

ES/RP 531  
Fundamentals of Environmental Toxicology

Lecture 18  
Beneficial Insects;  
Evolution of Resistance

Pesticide Hazards to Beneficial Insects

- Insects are the most diverse group of animals on earth
- Importance as pollinators
- Importance as biotic regulators of Arthropod populations and in some cases other Phyla



Bees are being "devastated" by the Varroa mite



Photos by Scott Bauer USDA ARS

Hazards of Pesticides to Bees

Davis & Williams (1990)

$$\text{Hazard Index} = \frac{\text{Application Rate}}{\text{LD50} \times 100}$$

Pesticide	LD50 (µg/bee)	Application Rate (g/ha)	Hazard Index
Imidacloprid	0.0179	224	125.1
chlorpyrifos	0.06	480	81.4
malathion	0.27	1260	46.7
carbaryl	1.3	850	6.5
permethrin	0.08	40	5.3
deltamethrin	0.04	7.5	2.1
Acetamiprid	7.07	168	0.24
2,4-D	>100	908	0.091
diuron	145	908	0.063

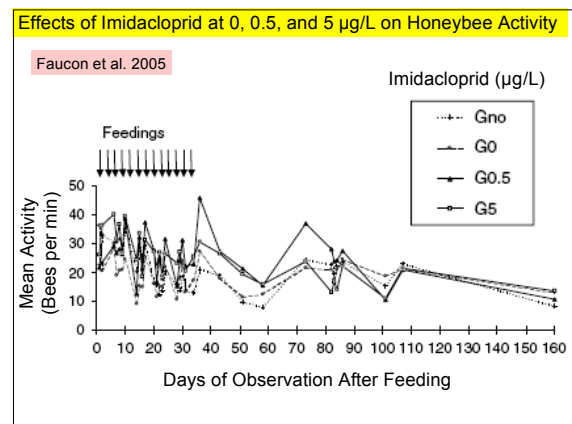
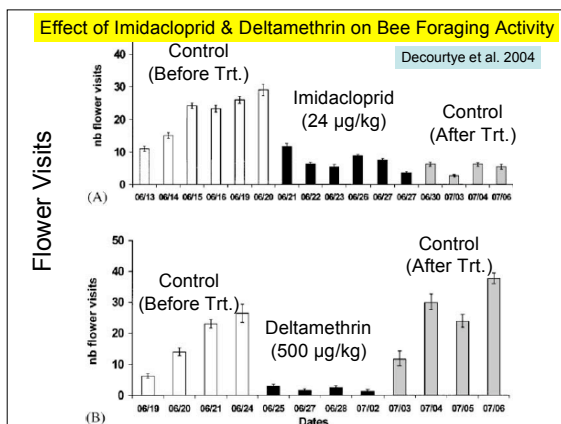
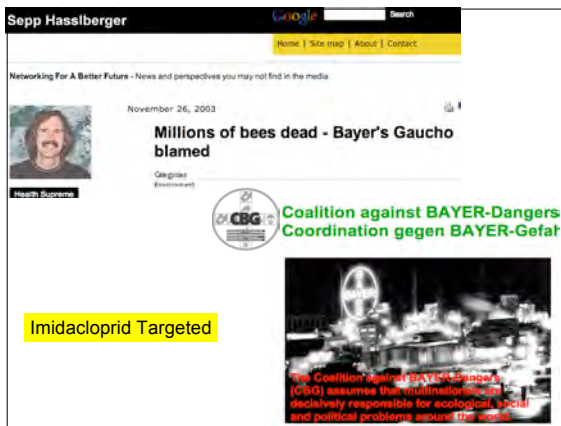
Selectivity of Imidacloprid Binding to Nicotinic Receptors

Specific Binding (DPM/µg of tissue)

Species	Brain	Head	Whole body
Vertebrates	<0.01		
Insects			
House fly		16	1.4
Fruit fly			2.1
Cricket	42	0.6	<0.05
Honeybee		2.3	0.33
Cockroach	24		0.09

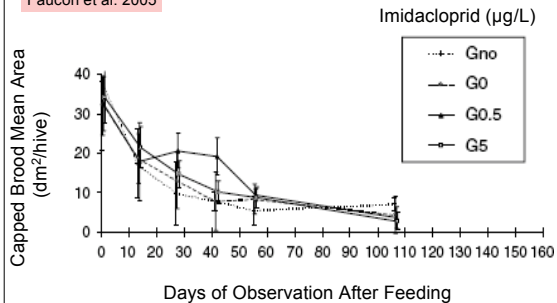
## Imidacloprid Has a Favorable Ecotoxicological Profile

Test Organism	Acute LC50	NOAEC
Daphnia ( $\mu\text{g/L}$ )	10,440 - 85,000	1800 - 3600
Trout ( $\mu\text{g/L}$ )	211,000	29,000 - 62,000
Quail (mg/kg)	1420	>243



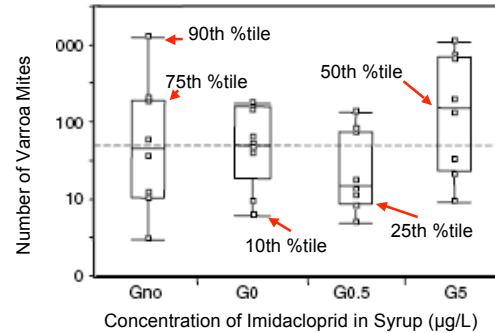
### Effects of Imidacloprid at 0, 0.5, and 5 µg/L on Colony Potential

Faucon et al. 2005



### Effect of Imidacloprid Exposure in Syrup on Infestation by Varroa Mites

Faucon et al. 2005



### Importance of Natural Enemies

- Natural enemies refers to Arthropod predators and parasitoids of pest insects and mites
- Biotic regulators of pest populations



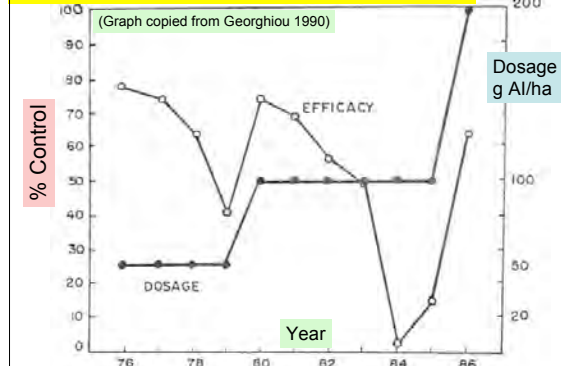
### The Problem with Broad Spectrum Insecticides

- Shortly after the widespread commercial introduction of DDT, it was noted that pest populations would resurge to even higher levels after some time
- Furthermore, secondary pests that were not economically important, became major pests
- Killing the natural enemies (predators and parasitoids), in combination with their greater susceptibility to DDT, reduced the natural mortality factors associated with all populations allowing pest resurgence and emergence of importance of secondary pests
  - Somewhat analogous to an exotic animal or weed going reproductively wild in a new habitat owing to the absence of naturally occurring biotic mortality factors

### Pesticide Resistance

- Definition (NRC 1986):
  - Inheritable ability in a strain of pest to tolerate doses of toxicant that would prove lethal to a majority of individuals in a normal [i.e., unselected or "naïve"] population of that species
    - Implies a statistically significant shift in LC<sub>50</sub> or LD<sub>50</sub> values that are normally established through lab bioassays
    - Lab documentation of resistance may or may not indicate a current or impending loss of economic pest control efficacy in the field
- Overlooked "ecological" effect by "mainstream" environmental toxicology research
- Consequences of chronic pesticide use in regional area or even at the field level
- Economic and social consequences

### Change in Efficacy and Dosage of Fenvalerate Against A Cotton Bollworm (*Heliothis armigera*)



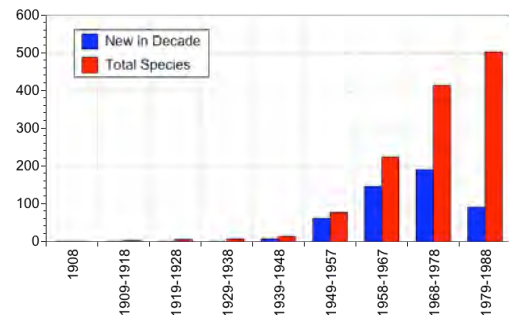
**Estimated Environmental Costs Due to Loss of Natural Enemies & Insecticide Resistance in Pest Insect & Mite Populations**

Total Added Insecticide Cost (millions \$) Due To:

System	Loss of Natural Enemies	Increased Resistance
Field crops	133.0	101.8
Vegetable crops	6.24	7.96
Fruits & Nuts	14.24	8.31
Livestock & Public Health	>0	15.0
<b>Total</b>	<b>153.5</b>	<b>133.1</b>

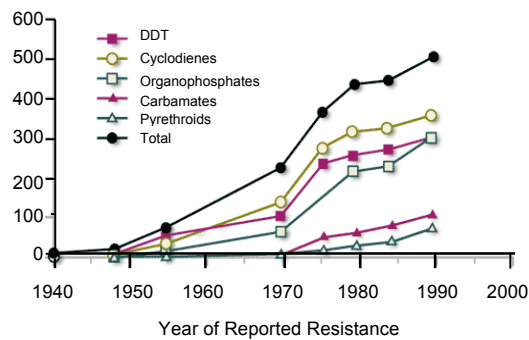
Pimentel et al. 1979

**Total Insect & Mite Species Restant to Insecticides (1908 - 1990)**



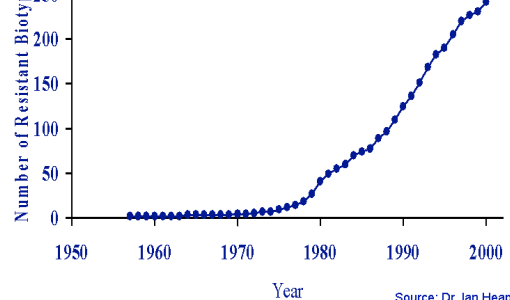
(based on Georgiou 1990)

**Number of Resistant Species by Insecticide Class**



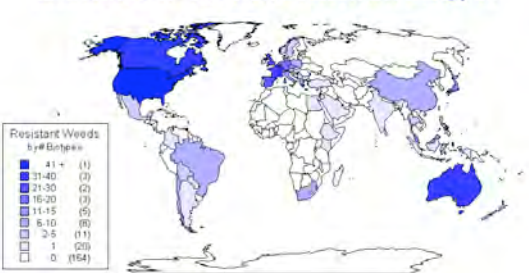
Futuyama URL: [http://evonet.sdsc.edu/evoscisociety/insect\\_pests.htm](http://evonet.sdsc.edu/evoscisociety/insect_pests.htm)

**The chronological increase in unique cases of herbicide-resistant weeds worldwide**

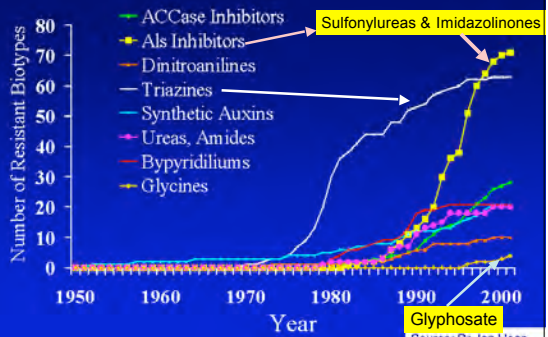


Source: Dr. Ian Heap  
[www.weedscience.com](http://www.weedscience.com)

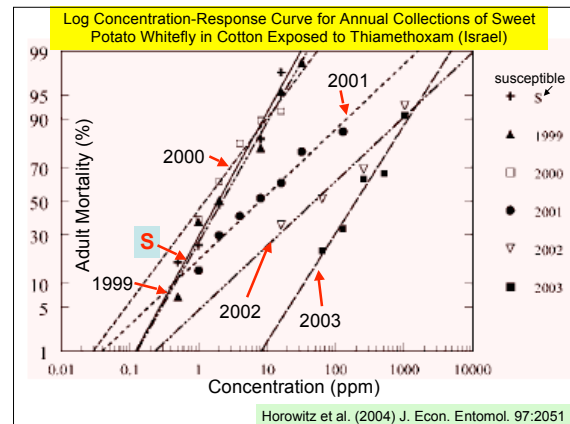
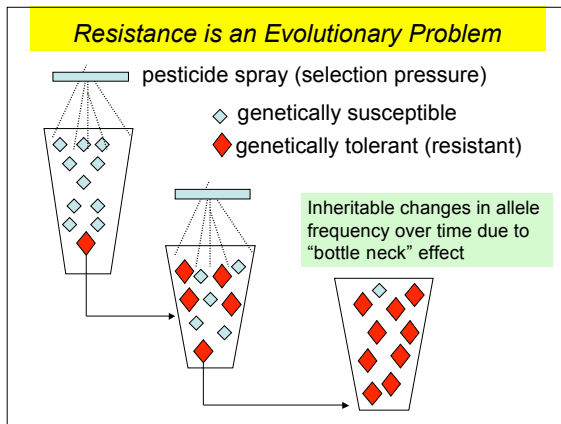
**Distribution of Herbicide Resistant Biotypes**



Source: Dr. Ian Heap  
[www.weedscience.com](http://www.weedscience.com)



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- Factors Influencing Evolution of Resistance**
- Genetic
    - Frequency of R alleles
    - Number of R alleles
    - Dominance of R alleles
    - Penetrance; expressivity; interactions of R alleles
    - Past selection by other chemicals
    - Extent of integration of R genome with fitness factors
- Georghiou & Tayler 1976

- Factors Influencing Evolution of Resistance**
- Biological (Biotic Factors)
    - Generation turn-over
    - Offspring per generation
    - Monogamy/polygamy/parthenogenesis
  - Biological (Behavioral Factors)
    - Isolation; mobility; migration
    - Monophagy/polyphagy
    - Fortuitous survival; refugia
- Georghiou & Tayler 1976

- Factors Influencing Evolution of Resistance**
- Operational (the Chemical)
    - Chemical characteristics
    - Biochemical relationship to previously used chemicals (i.e., mode of toxic action)
    - Persistence of residues; formulation
  - Operational (the Application)
    - Application threshold
    - Selection threshold
    - Life stage(s) selected
    - Mode of application
    - Space-limited selection
    - Alternating selection
- Georghiou & Tayler 1976

- Resistance in Fish Exposed to TCDD**
- Newark Bay, NJ considered on of the most contaminated in US with heavy metals and persistent organic pollutants (POPs; PCBs, TCDD, PAHs, DDTs)
    - TCDD found at levels of 260-430 ppt in sediments circa 1985
  - Fundulus heteroclitus (aka killifish or mummichog) collected from Newark Bay showed remarkable tolerance to the effects of TCDD
    - Fish found in both pristine and contaminated waters
    - No migration; restricted home range
- Prince & Cooper (1995) ETAC 14:579

