Protecting Natural Enemies from Pesticides

Read ch 21

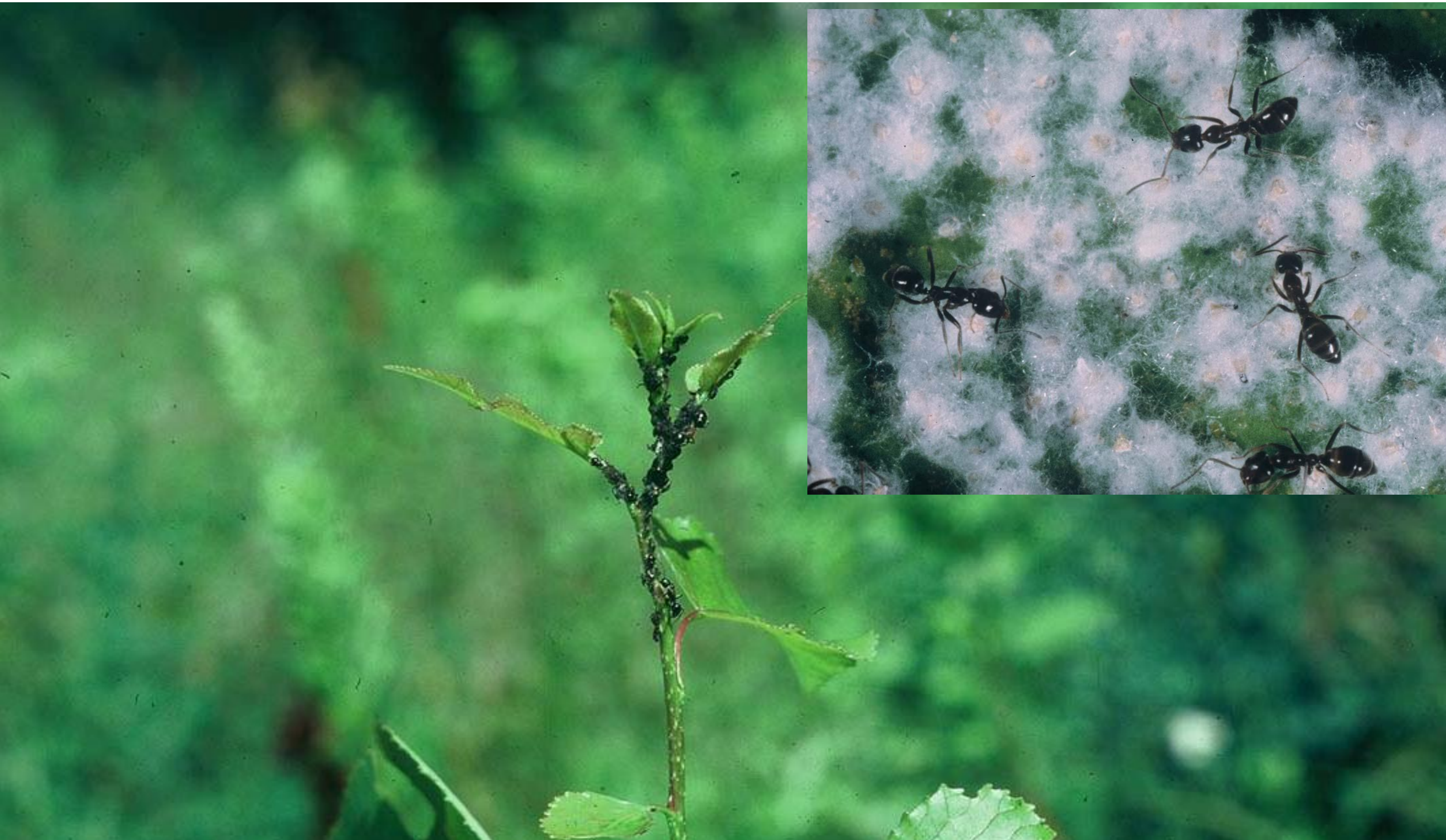
- find physiologically selective pesticides
- methods to make pesticides ecologically selective
- substitution by non-chemical control methods
- pesticide-resistant natural enemies

This is the principal way in which IPM systems try to retain natural enemies in crops

Influences that can harm natural enemies

- Pesticides (especially insecticides)
- Too much fertilizer
- Dust-in very dry climates
- Ants- homopteran-tending species

Some ants tend soft scales, whiteflies, mealybugs etc to gather honeydew, defending them from natural enemies



Dust, fertilizer

- **Dust** deters parasitoid foraging and promotes scale outbreak on edges of orchards near dirt roads

- **Fertilizer**, if overdone, can promote mite and thrips outbreaks by increasing their fecundity

Pesticide/Natural Enemy Conflicts

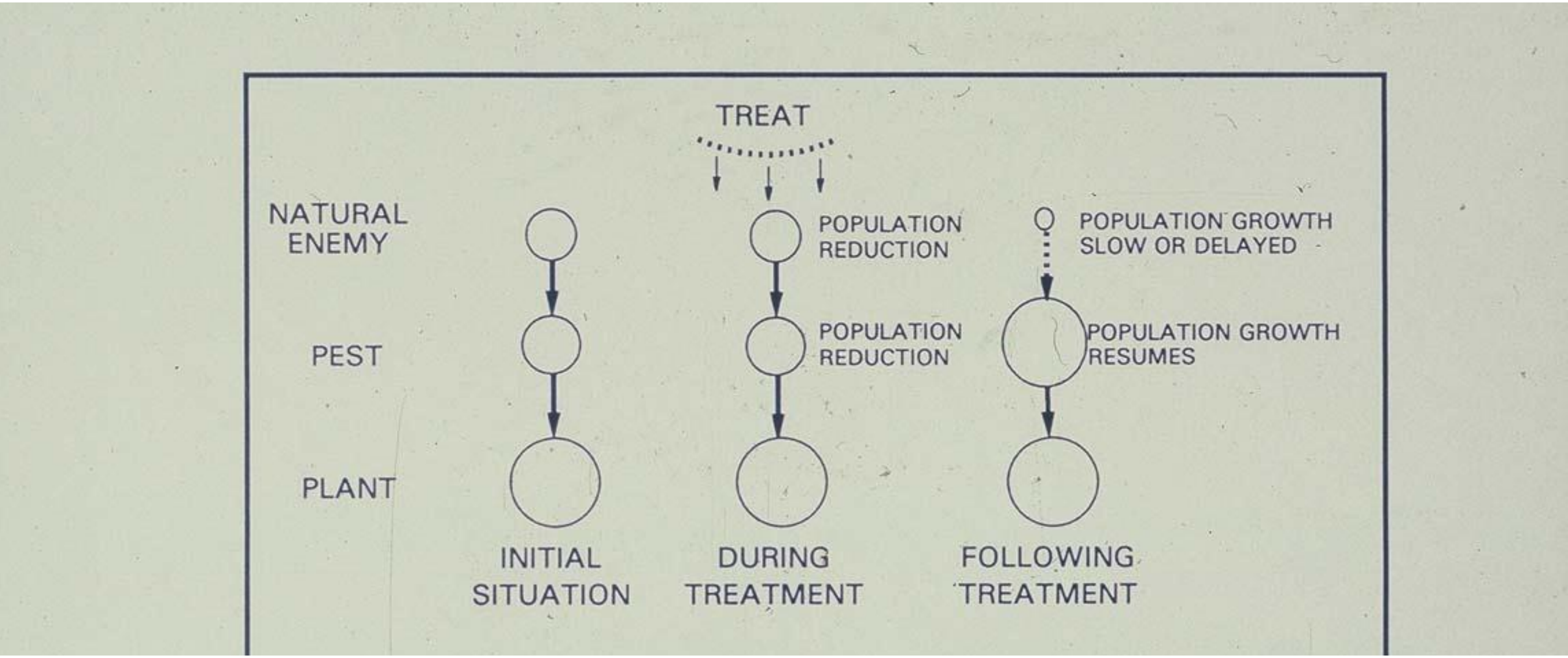
- **Direct toxicity**- pesticide kills natural enemies

- **Indirect toxicity** – pesticide residues make natural enemies weak, sick, or inefficient

- **Repellency**- natural enemy leaves areas with pesticide residues

- **Sterilization**- natural enemies exposed to pesticides lay fewer eggs

Pest Resurgence



1. **A pesticide is used to kill a pest**
2. **Pesticide also kills natural enemy of pest**
3. **After residues are gone pest/natural enemy ratio is worse and pest population growth rate is higher**
4. **Soon pest densities equal or exceed pre-spray levels**
5. **Requires that the pest have many generations per year. Pests with one per year are much less likely to act this way**

Pest Resurgence example #1

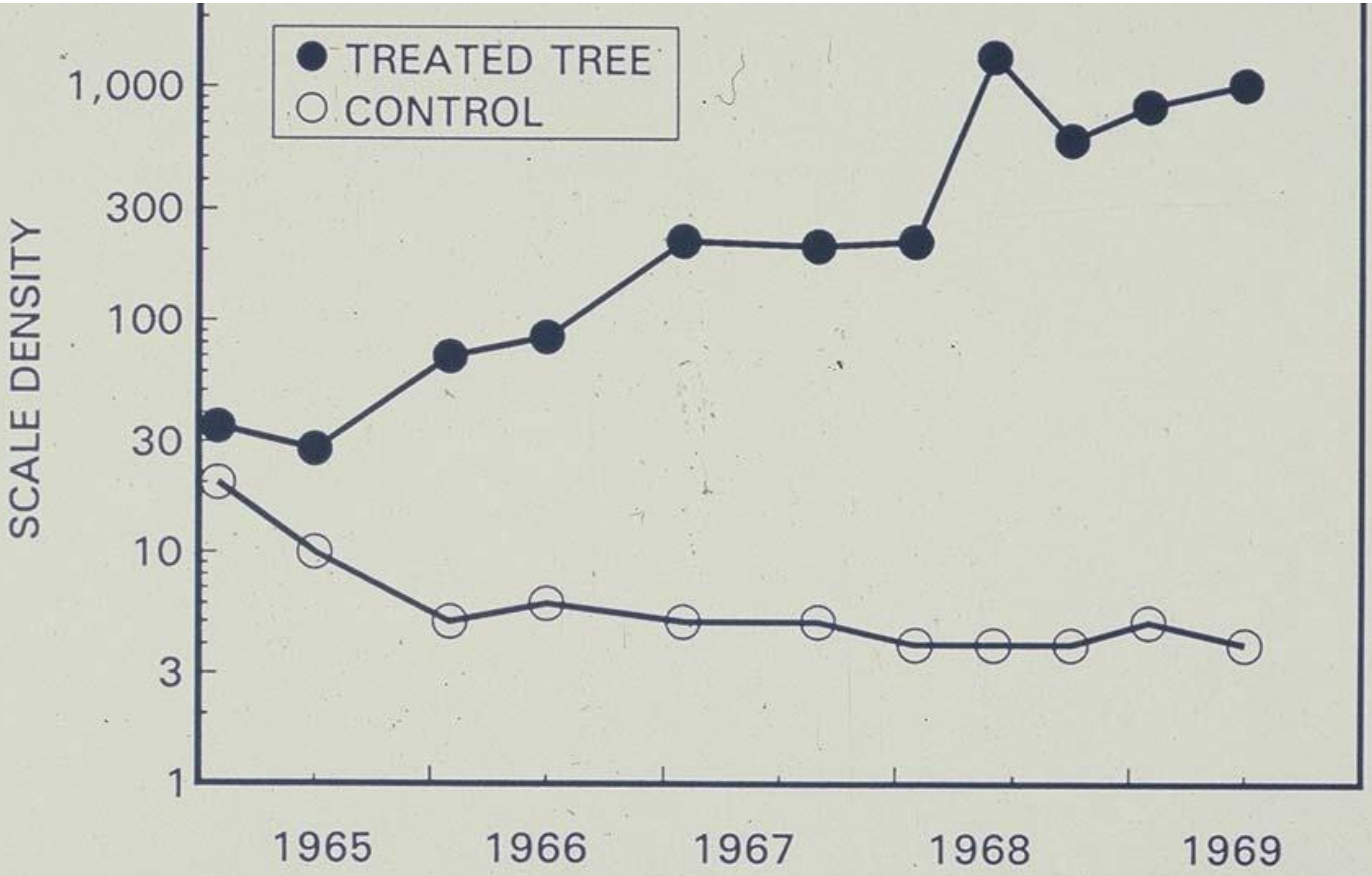


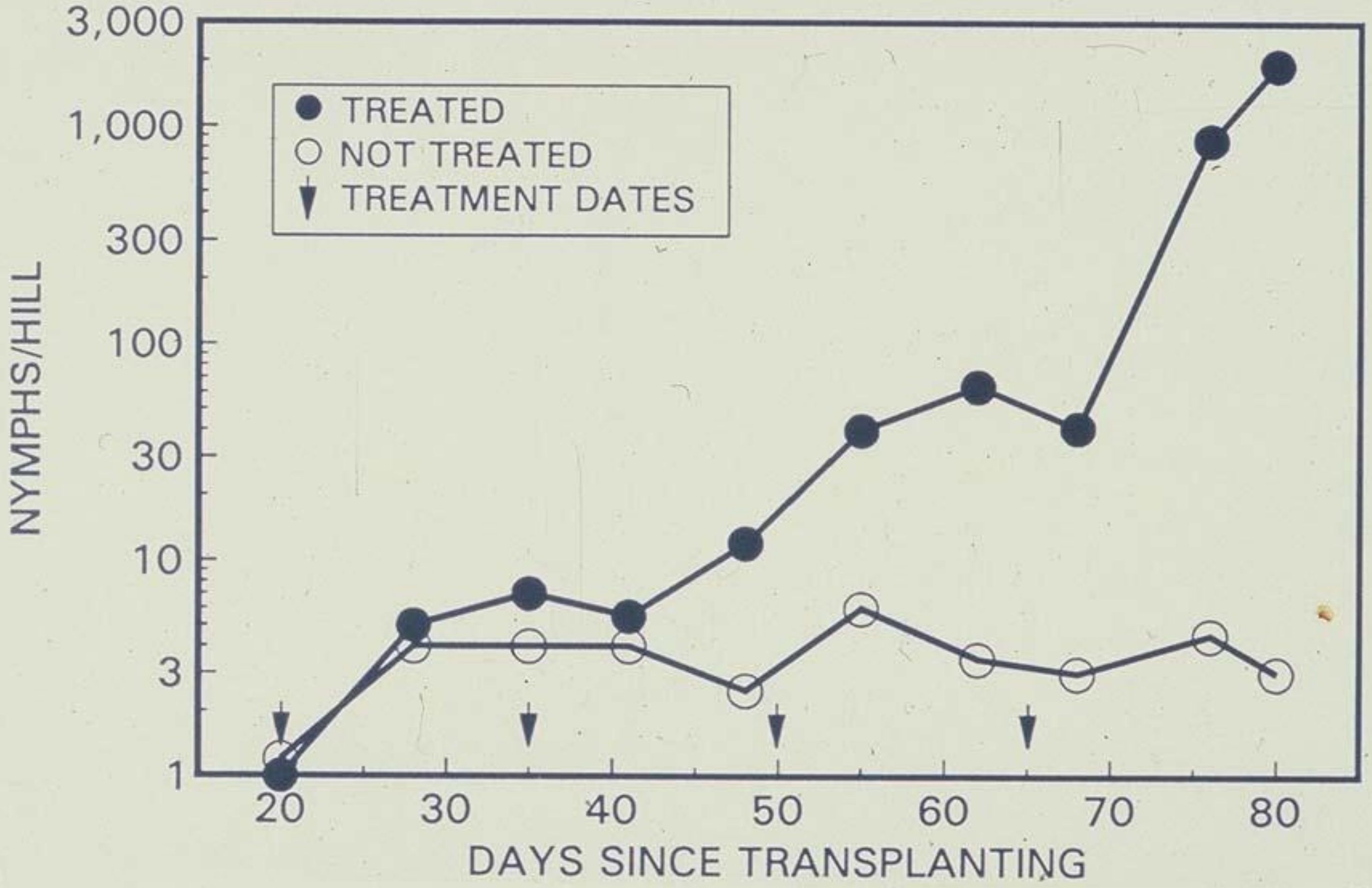
Fig. 7.4. Secondary pest outbreaks occur when pesticides are used against one pest and eliminate the natural enemies of another. In this case, treatments of the pesticide DDT on citrus severely reduced populations of the natural enemy Aphytis melinus DeBach, so populations of the California red scale, Aoniidiella aurantii (Maskell), increase substantially (after DeBach & Rosen 1991).

DeBach demonstrated resurgence by using DDT to eliminate *Aphytis melinus* from citrus groves. Red scale populations exploded

Pest Resurgence example #2-brown rice planthopper

Spraying rice

Intensification of rice production with fertilizers, improved varieties and pesticides, lead to pesticide induced outbreaks of rice brown plant hoppers in Asia

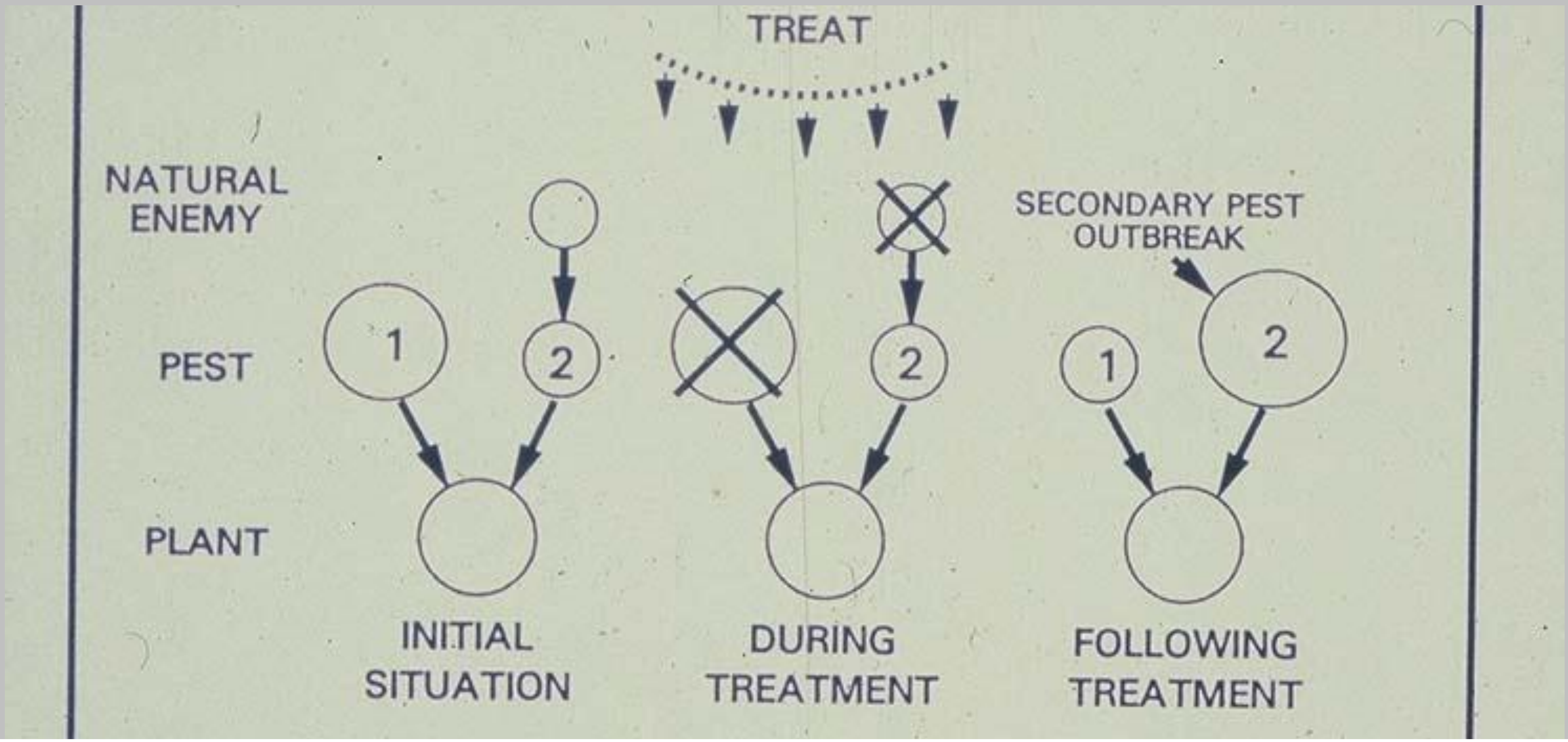


Pesticide use causes densities of rice brown planthopper, *Nilaparvata lugens*, to increase

Reason: pesticides killed spiders, which proved to be essential predators to keep rice brown planthoppers from increasing

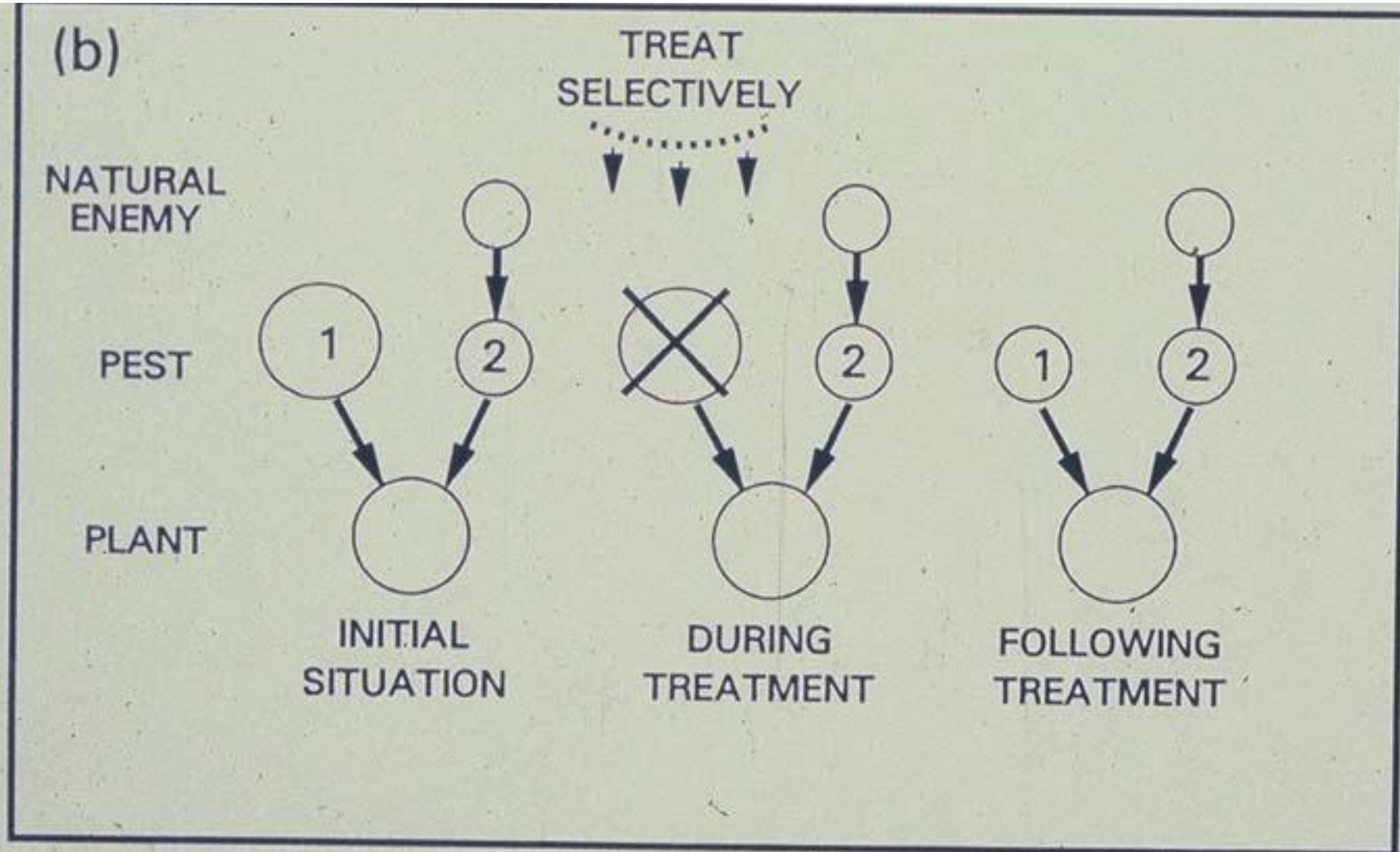
But note, in MA, spiders were studied and found to be unimportant in both apples and cranberries

Secondary Pest Outbreak

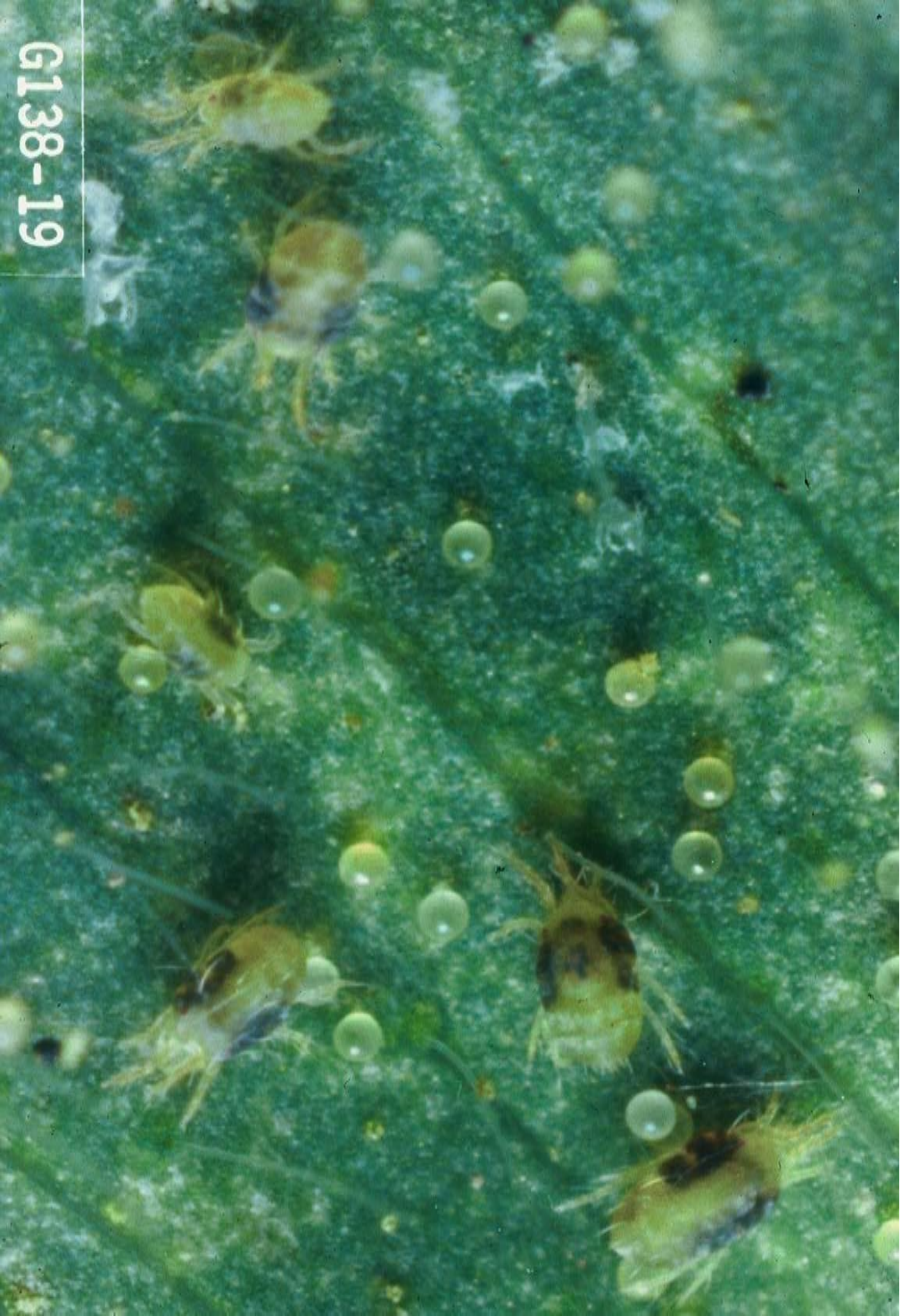


1. **A pesticide is used to kill a primary pest**
2. **Pesticide also kills natural enemy of minor herbivore**
3. **Loss of natural enemies of 2nd species causes it to reach higher densities and becoming a pest in it own right**
4. **Examples: spiders mites, leafminers in apple**

To prevent secondary pest outbreaks, use selective pesticides



1. To control primary pest, use a pesticide that is harmless to the secondary herbivore's natural enemies
2. Example: use granuolsis virus of codling moth, not organophosphate, to prevent outbreaks of pear psylla



Two spotted spider mites are suppressed in apple orchards by phytoseiid mites.

If these predators are killed by cover sprays for apple maggot, by mid summer there will be mite outbreaks

Use of poisoned AMF traps avoids this

Physiological Selectivity- the search for pesticides physiologically compatible with the key natural enemies

Kinds of selective pesticides

- **Viral biopesticides** are very selective
- **Bt biopesticides** are fairly selective and must be ingested to kill, so few natural enemies are affected
- **Insect growth regulators** only kill in the immature stages (at the molt) and so are fairly safe to natural enemies
- **Individual compounds**- may or may not be selective

<u>Direct Toxicity</u>: Survey to find pesticide least toxic to key predator mite (*Amblyseius fallacis*) in apple

Material	Rate/ 100 l	Bishop strain Mortality[1] (%)	Bishop strain Toxicity rating	Carlson strain Mortality[1] (%)	Carlson strain Toxicity rating
Insecticides					
methomyl 1.8EC	62 ml	100	High	—	—
carbaryl 50WP	119 g	100	High	89	High
phosalone 25WP	478 g	87	High	—	—
phosalone 3EC	187 ml	100	High	85	High
diazinon 50WP	119 g	70	High	—	—
demeton 6EC	23 ml	100	High	100	High
dimethoate 2.67EC	125 ml	96	High	—	—
fenvalerate 2.4EC	20 ml	100	High	—	—
permethrin 3.2EC	16 ml	100	High	—	—
phosphamidon 8EC	31 ml	46	Moderate	—	—
malathion 25WP	239 g	15	Low	—	—
phosmet 50WP	179 g	10	Low	7	Low
azinphosmethyl 50WP	74 g	12	Low	24	Low
methyl parathion 2FM	250 ml	12	Low	—	—
endosulfan 50WP	119 g	19	Low	16	Low
methoxychlor 50WP	358 g	3	Low	—	—

Note low toxicity of azinphosmethyl

A measure of physiological compatibility

LC50 natural enemy/ LC 50 pest

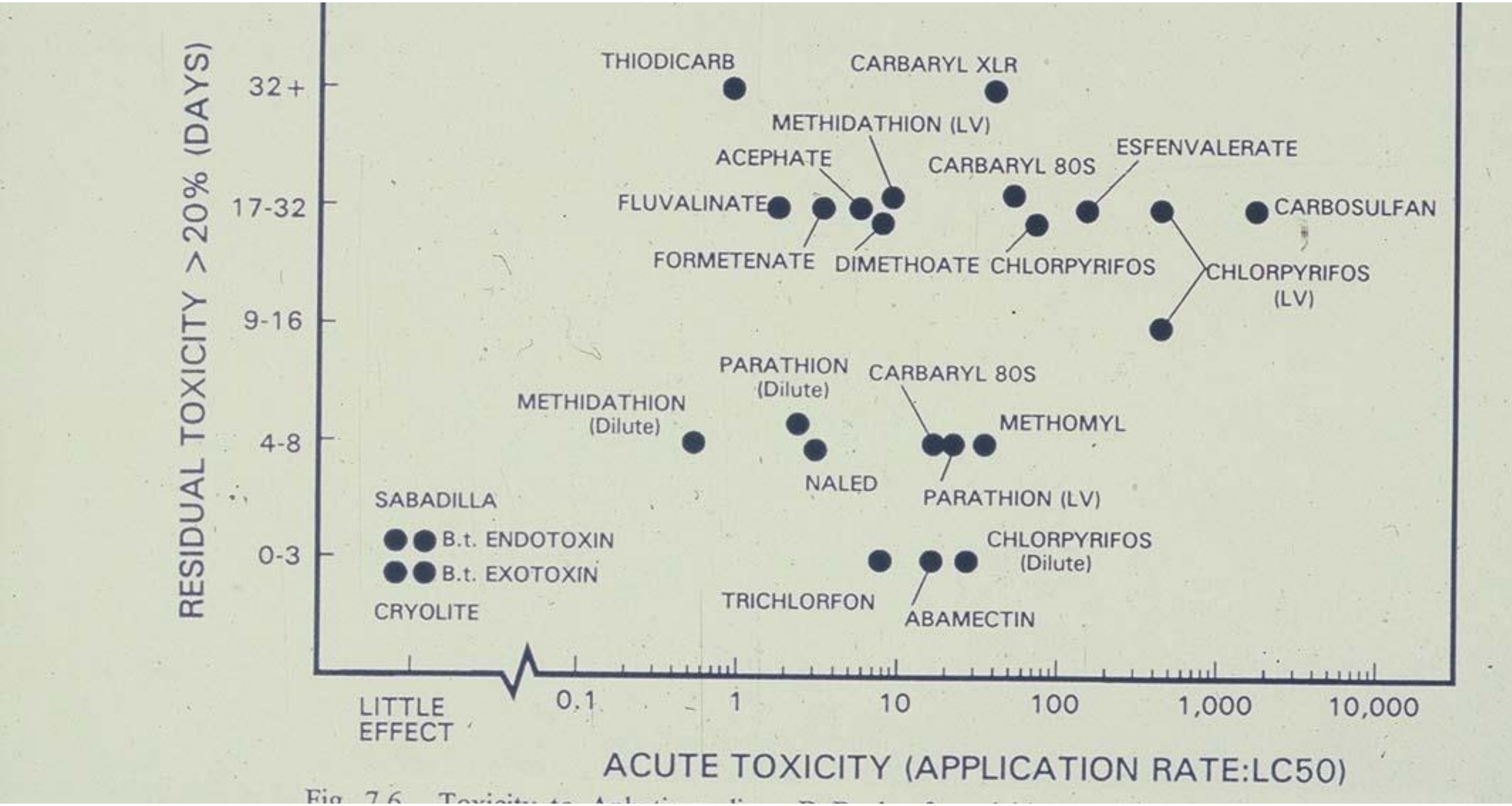
- LC (lethal concentration) 50 (50%) means the concentration of a pesticide solution that will kill half of the animals exposed.
- Highly toxic materials kill at lower concentrations and hence have LOW LC50 values
- LC50 natural enemy/ LC50 pest ratio of 1, implies no difference in concentration that kills pest or natural enemy.
- Higher values imply materials are LESS toxic to the natural enemy (CAREFUL this can be confusing!)

<u>Sterility:</u> laboratory screening of predator *A. fallacis* to detect effects of fungicides on its reproduction

Material	Mean no. eggs/female	
	Treated leaves	Check leaves
Insecticides		
phosmet 50WP	17.5	20.7
azinphosmethyl 50WP	21.6	19.1
Fungicides		
benomyl 50WP	0	22.6
dodine 65WP	21.0	22.2
captan 50WP	21.0	20.4
glyodin 30% EC	19.8	21.5

Note sterilizing effect of benomyl

Screening a crop's registered pesticides hoping for one that is selective



Acute toxicity (X axis) and duration of effect (Y) of citrus pesticides to *Aphytis melinus*, key CA red scale parasitoid

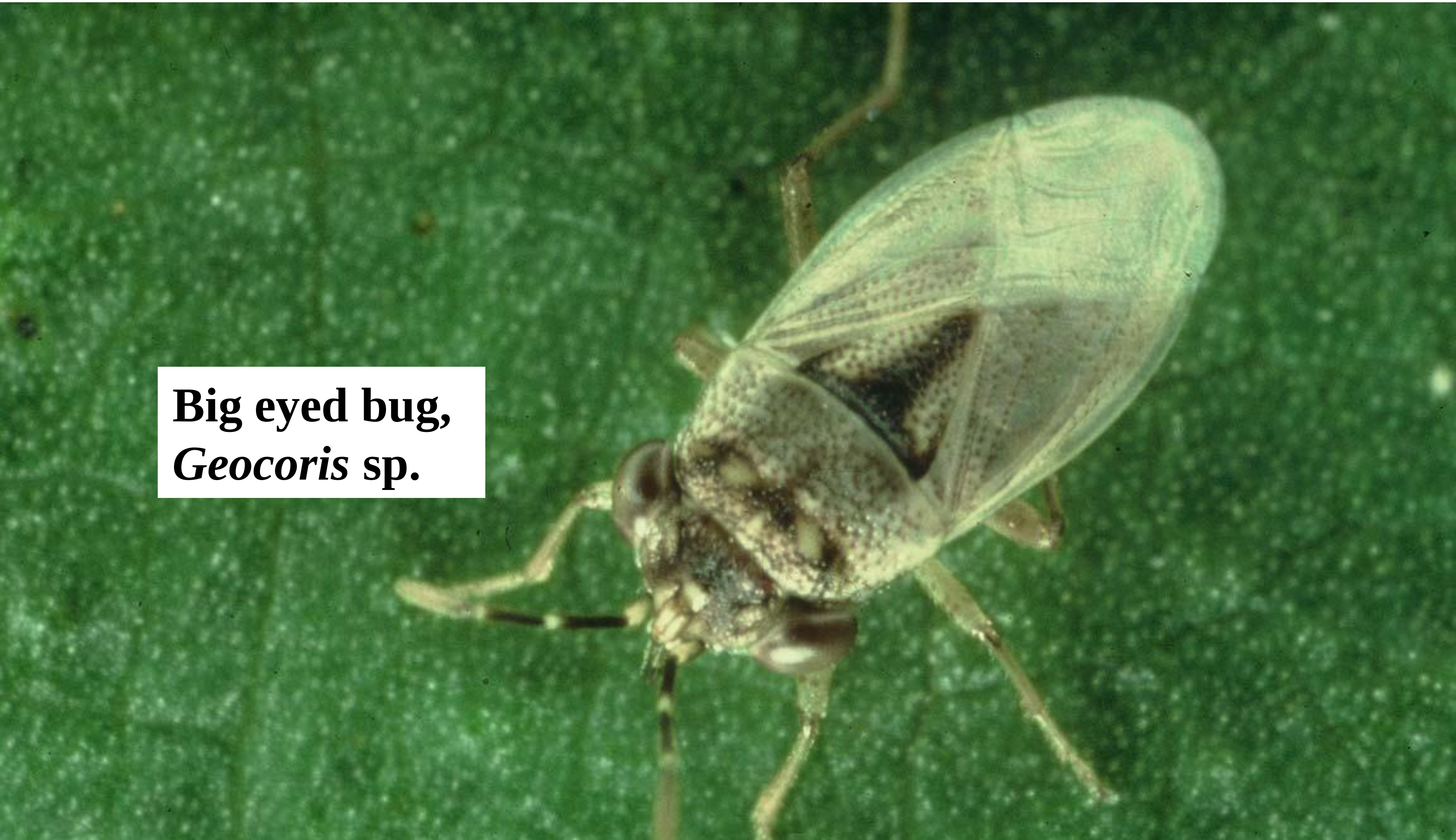
Ecological Selectivity-finding ways to make nonselective materials selective in practice through manner of application

Methods for ecological selectivity

- granules vs sprays
- contact vs stomach poisons
- skip-row applications
- precisely timed applications

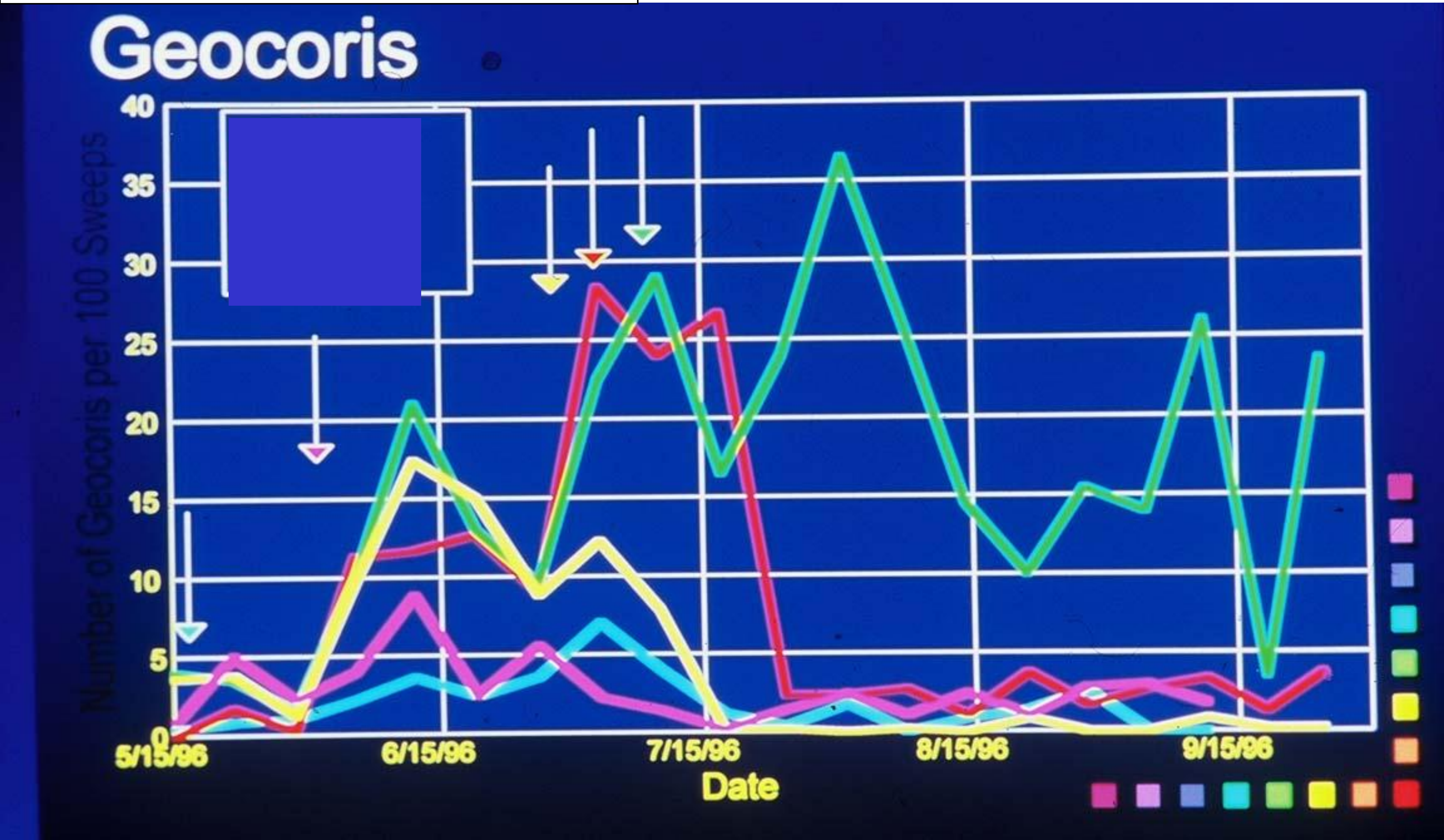
Granular vs liquid sprays differ in effect on parasitoids

Example of conservation: Using Bt cotton and IGRs to conserve whitefly predators



Needles-conventional-yellow
Mojave-conventional-red
Mojave- Bt + IGR-green

Geocoris density under different spray regimens



Economics of Insect Control in Mohave and Needles

Area	Type of Insect Control	Number of Pesticide Applications	Cost of Insect Control ($ per acre)	Average Stickiness Index
Needles	Conventional	5.6	$127	4.6
Mohave	Conventional	6.6	$147	1.6
Mohave	BT Cotton/IGR	2	$105	0.0
Mohave	BT Cotton/IGR without Applaud	1	$76	?

1. Control of major arthropod pests by commercialized Bt crops

Bt cotton (Naranjo et al. 2008)

28 lepidopteran pest species listed:

9 excellent control, 13 good control, 5 some control, 1 no control

No control of Hemiptera, Coleoptera, Thysanoptera, Acari

Bt maize (Hellmich et al. 2008)

15 lepidopteran pest species listed:

7 stemborers (5 excellent control, 2 good control)

8 other Lepidoptera (3 good control, 4 some control, 1 no control)

1 coleopteran pest with good control

No control of Hemiptera, other Coleoptera, Diptera, Thysanoptera, Acari

Slide of Franz Bigler

2. Changes of insecticide use in Bt cotton

Table 4.Impacts of Bt cotton on pesticide use and yield of Bt cotton compared to conventional cotton in several countries worldwide.

Country	Number of sprays			Average Pesticide (kg/ha)			Yield (kg/ha)			References
	Bt cotton	Non-Bt cotton	% change	Bt cotton	Non-Bt cotton	% change	Bt cotton	Non-Bt cotton	% change	
Argentina	2.5	4.8	-48	2.08	4.09	-49	2078	1572	+32	Qaim et al., 2003
USA [1]	3.74	5.2	-28.1				689	666	+3.3	Williams, 2003
Australia	4.5	9.9	-56	3.57 0.48 [2]	6.3 3.23	-43 -92	4762	4790	0	Fitt 2003; Pyke 2004
India	4.19	7.19	-42	0.43	1.41	-70	608 1238 [3]	337 706 [3] 370 [4]	+80 +75 +230	Qaim 2003; Qaim & Zilberman 2003; Bamberwale et al., 2004
China	8.1 6.6	19.8 19.8	-59 -66	21.7 [5] 12.1 18	65.6 60.7 46	-70 -80 -61	3264 3290	2741 3186	+19 +3	Pray et al., 2002; Huang et al., 2003; Lu et al., 2002
Sth Africa (small scale)				 97 [5]	 129	-25	464 471 576	348 261 395	+34 +80 +46	Ismael et al., 2002; Bennett et al., 2003; Yousef et al., 2001; Kirsten et al., 2002;
South Africa (large scale irrigated)				226 [5]	519	-56	4046	3413	+19	Kirsten et al., 2002
Mexico	2.3	4.9	-54				1645	1480	+11	Traxler et al., 2001

G. Fitt *et al*. (2004, 2008)

Slide of Franz Bigler

5. Summary of impact of Bt toxin and Bt crops on natural enemies – results from lab and greenhouse research

- **Bt effects were investigated on 31 species of natural enemies (publication status 2006)**
- **Bt crops: maize, cotton, potato, rice, oilseed rape**
- **Bt toxins: Cry1Ab, Cry1Ac, Cry3Aa, Cry3Bb, Cry9C**

Results:

- **No natural enemy species was directly affected by the Bt toxins.**
- **12 species were indirectly affected through reduced nutritional quality of Bt-sensitive prey.**

Slide of Franz Bigler

Romeis et al. 2006. Nature Biotech., 24: 63-71.

5. Summary of impact of Bt crops on natural enemies – results from field studies

- > 50 field studies published (in peer reviewed journals).
- Crops: maize, cotton, potato, tobacco, egg-plants.
- Bt toxins: Cry1Ab, Cry1Ac, Cry3Aa, Cry3B, Cry3Bb, Cry1Ab+VIP3A.

Results:

- Bt plants are very specific against target pests.
- No consistent adverse effects on natural enemies were found, except that host-specific natural enemies of target(s) were reduced (expected effect).
- Comparative studies showed pronounced adverse effects of insecticides to natural enemies and their biocontrol function.

Slide of Franz Bigler

Romeis et al. 2006, Nature Biotech., 24 (1): 63-71
Wolfenbarger et al. 2008, PloS One, 3 (5): e2118

Progress in Biological Control

Integration of Insect-Resistant Genetically Modified Crops within IPM Programs

Edited by
Jörg Romeis,
Anthony M. Shelton
and George G. Kennedy

Springer

Slide of Franz Bigler

Pesticide-resistant natural enemies

- Idea is to find a strain of a key natural enemy that has been selected in the field to be resistant to key pesticides, or create strain in lab
- First done with predacious mites of spider mites in apples; some use
- Drawback-requires continued pesticide use as selected strain is displaced by wild type in absence or continued pesticide selective pressure
- Big researcher in this (formerly): Marjorie Hoy, Univ Florida