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Plant Protection in Organic Farming

References

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Introduction

Organic farming is an increasingly popular approach worldwide, especially among environmentally conscious gardeners. One of the cornerstones of this agricultural practice is plant protection, which aims to minimize the use of chemicals and prioritize natural processes.

This module provides a detailed overview of the principles and practices of biological plant protection, which enable the effective control of pests while preserving soil and environmental health. The role of natural enemies—such as ladybugs, parasitic wasps, nematodes, and other beneficial organisms—is of key importance in organic farming. These organisms help keep pest populations in check, thereby reducing the need for chemical pesticides.

The module is designed for practicing gardeners who wish to apply these sustainable plant protection methods in real-world settings. The chapters place particular emphasis on how Integrated Pest Management (IPM) can be applied both in greenhouses and in open-field cultivation. In addition to biological control, we also explore mechanical and cultural methods, which offer further options for effective pest management.

The objective of this module is to equip gardeners with the knowledge to maintain their crops based on ecological principles and to reduce the damage caused by pests.

Fundamentals of Organic Plant Protection

Principles of Organic Farming

Organic farming offers a comprehensive approach to developing sustainable agricultural practices, aiming to align with natural resources and environmental protection. At the core of the system lie soil health, the preservation of biodiversity, and the minimization of harmful chemicals.

The Four Principles

Organic farming is based on four foundational principles: health, ecology, fairness, and care. These principles guide organic farming practices and ensure their sustainability and ethical integrity.

- **Health**: The goal of organic farming is to preserve and enhance the health of soil, plants, animals, and humans. Soil health directly influences the quality and nutritional value of crops.

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- **Ecology**: Organic farming is rooted in ecological systems and seeks to harmonize with natural processes and maintain ecological balance.
- **Fairness**: Organic farming upholds the rights of producers, workers, and consumers, while ensuring the fair use of natural resources.
- **Care**: The principle of care encourages farmers to act responsibly, taking into account environmental and social impacts, as well as the needs of future generations.

The following video helps to better understand the principles of organic farming and the connection between global food production and sustainability:

Plant Protection and Organic Farming (TED Video)

Principles of Organic Plant Protection and Its Differences from Conventional Methods

The differences between organic farming and conventional plant protection are fundamentally important for sustainability. While conventional agriculture often relies heavily on chemical pesticides and synthetic fertilizers, the goal of organic farming is to maintain natural balance and produce without harming the environment.

Objectives and Approaches of Organic Plant Protection

At the core of organic farming are soil health preservation, biodiversity maintenance, and the minimization of harmful chemicals. Organic farmers aim to protect crops from pests and diseases by leveraging natural processes and biological diversity. In contrast, conventional plant protection frequently depends on synthetic chemicals that offer fast and effective solutions but may have long-term negative impacts on soil, water, and biodiversity.

Organic plant protection emphasizes prevention—through methods such as crop rotation, companion planting, and biological control. These strategies not only manage pest populations but also support the long-term health of the soil and surrounding environment. Conversely, conventional approaches often focus on directly treating problems with chemical inputs that may offer immediate results but are not always sustainable in the long run.

Organic Certifications and Regulations

Organic farming must comply with both international and local regulations to ensure that production methods align with the principles of sustainability and environmental protection. Organic certifications,

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such as the EU organic label, guarantee that products meet strict ecological standards, including the prohibition of chemical substances, GMO-free production, and the preservation of biodiversity.

These certifications regulate not only production methods but also extend to processing and packaging, ensuring that the entire production chain is sustainable and environmentally friendly. Farmers must undergo rigorous inspections to obtain organic certification, which not only provides market advantages but also strengthens consumer trust.

Introduction to Integrated Pest Management (IPM)

Overview of IPM:

Integrated Pest Management (IPM) is an approach that emphasizes the combined use of various methods to control pest populations. Its goal is to manage pests in an economically viable, environmentally friendly, and socially acceptable manner. The main objective of IPM is to keep pest populations at levels that do not cause economic damage, while minimizing risks to humans, non-target organisms, and the environment.

Key components of IPM include:

- **Biological control:** The use of natural predators, parasitoids, and pathogens to regulate pest populations. This method reduces the need for chemical pesticides and helps maintain ecosystem balance.
- **Mechanical control:** The use of physical methods, such as traps, barriers, and manual removal, to reduce pest numbers. This approach is often used effectively in combination with other methods.
- **Cultural control:** Practices such as crop rotation, planting pest-resistant varieties, and maintaining proper hygiene help prevent pest problems by creating unfavorable conditions for pests.
- **Chemical control:** When necessary, chemical pesticides may be used, but within IPM, they are applied selectively and sparingly, using the least toxic options and only when monitoring indicates that pest populations have reached an intervention threshold.

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- **Monitoring and identification:** Regular monitoring and accurate pest identification are fundamental to IPM. This ensures that control methods are applied at the right time and targeted against the correct species.
- **Prevention:** IPM emphasizes the prevention of pest problems before they arise. This includes creating conditions that are unfavorable for pests but supportive of their natural enemies.

The Role of Biological Control in IPM

Biological control involves the use of natural enemies—predators, parasitoids, and pathogens—to manage pest populations in agricultural systems. This method reduces pest numbers without relying on chemical pesticides, offering significant advantages in organic farming.

Principles of Biological Control

Biological control uses living organisms to regulate pest populations and reduce the damage they cause. This strategy is applicable against a wide range of pests including insects, vertebrates, plant pathogens, and weeds, although the methods and organisms used may differ.

Introduction to Biological Control (YouTube)

- **Predators:** These consume a wide variety of pests. In biological control, insects and other arthropods are commonly used. Key predators include lady beetles, parasitic wasps, lacewings, and hoverfly larvae. These organisms reproduce quickly, and their populations can increase in response to higher pest densities.

Predatory Insects in Action (YouTube)

- **Parasitoids:** These are insects that spend part of their lifecycle within or on another insect host, eventually killing it. For example, *Encarsia formosa* wasp larvae develop inside whitefly nymphs, destroying the host. Since parasitoids usually have a narrow host range, accurate identification of both the pest and the parasitoid species is essential for successful biological control.
- **Pathogens:** This group includes bacteria, fungi, protozoa, and viruses that cause diseases in pests. These diseases can slow pest development, reduce reproduction, or kill them outright. Under certain environmental conditions, pathogens may naturally spread through pest populations, especially when pest density is high.

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Best Practices in Greenhouses

Biological control is particularly effective in greenhouses. For instance, *Encarsia formosa* wasps are successfully used against whiteflies in tomato and cucumber crops. Female wasps lay their eggs in whitefly nymphs, and the developing larvae kill the host from within.

Additionally, predatory mites and entomopathogenic fungi such as *Beauveria bassiana* can be effectively deployed to control pests—especially when pesticide use is minimized—helping to maintain a balanced and resilient growing environment.

The Impact of Pesticides on Natural Enemies

Pesticides used in horticulture affect not only pests but also beneficial natural enemies. The impact depends on the type of chemical used and how it is applied. Insecticides and acaricides are typically harmful to predatory insects and mites, while herbicides and fungicides can also cause collateral damage. For example, synthetic pyrethroids are particularly hazardous to beneficial organisms, whereas *Bacillus thuringiensis* and insect growth regulators tend to be less toxic.

Damage to natural enemies can be reduced by timing pesticide applications carefully and applying them in a targeted manner. Using short-residual pesticides and considering the life cycle of beneficial organisms helps minimize exposure. Spot treatments limited to affected areas can also protect natural enemies in other parts of the garden, allowing them to continue their beneficial activities.

Case Study: Use of *Neoseiulus cucumeris* Predatory Mite for Thrips Control

Background:

Thrips (*Frankliniella occidentalis*) are major pests causing serious damage to a wide range of crops, especially vegetables and ornamental plants in greenhouses. Traditional pesticide-based control has led to pesticide-resistant thrips populations, prompting organic growers to adopt biological control strategies.

Thrips Control Video (YouTube)

Life Cycle of Thrips:

Thrips pose a significant threat in greenhouse horticulture. They overwinter easily and attack crops early in the season.

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- **Eggs:** Kidney-shaped eggs are laid inside plant tissues—leaves, petals, and soft stems—after the female cuts an opening into the tissue.
- **Larvae:** After hatching, larvae feed on plant tissues, progressing from the first to the second larval stage, which is larger and more pigmented. At the end of the second stage, larvae typically fall to the soil to pupate.
- **Pupae:** Pupation occurs in natural cracks or on the undersides of leaves. Wing buds are visible in this stage.
- **Adults:** Adult thrips have fully developed fringed wings.

Damage: Thrips damage plants by puncturing cell walls and sucking out their contents, causing necrosis in affected tissues. Leaves develop silver-gray spots and black specks (thrips excrement). They can also transmit plant viruses, but fortunately, they can be controlled by natural enemies.

The Role of *Neoseiulus cucumeris*:

Neoseiulus cucumeris is a predatory mite that effectively targets and destroys young thrips larvae. These mites adapt well to greenhouse conditions, where humidity and temperature support their life cycle.

Application:

In greenhouses, *Neoseiulus cucumeris* is used preventively by distributing them among the plants or placing sachets that gradually release the mites. Their continuous presence ensures immediate intervention as soon as thrips populations begin to rise.

Results:

Trials in European greenhouses have shown that using *Neoseiulus cucumeris* significantly reduces thrips populations, resulting in less crop loss and improved plant quality. Additionally, by avoiding pesticide use, growers prevent the development of resistance in thrips populations, making this a more sustainable long-term pest control strategy.

Key Species in Biological Control

Below, we present—without claiming to be exhaustive—the roles of several highly useful species in biological control, along with details about their life cycles and practical applications.

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Encarsia formosa (Parasitic Wasp)

Role: Encarsia formosa is a parasitic wasp used primarily in greenhouses to manage whitefly populations. The female inserts her eggs into whitefly larvae, and the developing wasp larvae feed inside, ultimately killing the host.

Life Cycle: Adult females lay eggs in whitefly larvae; the eggs hatch into larvae that consume the internal tissues of the whitefly (one Encarsia larva develops per parasitized whitefly larva). Over time, the parasitoid larvae pupate, and adults emerge by chewing a circular exit hole through the host with their mouthparts.

Application: Encarsia formosa is commercially available as pupae attached to small paper cards. To check quality, place a card in a sealed jar at room temperature (20–25 °C), out of direct sunlight. After five days, count or estimate how many adults have emerged. Ideally, about 95 % of the pupae should produce adults.
E. formosa is most effective at 21–26 °C and 50–80 % relative humidity. Adults do not fly below 18 °C, and survival declines above 30 °C. Avoid using yellow sticky traps for 3–4 days after release to prevent capturing beneficial wasps—though some growers may still use traps at the start of release, they place them away from release point.

Deployment in Crops: Place the cards in the lower plant canopy to avoid drying by direct sunlight. Adults emerge from the pupae and fly upward. Release E. formosa weekly beginning at the first sign of whitefly presence, and continue until approximately 80 % of the whitefly population is parasitized (parasitized pupae turn black). E. formosa is highly sensitive to pesticides.

Amblyseius swirskii (Predatory Mite)

Role: Amblyseius swirskii is a generalist predatory mite used mainly against thrips and whiteflies. It is especially effective in warmer climates and widely employed in greenhouse cultivation. It has shown strong efficacy on greenhouse-grown peppers, cucumbers, and ornamental plants.

Life Cycle: These predatory mites attack a variety of small arthropods, especially early stages of thrips. A. swirskii performs most effectively at higher temperatures.

Application:

- **Quality control:** Predatory mites are delivered mixed in wheat bran or vermiculite, in bottles or small paper sachets. Inspect them under 10–15× magnification on the inner lid or within the

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carrier material. Healthy mites are light brown and move faster than their prey, which are smaller, slower, and more translucent or white. A strong ammonia odor upon opening indicates poor mite health.

- **Release in crops:** Mites can be released into the plant canopy by hand or with a dispenser. Regular, repeated applications are needed. Sachets containing mites and their food are hung in the crop and replaced every few weeks. Follow the supplier's detailed instructions. Release Amblyseius swirskii early in the growing cycle, before pest populations build up significantly. Regular releases help maintain effective protection.

Orius spp. (Minute Pirate Bugs)

Role: Orius species establish slowly on bedding plants and are used mainly in pollen-bearing crops or flowering ornamental peppers, serving as banker plants to attract thrips and retain predators. Orius feed on various insects including whiteflies, aphids, moth eggs, mites—and even each other.

Life Cycle: Adults are small, black-and-white; nymphs are orange-tinged. Nymphs emerging from plant tissues are predators, molting several times before becoming adults. Adults can fly and disperse within the greenhouse, feeding on any mobile thrips stage encountered.

Application:

- **Quality control:** Orius are shipped as adults mixed with buckwheat hulls in bottles. A large number of insects moving among the hulls should be visible once opened.
- **Release:** Release pirate bugs into the canopy, especially in areas with high thrips infestation. Orius can be difficult to establish, making repeated releases costly. Growers often use banker and habitat plants to sustain populations.

Bacillus thuringiensis (Bt) (Biological Insecticide)

Role: Bacillus thuringiensis (Bt) is a bacterial pathogen used as a biological insecticide. It is effective against several pests—such as caterpillars, plum sawfly larvae, and mosquito larvae—because it produces toxins that paralyze their gut.

Life Cycle: Under unfavorable conditions, Bt sporulates, producing spores and crystalline (Cry) proteins. When eaten by susceptible insects, Cry proteins activate in their gut, causing cell lysis, paralysis, and death. The bacterium then germinates inside the insect, kills it, and releases new spores into the environment, continuing the cycle.

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Application: Bt-based products are among the most well-known biological insecticides. They can be applied preemptively, such as before fungus gnat larvae emerge, since they work when ingested. Treatments are more effective on young (1st instar) larvae than on older ones. Applications should be repeated weekly until fungus gnat populations decline. Bt is not effective against shore flies.

Beneficial Nematodes (Steinernema spp.)

Role: Beneficial nematodes are used to control soil-dwelling pests like fungus gnats. They invade the host body and release symbiotic bacteria that kill the pest.

Life Cycle & Application: Nematodes move through soil or its surface, actively seeking out insects. Upon entering a host, they release symbiotic bacteria that multiply and kill it. Nematodes feed on the bacteria and insect tissue, then mate and reproduce. Within 1–2 weeks, new juveniles emerge from the insect cadaver to seek new hosts. This natural control method is especially effective against soil pests and is an environmentally friendly alternative to chemical pesticides.

Lady Beetles (Coccinellidae)

Role: Lady beetles, commonly known as ladybugs, are beneficial predators in agriculture, particularly effective at controlling aphid populations. Both adults and larvae feed voraciously on soft-bodied pests such as aphids, scale insects, and mites, making them valuable allies in integrated pest management (IPM).

Life Cycle: Lady beetles undergo four life stages: egg, larva, pupa, and adult. Females lay yellow egg clusters under leaves, often near aphid colonies. The dark-bodied, orange-tinted larvae begin feeding on aphids immediately after hatching. After several weeks of feeding, they pupate and later emerge as adult beetles. The full life cycle takes 4–7 weeks, depending on environmental conditions.

Application: Lady beetles are commercially available and commonly released in gardens and greenhouses to control aphid populations. They are most effective when released in the evening or early morning, when it's cooler and humidity is higher—conditions that help them stay in the release area. Release them directly onto infested plants and keep the surroundings moist to create a favorable environment. The release rate depends on infestation level, and additional introductions may be needed to maintain control. Lady beetles are active and reproduce best between 15–30 °C. Avoid pesticide use in areas where lady beetles are released, as many pesticides are harmful to them.

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References: Cornell University Biological Control: predators of aphids and other pests "Ladybugs: friend or foe?" — BugLogical

Providing Habitat and Resources for Natural Enemies

Natural enemies are generally inactive during the winter months. Therefore, unless they are reintroduced annually, they require suitable environments to survive the cold season. Some parasitoids and pathogens overwinter inside their hosts (which themselves have specific overwintering requirements), while others persist in crop residues, other vegetation, or soil. A classic example is the overwintering of predatory mites in orchards, where ground cover provides winter refuge, protection from pesticides used on fruit trees, and offers pollen and alternative prey sources.

Habitat Management

Many adult predators and parasitoids rely on or benefit from pollen, nectar, or honeydew (produced by aphids, for instance) during the summer. However, many cultivated crops only flower uniformly for a short period, so it may be necessary to plant flowering species along field margins or within the crop area to serve as supplementary pollen and nectar sources. Nevertheless, diversifying the plant community within a field can interfere with the ability of natural enemies—particularly specialist parasitoids that target one or a few host species—to locate their prey. Generalist predators (which feed on a wide variety of organisms) can have more stable populations when pollen and alternative prey are available, but their effectiveness still depends on how quickly they can respond—either through aggregation or reproduction—to pest outbreaks. Therefore, plant diversification or other supplemental feeding strategies for natural enemies are only effective when based on a solid understanding of predator and pest biology and behavior.

Selective Pesticide Use

The negative impact of pesticides on natural enemies can be minimized by carefully timing and targeting applications to reduce direct exposure. Using pesticides with shorter residual activity and applying them during periods when natural enemies are less active can significantly reduce harm.

Mass Rearing and Periodic Release of Natural Enemies

Periodic Inoculative Release

- **Concept:** In periodic inoculative releases, natural enemies are regularly reintroduced into the environment, particularly in controlled settings like greenhouses, where they cannot survive

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year-round. This strategy was originally developed around the use of the parasitoid Encarsia formosa against greenhouse whiteflies and the predatory mite Phytoseiulus persimilis against two-spotted spider mites. Over time, additional natural enemies have been introduced to target other pests such as thrips, leafminers, aphids, caterpillars, and other whitefly species. In Europe, the cost of biological control has become significantly lower than that of chemical control.

- **Practical Application:** Periodic inoculative release of parasitoids and predators has proven to be an extremely successful strategy for greenhouse biological control in Europe. Growers have embraced this approach due to increasing pesticide resistance in greenhouse pests and the rising costs of chemical control.

Inundative Release

- **Concept:** Inundative release resembles the use of biological control agents as pesticides. Natural enemies are released in large numbers, often as sprays, to rapidly suppress pest populations.
- **Practical Application:**
    - Inundative releases of insect and mite natural enemies in open fields are still relatively costly, due to the high expenses associated with mass rearing, storage, and shipping of live organisms.
    - Bt sprays function similarly to insecticides, incapacitating pests by paralyzing their digestive systems. However, the disease does not spread further within the pest population.
    - Beneficial nematodes are an example of live natural enemies used in inundative release. These nematodes are highly sensitive to desiccation, UV light, and extreme temperatures. They are most effective against pests living in soil or protected environments (e.g., internal plant feeders). Successful use requires adequate moisture and temperatures between 10–30 °C.

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IPM Strategies for Different Crops

Greenhouse Crops

1. Whitefly Control

The greenhouse whitefly (*Trialeurodes vaporariorum*) has been effectively managed for decades in European tomato and cucumber production. It currently poses little threat to flowering ornamental plants, where the primary concern is the B-biotype of the sweet potato whitefly (*Bemisia tabaci*), formerly known as the silverleaf whitefly (*Bemisia argentifolii*).

Natural Enemies:

- **Encarsia formosa:** This parasitoid has been successfully used for decades in Europe to control greenhouse whiteflies in crops like tomato and cucumber. However, its effectiveness is reduced on hairy-leaved tomato varieties, where the wasps struggle to detect whiteflies and have difficulty ovipositing in nymphs.
- **Amblyseius swirskii:** This predatory mite feeds on whitefly eggs and nymphs, making it a valuable tool for greenhouse pest management. It thrives in warmer conditions and should be released early in the crop cycle.
- **Fungal Pathogens:** Commercially available entomopathogenic fungi should be applied before whitefly populations grow large. *Beauveria bassiana* (e.g., Naturalis) and *Isaria fumosoroseus* can be used as foliar sprays. Ensure good coverage on the undersides of leaves to reach the immobile whitefly nymphs. Multiple applications may be needed. Humidity should remain above 80 % for spore germination and infection. Avoid using fungicides a few days before and after spraying; always follow label directions.
- **Banker Plants:** Growers use pollen-producing pepper plants to support populations of the pirate bug (*Orius insidiosus*). These are released at a rate of 60–80 individuals per pepper plant. The bugs lay eggs on these plants, often near flowers where thrips also lay eggs. One banker plant can support pest control over about 93 m^2. As long as the peppers flower and produce pollen, the pirate bugs will reproduce and disperse throughout the greenhouse to attack both larval and adult thrips. Pirate bugs only need to be released once onto the banker plants, which should be pruned monthly to maintain flowering.

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Monitoring and Timing: Regular monitoring is essential for effective whitefly control. Use yellow sticky traps to detect early infestations and track population trends. Biological control agents like *Encarsia formosa* are most effective when pest populations remain low, so timely intervention is critical.

2. Thrips Control

Western Flower Thrips (*Frankliniella occidentalis*): Thrips are more challenging to manage biologically than most other greenhouse pests.

Natural Enemies:

- **Amblyseius cucumeris and Amblyseius swirskii:** These predatory mites are effective against early larval stages of thrips. *A. swirskii* performs better in warmer conditions, while *A. cucumeris* is more effective in cooler environments.
- **Hypoaspis miles:** This soil-dwelling predatory mite feeds on thrips pupae and fungus gnat larvae in the growing medium. A single preventive release at planting is recommended to complement foliar applications of *A. cucumeris*.
- **Atheta coriaria:** This generalist predatory beetle feeds on thrips pupae, as well as fungus gnat and shore fly larvae.
- **Orius insidiosus (Pirate Bug):** A voracious predator of thrips in all life stages, *O. insidiosus* is well-suited to warm environments and is especially useful on flowering plants where it establishes more readily.

Monitoring and Timing: Continuous monitoring of thrips populations is crucial. Use blue or yellow sticky traps to detect early infestations. *A. swirskii* should be released preventively, while *O. insidiosus* is better introduced once thrips populations begin to rise.

Field Crops

- **Olive Trees**
  - **Pest Management:**
    - **Olive fruit fly (*Bactrocera oleae*):** This is the primary pest in olive cultivation. Biological control may include the release of parasitoids such as *Psyttalia concolor* and the application of *Bacillus thuringiensis* (Bt) to target larvae.

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        - **Cultural Practices:** Pruning to improve air circulation and removing fallen fruits can reduce pest populations.

    - **Monitoring and Timing:** Monitoring olive fruit fly populations using pheromone traps allows for optimal timing of natural enemy releases or Bt applications.

- **Grapevines**
    - **Pest Management:**
        - **European grapevine moth (Lobesia botrana):** A significant pest in viticulture. Biological control includes releasing Trichogramma wasps, which parasitize moth eggs.
        - **Cultural Practices:** Regular removal of infested berries and proper canopy management can lessen pest impact.
    - **Monitoring and Timing:** Pheromone traps are used to track moth activity, enabling timely release of Trichogramma or application of Bt to protect the grapes.
- **Vegetables (e.g., Tomato, Zucchini, Artichoke)**
    - **Pest Management:**
        - **Tomato:** Encarsia formosa and Amblyseius swirskii are effective against whiteflies and thrips.
        - **Zucchini and Artichoke:** Predatory beetles and beneficial nematodes can help control soil-dwelling pests like root flies.
        - **Cultural Practices:** Crop rotation and mulching are effective methods to reduce pest pressure in vegetable crops.
    - **Monitoring and Timing:** Regular scouting for signs of pest activity—such as leaf damage or the presence of larvae—is crucial. Timely use of biological agents like nematodes or predatory mites ensures effective pest control.

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Summary

The principles of ecological plant protection—based on preserving natural balance and implementing environmentally friendly practices—are becoming increasingly important in horticulture. Throughout this material, we have explored the effectiveness of biological control methods in both greenhouse and open-field cultivation. Beneficial insects and microorganisms such as lady beetles, parasitic wasps, and nematodes play a crucial role in sustainable pest management. These organisms are natural predators or parasites of pests, helping to reduce chemical pesticide use and supporting biodiversity conservation.

Integrated Pest Management (IPM) is a complex strategy that combines biological, mechanical, cultural, and chemical methods to ensure long-term sustainability and minimize environmental harm. Successful IPM requires careful and continuous monitoring of pest populations to enable timely interventions. Natural enemies like *Encarsia formosa*, *Amblyseius swirskii*, and various predatory beetles can be effectively used to protect crops such as tomatoes, peppers, and other vegetables.

In conclusion, the aim of this material is not only to provide gardeners with a theoretical understanding of biological pest control, but also to equip them with the practical skills to apply these methods effectively. By using the right techniques and tools, gardeners can reduce pest-related damage, promote optimal plant growth, and contribute to a more sustainable and healthier agricultural system.

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