THEORIES OF BIOLOGICAL CONTROL

Notes

I. Probability of Biological Control Success Correlated With Geographical Area.

A. "Island Theory" - Islands vs. Continental areas

Analysis of successes to date - ca. 67% of BC successes which occurred on islands later occurred in continental areas.

B. Tropical Areas vs. Temperate Areas. Successes in tropical areas were reinforced by the fact that initial BC successes occurred on tropical islands. Success was probably a product of the latitude. Successes in tropical areas are supported on a physiological basis. Comparison of Heterodynamous insects vs. Homodynamous insects:

1. Heterodynamous

   a. Unable to reproduce year round.
   b. Usually have discrete generations
   c. Require synchrony between natural enemy and pest

2. Homodynamous

   a. Capable of continuous reproduction
   b. Have overlapping generations with all stages present at any one time
   c. Easiest species to control with BC

II. Introduction Strategies

A. Pros and Cons of Multiple Introductions

1. Pemberton & Willard (1918) hypothesized that multiple parasitism was detrimental. Other natural enemy species thought to be decimated by inherently superior natural enemies when in competition as larvae. Ideas developed from work on *Biosteres humilis* and *Biosteres tryoni* on the Med Fly, *Ceratitis capitata* in Hawaii.
2. H. S. Smith refuted idea through analysis of data of Pemberton & Willard. Concluded that:

   a. Inherent reproductive capacity alone is rarely if ever an indication of the success of a parasitoid
   b. Competition between parasitoids for the same host resulted in more host mortality than produced by either natural enemy individually.

3. Two theoretical situations in which multiple parasitism could be detrimental:

   a. Parasitization of host (with overlapping generations) results in discrete generations due to elimination of a given host stage.

b. Parasitization of host by inefficient parasitoid which results in reduced "intraspecific" competition between individuals of the host species at high densities.

4. Advantages of multiple parasitism

   a. Increased probability for BC over entire geographical range of host
   b. Increased host mortality than expected with a single natural enemy alone
   c. Increased probability of natural enemy that can utilize alternative hosts when primary host population is low
   d. Potential attack of all host stages (sequence theory)

5. Intra-Guild Predation

   J.A. Rosenheim, University of California, Davis, discovered that among predators in cotton (in California), resulting levels of biological control could be manipulated by adding and subtracting predators. Also in papaya (in Hawaii), he found the presence of spiders in the spring eliminated staphylinid beetles that suppressed tetranychid spider mite populations before predatory mites excerted control. If spiders were present during the spring time, spider mite outbreaks would occur.

6. *Liriomyza* parasitoids may interfere with each other when larval ectoparasitoids (e.g., *Diglyphus* spp.) and larval-pupal endoparasitoids (e.g., *Chrysocharis oscinidis*, *Ganaspidium utilis*) are present in a cropping system. Larval ectoparasitoids adults are able to parasitize leafminers that already contain a living endoparasitoid larva, resulting in the death of the endoparasitoid. Endoparasitoids do not parasitize leafminers with ectoparasitoids because the parasitized hosts will not pupate so the endoparasitoids can complete their life cycles. On the other hand, there is no 'silver bullet' leafminer parasitoid, so many species are needed to control leafminers across different crop systems (e.g., tomatoes, cucumber, onions, celery, etc.)

B. Single introductions vs. multiple introductions

1. Turnbull and Chant (1961) again advanced the idea that the single "best" species should be introduced for BC
2. Currently, no way exists to totally evaluate successful natural enemy's performance in the field prior to release.
3. Effective BC may depend on a 2nd or 3rd natural enemy species to achieve an desirable level of BC
4. A major problem in biological control is the lack of predictive theory that permit one to predict the outcomes of natural enemy introductions for new exotic pest problems with no prior history of classical biological control efforts

C. The "Sequence Theory"

1. Howard and Fiske (1911) advanced the theory that control of an insect would be inefficient if only one developmental stage of the pest species was attacked. BC should be achieved through a variety of natural enemies attacking several developmental stages of the host

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2. In general, successful BC has been the result of a single "best" natural enemy
3. When satisfactory control is lacking, attempts should be made to complete the "sequence" of natural enemies

D. Time Factor with respect to expected results from introduced BC agent

1. Curtis P. Clausen (1951) concluded from worldwide analysis of BC projects that an effective natural enemy might be expected to show evidence of control *at the point of release* within a period of 3 host generations or 3 years.
2. Conclusions drawn from the theory:

    a. A fully effective natural enemy is always easily and quickly established
    b. Failure of a parasitoid/predator to become established easily and quickly is an indication that it will not be fully effective after establishment is achieved
    c. Colonization of an imported BC agent may well be discontinued after 3 years if there is still no evidence of establishment

3. An exception to the rule: the eucalyptus snout beetle, *Gonipterus scutellaris* and the mymarid egg parasitoid *Anaphoidea nitens* in South Africa. Twenty-five years were required for total success.

E. Elimination of hyperparasites prior to parasitoid introduction

1. Primary consideration in introduction phase of BC agent
2. DeBach's study indicates hyperparasitism can significantly reduce parasite's ability to control host
3. Host preference change of some parasitoids may reduce effective BC agents used in weed control

F. Geographic races

1. Must not be neglected
2. Refer to class notes on Walnut Aphid.

III. Characteristics of Biological Control Agents

A. Predaceous vs. parasitic (parasitoid) in nature

1. Ca. two-thirds of BC successes have been with parasitoids
2. Food requirements of parasitoids allow them to maintain a balance with their hosts at lower host densities as compared to predators
3. Importance of predators is just being realized and evidence indicates that they may be a great stabilizing influence in many situations

B. Specific vs. General natural enemies

1. BC agents which are specific to a given host are inherently closely attuned to the host species and are responsive to changes only in the host species

2. Problems may be encountered by a specific BC agent at low host densities when a less specific agent can switch over to other hosts to maintain its numbers
3. A high degree of specificity may be correlated with less adaptability to environmental change or spread
4. Recent concerns among nature conservationists are pressuring biological control researchers to introduce only natural enemies with very limited host / prey ranges to avoid non-taget impacts on desirable species (e.g., Kamehameha butterfly, endemic species)

C. Which make the best BC agents, "r" or "K" strategists???

1. "r" strategists may be better BC agents in "disturbed" ecosystems such as short term crops (i.e., vegetables)
2. "K" strategists may be better BC agents in long term ecosystems (i.e., orchard crops and forests)

D. Egg Parasitoids - can they effectively reduce hosts to low densities???

1. Usually egg parasitoids are not considered to be effective parasitoids
2. Eggs parasitoids such as *Anaphoidea nitens* which attacks the eucalyptus snout beetle prove that egg parasitoids can effectively control their hosts as low densities

IV. Characteristics of Pests that affect BC efforts

A. Exotic pests vs. indigenous pests

1. Usually introduced pests are not a problem in their native home and are quite amenable to BC by introduced natural enemies
2. Evidence suggests that there is potential for controlling some indigenous pests with the introduction of exotic natural enemies. Hokkanen and Pimentel (Cornell University) call this phenomena ‘new associations.’ Given a lack of prior co-evolution between the host and new natural enemy, a newly associated natural enemy may have an advantage over a natural enemy that evolved with the host. With respect to insect pests, closely related exotic hosts should be examined for their effective natural enemies.

   Example: Control of the coconut leafmining beetle, *Promecotheca reichei*, in Fiji by *Pleurotropis parvulus*, a parasitoid of another species of *Promecotheca* spp. from Java.

3. Potential is also good in the field of BC of weeds.

   Example: Native Bermuda cedars decimated by introduced diaspine scales, *Carulaspis visci* and *Lepidosaphes newsteadi*

B. Possibilities of effective biological control of those pests causing direct damage to crops as opposed to indirect damage.

1. Indirect damage is that damage caused to any part of the plant or animal that is not valued (i.e., leaves of an apple tree, skin covering head of beef cattle).

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2. Direct damage is that damage to the part of the plant or animal that is valued (i.e., apple fruit, meat derived from beef cattle).
3. Usually economic injury levels are so low for plant products that biological control is not effective enough to contain the injury below the economic threshold.
4. Exceptions to the norm: Control of the olive scale, *Parlatoria oleae*, by multiple parasitism by *Aphytis maculicornis* and *Coccophagoides utilis*.

C. Control of sedentary pests vs. mobile, active pests

1. Many successes in biological control have been with sedentary pests such as scales, aphids and mealy bugs.
2. Sedentary insects are easy to transport from location to location.
3. Sedentary insects are usually associated with stable ecosystems (i.e., orchard crops).
4. A great proportion of time and money in BC has been directed at the control of sedentary pests.

V. Types of Ecosystems - Short term crops vs. long term crops.

A. Short term crops include vegetables, cotton, and grains.
B. Long term crops include most fruits and nuts and lumber products.
C. Many short term crops are too "short" with respect to time for biological control to be depended on to regulate all pests associated with the crop.
D. Short term crops are the most unstable due to the growing season length, thus natural enemy populations are disturbed quite often by crop destruction practices.
E. Orchard crops are long term and natural enemy complexes remain within a stable environment.
F. Usually extremely low economic injury levels are associated with short term crops (i.e., high cosmetic standards for produce in the market place). Remember a parasitized larva in a tomato is just as bad as a healthy larva to a health inspector or produce manager.

QUESTIONS

1. Hawaii has an excellent record in biological control. Do you think that the successes are related to Hawaii being composed of small islands. Why?
2. Many people argue the virtues of single vs. multiple introductions of biological control agents. What is your position on the subject?
3. What is the sequence theory of biological control?
4. Is it possible to successfully use classical biological control against indigenous pests?
5. In general, how long should one wait to see if a biological control agent will impact the pest for which it was introduced.

REFERENCES

Doutt, R. L., & P. DeBach. 1964. Some biological control concepts and questions. p. 188–142. *In* Biological Control of Insect Pests and Weeds (Paul DeBach, editor). Chapman and Hall Ltd, London. 844 pp.

Huffaker, C. B., P. S. Messenger & P. DeBach. 1971. The natural enemy component in natural control and the theory of biological control. p. 16–67. *In* Biological Control (C. B. Huffaker, editor), Plenum Press, New York. 511 pp.

Huffaker, C. B., F. J. Simmonds & J. E. Laing. 1976. The theoretical and empirical basis of biological control. p. 41–78. *In* Theory and Practice of Biological Control (C. B. Huffaker and P. S. Messenger, editors). Academic Press, N. Y. 788 pp.

Mackauer, M., L. E. Ehler & J. Roland. 1990. Critical issues in biological control. Intercept, Andover, Hants, UK.

Price, P. W. 1975. Insect Ecology. John Wiley & Sons, N. Y. 514 pp.

van den Bosch, R., P. S. Messenger & A. P. Gutierrez. 1982. An introduction to biological control. Plenum Press, N. Y. 247 pp.