Biological control of pests

Pests: Weeds, insects, pathogens

Introducing an organism to control the population of another organism (often also introduced)

http://www.youtube.com/watch?v=hdTBQvbZHSU
http://www.youtube.com/watch?v=Hj3DwimxvvY

Applied Biological Control may be broken down into 3 major categories:

1. CLASSICAL BIOLOGICAL CONTROL: the control of a pest species by introduced natural enemies
2. AUGMENTATION OF NATURAL ENEMIES: actions taken to increase the populations or beneficial effects of natural enemies
3. CONSERVATION OF NATURAL ENEMIES: the premeditated actions purposely taken to protect and maintain populations of natural enemies

www.cnr.berkeley.edu/biocon/BC 20Class Notes/

History of Biocontrol

A. The preliminary efforts when living agents were released rather haphazardly with no scientific approach. Little precise information exists on successes during this time. Roughly 200 A.D. to 1887 A.D.;

B. The intermediate period intermediate period of more discriminating BC which started with the introduction of the Vedalia beetle, Rodolia cardinalis Mulsant, for control of the cottony cushion scale in 1888. Period extended from 1888 to ca. 1955; and

C. The modern period characterized by more careful planning and more precise evaluation of natural enemies. Period from 1956 to the present.

200 A.D. to 1200 A.D

1. Chinese were the first to use natural enemies to control insect pests. Nests of the ant Oecophylla smaragdina were sold near Canton in the 3rd century for use in control of citrus insect pests such as Tesseratoma papillosa (Lepidoptera)
2. Ants were used in 1200 A.D. for control of date palm pests in Yemen (south of Saudi Arabia). Nests were moved from surrounding hills and placed in trees
3. Usefulness of ladybird beetles recognized in control of aphids and scales in 1200 A.D.

1300 A.D. to 1799 A.D

Microbiologist Van Leeuwenhoek illustrated and discussed a parasite of a sawfly that feeds on willow in a publication in 1701. The first insect pathogen was recognized by de Reaumur in 1726. In 1734, de Reaumur suggested to collect the eggs of an "aphidivorous fly" (actually a lacewing) and place them in greenhouses to control aphids

The mynah bird, Acridotheres tristis, was successfully introduced from India to Mauritius (off coast of Madagascar) for control of the red locust, Nomadacris septemfasciata, in 1762. In the late 1700’s, birds were transported internationally for insect control

Control of the bedbug, Cimex lectularius, was successfully accomplished by releases of the predatory pentatomid Picromerus bidens in 1776 in Europe
1800 A.D. to 1849 A.D.
In the 1800's, Darwin discussed "Ichneumonids" as natural control factors for cabbage caterpillars.

Hartig (Germany) suggested the rearing of parasites from parasitized caterpillars for mass releases in 1827.
Kollar (Austria) put forth the concept of "natural control" in 1837.
Verhulst (1838) described the logistic growth equation but the idea lay dormant until 1920 when rediscovered by Pearl.
Expressed idea of "environmental resistance".
During the 1840's releases of predators were used for control of the gypsy moth and garden pests in Italy.

1850 to 1887
From 1850 to 1870 enormous plantings of many crops were being grown in the United States (especially California) and were initially free of pests.

First practical attempt at BC of weeds occurred in 1863 when segments of the prickly pear cactus, Opuntia vulgaris, infested with the imported cochineal insect, Dactylopius coccus, were transported from northern to southern India.

Riley conducted the 1st successful movement of parasites for biological control when parasites were moved from Kirkwood, Missouri, to other parts of the state for control of the weevil Conotrachelus nenuphar in 1870.

In 1873 Riley sent the predator mite Tyroglyphus phylloxerae to France to control the grape phylloxera. The mite was established but did not exert control as hoped.

Trichogramma sp. (egg parasites) were shipped from the U.S. to Canada for control of lepidopterous pests in 1882.

In 1883 the USDA imported Aphanes grommatus from England for control of Papile (the imported cabbageworm). Parasites were distributed in DC, Iowa, Nebraska, and Missouri.

1888 to 1889
Cottony cushion scale, Icerya purchasi Maskell, was introduced into California in ca. 1868 around the Menlo Park (CA) area. It spread to southern California and by 1887 was threatening to destroy the citrus industry.
Researchers were sent to Australia in 1888 to collect natural enemies of the scale - 12,000 individuals of Cryptochaetum iceryae and 129 individuals of Rodolia cardinalis (the vedalia beetle) were sent back.
Within the year, the cottony cushion scale ceased to be a substantial pest. The vedalia beetle controls the scale mainly in the inland desert areas and C. iceryae controls it in the coastal areas.
For the next 10-15 years there were many attempts at biocontrol but no notable success and it fell from favor.

1900 to 1930
The Gypsy Moth Project in New England (1905-1911), foreign exploration in Europe for parasites to be imported to the U.S.
The Cactus Beetle Project in Hawaii (1902) First published work on BC of weeds searched Mexico and Central America looking for phytophagous insects which were sent to Hawaii.
The Sugar-cane Leafhopper Project in Hawaii (1904-1920), Hawaiian Sugar Planters Association (HSPA) created a Division of Entomology in 1904, found the highly effective predator Typhus (=Cyrtorhinus) mundulus (Miridae) in Queensland, Australia, in 1920.

Bacillus thuringiensis was described in 1911 as causative agent of bacterial disease of the Mediterranean fruit moth.
California state insectary, Sacramento, CA, established in 1913. Facility moved to the University of California's Citrus Experiment Station in 1923 (now UC Riverside).
In 1946 Riverside and Albany (UC Berkeley) made up Department of Biological Control, UC.
USDA laboratory for biological control established in France in 1919.
The Imperial Bureau of Entomology created the Farmann House Laboratory for BC work in England in 1927.

1930 to 1955
Peak in BC activity in the world with 57 different natural enemies established at various places.
World War II caused a sharp drop in BC activity. BC did not regain popularity after WW II due to the production of relatively inexpensive synthetic organic insecticides.
Entomological research switched predominantly to pesticide research.

1957 to Present
In 1959, Vann Stern et al. (1959) conceived the idea of economic injury level and economic threshold which would permit growers to make informed decisions on when they needed to apply control tactics in their cropping systems and therefore eliminated the need for scheduled pesticide treatments.

Interest developed nationwide in ecology and the environment after 1962 with the publishing of Rachel Carson's book "Silent Spring." "Silent Spring" helped stimulate the implementation of the concept of Integrated Pest Management (IPM) in the late 1960's, and biological control was seen as one core component of IPM by some.
More emphasis was placed on conservation BC than classical BC.
In some areas in the USA (e.g., California, North Carolina, Kansas, Texas), IPM scouting was commercialized in the 1970's and natural enemies were relied upon to suppress pests in crops such as cotton, alfalfa, citrus, soybeans, and other crops.
During the 1970's and 1980's, pesticide resistant natural enemies in cropping systems.
In 1983, classical BC efforts impacted by concluding that classical BC of arthropods significantly contributed to extinction of desirable species (e.g., endemic).
- This eventually focused on reining of legislative guidelines as well as introduction methods which are still being changed today.
- In Hawaii, BC efforts were diminished significantly and have not been to levels prior to 1983.
- In Florida, BC efforts were diminished significantly and are still being diminished with the general results that many claims were unjustified, but some impacts were discovered. No specific extractions have been demonstrated to have resulted from classical BC efforts to date.

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Biocontrols

- Insects
- Pathogens
- Fungi
- Nematodes

A. Pathogen: A microorganism that lives and feeds (parasitically) on or in a larger host organism and thereby causes injury to it.

B. Predator: An animal that feeds upon other animals (prey) that are either smaller or weaker than itself.

C. Parasitoid: A parasitic insect that lives in or on and eventually kills a larger host insect (or other arthropod).

Advantages

- High level of pest control at low cost;
- Once a population of biocontrol agents is established, minimal effort is required to conserve it.
- Almost total absence of harmful effects on man and the environment; Less disruptive ecologically and natural biodiversity is maintained.
- Utility of some types of BC agents as biotic insecticides;
- General inability of pests to develop resistance to BC agents (new evidence suggests this may not hold up);
- The use of natural enemies does not require a high level of technology.

Disadvantages

- The host (pest) population will continue to exist at a level determined by the properties of the host, its natural enemies and of the habitat they occupy;
- The effectiveness of natural enemies must be considered relative to man’s economic thresholds;
- The attainment of biological control of one major pest on a crop necessitates the elaboration of a system of integrated control for other pests of the crop, if any exist;
- The research necessary in seeking a biological control solution to a problem is often demanding in terms of scientific and technical staff, funds, and time, and a solution cannot be guaranteed in advance.

Problems

- What if it begins to eat the wrong thing?
- What if it becomes a crop pest?
- What if it displaces a beneficial organism?
- What if it doesn’t do anything?
- How much does the testing cost?

Weeds

- A weed is a plant growing where it is not wanted. In other places or times a weed species may be considered either neutral or beneficial.
- There are ~2,200 weeds of importance in the U.S. More than half of the weed species were either accidentally introduced as seed, feed, or ship’s ballast contaminants or purposely introduced as ornamentals which escaped cultivation.
- Direct crop losses from weeds are estimated at $10 Billion annually. Weed control costs $6.2 billion/year of which $3.6 billion is spent on herbicides. Herbicides account for 57% of all pesticides sold. Weeds are the second most important agricultural and forest problem – second only to soil erosion. Losses far exceed insect problems.

http://www.nysaes.cornell.edu/ent/biocontrol/weedfeeders/wdfdrintro.html
Types of losses due to weeds:

Quantity and quality of crop yields reduced due to weed competition for common resources;
Higher cultivation costs (machinery, fuel, manpower) used for weed control;
Reduced seed quality and increased costs for special seed and grain cleaning;
Loss in food quality due to off-flavor and color of agricultural products (dairy products especially);
Direct injury caused to man and livestock from internal and external poisoning, mechanical injury (thorns), and pollinosis (hayfever);
Blockage of waterways due to aquatic weeds which stop water flow, provide environments for mosquito breeding, ruin recreational activities, increase evaporation from reservoirs (through transpiration), and affect color and flavor of drinking water; and
Serve as alternate hosts for insect pests and plant pathogens.

Biological Control of Weeds

• The use of plant-feeding organisms or diseases to reduce the population of a plant species that has risen to the status of a weed. (Note that objective is reduction not eradication of weed species)
• Many of the worst weeds in the U.S. are of foreign origin. Their aggressiveness in the U.S. may not always be due to the absence of their phytophagous enemies.
• Aggressiveness of an alien weed in a new area may also be due to more favorable climatic and/or edaphic conditions or relative freedom from competition with other plants.
• However, the fact that many alien weeds have no or only a few insects specifically feeding on them in the areas of introduction as compared to their country of origin is the basis upon which the study of BC of weeds is based.
• Theoretically, the introduction of host specific phytophagous insects (minus the insects’ own complements of natural enemies) should reduce the abundance of an alien weed.

Considerations

• Eradication of the weed may really be desired (i.e., weed toxic to livestock).
• Biological control is selective and usually aimed at one species only. It is best used when weed is devastatingly abundant and aggressively spreading in dense stands.
• Biological control is a relatively slow method. Usually it takes about 5 years between initiation of a project and importation of the first natural enemy. It may require several more years after the introduction of the first natural enemies to get control.

Methods used for weeds

• Two surveys should be conducted prior to the foreign exploration. These include:
  – A survey to obtain from the literature and specialists as much information as possible pertaining to the target weed and its natural enemies (refer to notes on foreign exploration - “Accumulation and evaluation of available information”)
  – A survey to determine what organisms are feeding on the target weed in the areas for which control is desired. This survey is concerned with determining what kinds of organisms feed on the target weed and the damage they cause. This is very important to do and can result in savings of funds and time. Effective local insects may be present or some insects may already have been introduced.
• Foreign exploration
  – Selection of candidate phytophagous insects for importation are based on two criteria:
    – The width of the range of host plants (none can be crop plants).
    – The plant structures attacked by the plant-feeding stages (larvae, nymphs, adults) that are vital to the plant (growing tips, stems, seeds, etc.).

http://www.youtube.com/watch?v=Zt0EgLN_obM
http://www.youtube.com/watch?v=2Z0EgLN_obM
Studies Abroad

- These should be conducted near the habitat of the target weed and its natural enemies. This allows the avoidance of the problem of crossing political borders with plants and insects. It also insures a ready supply of material for study and allows time for observations on natural enemy/plant relationships under natural conditions.
- Two types of laboratory studies should be conducted:
  - Starvation Tests: provide insect with only one type of plant and see if it will attack it or lay eggs.
  - Multiple Choice Tests: follows starvation tests and allows determination of insects' preference for test plants.
- Types of plants used in testing include:
  - Representative economic and desirable plants to which the insects would be exposed in the target weed area.
  - A systematically arranged spectrum of plants related to the target plant.
  - Plants that are known to contain chemical constituents that are similar to those of the target plant. Plants from which the candidate insect has been reported collected or associated with in the literature.
- After above information is obtained then permission is requested to import the candidate species into quarantine in the country of introduction.

Domestic Studies

- After shipping to quarantine, complete host plant specificity testing is a major phase of work at the domestic laboratory. Additional studies conducted include feeding tests on:
  - Ornamentals, crop, and forage plants that would have been difficult to obtain or grow abroad
  - Native plants in the vicinity of introduction that provide browse for domestic and wild animals, are necessary as food and shelter for wildlife, or have other redeeming qualities.
- If any of the above plants were taken abroad they could potentially become a weed problem.

Domestic Release

- When ready to release a phytophagous BC agent, accumulated data must be submitted to the "Working Group on Biological Control of Weeds" (Joint Committees of the USDA and the US Dept. of Interior (in charge of National Parks). If importation is approved by the "working group" then permits are sought from APHIS (USDA) and the associated state DOA’s. When obtained then BC agent can be released.

Evaluation of BC of weeds projects through 1984

- There have been 174 projects worldwide against 101 weed species. In all, 39% of the projects resulted in successful control and 48% of the 101 weed species were controlled in at least one project.
- A total of 499 species of natural enemies have been released against the 101 weed species in 70 countries. Establishment of natural enemies occurred in 64% of the releases. Agents were effective in controlling the weed in 29% of all releases or 47% of the releases which resulted in establishment.
- C. Releases of native natural enemies resulted in effective control in 62% of the cases compared to 29% when exotic natural enemies were used. This may result from native agents being used in inundative programs compared to exotic agents which are often released without any follow-up programs or additional aid.

**Diorhabda elongata** Brulle – "Salt Cedar Leaf Beetle"

- Biocontrol for invasive salt cedar
- **Feeding Damage:** *Diorhabda elongata* feeds on the plant foliage during both the adult and larval stages. The beetles have been reported to defoliate entire trees and, in some areas of China where tamarisk is planted, the beetles have to be controlled to protect the plantings.
- **Operational Status:** Releases have begun in several areas of the country. Individuals for release were obtained from field cages, which were setup for a minimum of one growing season. Based on establishment within the cages field establishment should be successful and evaluations are continuing.