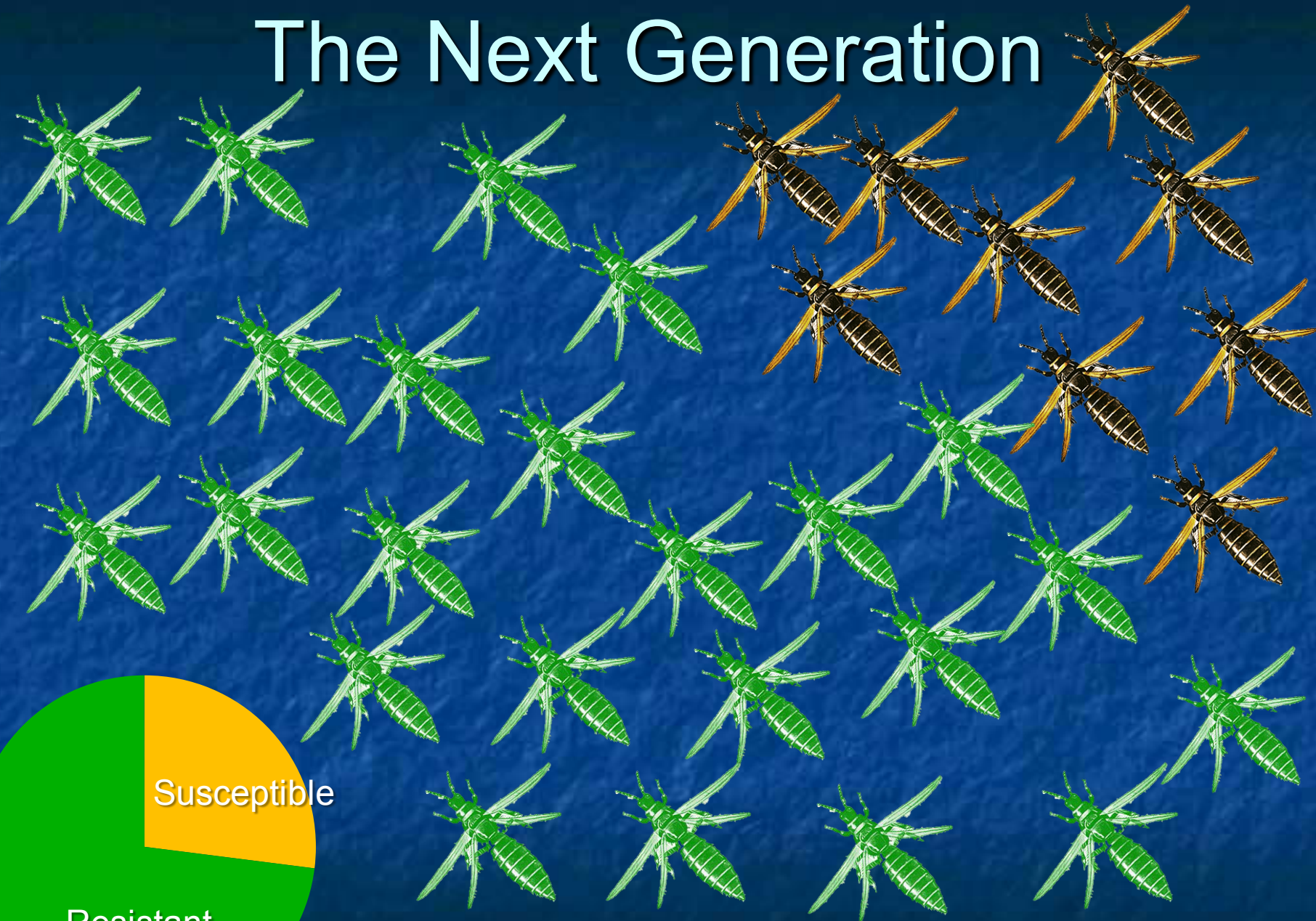


# After a Second Insecticide Application



80% of Susceptibles Killed  
0% of Resistants Killed

# The Next Generation



# After a Third Insecticide Application



80% of Susceptibles Killed  
0% of Resistants Killed

# Resistance

- Insecticides become less effective
- Pest populations do not decrease after application
- More widespread than certain parts of a field



# Resistance Mechanisms

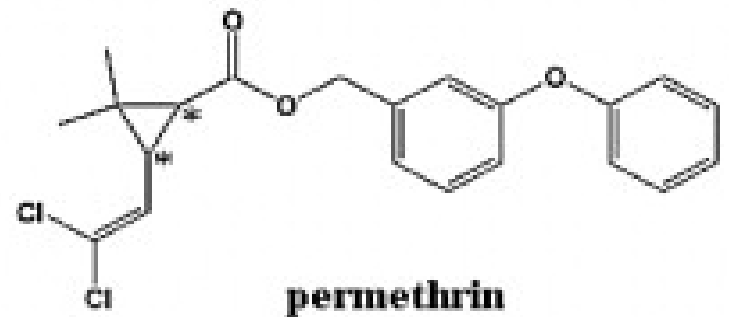
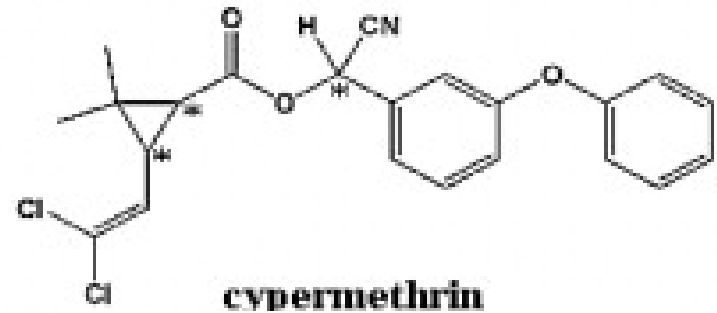
- Metabolic resistance
- Target-site resistance
- Penetration resistance
- Behavioral resistance



# Mode of Action

Active ingredients in the same group have

1. similar chemistry
2. affect the pest in a similar manner.



Pyrethroids – Sodium Channel Modulators

# Label Information

GROUP 1A INSECTICIDE

Mode of Action Group



**DuPont™**  
**Lannate® LV**  
insecticide

Trade name (Product name) = Lannate LV

Concentration = 2.4 lb ai per gallon of product

**Water Soluble Liquid**

Contains 2.4 lbs active ingredient per gallon

*Active Ingredient* *By Weight*

Methomyl	
(S-methyl-N-[(methylcarbamoyl oxy)thioacetimidate])	29%
<i>Other Ingredients</i>	71%
TOTAL	100%

Common name = methomyl

Chemical name

EPA Reg. No. 352-384

EPA Est. No. \_\_\_\_\_

# RESTRICTED USE PESTICIDE

## Due to High Acute Toxicity to Humans.

For retail sale and use only by Certified Applicators or persons under their direct supervision and only for those uses covered by the Certified Applicator's certification. Direct supervision for this product requires the certified applicator to review federal and supplemental label instructions with all personnel prior to application, mixing, loading, or repair or cleaning of application equipment.

GROUP 1A INSECTICIDE



# DuPont™ Lannate® LV

insecticide

### Water Soluble Liquid

Contains 2.4 lbs active ingredient per gallon.

Active Ingredient	By Weight
-------------------	-----------

Methomyl (S-methyl-N-[(methylcarbamoyl)oxy]thioacetimidate)	29%
--	-----

Other Ingredients	71%
TOTAL	100%

EPA Reg. No. 352-384

KEEP OUT OF REACH OF CHILDREN  
**DANGER POISON**  
**PELIGRO** 

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand this label, find someone to explain it to you in detail.)

### FIRST AID

**This Product is an N-Methyl Carbamate insecticide.**  
**IF SWALLOWED:** Call a poison control center or doctor immediately for treatment advice. Drink 1 or 2 glasses of water and induce vomiting by touching back of throat with finger. Do not induce vomiting or give anything by mouth to an unconscious person.  
**IF IN EYES:** Hold eye open and rinse slowly and gently with water for 15-20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. Call a poison control center or doctor for treatment advice.  
**IF INHALED:** Move person to fresh air. If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably by mouth-to-mouth, if possible. Call a poison control center or doctor for further treatment advice.  
**IF ON SKIN OR CLOTHING:** Take off contaminated clothing. Rinse skin immediately with plenty of water for 15-20 minutes. Call a poison control center or doctor for further treatment advice.  
**ATROPINE IS AN ANTIDOTE --SEEK MEDICAL ATTENTION AT ONCE IN ALL CASES OF SUSPECTED POISONING.**



# DuPont™ Vydate® L

insecticide/nematicide

### Water Soluble Liquid

1 GALLON CONTAINS 2 LBS. ACTIVE INGREDIENT

Active Ingredient	By Weight
-------------------	-----------

Oxamyl [Methyl N,N'-dimethyl-N-[(methyl carbamoyl)oxy]-1-thioxamimidate]	24%
---	-----

Inert Ingredients	76%
TOTAL	100%

Contains Methanol  
EPA Reg. No. 352-372 EPA Est. No. \_\_\_\_\_

### Nonrefillable Container

Net: \_\_\_\_\_

OR

### Refillable Container

Net: \_\_\_\_\_

GROUP 1A INSECTICIDE

### FIRST AID (cont'd)

**ATROPINE IS AN ANTIDOTE -- SEEK MEDICAL ATTENTION AT ONCE IN ALL CASES OF SUSPECTED POISONING**

If symptoms appear (see SYMPTOMS) get medical attention.

Have the product container or label with you when calling a poison control center or doctor, or going for treatment. You may also contact 1-800-441-3637 for emergency medical treatment information.

**SYMPTOMS**--Oxamyl poisoning produces effects associated with anticholinesterase activity which may include weakness, blurred vision, headache, nausea, abdominal cramps, discomfort in the chest, constriction of pupils, sweating, slow pulse, muscle tremors.

### NOTE TO PHYSICIAN

**TREATMENT**--Atropine sulfate should be used for treatment. Administer repeated doses, 1.2 to 2.0 mg intravenously every 10 to 30 minutes until full atropinization is achieved. Maintain atropinization until the patient recovers. Artificial respiration or oxygen may be necessary. Allow no further exposure to any cholinesterase inhibitor until recovery is assured.

Do not use 2-PAM for exposure to VYDATE® L alone. However, for exposure to combinations of VYDATE® L and organophosphorous insecticides, 2-PAM may be used as required to supplement the atropine sulfate treatment. Do not use morphine.

For medical emergencies involving this product, call toll-free 1-800-441-3637.

**PRECAUTIONARY STATEMENTS  
HAZARDS TO HUMANS  
AND DOMESTIC ANIMALS**

**DANGER-POISON!** Fatal if swallowed. May be fatal if

KEEP OUT OF REACH OF CHILDREN  
**DANGER POISON**  
**PELIGRO** 



# Beleaf

50 SG INSECTICIDE

EPA Reg. No. 71512-10-279 EPA Est. 279-NY-1

<b>Active Ingredient:</b>	<b>By Wt.</b>
*Flonicamid .....	50.0%
<b>Other Ingredients</b> .....	50.0%
<b>Total</b>	100.0%

\*Contains 0.5 pounds active ingredient per pound of formulated product

**KEEP OUT OF REACH OF CHILDREN**

## CAUTION

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand this label, find someone to explain it to you in detail.)

Net Contents: 1.5 lbs.

Manufactured for:

GROUP	9C	INSECTICIDE
-------	----	-------------

### FIRST AID

**If Swallowed:** Call a poison control center or doctor immediately for treatment advice. Have person sip a glass of water if able to swallow. Do not induce vomiting unless told to do so by the poison control center or doctor. Do not give anything by mouth to an unconscious person.

**If on Skin or Clothing:** Take off contaminated clothing immediately with plenty of water for 15 to 20 minutes. Call a poison control center or doctor for treatment advice.

**If in Eyes:** Hold eye open and rinse slowly and gently with water for 15 to 20 minutes. Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. Call a poison control center or doctor for treatment advice.

**If Inhaled:** Remove person to fresh air. If person is not breathing, if necessary, give artificial respiration, or CPR, if you have been trained. Call a poison control center or doctor for treatment advice.

**Note to Physician:** Treatment is otherwise controlled by exposure followed by symptomatic and supportive care.

### HOTLINE NUMBER

Have the product container or label with you when calling a poison control center or doctor, or going for treatment. You may also call 1-800-331-3148 for emergency medical treatment information.

See other panels for additional precautionary statements.

### PRECAUTIONARY STATEMENTS

#### Hazards to Humans (& Domestic Animals)

**CAUTION**  
Harmful if swallowed or absorbed through the skin. Causes eye irritation. Do not get on skin, in eyes or on clothing. Wash thoroughly with soap and water after handling and before eating, drinking gum or using tobacco. Remove and wash contaminated clothing before reuse.

**Personal Protective Equipment (PPE)**  
Applicators and other handlers must wear long-sleeved shirts, pants, shoes plus socks, and waterproof gloves.

Follow manufacturer's instructions for cleaning/maintaining. If there are no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry. Do not use closed systems, enclosed cabs or aircraft in a way that meets the requirements listed in the Worker Protection Standard for agricultural pesticides [40 CFR 170.240(d)(4-6)], the requirements may be reduced or modified as specified in the label.

### User Safety Recommendations

**Users should:**  
Remove clothing/PPE immediately if pesticide gets in eyes. Wash thoroughly and put on clean clothing.  
Remove PPE immediately after handling this product. Wash thoroughly before reuse.

## Specimen Label

 Dow AgroSciences

# Radiant

SC

Insecticide

™Trademark of Dow AgroSciences LLC

For control or suppression of lepidopteran larvae (worms, caterpillars), dipterous leafminers, and certain psyllids in asparagus, bulb vegetables, cereal grains (except rice), cole crops, corn (field corn, sweet corn, popcorn, and corn grown for seed) and teosinte, cotton, cucurbits, fruiting vegetables (tomato, peppers, and eggplant) and okra, herbs, leafy vegetables and leaves of root and tuber and legume vegetables, legume vegetables (succulent and dried beans and peas), mint, peanut, potatoes and tuberous and corm vegetables, root vegetables, soybean, and strawberry

Group	5	INSECTICIDE
-------	---	-------------

Active ingredient:

spinetoram, a mixture of 1H-as-indacene[2,3-d]hexacyclododecin-7,15-dione, 2-[(6-deoxy-3-O-ethyl-2,4-di-O-methyl-α-L-mannopyranosyl)oxy]-13-[[[(2R,5S,6R)-5-(dimethylamino) tetrahydro-6-methyl-2H-pyran-2-yl]oxy]-9-ethyl-2,3,3a,4,5,5a,5b,6,9,10,11,12,13,14,16a,16b-hexadecahydro 14-methyl-, (2R,3aR,5aR,5bS,9S,13S,14R,

GROUP	1A	INSECTICIDE
-------	----	-------------



# DuPont

## Lannate<sup>®</sup> LV

Insecticide

*Soluble Liquid*

2.4 lbs active ingredient per gallon.

Ingredient	By Weight
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yl-N-[(methylcarbamoyl)ioacetimidate)	29%
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redients	71%
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	100%
--	------

No. 352-384

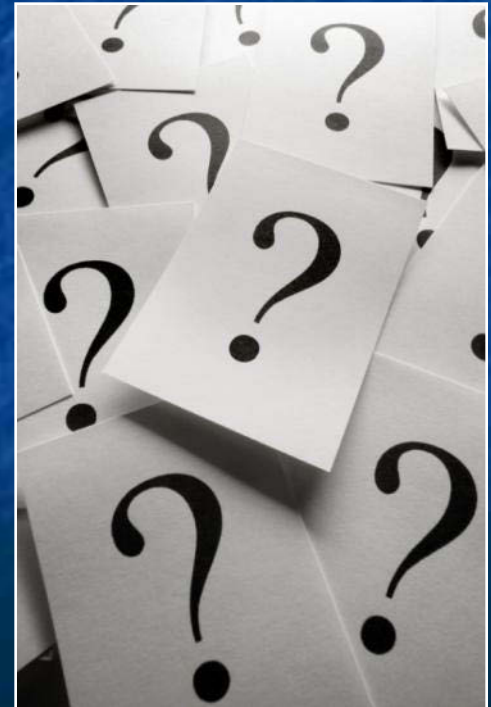
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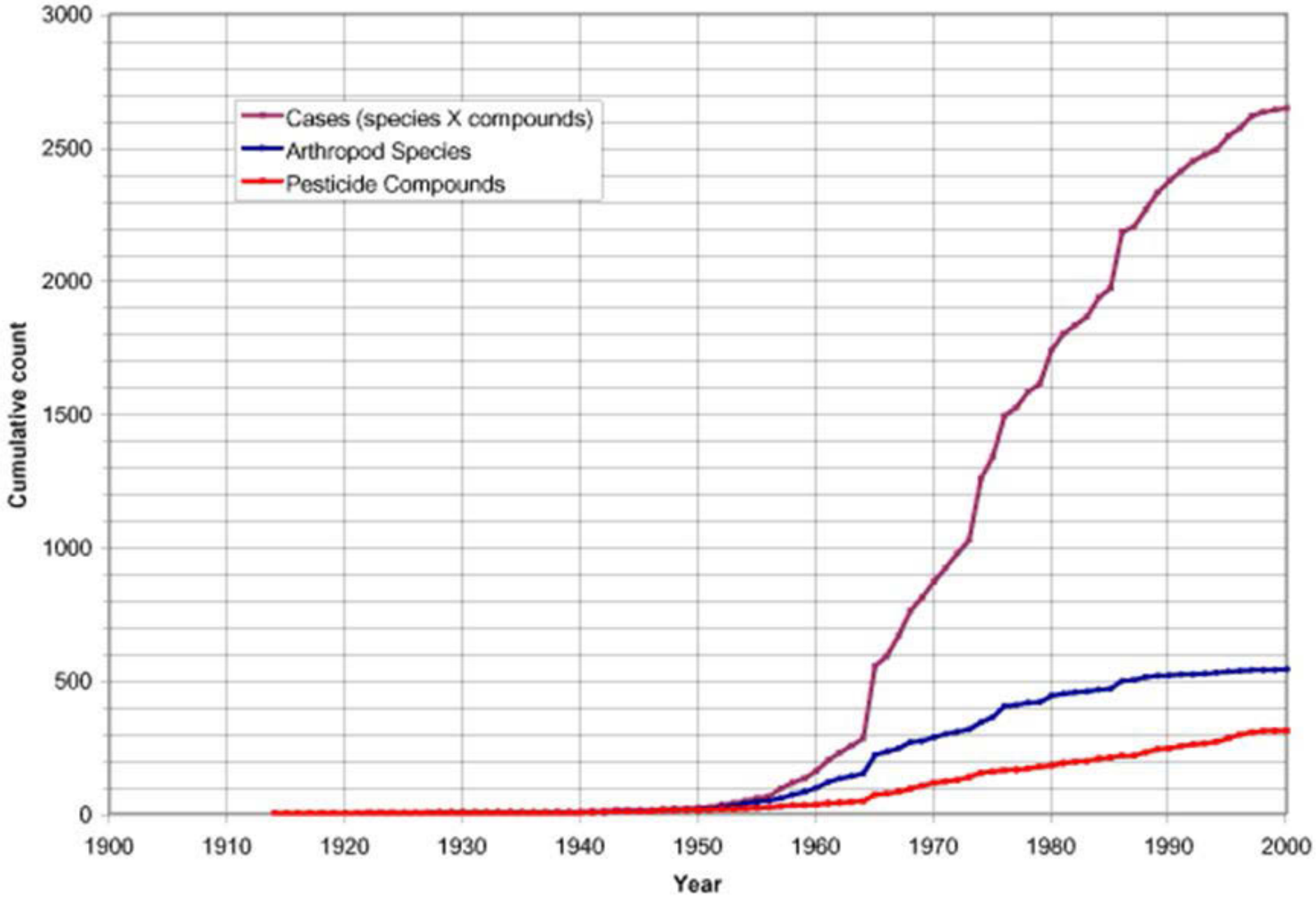
# Cross Resistance

- Resistance mechanism confers resistance to multiple insecticides
- Cross resistance can occur within or across insecticide groups

# Factors Affecting Selection for Resistance

- Crop production practices
- Insect biology
- Insecticide properties





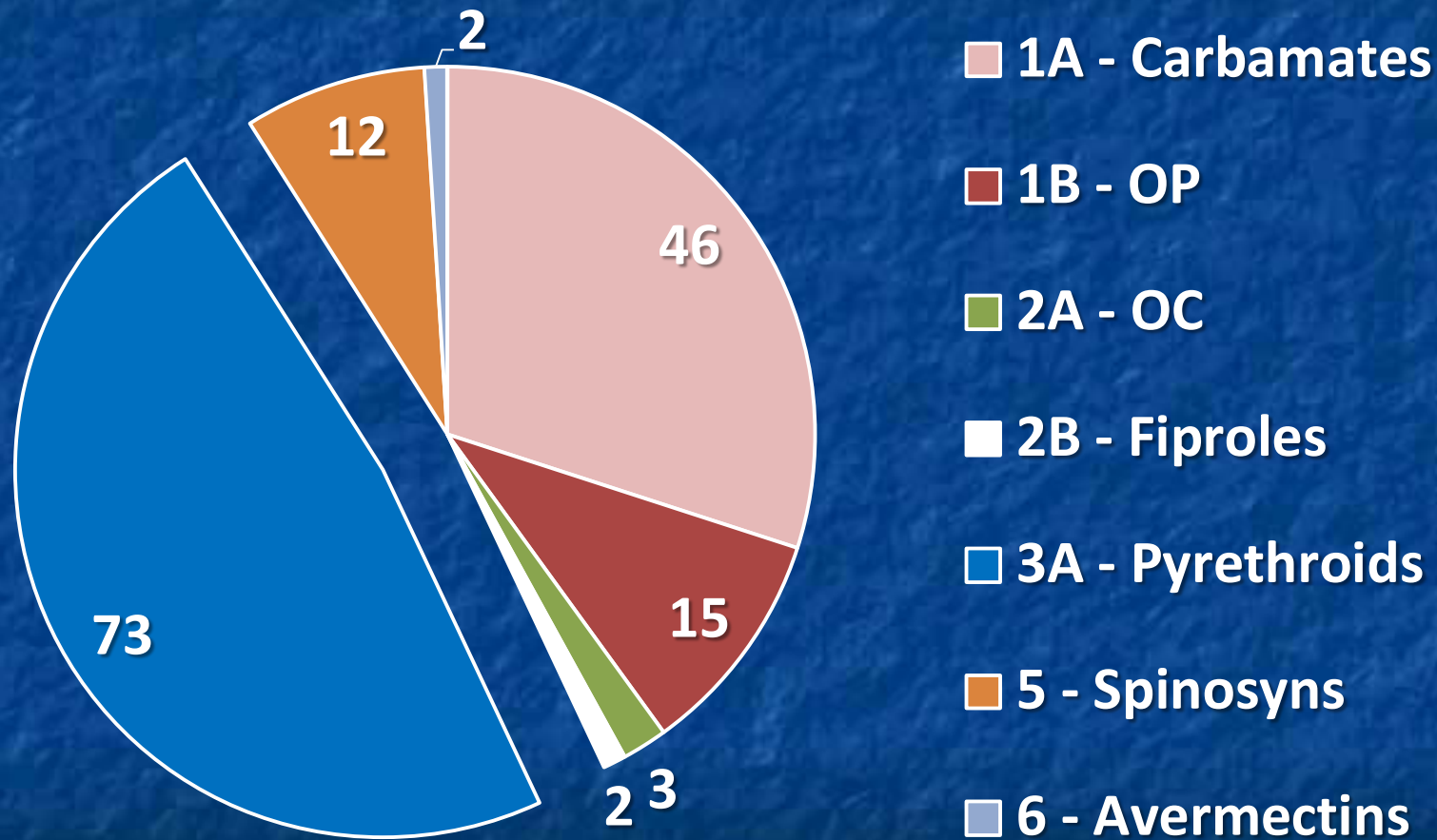
# Propensity for Resistance

- Some species are more prone to develop insecticide resistance
- 
- Populations of **> 500** species of insects have developed resistance

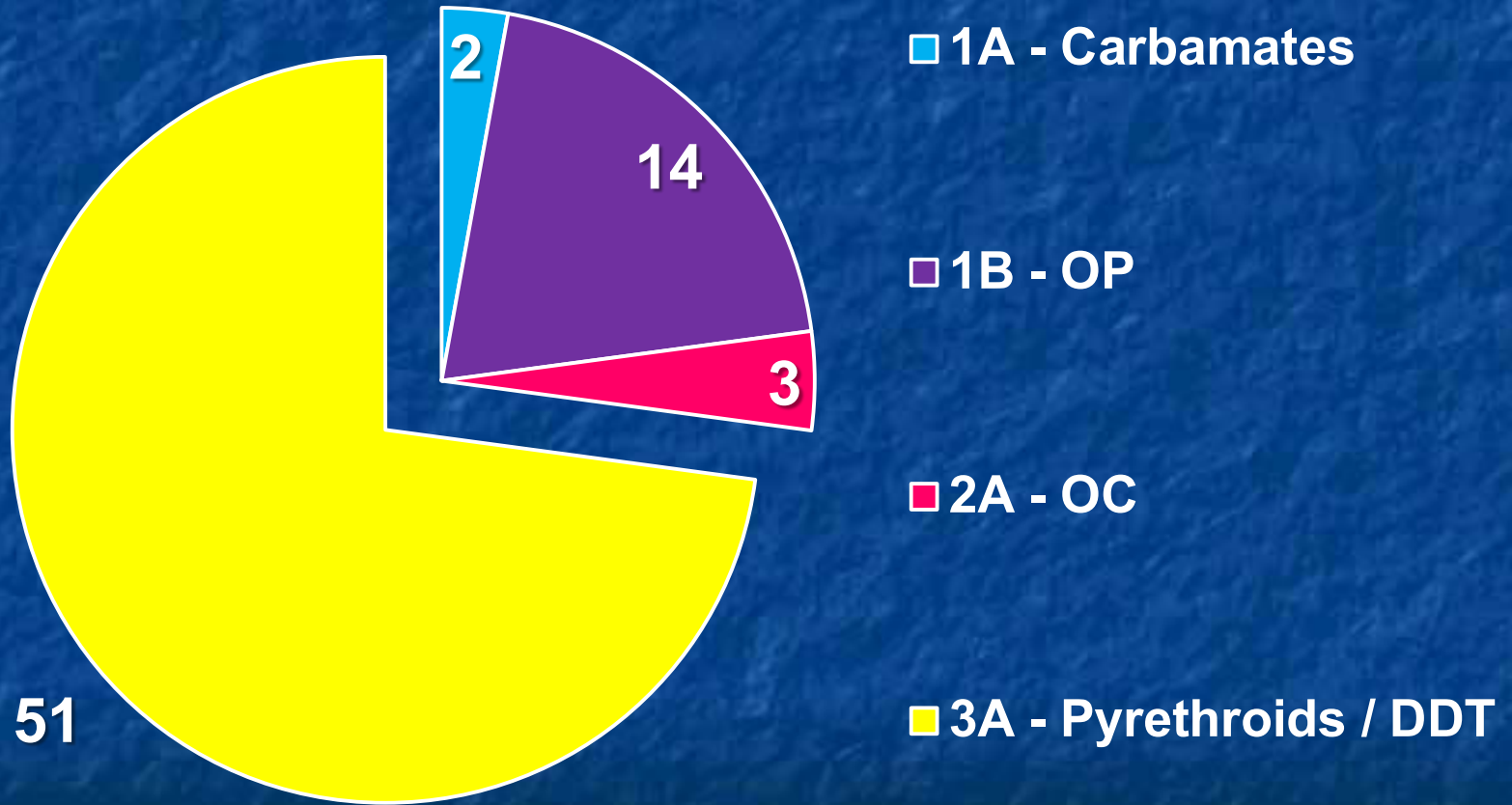




# WFT Resistance by IRAC Class



# Onion Thrips Resistance by IRAC Class



# Codling Moth

- Carbamates – Group 1A
- Organophosphates – Group 1B
- Pyrethroids – Group 3A
- Neonicotinoids – Group 4A
- Spinosyns – Group 5
- Avermectins – Group 6
- Fenoxycarb – Group 7B
- Benzoylureas – Group 15
- Diacylhydrazines – Group 18
- Indoxacarb – Group 22A



# Green Peach Aphid

Acephate	Dioxacarb	Methamidophos	Phosmet
Azinphos-ethyl	Disulfoton	Methidathion	Phosphamidon
Azinphos-methyl	Disulfoton Sulphone	<u>Methomyl</u>	Pirimicarb
Bromophos	Endosulfan	Mevinphos	Propoxur
Carbaryl	Endothion	Monocrotophos	Prothoate
Carbofuran	Ethiofencarb	Naled	Pyrethrins
Chlordane	Fenitrothion	Neopynamin	Quinalphos
Chlorpyrifos	Fenthion	Omethoate	Ronnel
Clothianidin	Fenvalerate	Organophosphates	Sulfotep
Cyfluthrin	Fluvalinate	Oxydemeton-methyl	Tetrachlorvinphos
<u>Cyhalothrin-lambda</u>	Formothion	Oxydeprofos	<u>Thiamethoxam</u>
Cypermethrin	Hch-gamma	Oxydisulfoton	Thiocarboxime
DDT	Heptenophos	Paraoxon	Thiometon
Deltamethrin	<u>Imidacloprid</u>	Parathion	Thionazin
Demephion	Isofenphos	Parathion-methyl	
Demeton	Isolan	Permethrin	
Demeton-s-methyl	Leptophos	Phenothrin-d	
Diazinon	Malathion	Phenthoate	
Dichlorvos	Menazon	Phorate	
<u>Dimethoate</u>	Mephosfolan	Phosalone	



392 cases of resistance to  
71 active ingredients

# Potato Aphid

*(Macrosiphon euphorbiae)*



0 cases of resistance

# Is Resistance to Blame?

- The pest was not identified correctly and the wrong pesticide was used
- Poor application technique or incorrect insecticide dose
- Inappropriate timing (i.e., pest target was not in the area at the time of treatment or was in a life stage not susceptible to the pesticide); and,
- Some insects are more susceptible to insecticides during earlier life-stages.

# Is Resistance to Blame?

- You killed them, but they came back
  - Pests re-infest the area following the pesticide application.
  - Dispersal from neighboring fields
- Pest resurgence
  - Natural enemies are eliminated
  - Remaining pests reproduce like rabbits
- Secondary pests
  - Target pest killed, but other pests cause damage

# Managing Resistance

Reduce insecticide needs

- Using tolerant or resistant crop varieties



- Using cultural controls

- Using biological controls





# Managing Resistance

- Only using pesticides when necessary
  - Monitoring to make sure pesticides are applied at the most effective time
- Use the “best” insecticides
  - Using selective insecticides that break down quickly
  - Only using tank mixtures of insecticides with different modes of action

# Managing Resistance

- Use Insecticides correctly
  - Recommended application rate
  - Avoid low rates with marginal pest control
  - Thorough coverage
- If an insecticide doesn't work, do not re-treat with another with the same MoA
- **Rotate / Alternate** among different groups of insecticides

How to properly alternate insecticides to avoid or delay the onset of resistance?



# Alternating Modes of Action

- Individuals resistant to one Mode of Action are not resistant to a different MoA
- Alternating MoA avoids selecting for resistant individuals
- Avoid treating successive generations with the same MoA

# Insecticide Sequences

- Monitor pest populations
- No more than 2 sequential applications
- Apply within in “treatment windows” to avoid treating overlapping generations
- Treatment windows – relatively short to avoid treating multiple generations

# One Example

- Onion Thrips
  - Movento (2x)
  - Agrimek (2x)
  - Radiant (2x)
  - Lannate (2x)

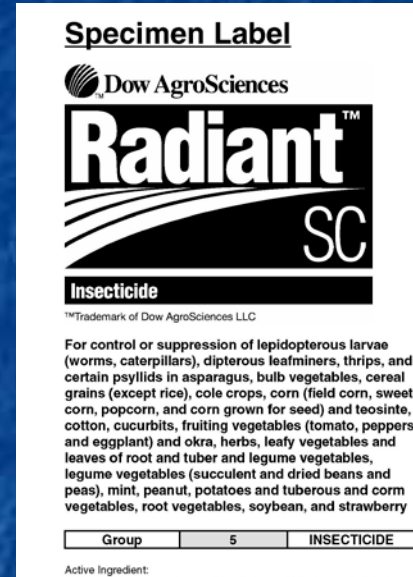




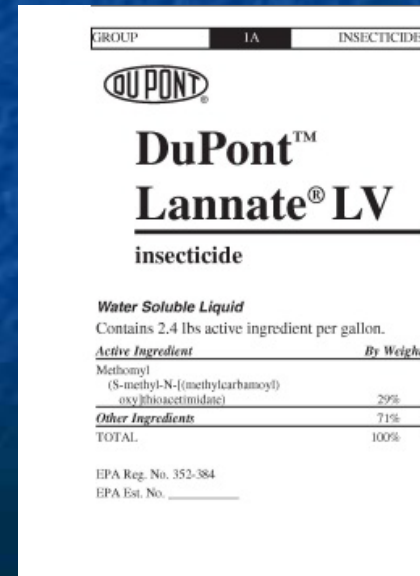
← Group 23



← Group 6



← Group 5



Group 1B →

4 Modes of Action

Resistance doesn't build up against any one

# Neonicotinoid Resistance Management in Potato

- Neonicotinoids – Group 4A
- **At planting / seed treatments** : Admire Pro, Gaucho, Platinum, CruiserMaxx, Venom, Belay
- **Foliar products**: Admire Pro, Leverage, Actara, Venom, Belay
- If applied in-furrow or as a side dress or seed treatment, **do not** use any foliar neonicotinoid in the same field in the same season
- Including package mix products (e.g., Leverage, Endigo, Voliam Flexi, Brigadier, Athena)



# Neonicotinoid Resistance Management in Potato

- At planting / seed treatment products – long residual time
- Adding a foliar treatment would mean treating multiple, successive generations within one season

# Reversing Resistance

- Cease use of pesticide causing resistance
  - Problems
    - Probably the preferred control
    - May be used for other pests
    - Area-wide enforcement usually necessary
  - Refugia
  - Use synergists

# Final Points

- Resistance is an inherent risk with the use of any pesticide
- Scouting is critical to resistance management
  - Before and after assessments
- Use multiple Modes of Action
- Plan to use them in sequences/rotations