Mansoura University
Faculty of Agriculture
Entomology Department

ADVANCED BIOLOGICAL CONTROL

PREPARED BY

PROF. DR.
ADEL HASSAN ABDEL-SALAM

2006/2007

Chapter 1

NATURE AND SCOPE OF BIOLOGICAL CONTROL

I. DEFINITIONS

A. H. S. Smith (1919) first used term "biological control" to signify the use of natural enemies (whether introduced or otherwise manipulated) to control insect pests.

B. P. DeBach (1964) further refined the term and distinguished "natural control" from "biological control": Natural control is "the maintenance of a more or less fluctuating population density of an organism within certain definable upper and lower limits over a period of time by the actions of abiotic and/or biotic environmental factors" (see Fig. 1.1).

Biological control (from the ecological viewpoint) is "the action of parasites, predators, or pathogens in maintaining another organism's population density at a lower average than would occur in their absence" (see Fig. 1.2).

C. van den Bosch et al. (1982) modified the terms somewhat and referred to: Applied biological control as the "manipulation of natural enemies by man to control pests"; and Natural biological control as that "control that occurs without man's intervention".

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 AND ENHANCEMENT OF NATURAL ENEMIES: the pre mediated actions purposely taken to protect and maintain populations of natural enemies

D. Later definitions were expanded by "non-biological control purists" to include factors such as host plant resistance, auto sterilization, genetic manipulation of species (including genetic engineering), cultural controls, non-conventional insecticides (insect growth regulators, etc.), and transgenic plants. In this course these methods will not be considered as "biological control." Biological control will be discussed as the science that deals with the role that natural enemies play in the regulation of the numbers of their hosts, especially as it applies to animal or plant pests.

II. Major Types of Organisms Targeted for Classical Biological Control

A. Arthropod pests (mainly insects and mites)
B. Weed species (herbs and shrubs)
C. Other (vertebrates, snails, algae, fungi, trees)
D. Animal by-products (cattle dung)

III. Types of Natural Enemies

A. Pathogens: viruses, bacteria (and their toxins), protozoa, fungi, nematodes
B. Parasitoids and Predators:
1. Insects and Mites (major groups worked with)
2. Other: snails, vertebrates

IV. Brief definitions

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).

V. General comparison of an insect parasite (medical term) and a parasitoid

A. Parasitoids usually destroy their hosts during development; parasites do not.
B. The parasitoid's host is usually in the same taxonomic class (Insecta); not the case for parasites.
C. Parasitoids are large relative to their host; parasites are small compared to hosts.
D. Parasitoid adults are free living while only the immature stages are parasitic; not the case for parasites.
E. Parasitoids develop on only one host individual during the immature stages; parasites change hosts.
F. With respect to population dynamics, parasitoids are similar to predatory insects; not the case for parasites.

VI. General Advantages of Biological Control include:

A. High level of pest control at low cost;
B. Self -perpetuation at little or no cost following the initial effort;
C. Almost total absence of harmful effects on man and the environment;
D. Utility of some types of BC agents as biotic insecticides; and
E. General inability of pests to develop resistance to BC agents (new evidence suggests this may not hold up).

VII. General Limitations of Biological Control include:

A. 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;
B. The effectiveness of natural enemies must be considered relative to man's economic thresholds;
C. 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; and
D. 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.

VII. Scope of Biological Control

Biological control is a sub-discipline of applied ecology. To adequately practice it, one should have a firm understanding of population and behavioral ecology. Without systematics and proper identification of pests and their associated natural enemies, biological control as a science would fail to function. In this course, the following topics will be addressed over the next several weeks:

- History and Development of Biological Control
- Relationship of Systematics to Biological Control
- Biology and Impact of Predators
- Biology and Host Relationships of Parasitoids
- Traits Common to Predators and Parasitoids

- Insect Pathology in Biological Control
- Biological Control of Weeds
- Population Dynamics - Considerations
- Factors Affecting Population Growth
- Factors Limiting Parasitism
- Density Independent Mortality & Population Regulation Theories
- Foreign Exploration and Importation of BC Agents
- Trials and Tribulations of a Foreign Explorer
- Environmental Concerns relative to Biological Control
- Establishment and Evaluation of the Impact of Natural Enemies
- Theories of Classical Biological Control
- Analysis of BC Successes and Case Histories
- Conservation of Natural Enemies
- Enhanced Biological Control Through Pesticide Selectivity
- Augmentation of Natural Enemies
- Natural Enemies in IPM Systems

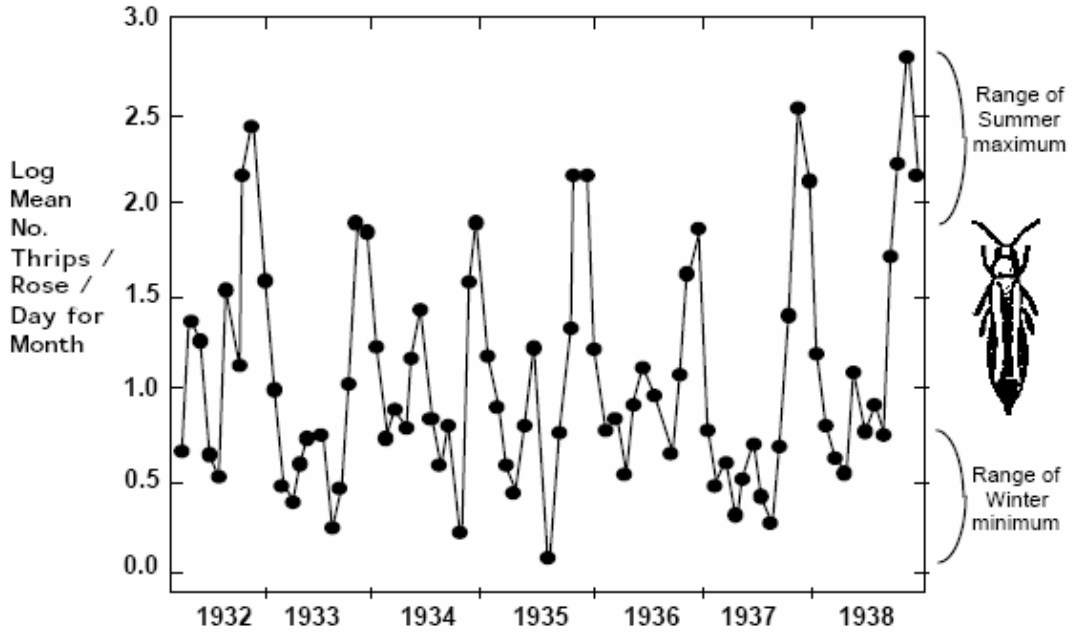

Fig. 1.1. Mean monthly population density counts of adult *Thrips imaginis* on roses at Adelaide, Australia. Modified from Varley et al. (1974); consult for more information.

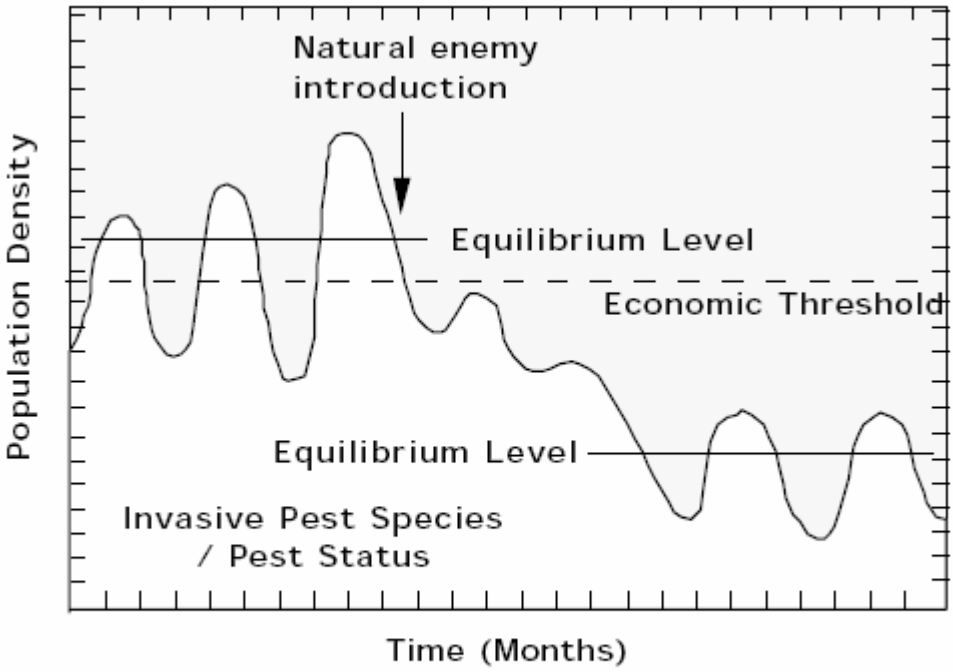

Fig. 1.2. Reduction in pest numbers following introduction of natural enemy: premise of classical biological control. Figure modified from van den Bosch *et al.* (1982).

Chapter 2
HISTORY AND DEVELOPMENT OF BIOLOGICAL CONTROL

I. The history of Biological Control may be divided into 3 periods:

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 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.

II. Early History: 200 A.D. to 1887 A.D.

A. 200 A.D. to 1200 A.D: BC agents were used in augmentation

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. 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.

B. 1300 A.D. to 1799 A.D.: BC was just beginning to be recognized.

1. Aldrovandi noted the cocoons of *Apanteles glomeratus* on a parasitized *Pieris rapae* in 1602 A.D., but thought cocoons were insect eggs

2. Vallisnieri interpreted the phenomenon of insect parasitism (parasitoid) in 1706 A.D. However the honor of being first to understand insect parasitism may belong to the microbiologist Van Leeuwenhoek who illustrated and discussed a parasite of a sawfly that feeds on willow in a publication in 1701.

3. The first insect pathogen was recognized by de Reaumur in 1726. It was a *Cordyceps* fungus on a noctuid

4. In 1734, de Reaumur suggested to collect the eggs of an "aphidivorous fly" (actually a lacewing) and place them in greenhouses to control aphids

5. 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

6. In the late 1700's, birds were transported internationally for insect control

7. Control of the bedbug, *Cimex lectularius*, was successfully accomplished by releases of the predatory pentatomid *Picromerus bidens* in 1776 in Europe *History of Biological Control*

C. 1800 A.D. to 1849 A.D. During this period advances were made in Europe which were both applied and basic

1. In the 1800's, Darwin discussed "Ichneumonids" as natural control factors for cabbage caterpillars

2. Malthus (in England) published *Essays on the Principles of Population* in 1803

3. Hartig (Germany) suggested the rearing of parasites from parasitized caterpillars for mass releases in 1827

4. Kollar (Austria) put forth the concept of "natural control" in 1837

5. Verhulst (1838) described the logistic growth equation but the idea layed dormant until 1920 when rediscovered by Pearl. Expressed idea of "environmental resistance".

6. During the 1840's releases of predators were used for control of the gypsy moth and garden pests in Italy

D. 1850 to 1887. During this time the focus on BC switched to the United States.

1. From 1850 to 1870 enormous plantings of many crops were being grown in the United States (especially California) and were initially free of pests. Later farmers saw their crops destroyed by hordes of alien pests

2. Asa Fitch (New York) suggested importing parasites from Europe to control the wheat midge, *Contarinia tritici*, in 1856. No action was taken. In 1860 parasites were requested from Europe, but none where received

3. During this time period, Benjamin Walsh (Illinois) actively worked for the importation of natural enemies to control the exotic insects in the United States but was unsuccessful. Fortunately, he influenced Charles V. Riley greatly who was in Missouri during Walsh's campaign

4. 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 ceylonicus*, were transported from northern to southern India

5. 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

6. LeBaron transported apple branches infested with oyster-shell scale parasitized by *Aphytis mytilaspidis* from Galena to Geneva, Illinois in 1871

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

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

9. In 1883 the USDA imported *Apanteles glomeratus* from England for control of *P. rapae* (the imported cabbageworm). Parasites were distributed in DC, Iowa, Nebraska, and Missouri. First intercontinental shipment of parasites.

III. The Intermediate Period: 1888 to 1955

A. 1888 to 1889: *The Cottony Cushion Scale Project*

1. Cottony cushion scale, *Icerya purchasi* Maskell, was introduced into California in ca. 1868 around the Menlo Park (CA) area (near San Francisco)

2. It spread to southern California and by 1887 was threatening to destroy the infant citrus industry

3. C. V. Riley (Chief of the Division of Entomology, USDA) employed Albert Koebele and D. W. Coquillett in research on control of the cottony cushion scale

4. No method was working in 1887

5. Koebele was sent to Australia in 1888 to collect natural enemies of the scale

6. He sent ca. 12,000 individuals of *Cryptochaetum iceryae* and 129 individuals of *Rodolia cardinalis* (the vedalia beetle)

7. Within the year, the cottony cushion scale ceased to be a substantial pest

8. The vedalia beetle controls the scale mainly in the inland desert areas and *C. iceryae* controls it in the coastal areas of California.

B. 1890 to 1899: Growing pains for BC

1. Following the success in 1889, California put pressure on Riley to send Koebele back to Australia in search of parasites for other scale parasites in California

2. Koebele went on foreign exploration, but on his return he was recalled from California. Koebele resigned his position and went to work for the Republic of Hawaii in 1893. He worked on BC projects in the interest of Hawaii until 1912 when he retired due to ill health.

3. Due the success of the vedalia beetle, great emphasis was placed on importation of coccinelids for BC initially in California and Hawaii. It is believed that California was set back many years by promoting mostly biological control projects and not researching alternative control methodologies.

4. L. O. Howard replaced C. V. Riley as Chief of the Division of Entomology, USDA in 1894. Howard was prejudice against BC due to the problems he saw in California

5. George Compare began as a foreign explorer for California in 1899

C. 1900 to 1930: New faces and more BC projects

1. The Gypsy Moth Project in New England (1905-1911). W. F. Fiske was in charge in Massachusetts. Howard conducted foreign exploration in Europe and arranged for parasites to be imported to the U.S. Many prominent entomologists employed on the project: Harry Scott Smith, W. R. Thompson, P. H. Timberlake.

2. The *Lantana* Weed Project in Hawaii (1902) First published work on BC of weeds. Koebele went to Mexico and Central America looking for phytophagous insects which were sent to R. C. L. Perkins in Hawaii.

3. The Sugar-cane Leafhopper Project in Hawaii (1904-1920). Hawaiian Sugar Planters Association (HSPA) created a Division of Entomology in 1904. R. C. L. Perkins was appointed superintendent. Staff consisted of O. H. Swezey, G. W. Kirkaldy, F. W. Terry, Alexander Craw, and Albert Koebele. Later Frederick Muir was employed due to Koebele's health problems. Muir found the highly effective predator *Tytthus* (= *Cyrtorhinus*) *mundulus* (Miridae) in Queensland, Australia, in 1920.

4. Berliner described *Bacillus thuringiensis* in 1911 as causative agent of bacterial disease of the Mediterranean flourmoth

5. Prof. H. S. Smith appointed superintendent of California state insectary, Sacramento, CA, in 1913. Facility moved to the University of California's Citrus Experiment Station in 1923 (now UC Riverside). Smith started another facility at Albany, CA, in 1945. Riverside and Albany (UC Berkeley) made up Department of Biological Control, UC.

6. USDA laboratory for biological control established in France in 1919.

7. The Imperial Bureau of Entomology created the Farnham House Laboratory for BC work in England in 1927. This was later directed by W. R. Thompson in 1928.

D. 1930 to 1955: Expansion and decline of BC

1. From 1930 to 1940 there was a peak in BC activity in the world with 57 different natural enemies established at various places.

2. World War II caused a sharp drop in BC activity.
3. 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.

4. In 1947 the Commonwealth Bureau of Biological Control was established from the Imperial Parasite Service. In 1951 the name was changed to the Commonwealth Institute for Biological Control (CIBC). Headquarters are currently in Trinidad, West Indies.

5. In 1955 the Commission Internationale de Lutte Biologique contre les Enemis des Cultures(CILB) was established. This is a worldwide organization with headquarters in Zurich, Switzerland. In 1962 the CILB changed its name to the Organisation Internationale de Lutte Biologique contre les Animaux et les Plants Nuisibles. This

organization is also known as the International Organization for Biological Control (IOBC). Initiated the publication of the journal "Entomophaga" in 1956, a journal devoted to biological control of arthropod pests and weed species.

IV. The Modern Period: 1957 to Present.

A. In 1959, Vern 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.

B. Interest developed nationwide in ecology and the environment after 1962 with the publishing of the Rachel Carson's book "Silent Spring."

C. "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 a core component of IPM by some. More emphasis was placed on conservation BC than classical BC.

D. In 1964, Paul DeBach and Evert I. Schliner (Division of Biological Control, University of California, Riverside) publish an edited volume titled "Biological Control of Insect Pests and Weeds" which becomes a major reference source for the biological control community. This was basically a California based book with international application.

E. 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.

F. During the 1970's and 1980's, Brian Croft and Marjorie Hoy made impacts by using pesticide resistant natural enemies in cropping systems.

G. In 1983, Frank Howarth published his landmark paper titled "Biological Control: Panacea or Pandora's Box" and significantly impacted classical BC efforts by concluding that classical BC of arthropods significantly contributed to extinction of desirable species (e.g., endemic).

1. This eventually forced a rethinking of legislative guidelines as well as introduction methods which are still being changed today.
2. In Hawaii, BC efforts were diminished significantly and have not risen to levels prior to 1985.
3. Research efforts into this area were stimulated with the general results that many of Howarth's claims were unjustified, but some impacts were discovered. No species extinctions have been demonstrated to have resulted from classical BC efforts to date.

H. In the 1990's, two additional biological control journals appeared, "Biological Control - Theory and Application in Pest Management" (Academic Press) and "Biocontrol Science and Technology" (Carfax Publishing). Additionally, "Entomophaga" changed its name to "Biocontrol" in 1997.