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An Overview of Biological Pest Control Strategies

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Introduction:

Biological control employs living organisms to reduce pest populations, forming an ecologically based pest management strategy. Natural enemies like parasitoids, predators, and herbivorous insects are utilized to control pests such as scales, mites, and weeds. Pathogens like bacteria, viruses, and fungi also play a role in pest suppression. This environmentally friendly approach can be cost-effective and long-lasting compared to synthetic pesticides, offering benefits for years despite initial costs. Biological control has evolved over 125 years, from understanding the relationships between predators, parasites, pathogens, and pests to practical manipulation of these interactions. Initially focused on agricultural pests, biological control expanded in the 1990s to address environmental pests. Factors driving its growing interest include environmental stewardship, pesticide-resistant pests, and consumer demand for pesticide-free produce. However, adoption by growers has been slow due to concerns about efficacy, predictability, and cost.

Principles of Biological Control

- **Importation (Classical Biological Control):** This strategy involves the deliberate introduction of natural enemies from their native habitat to control pests in a new environment where they are not naturally present. The goal is permanent establishment and long-term pest control. Typically regulated by government authorities, this approach has faced scrutiny for its potential non-target effects. The process involves several steps:
  - **Societal Agreement:** There should be consensus that the chosen species are pests needing density reduction.
  - **Correct Identification:** Crucial to avoid project delays or failures.
  - **Locating Natural Enemies:** Pinpointing where the pest evolved helps in locating specialized natural enemies.
  - **Extensive Surveys:** Necessary to find effective natural enemies.
  - **Quarantine Labs:** Promising natural enemies are shipped here for further study.
  - **Understanding Biology:** Ensures safe

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selection for importation.

- **Multiple Releases:** Occur in locations where the pest is present until effective establishment methods are identified.
- **Field Experiments:** Compare pest densities in plots with and without introduced enemies to measure reduction efficacy.
- **Recording Outcomes:** Economic and ecological outcomes are recorded and published.

❖ **Augmentation:** This involves the periodic release of natural enemies to supplement existing populations, which may be insufficient to keep pest populations below damaging levels. There are two approaches:

- **Inundative Release:** Releasing large numbers of natural enemies for immediate pest population reduction.
- **Inoculative Release:** Releasing small numbers of natural enemies at intervals throughout the pest period, aiming to prevent pest populations from reaching economically damaging levels.

Conservation: This strategy focuses on modifying the environment or existing practices to enhance the activity of natural enemies, thus reducing pest impact. It includes habitat manipulation to increase species diversity and provide resources for natural enemies. Examples include the establishment of flowering strips or shelter habitats to attract and sustain diverse communities of natural enemies.

Predation

Human understanding of vertebrate predation on other vertebrates has ancient roots. Farmers in Yemen and China thousands of years ago observed ants preying on citrus pests and used this knowledge to control pests by relocating ant colonies. During the Renaissance in Europe, naturalists recognized predatory relationships among insects. By the early 1800s, suggestions of using predatory insects to control pests through releases laid the groundwork for modern augmentative biological control methods in agriculture. Common predatory insects used in biological control include:

- Ladybugs are well-known predators of aphids and other soft-bodied insects. Both adults and larvae feed on pests, making them effective biological control agents.
- Green lacewing adults primarily feed on nectar but also consume small insects. Their larvae, known as "aphid lions," are voracious predators capable of feeding on aphids, caterpillars, and other small insects.
- Predatory stink bug preys on plant-damaging bugs, beetles, and caterpillars. Both nymphs and adults of

the predatory stink bug contribute to pest control.

Parasitism

Before the invention of magnifying lenses, the intricate interactions between insect parasitoids and their hosts were not easily observable, delaying the recognition of parasitism. Parasitoids, which often feed inside their hosts, were not readily detectable without rearing or dissecting insects. By the 1600s, European naturalists began to observe parasitoids, with Aldrovandi documenting parasitoid wasps emerging from butterfly pupae in 1602, albeit with a misunderstanding of the process. The first accurate interpretation of insect parasitism was published by Martin Lister in 1685, who identified ichneumon wasps as distinct insects originating from eggs laid within caterpillars. Practical applications of parasitoids were not considered until Asa Fitch proposed their importation from Europe to America in 1855 to control wheat midge infestations. However, it wasn't until the 1880s that the first importations of exotic parasitoid species occurred, such as *Cotesia glomerata* being brought to the United States to control *Pieris rapae*, a European cabbage pest that had invaded North America in 1860. Parasitoids are organisms that exhibit a parasitic relationship with another organism, typically an insect host. Parasitoids sterilize, kill, or consume their host during their life cycle and emerge as free-living organisms. Types of parasitoids include idiobionts, which prevent further development of the host, and koinobionts, which allow the host to continue its development while feeding upon it.

Insect Diseases

Insect pathology, the study of insect diseases, initially focused on safeguarding economically vital species like silkworms and honey bees. In the 19th century, advancements in microscopy enabled the observation of bacteria and fungi as pathogens of domesticated insects, laying the groundwork for this field. Agostino Bassi's work in 1835, investigating a fungal disease in silkworm larvae caused by *Beauveria bassiana*, marked the first demonstration of the infectious nature of insect diseases. Louis Pasteur continued research on silkworm diseases in the 1860s. The earliest attempt to use pathogens to control pest insects occurred in 1884 when Russian entomologist Elie Metchnikoff applied fungal spores of *Metarhizium anisopliae* to combat the sugar beet curculio. In 1911, German scientist Berliner identified a bacterial disease in flour moth larvae, leading to the commercialization of *Bacillus thuringiensis* as a microbial pesticide for caterpillar control by 1938. These endeavours highlighted insects' susceptibility to infectious diseases and the potential for artificially propagating causative agents.

- **Bacteria:** Bacteria like *Bacillus thuringiensis* are effective microbial pesticides, especially against caterpillars, mosquito larvae, and beetles. They are mass-reared economically and can be applied without living hosts. *Bt* has long been used as a microbial spray pesticide by farmers and home gardeners to manage pest insects. The bacterium occurs commonly in soils, with many insecticidal strains isolated from soil samples. Different strains of *Bt* may target specific insect species or groups. For example, *Bacillus thuringiensis* var. *kurstaki* is effective against a wide range of butterfly and moth caterpillars, while *Bacillus thuringiensis* var. *sandiego* and *Bacillus thuringiensis* var. *tenebrionis* exhibit toxicity to specific beetle species, *Bacillus thuringiensis* var. *israelensis* played a significant role in the successful control program for onchocerciasis (river blindness) in West Africa, where resistance to organophosphate insecticides threatened program effectiveness. *Bacillus thuringiensis* renowned for its ability to produce crystalline proteins known as *Cry* proteins. *Bt Cry* toxins are the active ingredients in many widely used biological insecticides and insect-resistant transgenic crops.
- **Fungi:** Over 750 fungal species from more than 90 genera have been identified as pathogenic to various insect species. Despite this diversity, only a limited number of entomopathogenic fungi species are currently utilized for pest management at the grower level. Certain fungal species, like *Beauveria bassiana* and *Metarhizium anisopliae*, have shown promise in controlling pests while minimizing negative environmental impacts. They are environmentally friendly alternatives to chemical pesticides. Fungal spore germination requires specific environmental conditions, limiting their widespread use. Commercial availability is also limited. Fungal endophytes, which inhabit plant tissues, have been implicated in plant growth promotion, herbivore resistance, and disease resistance.
- **Nematodes:** Nematodes from families Steinernematidae and Heterorhabditidae are effective against pests like fungus gnats and borers. EPNs can be mass-produced using *in vivo* or *in vitro* methods. *In vivo* production involves culturing nematodes in live insect hosts, while *in vitro* methods include solid or liquid culture techniques. Each production method has its own level of technology, startup costs, and efficiency, with *in vitro* liquid culture being the most cost-efficient but requiring

higher startup capital. EPNs are sensitive to desiccation, limiting their effectiveness in dry environments. Applications to dry foliage are ineffective. Unlike chemical pesticides, EPN applications do not require safety equipment, and issues such as re-entry time, residues, groundwater contamination, and pollinator safety are not concerns. EPNs, in collaboration with symbiotic bacteria, can kill insects within 24-48 hours, providing rapid pest control. EPNs such as *Steinernema carpocapsae* and *Heterorhabditis bacteriophora* have shown high virulence and efficacy against specific pest species, making them promising biocontrol agents.

- **Viruses:** Baculoviruses are a diverse group of double-stranded DNA viruses, with nearly 1000 species identified. They are primarily found in several insect orders, including Lepidoptera, Diptera, Hymenoptera, and Coleoptera. Baculoviruses have genomes ranging in size from 80 to 200 kb. Individual baculoviruses typically exhibit a narrow host range, often limited to closely related species. One of the most extensively studied baculoviruses is *Autographa californica* Nucleopolyhedrovirus (AcMNPV). Baculoviruses are safe for people and wildlife and infect only insects. They have been considered for pest control, but high host specificity and the need for live host insects for production make them less economically viable. Reliance on live host insects for production makes viral products relatively expensive. Limited success in commercial markets due to high host specificity. Commercial production of baculoviruses has typically been carried out *in vivo*, either by applying the virus against host insects in the field or by producing the target insects in the laboratory on an artificial diet. Baculoviruses' effectiveness against their natural hosts can be enhanced through various methods, including the introduction of insect-specific toxins or interference with insect physiology.

Conclusion

Biological control offers an environmentally friendly, sustainable approach to pest management. By harnessing natural enemies, it provides long-term solutions with minimal harm to humans and ecosystems. Although challenges exist in terms of adoption and implementation, the benefits in reducing chemical pesticide use and ensuring sustainable pest suppression make biological control a vital component of integrated pest management strategies.

References

1. Baker, B.P., Green, T.A and Loker, A.J. 2020. Biological control and

integrated pest management in organic and conventional systems. *Biological Control*, 140, p.104095.

2. Hoddle M.S and Van Driesche, R.G. Biological control of insect pests. In: Encyclopedia of Insects. California, USA: Elsevier Inc., Academic Press; 2009. pp. 91-101.
3. Sanda, N.B and Sunusi, M. 2014. Fundamentals of biological control of pests. *International Journal of Clinical and Biological Sciences*, 1(6), 1-11.
4. Stenberg, J.A., Sundh, I., Becher, P.G., Björkman, C., Dubey, M., Egan, P.A., Friberg, H., Gil, J.F., Jensen, D.F., Jonsson, M and Karlsson, M. 2021. When is it biological control? A framework of definitions, mechanisms, and classifications. *Journal of Pest Science*, 94(3), 665-676.
5. Vega, E and Kaya, H.K. 2012. *Insect Pathology*, Academic Press, pp. 171-220.