Chapter 17
ENHANCED BIOLOGICAL CONTROL THROUGH PESTICIDE SELECTIVITY

I. Effects of Pesticides on Natural Enemies

A. Direct Effects

1. Short-term mortality (<24 hrs)

a. Biological factors that influence the way in which toxins cause relatively immediate mortality in natural enemies:

- individual weight
- size and sex
- developmental stage
- starvation and nutritional effects
- diapause state
- circadian rhythm
- behavior.

b. Behavior of natural enemies, particularly searching behavior, may greatly affect their response to pesticides.

c. Predators are usually more tolerant of pesticides than parasitoids

2. Long-term, sublethal effects

a. Relatively little attention has been directed towards long-term (>24 hrs), sublethal effects of pesticides on natural enemies

b. Sublethal residues may affect natural natural enemies which survive pesticide applications, emerge as adults from protected quarters, or disperse into previously treated areas where residues exist.

c. Sublethal doses of pesticides can have positive or negative effects on natural enemies. **Positive effects include**:

- increased fecundity
- enhanced parasitoid efficiency
- increased mobility
- reduced developmental periods

Detrimental effects include:

- reduced daily fecundity
- reduced total progeny production
- decreased viability
- altered predation or parasitism behavior; loss of the ability to recognize hosts; loss of coordination; reduction of predation efficiency; temporary paralysis or knockdown; termination of feeding; and repellency from treated hosts/prey
- increased developmental times
- decreased production of F1 female progeny
- reduced survival of F1 progeny
- production of deformed F1 progeny

d. Sublethal residues probably reduce longevity and fecundity significantly. Reduced progeny production resulting from decreased adult longevity has been reported in one predator and four parasitoid species. Reduced daily fecundity rates have been reported in five predator and four parasitoid species

e. Reduced daily fecundity can be a product of either physiological impairment of the natural enemy's reproductive system and/or disruption of the natural enemy's searching and oviposition behavior.
f. Because searching behavior is an important factor in the ability of a natural enemy to regulate its prey or host at low densities, impairment of this behavior could seriously affect the effectiveness of efficient natural enemies. Perera (1982) demonstrated reduced rates of whitefly parasitism and significant changes in the functional response of *Encarsia formosa* when the parasitoid was provided whitefly hosts on *Phaseolus vulgaris*
leaves treated with sublethal doses of resmethrin.
g. Due to the many possible sublethal effects of pesticides, lack of significant natural enemy mortality following a pesticide application in the field could be misleading as to the true impact of the toxin on the natural enemies.

B. Indirect Effects

1. Reduction of host/prey populations
a. Perhaps the greatest detriment to natural enemy populations other than acute mortality following pesticide treatments is the reduction in population density of susceptible pests which serve as their food sources.
b. Systemic pesticides have been suggested as being a potential solution to the high acute mortality of natural enemies associated with most conventional pesticide applications. Problems may occur when pest densities are reduced to such low levels that natural enemies are decimated by lack of prey or hosts or they are forced to emigrate
2. Ingestion of pesticide-contaminated hosts or prey

II. Consequences of Disrupting Biological Control

A. Resurgences. Consult prior class notes on Conservation.
B. Secondary Pest Outbreaks. Consult prior class notes on Conservation.

III. Techniques to Reduce the Negative Impact of Chemicals on Natural Enemies

A. Crop monitoring and economic thresholds
1. Probably the best method for reducing the overall negative impact of chemicals on natural enemies is to apply pesticides only when necessary. Decisions to apply pesticides require knowledge of the impact of pest species on the commodity in question and some method of monitoring the pest to determine when it may cause problems
2. An understanding of the effectiveness of natural enemies is essential to avoid applying pesticides when biological control is adequate
3. Few monitoring systems have been developed which consider the influence of natural enemies on pest population increase with respect to the need for chemical intervention. One of the first systems developed was used to predict the necessity of acaricide treatments for European red mite control on apple. Treatment decisions are based on the relative densities of the spider mite and its predator, *Amblysieus fallacis*. Using predator/prey ratios, the probability of biological
control within a week's time is estimated. Acaricide applications are recommended only when biological control is estimated to be inadequate.
4. The impact of pesticide treatments on natural enemies of secondary pests should also be considered when decisions are made to treat for primary pests.

5. Pest management manuals produced for alfalfa hay (Flint 1985c), almonds (Flint 1985b), cotton (Flint 1984), tomatoes (Flint 1985a), and walnuts (Flint 1987) advise growers of the various natural enemies that should be conserved to avoid secondary upsets when pesticides are applied for primary pests.
6. Once the decision has been made to apply pesticides, several parameters must be considered so that the pesticide can be used in the most efficient and least disruptive manner. One must first define the *biological target*.

7. Prerequisites for defining the *biological target* are:

a. Identification of all pests and associated natural enemies potentially affected by pesticide applications in a given crop habitat
b. Knowledge of the behavior and micro-habitats of targeted pests and associated natural enemies
c. Knowledge of the dosage responses of pests and associated natural enemies to available pesticides
d. Knowledge of all feasible application methods for each compound. This information will provide the basic foundation for maximizing benefits derived from pesticide selectivity.
8. After the *biological target* is defined, one must then determine options available for the most efficient use of a pesticide with minimum non target effects.
B. Pesticide selectivity
1. *Pesticide selectivity* is the capacity of a pesticide treatment to spare natural enemies while destroying the target pest.
2. *Pesticide specificity* is the capacity of a compound to cause extraordinarily high mortality in a particular species. Specificity may be considered as an extreme type of selectivity.
3. Selectivity is a relative measure expressed as the natural enemy/pest ratio produced by one pesticide treatment compared with the ratio produced by a reference pesticide treatment.
4. Pesticide selectivity may be divided into *physiological selectivity* and *ecological selectivity* based on the mechanism by which a pesticide treatment is preferentially toxic to pests versus their natural enemies.
5. Strategies used to develop selective techniques of pesticide use are dependent upon the system under consideration.
6. To date, pesticide selectivity has been achieved predominantly by using insecticides to which biological control agents are naturally tolerant. This approach is restricted by the limited commercial availability of selective compounds.
7. Negative impact of insecticides on beneficial can also be ameliorated by laboratory selection for insecticide resistance to those compounds not naturally selective for natural enemies. However, this has not been a major path traveled for a variety of reasons. See notes on Augmentation for more information.
C. Physiological selectivity
1. Physiological selectivity results from physiological differences in susceptibilities of pests and associated natural enemies to a pesticide. Such physiological differences in the natural enemy may be inherent or a product of laboratory or field selection.
2. Effective use of physiologically selective compounds to enhance biological control is dependent on several factors including:
a. The type of pests (primary, secondary) targeted for control
b. Relative levels of pesticide resistance in non-targeted pest species.
3. When pest resurgence is the primary consideration, the major objective of physiological selectivity is to manipulate the natural enemy/pest ratio to favor the

natural enemies by differential mortality of the pest. However, high pest mortality is counterproductive if surviving natural enemies starve or emigrate from the treated crop habitat in search of prey or hosts. Loss of natural enemies due to starvation or emigration may produce results similar to a pest resurgence. Therefore, successful prevention of pest resurgences using physiological selectivity requires that a significant portion of the pest population survives the treatment. The pest density which can be tolerated is a function of many factors including the economic threshold, densities of pest and natural enemies following the pesticide treatment, numerical responses of the pest and natural enemies, host crop, and relevant environmental parameters (e.g., temperature, humidity, etc.).

4. When secondary pest outbreaks are the foremost concern and the primary pest lacks effective natural enemies, survival of the primary pest after treatment is less important than for a potential resurgence problem. In situations where the secondary pest exhibits pesticide resistance to a wide range of compounds, it will generally be preferable to use compounds with high *specificity* to control the primary pest. This tactic avoids destruction of the secondary pest's natural enemies and reduces further development of resistance in the secondary pest.

5. Current development and production of selective compounds by private industry is limited due to small market demand, development costs, and potential investment losses if targeted species develop pesticide resistance.

6. Efforts have been made in Europe by the Working Group on Pesticides and Beneficial Organisms, International Organization for Biological Control, West Palaearctic Regional Section (IOBC/WPRS), to identify registered pesticides (acaricides, fungicides, insecticides, herbicides) and plant growth regulators that have selective properties when used at recommended field rates (Franz et al. 1980, Hassan et al. 1983, 1987).

D. Ecological selectivity

1. Ecological selectivity results from differential exposure of pests and natural enemies to a pesticide.

2. Due to the limited number of physiologically selective compounds available, the greater potential for achieving pesticide selectivity appears to be through the development and use of ecologically selective strategies.

3. Modification of the pesticide

a. Reduction of application rates

b. Non-persistent pesticides

4. Modification of application methods

a. Temporal discrimination - application of pesticides when pests are present and natural enemies separate at any time

b. Habitat discrimination - application of pesticides to the parts of the habitat where the pest is more frequently found than the natural enemy.

c. Habitat partitioning - division of the targeted area so that pesticides are only applied to parts of the area. Both pests and natural enemies are reduced, but natural enemies are not totally decimated in the crop because they survive in the untreated portions of the crop and move into and survive in the treated portions following degradation of the residues.

1) Spot treatments

2) Crop partitioning