Department of plant protection

College of Agricultural Engineering Sciences

University of Salahaddin

Subject: Biological control of pests and disease

Course Book – (Year 4)

Sahand K. Khidr

Academic Year: 2023-2024

Course Book

1. Course name	**Biological control of pests and disease**
2. Lecturer in charge	**Sahand K. Khidr**
3. Department/ College	**Plant Protection/ Agriculture**
4. Contact	**e-mail: sahand.khidr@su.edu.krd** **Tel: (optional)**
5. Time (in hours) per week	**For example Theory: 2** **Practical: 2**
6. Office hours	**Sunday to Thursday**
7. Course code	
8. Teacher's academic profile	I have obtained Bachelor degree is in the department of Microbiology, college of Science, university of Salahaddin in 1997. Since 1998 worked in the college of agriculture as a lab assistant. In 2002 graduated obtaining M.Sc. Degree in the field of plant entomology. In 2008 I have travelled to the UK in order to study PhD in Nottingham University. I have taught Applied Entomology module at Nottingham University in 2010 and 2011. Later awarded PhD in the University of Nottingham in 2012 in Agriculture and Environmental Sciences, School of Biosciences named Biology and biological potential of Bethylid wasps. I was able to publish several papers in international journals with impact factors.
9. Keywords	**Biocontrol agents, natural enemies, pathogens, predators, host location , pest population**

10. Course overview:

The aim of the module and why consider Biological control

The practice of human agriculture is thought to have started around 10,000 years ago. It is to be expected that agriculturalists will struggle to improve both quality and production. In the present day, demand for enhanced food production is as topical as ever due to human population growth. Global food security involved both improved production and improved protection of agricultural products. High proportions of produce may be lost to agricultural pest, both pre- and post harvest.

Strategies of pest control have thus attracted a great deal of attention. Chemical control for pests might achieve higher yields but a major problem is that their toxicity has a negative impact on both humans as well as the environment. There are further reasons for finding alternative methods of chemical pesticides. For instance if biodiversity in agroecosystems declines, many natural enemies as well as pest species will be killed. This can lead to a resurgence of pest problems in the absence of natural enemies. Secondly the poisonous residues on food raise a major concern for food safety. Finally applying of powerful chemical agents might cause the appearance of resistant strains making pesticide application a poor long term solution.

Thus, emphasis has been placed on alternative such as biological control which is the deliberate use of living organisms, termed natural enemies, to reduce the undesirable effects of pests and disease through regulating their population densities. Natural enemies include parasitoids, predators and pathogens. The latter category includes micro-organisms such as fungi, nematodes, protozoa, bacteria and viruses. These natural enemies have the potential to maintain the pest population below the economic damage threshold within the released environment.

In general biological control can be considered a relatively cheap method in which the benefits far outweigh the costs when it is successful with potentially minimal effects on the environment and little or no health risk to humans. Thus our aims are to better understand how to minimize the lost of crop production and orchards in Kurdistan through using biological control without pesticide application. The ability to identify the different species of natural enemies that directly associated with pests, together with access to information about their biology, is important to be able to support effective control measures against pests.

11. Course objective:

Crop production in Kurdistan is in continuous decline owing to drought, lack of financial support to famers and thus importing most commodities from abroad rather than encouraging local production. Further, with the current losses due to pests and diseases, beside other factors, are considered a major constraint in increasing crop production both quantitatively and qualitatively in our country. Thus our aims are to better understand how to minimize the lost of crop production and orchards in Kurdistan through using biological control without pesticide application and finding suitable solutions which have minimal effects on the environment and little or no health risk to humans.

The ability to identify the different species of pests with their efficient biocontrol organisms is important to be able to support effective control measures against them.

12. Student's obligation

Weekly quizzes, attendances, visit to fields, 2 monthly exams

13. Forms of teaching

Datashow, powerPoint, Whiteboard, Handouts

14. Assessment scheme

Students are evaluated during the semester by:

- Short exams (quizzes): 5%
- Two monthly exams: 15%

- Subtotal total 20%
- Final exam : 50%
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- **Total for the theoretical part: 65%**
- **The practical part is given 35 marks in total including monthly exams and final exams.**

15. Student learning outcome:

Students would be educated about Biological control organisms and main approaches to Biological Control. They would be familiar with major orders and species that use as control agents , their biology and their favourable condition in order to minimize the lost of pests. Further, capability to recognize and identify major parasitoids, predators and pathogens are very important to find suitable solutions. Students would be able to overcome problems in relation to this module when graduated and appointed to identify different kind of infection in the field and seek the control agents to know whether it is sufficient or chemical control should apply.

16. Course Reading List and References:

1- Andrew Austin, Mark Dowton, A. Austin, M. Dowton Hymenoptera- Evolution, Biodiversity and Biological Control 2000

2- Lester E Ehler, Rene Sforza, Thierry Mateille Genetics, Evolution and Biological Control 2003

3- P. Neuenschwander, C. Borgemeister, J. Langewald Biological Control in IPM Systems in Africa (Cabi Publishing) 2003

4- Ann E. Hajek Natural Enemies- An Introduction to Biological Control 2004

17. The Topics:

Course plan

week	Subjects covered
1	Introduction to the Biological Control: 1. Ancient origin and development of the Biological Control methods (History of the Biological Pests Control). 2. Some useful Biological Control Terminology.
2	Biological Control Strategies: Classical Biological Control (Importation of the Biological Enemies). Uses and success of Classical Biological Control with examples Economics & Methods for practicing classical biological control
3	Augmentation of the Biological Enemies: inundative and inoculative biological control. Mass production, Storage and release
4	Conservation of Biological Enemies Enhancing natural enemy populations

5	Basic parasitoid life-cycle and life-history terms describing the major variants. Locating and parasitizing a host,types of semiochemicals	
6	**First exam + The battle between parasitoids and host**	
7	Values of the Biological Pests: advantages & disadvantages. The important characteristics of the successful biological enemy	
8	The Parasitoids. Types of Parasitoids according to their development, eggs laying, life stages of the target host and orders of parasitoids	
9	The predatory groups. a- The important vital characteristics of the predator. b- The important orders of the predatory insects, the target pests and biology. c- Intraguild predation	
10	Pest Control by microorganisms a- The important characteristics of the successful microbial control agent. b- The benefits of the microbial pests control. Kind of microorganisms to control pests	
11	**Second Exam +** Bacterial pathogens on invertebrates	
12	Fungal pathogens on invertebrates and their diversity	

13	Viral pathogen
14	**Eological basis for use of predators, parasitoids, and pathogens include:** Interactions between natural enemies and Hosts or pray Population regulation Stability for coexistence of natural enemies and hosts

19. Examinations:
Some examples regarding the questions

- Definitions, such as: classical biological control, mass-reared, ...
- Mention the benefits of inundative control
- Mention main characteristics of successful parasitoids
- Compare between pesticides & biological control, proovigenic & synovigenic?
- Fill the blanks?

20. Extra notes:

21. Peer review

Introduction to Biological control

Covers: Definitions and brief overview of biological control issues.

The Three Main Approaches to Biological Control

Classical Biological Control (importation) involves traveling to the country or area from which a newly introduced pest originated and returning with some of the natural enemies that attacked it and kept it from being a pest there. New pests are constantly arriving accidentally or intentionally. Sometimes they survive. When they come, their enemies are left behind. If they become a pest, introducing some of their natural enemies can be an important way to reduce the amount of harm they can do.

Augmentation is a method of increasing the population of a natural enemy which attacks a pest. This can be done by mass producing a pest in a laboratory and releasing it into the field at the proper time. Another method of augmentation is breeding a better natural enemy which can attack or find its prey more effectively. Mass rearings can be released at special times when the pest is most susceptible and natural enemies are not yet present, or they can be released in such large numbers that few pests go untouched by their enemies. The augmentation method relies upon continual human management and does not provide a permanent solution unlike the importation or conservation approaches may.

Conservation of natural enemies is an important part in any biological control effort. This involves identifying any factors that limit the effectiveness of a particular natural enemy and changing them to help the beneficial species. Conservation of natural enemies involves either reducing factors which interfere with the natural enemies or providing needed resources that help natural enemies.

Note that biocontrol is *not* new: people have, for example, been deploying cats to catch mice for a very long time. What is (relatively) new is the ecologically informed usage of natural enemies such as parasitoid wasps, to attempt to control insect pest populations while minimising negative side effects (non-target effects).

Some biological control attempts have been successful (Box 1). Some have not. Some have even been disastrous (Gypsy moth, Box 2). Currently, is to proceed with caution to try to avoid problems caused by imported agents. The *screening* phase of a biological control programme is thus very important in minimizing the risk of unanticipated negative effects.

Glossary: Some useful Biological Control (and associated) Terminology

Biological control: Termed Biocontrol is the use of living organisms such as predators, parasitoids, and pathogens, or use of modified organisms, genes or gene products to reduce the effects of undesirable organisms or control pest insects, weeds, or diseases The use of natural or modified organisms, genes or gene products.

Classical biological control: The importation of foreign natural enemies to control previously introduced, or native, pests.

Augmentation: Biological control practices intended to increase the number or effectiveness of existing natural enemies.

Conservation: Any biological control practice designed to protect and maintain populations of existing natural enemies.

Density (insect populations): The number of insects per unit of measure (*e.g.* beetles per square meter).

Generalist: A pest or natural enemy that can utilize a wide range of species as host or prey.

Habitat manipulation: Manipulation of agricultural areas and surrounding environment with the aim of conserving or augmenting populations of natural enemies (e.g., the planting of a refuge for natural enemies).

Host: The organism in or on which a parasitoid lives; a plant on which an insect feeds.

Integrated pest management (IPM): An approach to the management of pests in which all available control options, including cultural, physical, biological controls and chemical are evaluated and integrated into a unified program.

Mass-reared: Produced in large numbers, as in natural enemies produced for release programs.

Natural enemies: Living organisms found in nature that kill, weaken, or reduce the reproductive potential of other organisms, such as Predators, parasitoids and pathogens can be termed '*natural enemies*' of their prey or hosts

Pest: An organism that interferes with human activities, property, or health and causes damage depending upon the importance, pests may be agricultural forest, household, medical, and veterinary pests.

Pest Outbreak: is an explosive increase in population of particular species, that occur over a short period of time (eg.) Attack of locust, army worm etc.

Pest Resurgence: the rapid reappearance of pest population in injurious usually brought about after the application of broad spectrum pesticides, because it kill also natural enemies of the pest (e.g.) Resurgence of sugarcane leafhopper.

Based on Origins of Pests:

Indigenous (native) - organisms in a specified area that evolved in that location

Adventive (exotic) - organisms in a specified area that did not evolve there, but arrived from somewhere.

Based on level of infestation

Pest epidemic: Based on level of infestation a sudden outbreak of a pest in a severe form in a region at a particular time.

Endemic pest: Based on level of infestation an occurrence of the pest in a low level, regularly and confined to particular area.

Pesticide: A substance or mixture of substances intended for preventing, killing, repelling, or mitigating any pest.

Insecticide resistance: genetically inherited ability to withstand doses of pesticide that would kill individuals from strains whose ancestors had not been exposed to the pesticide

Population: A group of individuals of the same species within a given space and time.

Specialist: A pest or natural enemy that utilizes a narrow range of species for its host or prey.

Trap crop: A small area of a crop used to divert pests from a larger area of the same or another crop. The pests, once diverted to the trap crop, may be treated with an insecticide.

Sampling: estimating the density of organisms (pests or natural enemies) or damage by examining a defined portion of the crop

Insect growth regulators (IGRs): interfere with embryonic, larval and nymphal development, disrupt metamorphosis and reproduction. They are highly selective to insects and arthropods but because they kill through disruption of growth and development they take more time to reduce insect population than conventional insecticides.

Economic-injury level (EIL): the lowest population density that will cause economic damage. Economic damage is the amount of injury, which will justify the cost of artificial control measures; consequently, the economic-injury level may vary from area to area, season to season, or with man's changing scale of economic values.

Economic threshold (ET): the density at which control measures should be determined to prevent an increasing pest population from reaching the economic-injury level. The economic threshold is lower than the economic injury level to permit sufficient time for the initiation of control measures and for these measures to take effect before the population reaches the economic-injury level (Figure1).

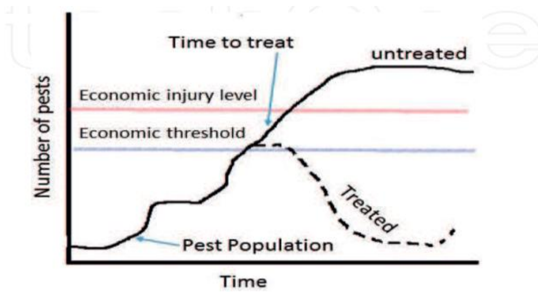

Figure 1.
The economic threshold and the economic injury level.

BIOLOGICAL CONTROL AGENTS (BCA)

Biological control agents are organisms that control pathogens and diseases through antagonists. Microbial antagonism of plant pathogens occurs in several ways, the most common mechanisms being parasitism and predation, competition for nutrients or space, production of antimicrobial substances, lytic enzymes and induced resistance.

CHARACTERISTICS OF THE SUCCESSFUL BIOLOGICAL AGENTS

1. Highly effective bio-control agents must have the below criteria:

- Be able to compete and live longer in soil and host tissue
- Be able to colonize and proliferate
- Be non-pathogenic to host plant and environment

2. Inexpensive production and formulation of agent must be developed

- Production must result in biomass with excellent shelf live

- Able to produce in large quantities,
- Maintain viability
- Must ensure agents will grow and achieve their purpose

General information required to safely deploy a biocontrol plan

Four major types of information are important.

1. A clear host range assessment must be undertaken to determine if the agent can be successful on the target species. A clear knowledge of the biological agent and the host(s) must be available.

2. Abiotic and biotic factors should be determined and especially an understanding of the similarities between region of bioagent collection and the region of planned release. It may also be vital to have knowledge about the synchronization of development of the host and its natural enemies.

3. Knowledge of effective dispersal mechanisms of biocontrol agents can provide important data. Dispersal protocols of the biological agent may be affected by geography and behavioral traits such as ranging and host foraging.

4. Potential direct or indirect effects on non-target organisms should be understood as completely as possible.

Main benefits of biocontrol

There are many benefits to agriculture using biocontrol methods :

1. Chemical pesticides can spoil agricultural land by affecting beneficial insect species, soil microorganisms, and worms responsible for soil health.

2.Chemicals also disturb plant root and immune systems, and thus reduce concentrations of nitrogen and phosphorous in soil which are essential plant nutrients.

3. Reduces acute and long-term impact of chemical pesticides on humans, animals, non-target organisms and the environment. Biocontrol agents are usually very specific and present less danger to the environment and water.

4. There is no resistance buildup making treatment increasingly less effective.

5-Biodiversity in agroecosystems will be preserved, thus many natural enemies and beneficial organisms will be saved

6. Avoid the resurgence of pest problems that might occur in the absence of natural enemies.

7. Potential to be permanent reductions of pest organisms.

8. The use of biological agents in agriculture has a high benefit to cost ratio.
9. The public is more accepting of biological control than chemical agents.

Box 1: Successful Biological Control: Cottony cushion scale

Over the winter of 1888-1889 a lady beetle called vedalia beetle (*Rodolia cardinalis*) was introduced into California from Australia to combat cottony cushion scale, *Icerya purchasi* - also an introduced species.
Cottony cushion scale was causing infestations so severe in California citrus groves that growers were pulling out their trees and burning them. Orchard values were plummeting. Yet, by the fall of 1889, the pest was completely controlled in the areas of introduction. The vedalia beetle literally saved the California citrus industry, and since the California success, it has been exported to many other parts of the world, often with equally successful results.

The introduction of the vedalia beetle is considered to be the beginning of classical biological control. The interest of scientists, growers and the public in this project was due to its spectacular success which was striking because the financial threat to the California citrus industry was acute; the pest itself was showy and its damage was obvious and critical; growers took the initiative and applied the natural enemies themselves; the natural enemies were visibly voracious and active; and the destruction of the pest and the recovery of the trees was evident within months. The cost of the project was about $1500.

The original 514 beetles imported over the winter of 1888-89 multiplied so quickly that by June 12, officials were able to distribute10,555 vedalia beetles to 208 growers around the state. The rapidity and extent of the subsequent control was reported to be nearly unbelievable. One grower who had abandoned hope for his young orange trees was able to harvest two to three boxes of oranges from each tree at the end of the season in 1889. By October, it had become very difficult to find a living specimen of *Icerya* in the vicinity of Los Angeles, the area where the introductions were made.

Together with an imported parasitoid, *Cryptochetum iceryae*, *Rodolia cardinalis* keeps California populations of cottony cushion scale at extremely low levels in orchards and on ornamentals.

The vedalia beetle is very sensitive to Baythroid, an insecticide being used for citrus thrips control. Baythroid kills the beetles and prevents them from laying eggs for about one month. The vedalia beetle is also very sensitive to the new insect growth regulators, Esteem (pyriproxifen) and Applaud (buprofezin), which are applied for California red scale control.

The insect growth regulators prevent vedalia from pupating and emerging as adults and in the case of Esteem they prevent the adults from laying fertile eggs. The effects of the insecticides are long lasting (4-6 months). After sprays were applied in the summer of 1898, live vedalia beetles could not be found in California for 9 months.
Over the years, there have been other times that vedalia beetle has been eliminated from orchards by insecticide applications. During the years that DDT was used extensively, the vedalia beetle population in orchards in the Central Valley of California was decimated. It took three years for growers to modify their spray programs and recolonize their orchards with the beetle. In the meantime, some trees were killed, many orchards were defoliated by the scale, and growers paid up to $1.00 per vedalia beetle in their eagerness to re-establish the scale predator.

Box 2. Gypsy moth

A round 1869, an amateur scientist named Étienne Léopold Trouvelot staked his claim to entomological infamy when he accidentally released imported gypsy moths *Lymantria dispar* from his Massachusetts home. The price paid for this little mistake by Trouvelot (who later abandoned both the study of insects and what became his moth-infested neighborhood). The disappearance of species of giant silk moths, a spectacular group of native insects that includes the largest and some of the most elegant moths in the country.

The problem, according to a new study published in Conservation Biology, is not the gypsy moth itself, but a parasitic fly *Compsilura concinnata* brought from Europe and released into the wild to get rid of it. The fly is not only killing gypsy moths but huge numbers of wild giant silk moths. It remains unclear whether the fly is harming any of the 200 or so other species of insects.

Researchers praised the findings as the best explanation yet for declines in wild silk moths in the Northeast. But even more important, scientists say the study provides some of the first compelling evidence of the damage that can be done when foreign species are released into the wild to get rid of pests. But still, nearly all the scientists agree that biological control itself should not be abandoned.

At the beginning scientists had considered habitat loss, pesticide use and city lighting, which disrupts moth mating, as possible causes, but none adequately explained the timing and extent of the declines. To test whether the fly, known as *Compsilura concinnata*, might be at fault cecropia and promethea moth caterpillars placed in the field. They found that most were fatally attacked by *Compsilura*. And, the researchers found more than a third of its caterpillars studied were killed by the foreign fly.

The fact that *Compsilura concinnata* can and does attack so many species besides gypsy moths, researchers say, makes it the perfect example of the kind of species that should never be used for biological control. The ideal control agent is a specialist that will knock out only the pest species. And still, the researchers say, it remains a matter of debate how much benefit the fly has been in controlling gypsy moths. *Compsilura*, which has also been used to control other insect pests, appears to have been abandoned as a biological control agent in 1986 after decades of use and after it was released in 30 states.