Chapter 19
THE IMPORTANCE OF NATURAL ENEMIES IN IPM SYSTEMS

I. Problems Resulting From Total Reliance on Pesticides

A. Development of insecticide resistance in pest species

1. As of 1990, >500 cases of insecticide resistance had been reported in those species classified as pests.

2. Very few cases of resistance were reported in those species classified as natural enemies (<5% of total for pests).

a. Predators are more tolerate to pesticides than parasitoids

b. In the field, natural enemy mortality due to pesticide residues declines as residues degrade

c. Susceptibility of a natural enemy may be a function of "area of discovery"

d. Phytophagous species are more capable of developing resistance than natural enemies due to a variety of reasons (e.g., their continued adjustment to plant produced toxicants)

3. Populations of *Amblyseius fallacis* naturally developed resistance to over 15 organophosphate insecticides (Studies conducted by Brian Croft, Univ. of Oregon).

4. Laboratory strains of *Metaseiulus* (*Typhlodromus*) *occidentalis* were bred for resistance to carbaryl and permethrin (Studies conducted by Marjorie Hoy, UC-Berkeley).

5. Populations of *Diglyphus begini* naturally developed resistance to 2 carbamate and 2 pyrethroid insecticides (Studies conducted by Robin Rathman, Univ. of Hawaii).

B. Resurgences of treated populations which are characterized by an abnormally rapid return of a pest to economic abundance after initial suppression by a pesticide which also destroyed the pest's natural enemies (which provided only partial control).

C. Pest Upsets of secondary pests (secondary pest outbreaks) which are characterized by the rise to economic prominence of an insect which is relatively unaffected by a pesticide treatment for another insect pest, but whose normally efficient natural enemies are affected.

D. Residue problems, hazards, and legal complications.

E. Destruction of beneficial species (e.g., honeybees).

F. Increased production costs (insecticide material, labor & equipment).

II. Management practices that Result in the "Pesticide Syndrome."

A. Doutt & Smith (1971) defined *the closed self-perpetuating system employing a completely unilateral method of chemical pest control that does not question whether a treatment was really necessary* as the "Pesticide Syndrome".

B. van den Bosch referred to *the situation of substituting one pesticide for another as the first one became useless* as the "Pesticide Treadmill".

C. The pesticide syndrome consists of many stages. The best known example of the pesticide syndrome is from the Canete Valley of Peru (1940-1960) which is an intensively farmed area.

1. Exploitation phase. Crop protection measures introduced to protect large valuable crops. Attempts are made to maximize yields by the use of scheduled insecticide treatments. This results in high numbers of pesticide applications. From 1943 to 1949, there were 3 main pests of cotton in the Canete Valley. These were the tobacco

budworm, a weevil (*Anthonomus vestitus*), and a leafworm (*Anomis texana*). Mostly arsenicals and
nicotine sulphate was used for control along with some organic insecticides. Yields increased initially, but dropped in 1949. Severe outbreaks of the budworm and aphids occurred in 1949.
2. Crisis phase. More frequent pesticide applications are needed to obtain effective control. Pest populations resurge rapidly after treatments to higher levels. Pest populations develop resistance to pesticides in use. Additional pesticides become useless more rapidly than the original pesticides used. Pest upsets begin to occur. From 1949 to 1955, the growers in the Canete Valley would not return to their old cultural methods or insecticides. It was suggested that growers only grow one year old ratoon crops. However, they would not comply. Reliance was placed on newly available organic insecticides at that time such as DDT, BHC, Toxaphene, etc. Cultural practices were modified to increase yields. New, highly productive strains of cotton were introduced and efficient irrigation practices were initiated. **These new measures resulted in**:
a. Doubling of yields
b. The philosophy that more pesticides meant higher yields
c. The valley being blanketed with insecticides
d. Most beneficial insect species being eliminated
e. The number of insecticide treatments increased
f. Loss of several pesticides
g. Secondary pest outbreaks and insecticide resistance development
h. Alternate insecticides used more frequently
i. Six new pest species appeared
3. Disaster phase: At this point, heavy pesticide usage increases production costs to a point where the crop can no longer be grown. Initially only growers on marginal land are affected. Eventually, all the growers are wiped out. From 1955 to 1956, economic disaster hit the Canete Valley. Millions of bales of cotton were lost to insect damage and yields dropped to the lowest level ever recorded.
4. Recovery phase (introduction of IPM). Crop protection system is employed which comprises a variety of control procedures rather than pesticides alone. Attempts are made to modify the environmental factors that permit the insects to achieve a pest status. Fullest use is made of biological control. Post 1956 in the Canete Valley, growers approached their Experiment Station for assistance. Many changes were introduced which included:
a. Cotton production was forbidden on marginal land
b. Ratoon cotton was prohibited
c. The valley was repopulated with natural enemies from neighboring valleys
d. Cultural practices which aided insect control were re-established such as uniform planting dates and cotton-free periods
e. Use of synthetic organic insecticides was prohibited except by approval of a special commission
f. Return to using arsenicals and nicotine sulphate insecticides
These changes resulted in a rapid and striking reduction in the severity of the cotton pest problems:
a. Secondary pests subsided
b. Problems with key pests were reduced
c. Overall reduction of indirect pest control costs
d. Cotton yields surpassed those previously recorded and were maintained at that level

III. Integrated Pest Management

A. Bartlett (1956) proposed "Integrated Control"

1. Integrated control denoted applied control that combined or integrated biological control and chemical control methods into a single unified pest control program.

2. Chemical control was used when and where necessary in a manner least disruptive to parasitoids, predators, and pathogens.

B. Around the 1960's, suggestions were made to broaden integrated control to include other control measures which evolved into the term "pest management" or "integrated pest management" (IPM).

C. Several definitions exist for IPM. Two examples are:

1. All practices, procedures and techniques relating to crop protection in a single unified program aimed at holding pests at sub-economic levels

2. The reduction of pest problems by actions selected after the life systems of the pests are understood and the ecological as well as the economic consequences of these actions have been predicted, as accurately as possible, to be in the best interest of mankind.

IV. General Considerations for Use of BC in IPM

A. Advantages of biological control in IPM systems

1. It is a safe approach provided the proper preliminary research is conducted prior to natural enemy introductions.

2. It is a relatively permanent control method given no pesticidal interference.

3. It is relatively economical after efficient natural enemies are established.

B. Limitations of biological control in IPM systems

1. Severely limited on crops with extremely low economic thresholds or where insects are vectors of plant diseases.

2. Effectiveness is generally inversely proportional to the time required for crop production.

3. It does not work well with all insect species.

4. It does not integrate well with insecticide programs unless selective insecticides or selective application methods are employed.

5. A significant time factor is involved in control of pests as opposed to almost instantaneous control with effective insecticides.

V. Examples of Natural Enemies in IPM Programs.

A. Citrus in Ventura County, CA. Presently there are ca. 10 pests of citrus under management in the area. Ca. 70 years ago, the major pest problem on citrus was black scale, *Saissetia oleae* (Olivier).

1. The scale was commonly treated with insecticides and by fumigation.

2. Importation of *Metaphycus helvolus* resulted in substantial control of the pest.

3. Currently, less than 5% of the citrus groves are treated for this pest. With control of black scale, parasitoids (*Aphytis* spp.) are released on an inundative basis to control California red scale, yellow scale, and others. Pests such as the citrus red mite, citrus aphid and navel orange worm are partially controlled by native (or indigenous) natural enemies, but sometimes require spot treatments when densities become high. The use of highly toxic broad spectrum insecticides such as parathion, malathion and carbaryl (Sevin) is discouraged due to the potential problems of pest upsets.

B. Apples in Michigan. Several pests are found on apples including the codling moth, *Laspeyresia pomonella*. It is not unusual to have up to 15 insecticidal treatments per season. Reduction of pesticide applications are achieved by monitoring the populations of the European red mite, two-spotted spider mite, and apple rust mite along with the predatory mite *Amblyseius fallacis*. Croft developed a system to determine whether insecticide treatments were needed in an orchard. Decisions to treat for mites were based upon the ratio of predatory mites to the spider mites (see Fig. 24.1 on following page).

C. Watermelon in Hawaii. Several indirect pests are found on watermelon including agromyzid leafminers, thrips, aphids, whiteflies and spider mites. In 1978, growers predominantly controlled leaf miners by insecticide treatments which resulted in leaf miner resurgences and the development of insecticide resistance in the leaf miners. In 1984, an IPM program was implemented based on biological control of leaf miners by conservation. Significant reductions in pesticide usage were achieved with increases in the biological control of leaf miners and aphids.

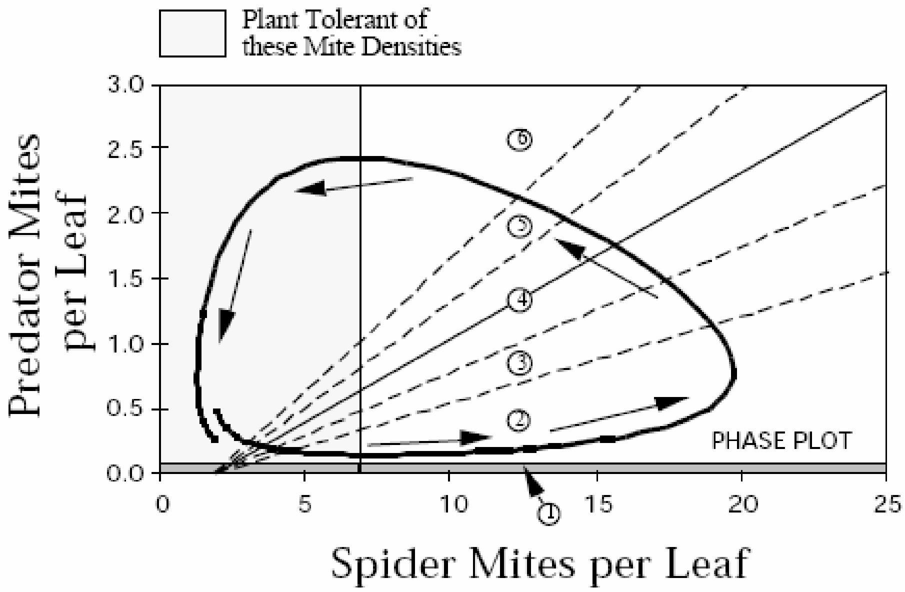

Fig. 24.1. The above graphic demonstrates how Croft's decision-making index works with respect to the population dynamics of the predator/prey system. Changes in the ratio of predators to spider mites are based on changes in time. Probabilities for control of spider mites by predatory mite are: very low in region 1; equal to or less than than 10% in region 2; greater than 10% and less than 50% in region 3; approximately 50% in region 4; greater than 50% and less than 90% in region 5; and approximately 100% in region 6. Figure modified from Croft (1975).