Chapter 18
AUGMENTATION OF NATURAL ENEMIES

I. Augmentation of Natural Enemies

A. This area of research should be given the lowest priority in biological control research endeavors and not be resorted to until it has been determined that the solution does not lie in foreign exploration and importation of new natural enemies or some type of conservation. Augmentation techniques are more expensive to develop as well to apply.

B. Augmentation can be divided into 2 major divisions:

1. Periodic colonization procedures; and
2. Development of adapted strains of natural enemies.

II. Periodic Colonization Procedures

A. Two types of procedures are used to obtain biotic reduction of a pest.

These are:

1. Inundative releases. These are made to control a pest mainly through the mortality caused by the natural enemies released and not their progeny. This type of control is similar to that obtained through the use of pesticides since the mortality of the pest is basically immediate and there is no prolonged interaction of the populations. BC agents in this type of release are referred to as "biotic insecticides". This method is best employed where:

a. Control is aimed at pests infesting high value crops with low infestations;

b. Pest species targeted are univoltine, or, if multivoltine, ones that reach injurious numbers during but a single generation a year.

c. Cost is prohibitive here if multiple releases are desired except in the case of insect pathogens.

2. Inoculative releases. Control is dependent upon the progeny being produced for more than one generation following the colonization of individuals of the beneficial species. Control using this method usually lasts longer than with inundative releases.

B. Examples of natural enemies used in mass releases

1. *Phytoseiulus persimilis*: Predatory mite which attacks tetranychid spider mites. Used extensively in Great Britain and the Netherlands in greenhouse production of vegetables. Prices for 1000 individuals vary around $12.50. An effective field release rate of 312,500 *P. persimilis* per ha priced at $25/1000 predators would cost $7800 per ha to control two-spotted spider mite in strawberries.

2. *Encarsia formosa*: Aphelinid parasite of the greenhouse whitefly, *Trialeurodes vaporariorum*. Used in same conditions as the above species in Europe. Not used extensively in U.S. Claims have been made that good whitefly control on cucumber could be achieved with releases of 100,000 parasites per ha for ca. $40.00 per ha.

3. *Chrysoperla carnea*: Has been used in several crops for various pests including mealybugs (on pear), *Heliothis* spp. (in cotton), and aphids (ornamentals). In cotton, numbers required to suppress *Heliothis* spp. were near 1 million per ha. Predators are $12.50 per 4,000 predators.

4. *Trichogramma* spp.: This egg parasite is the most widely augmented entomophagous arthropod in the world. They are used extensively in the USSR (8 million ha) and in the People's Republic of China (2 million ha). In the U.S., *Trichogramma* spp. may be released over as many as 200,000 ha. One commercial insectary reported producing from 50 to 100 million wasps per day. Parasites are released to control lepidopterous larvae on cotton, corn, apple, spruce, and avocado.

No one has ever shown conclusively that *Trichogramma* releases alone can provide control as well as insecticides. Parasites cost ca. $0.12 per 1000 individuals. In cotton it required up to 957,000 parasites per ha to reduce *Heliothis* larval populations.

C. Need for quality control

1. Consumers should receive what they pay for. However, this not always the case with mass reared biological control agents from commercial insectaries and other production units.
2. Common problems seen in shipments of natural enemies to the consumer include:
a. Contamination with incorrect species of BC agent
b. Fewer individuals than ordered (maybe zero)
c. Poor quality of individuals due to diet or perhaps shipping
d. Poor viability due to being too long in culture
3. **Randy Gaugler et al.**, Rutgers University, NJ, did a study on quality of entomopathogenic nematodes ordered from commercial companies that produced them and several weaknesses were discovered. One shipment contained no nematodes, and many did not have the specified numbers of nematodes purchased. Some of the nematodes were not very pathogenic and some had mixes of nematode species.
4. **The Association of Natural Biocontrol Producers** is working to correct these types of problems and facilitate voluntary quality adherence among producers of biological control agents so government will not feel the need to step in and institute regulations.

III. Development of adapted strains of natural enemies.

A. This field of augmentation is relatively new (last 30 years, although it is an old idea) compared to the idea of augmentative releases, and relatively very little work has been done in it.
B. Most effort has been on the development of pesticide resistant strains of natural enemies (predators and parasitoids) to reduce the impacts of pesticides that contribute to pest outbreaks via resurgences and secondary upsets.
C. Review of the field to date (Johnson & Tabashnik 1994), indicated that for all selection programs to improve pesticide resistance in natural enemies, only about 3% ever produce strains that are successfully established in the field.

D. Examples of this augmentation method follow below.

1. Selection of *Aphytis linganensis* for more extreme temperatures for use against the California red scale in the variable climates of the Central Valley of California. This work was conducted ca. 30 years ago and did achieve a population of more tolerant parasites. However, release of *Aphytis melinus* made the selected parasites worthless due to the former's ability to withstand more extreme temperatures (conducted by Paul DeBach, UC-Riverside).
2. Selection of the predatory mite *Typhlodromus* (= *Metaseiulus) occidentalis* (Nesbitt) for resistance to pesticides has yielded some outstanding results in recurrent selection and has proven to be a valuable predator strain (conducted by Marjorie Hoy, UC-Berkeley, now at U. of Florida, Gainesville) in the field. Resistance to carbaryl, methomyl, dimethoate, permethrin, and fenvalerate has been achieved. Selected strains of *T. occidentalis* are now commercially produced for mass releases in almond and apple orchards resulting in substantial economic benefits to California agriculture.
3. Selection of the green lacewing, *Chrysoperla carnea* (Neuroptera: Chrysopidae) for carbaryl resistance. Accomplished by Elizabeth Grafton-Cardwell & M. A. Hoy.

4. Work has been completed in the selection of *Aphytis melinus* for pesticide resistance to carbaryl. Attempts were made to establish resistance populations in the field (conducted by Jay Rosenheim, Kevin Spollen & M. A. Hoy).
5. Selection of *Trioxys pallidus* (attacks walnut aphid) for pesticide resistance to azinphosmethyl (guthion) (conducted by M. A. Hoy).
6. Selection of an entomopathogenic nematode to increase its searching abilities was accomplished by Randy Gaugler et al. at Rutgers University.
7. Selection of the leafminer parasitoid *Ganaspidium utilis* for resistance to fenvalerate was achieved by Hong Chen Willis and M. W. Johnson at the Univ. of Hawaii at Manoa. Individuals from the selected strain have been sent to the Maldives Islands for release and establishment. E. M. Hoy and her graduate student Jim Presnail (Presnail & Hoy 1992) inserted a marker gene into a predatory mite, *Metaseiulus occidentalis*. This is the first example of a transgenic natural enemy. Their methodology may lead the way to insert pesticide resistant genes into natural enemies, thereby eliminating the need to do laboratory selection for pesticide resistance in natural enemies.

F. In the near future, researchers will probably accomplish the development of transgenic natural enemies with resistance genes. The three biggest challenges are probably locating resistance genes in pest species to transfer, inserting the genes, and obtaining permission to release the transformed strains into the environment.