18(1s), Spring 2026

Journal of Animal Environment

(E-ISSN 2717-1396, ISSN 2717-1388)

Original Research Paper

Biological Control Agents in Agriculture: Evaluating Their Potential as Vectors of Human Pathogens

Dr. Karpagavalli[1*], Uma Bhardwaj[2], Ms. Anusha K[3], Parthasarathy R[4], Vasanthapriya J[5], Dr. Dhanalakshmi S[6]

[1*]Professor cum HoD, Meenakshi College of Pharmacy, Meenakshi Academy of Higher Education and Research. karpagavalli@maher.ac.in

[2]Professor, Department of Biotechnology and Microbiology, Noida international University, Uttar Pradesh, India. vc@niu.edu.in 0000-0002-6414-9731

[3]Lecturer, Meenakshi College of Pharmacy, Meenakshi Academy of Higher Education and Research. anushakpharmacy@maher.ac.in

[4]Meenakshi College of Physiotherapy, Meenakshi Academy of Higher Education and Research, partha@maher.ac.in, 0000-0001-5707-835X

[5]Meenakshi College of Nursing, Meenakshi Academy of Higher Education and Research, vasantha@maher.ac.in, 0000-0001-9953-9505

[6]Professor, Meenakshi College of Pharmacy, Meenakshi Academy of Higher Education and Research. sdhanalakshmi@maher.ac.in

Abstract: Biological control agents (BCAs) are increasingly employed in sustainable agriculture as environmentally friendly alternatives to synthetic pesticides for the management of insect pests and plant diseases. Predatory insects, parasitoids, entomopathogenic fungi, bacteria, nematodes, and insect-specific viruses contribute significantly to integrated pest management by reducing pesticide use, preserving biodiversity, and enhancing ecosystem resilience. Despite their well-established agricultural benefits, concerns have emerged regarding their potential role as reservoirs or mechanical carriers of human pathogens due to their interactions with soil, irrigation water, organic amendments, crops, and contaminated environments. This review examines the diversity of biological control agents, their mechanisms of pest suppression, and the environmental pathways through which they may encounter microorganisms of public health importance. Particular emphasis is placed on differentiating biological transmission from incidental mechanical carriage and evaluating current evidence regarding pathogen persistence and dissemination. The review further discusses modern pathogen detection techniques, biosafety assessment frameworks, regulatory guidelines, and quality assurance practices governing the production and application of biological control agents. Current evidence indicates that approved biological control agents generally pose a very low risk to human health when produced and applied under appropriate regulatory standards. Future research integrating genomics, metagenomics, microbiome analysis, and One Health approaches will strengthen biosafety evaluation while supporting the continued expansion of sustainable biological pest management in modern agriculture.

Keywords: Arthropod Vectors, Veterinary, Entomology, Zoonotic Diseases, Transmission, Public Health, Livestock, Integrated Surveillance, Mitigation System.

I. Introduction

The growing demand for sustainable agricultural production has accelerated the transition from conventional chemical pest management toward environmentally friendly alternatives that maintain crop productivity while minimizing ecological degradation. For several decades, synthetic pesticides have played a crucial role in controlling agricultural pests and improving food security [1]. However, their excessive and indiscriminate use has resulted in numerous environmental and public health concerns, including pesticide resistance,

***Corresponding Author:**

Received: 05th March, 2026; Revised: 11th April, 2026; Accepted: 2nd May, 2026; Available Online: 20th May, 2026

(DOI): 10.70102/AEJ.2026.18.1s.43

contamination of soil and water resources, reduction of beneficial insect populations, biodiversity loss, accumulation of chemical residues in food products, and adverse effects on human and animal health. These challenges have intensified global interest in integrated pest management (IPM), where biological control agents (BCAs) have emerged as one of the most effective and sustainable pest management strategies.

Biological control agents comprise a diverse group of beneficial organisms, including predatory insects, parasitoids, entomopathogenic fungi, bacteria, nematodes, viruses, and beneficial microorganisms that naturally suppress agricultural pests through predation, parasitism, pathogenicity, or competition. Unlike chemical pesticides, these agents selectively target pests while preserving ecological balance and minimizing impacts on non-target organisms. Their successful application in field crops, horticultural systems, orchards, greenhouse production, and forestry has substantially reduced reliance on chemical pesticides and contributed to environmentally sustainable agriculture [2]. Consequently, biological control has become an essential component of modern IPM programs and is increasingly promoted worldwide as part of climate-smart and sustainable farming practices.

Despite these well-recognized benefits, biological control agents function within complex agricultural ecosystems where they continuously interact with soil, irrigation water, plant surfaces, insect hosts, livestock, wildlife, organic amendments, and diverse environmental microorganisms. These interactions have generated increasing scientific interest regarding whether beneficial organisms could occasionally acquire, retain, or mechanically disseminate microorganisms of public health significance [3]. Agricultural environments frequently contain foodborne pathogens such as *Salmonella enterica*, pathogenic *Escherichia coli*, *Listeria monocytogenes*, and other opportunistic bacteria originating from contaminated irrigation water, untreated manure, wildlife activity, or inadequate agricultural hygiene. Since many biological control agents move extensively among plants, insects, soil, and surrounding environments, questions have emerged regarding their possible role as incidental carriers of these microorganisms.

It is important to distinguish between biological transmission and mechanical carriage. Biological transmission involves pathogen survival, multiplication, or development within a vector before infecting a new host, whereas mechanical carriage simply refers to the passive transfer of microorganisms on external body surfaces or through transient gastrointestinal passage. Current scientific evidence indicates that most commercially approved biological control agents are not biological vectors of human pathogens. Nevertheless, under specific environmental conditions they may temporarily acquire microorganisms from contaminated agricultural environments and mechanically redistribute them to nearby surfaces. Understanding the magnitude and significance of such interactions is essential for ensuring both agricultural sustainability and food safety.

Recent advances in microbial ecology, genomics, metagenomics, whole-genome sequencing, microbiome research, and molecular diagnostics have significantly improved the ability to investigate microbial communities associated with beneficial organisms. Simultaneously, the One Health framework has emphasized the interconnected relationships among human health, animal health, plant health, and environmental quality, encouraging multidisciplinary evaluation of biological control systems beyond pest suppression alone. Modern biosafety assessments therefore consider not only the efficacy of biological control agents against target pests but also their environmental persistence, microbial interactions, occupational safety, manufacturing quality, and potential implications for food production systems.

Although numerous reviews have examined the effectiveness of biological control agents in sustainable agriculture, comparatively fewer studies have critically evaluated their potential association with human pathogens from a food safety and public health perspective. Existing literature is often fragmented, focusing separately on beneficial insects, microbial pesticides, foodborne pathogens, or regulatory issues without integrating these aspects into a comprehensive biosafety framework. Furthermore, many discussions fail to distinguish between hypothetical pathogen detection and experimentally demonstrated transmission, leading to misconceptions regarding the actual risks associated with biological control practices.

II. Human Pathogens Associated with Biological Control Agents

Biological control agents are deliberately introduced, augmented, or conserved within agricultural environments because of their capacity to suppress crop pests and plant diseases. Predatory insects, parasitoids, entomopathogenic microorganisms, beneficial nematodes, and other natural enemies are generally regarded as environmentally preferable alternatives to broad-spectrum chemical pesticides [4]. The Food and Agriculture Organization recognizes that biological pest control agents generally present comparatively low risks to human health and the environment when they are properly selected, produced, evaluated, and applied. Nevertheless, because these agents are living organisms that interact continuously with soil,

irrigation water, plant surfaces, animal waste, insects, and decomposing organic matter, their possible contact with microorganisms of public-health importance cannot be completely excluded.

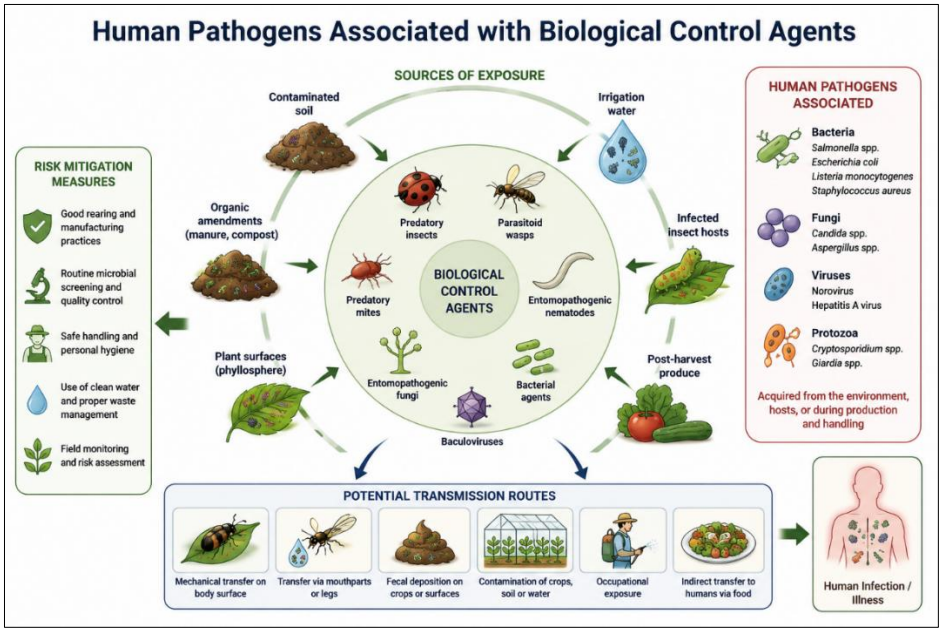


Figure 1. Human pathogens associated with biological control agents in agricultural ecosystems.

The principal concern is not that commonly used biological control agents are inherently human pathogens. Rather, certain agents may acquire, retain, and mechanically redistribute pathogenic microorganisms after contacting contaminated environmental materials. Microbial biological control products may also present risks if the production strain is incorrectly identified, carries undesirable virulence or antimicrobial-resistance determinants, produces harmful metabolites, or becomes contaminated during mass production. The assessment must therefore distinguish among the pathogenicity of the biological control agent itself, contamination of commercial formulations, and passive carriage of external human pathogens.

Within this context, the term **vector** should be applied cautiously. A biological vector supports the survival, multiplication, or developmental transformation of a pathogen within its body before transmission to a susceptible host. A mechanical vector, in contrast, transports microorganisms externally on its cuticle, legs, mouthparts, setae, or internally within the digestive tract without an essential biological development stage. Most concerns involving beneficial arthropods in crop production relate to possible mechanical carriage rather than proven biological transmission.

A. Human Pathogens in Agricultural Ecosystems

Agricultural ecosystems contain diverse microbial communities originating from soil, water, plants, animals, insects, workers, fertilizers, compost, and farm infrastructure. Most of these microorganisms are harmless or beneficial; however, agricultural environments may also contain bacterial, fungal, viral, and parasitic agents capable of causing disease in humans [5]. Their occurrence is especially relevant in production systems involving raw manure, inadequately treated compost, contaminated irrigation water, livestock intrusion, wildlife activity, poor worker hygiene, or insufficient sanitation of harvesting and processing equipment.

Foodborne bacterial pathogens such as *Escherichia coli*, particularly Shiga toxin-producing strains, *Salmonella enterica*, *Listeria monocytogenes*, *Campylobacter* spp., *Staphylococcus aureus*, and members of the *Bacillus cereus* group may persist in agricultural environments under suitable conditions. Opportunistic organisms belonging to genera such as *Pseudomonas*, *Enterococcus*, *Klebsiella*, *Serratia*, and *Enterobacter* may also occur in soil, water, plants, insects, and organic wastes. Their public-health significance varies according to the species or strain, infectious dose, virulence properties, route of exposure, host susceptibility, and ability to survive on fresh produce.

Fresh fruits and vegetables are particularly important because many are consumed raw or undergo only minimal processing. Microbial contamination occurring before harvest may therefore persist through harvesting, distribution, and consumption. Leaf surfaces, damaged tissues, stomata, roots, floral structures, and biofilms may provide temporary or protected sites for microbial persistence. Insects moving between manure, soil,

decaying organic material, livestock facilities, and crop surfaces can contribute to microbial redistribution. Arthropods are broadly recognized as capable of mechanically transporting pathogenic microorganisms, although the epidemiological relevance differs substantially among insect species and agricultural settings [6].

Beneficial organisms released for biological control operate within the same environmental matrix. Predators may consume contaminated prey, parasitoids may encounter microorganisms while searching on plant surfaces or developing within hosts, and microbial control agents are directly applied to crops and soils [7]. Consequently, exposure of biological control agents to human pathogens is biologically plausible. However, detection of a pathogen on or within an agent does not by itself demonstrate that the agent transmits a sufficient quantity to food, workers, livestock, or consumers to cause disease.

B. Comparative Assessment of Potential Human-Pathogen Associations

Table 1. Potential pathways through which major biological control agents may acquire or transmit microorganisms of human-health relevance

Biological Control Agent	Main Agricultural Role	Possible Pathogen Exposure	Potential Transmission Route	Relative Risk
Predatory insects [8]	Control aphids, mites, whiteflies, and small pests	Contaminated prey, soil, water, and plant surfaces	External carriage, ingestion, fecal deposition	Low to moderate
Parasitoid wasps [9]	Parasitize pest eggs, larvae, and adults	Contaminated hosts, honeydew, and crop surfaces	Body contact, probing, and host feeding	Low
Predatory mites [10]	Control mites, thrips, and whiteflies	Contaminated leaves, prey, and rearing materials	Localized mechanical transfer	Low
Entomopathogenic nematodes [11]	Control soil-dwelling insect pests	Soil, water, and infected insect cadavers	Association with symbiotic bacteria	Low
Entomopathogenic fungi [12]	Infect and kill insect pests	Production systems, infected insects, and crop surfaces	Spore contact and inhalation during handling	Low, with occupational concern
Bacterial biocontrol agents [13]	Produce insecticidal or antagonistic compounds	Manufacturing materials and agricultural environments	Direct exposure to applied cells or spores	Strain-dependent

The table illustrates that the nature of concern differs between macrobiological and microbial agents. Predators and parasitoids are primarily evaluated as possible mechanical carriers, whereas microbial products require direct evaluation of the biological properties of the applied strain. In both situations, contamination introduced during production may be more controllable and potentially more consequential than incidental environmental acquisition after release.

C. Environmental and Agricultural Factors Influencing Transmission

1. Temperature and Humidity

Temperature affects both the activity of biological control agents and the survival of microorganisms. Warm conditions may increase insect movement, feeding, and defecation, while also supporting or suppressing different pathogens. High relative humidity can prolong bacterial survival on surfaces and promote fungal spore germination. Conversely,

desiccation and ultraviolet exposure may rapidly reduce viable microbial populations.

Greenhouse environments commonly maintain moderate temperatures and high humidity favorable to both biological control performance and microbial persistence. Their enclosed nature may increase repeated contact among insects, plants, workers, and equipment. However, controlled production systems also permit more effective sanitation, monitoring, and traceability than open fields.

2. Crop Type and Edible Plant Surface

The public-health significance of microbial transfer depends strongly on whether the edible portion is exposed. Biological control agents moving on lettuce, spinach, herbs, strawberries, tomatoes, and other fresh produce may contact parts consumed raw. In contrast, agents active in soil around crops whose edible portions are cooked, peeled, or physically protected may present lower consumer exposure.

Rough, folded, hairy, cracked, or damaged plant surfaces may retain microorganisms more effectively than smooth intact surfaces. Flowers and stem scars can also provide protected entry sites.

3. Time Between Release and Harvest

Microbial populations generally decline over time when environmental conditions do not support multiplication. Therefore, the interval between biological control release, potential contamination, and harvest can influence exposure. Releases made close to harvest may warrant greater attention in crops consumed raw, particularly where environmental contamination is already present.

This does not imply that universal preharvest intervals are necessary for all biological control agents. Rather, timing should be considered within crop-specific and agent-specific risk assessments.

4. Biological Control Agent Density

Augmentative biological control may involve the release of large numbers of organisms. Higher densities could increase the number of contacts with plants and prey. However, transmission risk does not necessarily increase proportionally because most released individuals may be free of relevant pathogens.

The more important issue is whether contamination is widespread in a production batch. A low prevalence of contamination among mass-reared agents may still produce broad environmental distribution when millions of organisms are released. Batch screening and production hygiene are therefore important risk-control measures.

5. Feeding and Movement Behavior

Agents that move between soil, manure, decomposing matter, and crop canopies may have more opportunities to acquire and redistribute microorganisms than agents confined to a particular plant compartment. Generalist predators may feed on diverse resources, whereas specialist parasitoids interact with narrower host ranges.

Flight capacity, walking behavior, grooming, gut retention time, and defecation patterns influence transfer potential. These characteristics should be incorporated into realistic experimental designs.

6. Existing Microbial Contamination

Biological control agents cannot acquire pathogens that are absent from their environment. Their potential role is therefore secondary to the original contamination source. Farms with clean irrigation water, properly treated organic amendments, effective exclusion of livestock and wildlife, hygienic worker practices, and sanitized equipment are expected to present substantially lower opportunities for pathogen acquisition.

Consequently, biological control risk management should not replace established food-safety systems. It should be integrated into good agricultural practices, hazard analysis, water management, manure treatment, worker hygiene, and environmental monitoring.

7. Microbiome of the Biological Control Agent

The resident microbiome of an insect can inhibit, tolerate, or facilitate externally acquired microorganisms. Competition for nutrients, antimicrobial compounds, gut pH, immune responses, and symbiotic interactions may prevent long-term colonization. Alternatively, some gut environments may permit temporary persistence.

Metagenomics and culture-based investigations can identify microorganisms associated with biological control agents, but molecular detection alone cannot determine viability or transmission potential. Combining sequencing with culture, viability assays, microscopy, and controlled transfer experiments provides stronger evidence.

D. Evidence, Uncertainty, and Interpretation

A central challenge in this field is the difference between hazard identification and risk characterization. Hazard identification asks whether an organism is capable of carrying or causing harm. Risk characterization asks whether harmful exposure is likely under realistic conditions and whether the resulting dose is sufficient to cause disease.

Several types of evidence are commonly reported:

1. detection of microbial DNA on an insect;
2. isolation of viable microorganisms from an insect;
3. persistence of the organism for a defined period;
4. deposition of viable microorganisms onto a plant surface;
5. survival or multiplication on the plant;
6. transfer to harvested produce;
7. exposure of humans through handling or consumption; and
8. confirmed illness epidemiologically linked to the biological control agent.

Evidence at the first or second level is insufficient to establish the final epidemiological link. Detection through polymerase chain reaction may indicate DNA from dead cells, transient contamination, or environmental exposure. Similarly, laboratory experiments using unusually high pathogen concentrations may demonstrate a possible transfer mechanism without representing ordinary agricultural conditions.

Future studies should therefore use realistic inoculum levels, commercial release densities, representative crops, appropriate environmental conditions, viable-cell measurements, negative controls, untreated comparison groups, and sufficient observation periods. The background contamination of soil, water, crops, and conventional farm insects should also be measured. Without such comparisons, the contribution of biological control agents may be overestimated.

E. One Health Significance

The One Health perspective recognizes that human health, animal health, plant health, biodiversity, and environmental quality are interconnected. Biological control contributes positively to One Health by reducing chemical pesticide use, protecting beneficial organisms, lowering residues, delaying pesticide resistance, and supporting ecological resilience. A recent systems-level assessment emphasized these cross-sector benefits and argued for wider integration of biological control into One Health policy and research.

At the same time, One Health requires that biological control programs consider microbial safety throughout the production and application chain. This includes the origin and identity of biological agents, health status of rearing colonies, purity of microbial cultures, quality of water and substrates, worker safety, environmental persistence, food-contact exposure, and the vulnerability of immunocompromised individuals.

The appropriate response is therefore not to avoid biological control because of hypothetical pathogen transmission. Instead, proportional and evidence-based safeguards should be adopted. These may include strain-level identification, whole-genome characterization, pathogen screening, antimicrobial-resistance evaluation, validated sanitation procedures, batch traceability, environmental monitoring, personal protective equipment during microbial application, and post-release surveillance when justified.

Overall, available evidence supports the continued use of well-characterized and properly produced biological control agents as important components of sustainable agriculture. Their possible role as carriers of human pathogens should be treated as a specific, testable biosafety question rather than a general assumption. The greatest priorities are to identify conditions under which viable pathogens persist, quantify actual transfer to edible crops, determine whether infectious doses can be reached, and develop proportionate controls that preserve the environmental benefits of biological pest management.

III. Risk Assessment, Biosafety, and Future Perspectives

The expanding adoption of biological control agents (BCAs) has transformed sustainable agriculture by reducing dependence on synthetic pesticides while preserving ecosystem services and biodiversity. Although biological control is generally recognized as environmentally safe, increasing interactions among beneficial organisms, crops, environmental microorganisms, and agricultural workers have highlighted the need for comprehensive biosafety evaluation. Current evidence indicates that most approved biological control agents present a very low direct risk to human health; however, their extensive exposure to soil, irrigation water, organic fertilizers, and contaminated environments necessitates systematic assessment of their potential role in acquiring and mechanically disseminating human pathogens. Consequently, modern biological control programs should integrate efficacy with food

safety, environmental monitoring, and public health considerations under the One Health framework.

A. Detection and Monitoring of Human Pathogens

Reliable detection of human pathogens associated with biological control agents is fundamental for accurate risk assessment. Conventional culture-based techniques remain useful for isolating viable microorganisms such as *Salmonella*, *Escherichia coli*, *Listeria monocytogenes*, and *Staphylococcus aureus*. However, many environmental microorganisms cannot be readily cultured, limiting the sensitivity of traditional microbiological approaches.

Molecular diagnostic techniques have therefore become increasingly important. Polymerase chain reaction (PCR), quantitative PCR (qPCR), multiplex PCR, loop-mediated isothermal amplification (LAMP), and next-generation sequencing (NGS) enable rapid and highly sensitive detection of pathogenic microorganisms. Whole-genome sequencing further allows strain identification, virulence gene characterization, antimicrobial resistance profiling, and source tracking. In addition, metagenomic analysis provides comprehensive characterization of microbial communities associated with insects, soil, plant surfaces, and commercial biological control formulations.

Routine monitoring should include quality assessment of rearing facilities, irrigation water, production substrates, commercial formulations, and released biological control agents. Continuous surveillance enables early identification of contamination events and supports evidence-based biosafety management.

Table 2. Major Techniques for Detecting Human Pathogens Associated with Biological Control Agents

Technique	Primary Purpose	Advantages	Limitations
Culture-based isolation	Recovery of viable pathogens	Simple, inexpensive	Slow and may miss unculturable organisms
PCR / qPCR	Rapid pathogen detection	High sensitivity and specificity	Detects DNA from both viable and non-viable cells
Whole-genome sequencing	Strain identification and genomic analysis	High resolution and source tracing	High cost and computational requirements
Metagenomic sequencing	Microbiome characterization	Detects diverse microbial communities	Requires advanced bioinformatics
Immunological assays (ELISA)	Detection of microbial antigens	Rapid screening	Lower specificity than molecular methods

B. Risk Assessment Framework

Risk assessment provides a scientific basis for evaluating whether biological control agents present meaningful hazards to humans, animals, or the environment. International regulatory agencies generally employ a structured framework consisting of hazard identification, hazard characterization, exposure assessment, and risk characterization.

Hazard identification determines whether the biological control agent or associated microorganisms possess characteristics capable of causing adverse health effects. Hazard characterization evaluates pathogenicity, infectivity, toxigenicity, allergenicity, environmental persistence, and antimicrobial resistance. Exposure assessment estimates the likelihood that agricultural workers, consumers, livestock, or wildlife may encounter the biological control agent or contaminating microorganisms during production, application, harvesting, processing, or consumption. Finally, risk characterization integrates hazard and exposure information to determine the overall level of public health concern.

Because many beneficial organisms only mechanically acquire environmental microorganisms, exposure assessment is often the critical determinant of actual risk. Detection of a pathogen alone does not necessarily indicate an epidemiologically significant transmission pathway.

Table 3. Components of Biosafety Risk Assessment

Risk Assessment Component	Objective
Hazard identification	Identify potentially harmful microorganisms or traits
Hazard characterization	Evaluate pathogenicity, toxicity, infectivity, and persistence
Exposure assessment	Estimate likelihood of human or environmental exposure
Risk characterization	Determine overall biosafety risk
Risk management	Implement mitigation and monitoring strategies

C. Biosafety Regulations and Quality Assurance

International organizations including the Food and Agriculture Organization (FAO), World Health Organization (WHO), European Food Safety Authority (EFSA), and national regulatory authorities have established guidelines governing the safe development and application of biological control agents. Regulatory evaluation generally includes taxonomic confirmation, ecological safety, non-target organism assessment, human health evaluation, manufacturing quality control, and environmental risk analysis before commercial approval.

Commercial production facilities should implement Good Manufacturing Practices (GMP), quality assurance protocols, contamination screening, microbial purity testing, and traceability systems. Periodic monitoring of microbial contamination during mass rearing and formulation production minimizes the introduction of unintended microorganisms into agricultural systems.

Worker safety also remains an important consideration, particularly during handling of microbial formulations containing fungal spores or bacterial preparations. Appropriate personal protective equipment, hygiene practices, and training reduce occupational exposure.

D. Knowledge Gaps and Future Research

Despite decades of successful biological control applications, several important research gaps remain. Most available studies emphasize pest suppression efficiency, whereas comparatively fewer investigations evaluate interactions between biological control agents and human pathogens under realistic field conditions.

Future research should prioritize:

- Standardized protocols for evaluating pathogen persistence on biological control agents.
- Long-term field studies quantifying microbial transfer under commercial agricultural conditions.
- Comparative analysis of conventional and organic farming systems.
- Microbiome studies investigating interactions among beneficial organisms, pathogens, and crops.
- Whole-genome sequencing to identify virulence genes and antimicrobial resistance determinants.
- Artificial intelligence and biosensor-based surveillance for real-time pathogen monitoring.
- Development of internationally harmonized biosafety standards for commercial biological control production.

Advanced technologies including environmental DNA (eDNA), metagenomics, portable sequencing platforms, Internet of Things (IoT)-enabled biosensors, artificial intelligence, and machine learning are expected to substantially improve biosafety monitoring while supporting precision agricultur

IV. Conclusion

Biological control agents have become indispensable components of sustainable agriculture by providing environmentally friendly alternatives to synthetic pesticides while supporting biodiversity conservation, integrated pest management, and long-term ecosystem stability. Predatory insects, parasitoids, entomopathogenic fungi, bacteria,

nematodes, and viruses effectively suppress numerous agricultural pests with comparatively low ecological impact. However, their continuous interaction with soil, irrigation water, crops, insects, and other environmental components has raised important questions regarding their potential role in acquiring and mechanically disseminating human pathogens. Current evidence indicates that most approved biological control agents are not significant human pathogens and generally present a very low risk when produced, regulated, and applied according to established biosafety guidelines. Nevertheless, contamination during mass production, exposure to contaminated agricultural environments, and inadequate quality control may increase opportunities for incidental microbial transfer.

References

[1] Xu, J.; Zhang, N.; Wang, K.; Xian, Q.; Dong, J.; Chen, X. Exploring new strategies in diseases resistance of horticultural crops. *Front. Sustain. Food Syst.* 2022, *6*, 1021350.

[2] Ali, S.; Tyagi, A.; Rajarammohan, S.; Mir, Z.A.; Bae, H. Revisiting *Alternaria*-host interactions: New insights on its pathogenesis, defense mechanisms and control strategies. *Sci. Hortic.* 2023, *322*, 112424.

[3] Chaerani, R.; Voorrips, R.E. Tomato early blight (*Alternaria solani*): The pathogen, genetics, and breeding for resistance. *J. Gen. Plant Pathol.* 2006, *72*, 335–347.

[4] Utkhede, R.S.; Mathur, S. Preventive and curative biological treatments for control of *Botrytis cinerea* stem canker of greenhouse tomatoes. *BioControl* 2006, *51*, 363–373.

[5] Charoenporn, C.; Kanokmedhakul, S.; Lin, F.C.; Poeaim, S.; Soytong, K. Evaluation of bio-agent formulations to control *Fusarium* wilt of tomato. *Afr. J. Biotechnol.* 2010, *9*, 5836–5844.

[6] Panno, S.; Davino, S.; Caruso, A.G.; Bertacca, S.; Crnogorac, A.; Mandić, A.; Noris, E.; Matić, S. A review of the most common and economically important diseases that undermine the cultivation of tomato crop in the Mediterranean Basin. *Agronomy* 2021, *11*, 2188.

[7] Khodadadi, F.; González, J.B.; Martin, P.L.; Giroux, E.; Bilodeau, G.J.; Peter, K.A.; Doyle, V.P.; Aćimović, S.G. Identification and characterization of *Colletotrichum* species causing apple bitter rot in New York and description of *C. noveboracense* sp. nov. *Sci. Rep.* 2020, *10*, 11043.

[8] Marquez, N.; Giachero, M.L.; Declerck, S.; Ducasse, D.A. *Macrophomina phaseolina*: General characteristics of pathogenicity and methods of control. *Front. Plant Sci.* 2021, *12*, 634397.

[9] Tripathi, A.N.; Singh, B.P. Evaluation of seed health of seeds of different vegetable crops. *Veg. News Letter* 2022, *9*, 7.

[10] Sundin, G.W.; Wang, N. Antibiotic resistance in plant-pathogenic bacteria. *Annu. Rev. Phytopathol.* 2018, *25*, 161–180.

[11] Sánchez-Hernández, E.; González-García, V.; Martín-Gil, J.; Lorenzo-Vidal, B.; Palacio-Bielsa, A.; Martín-Ramos, P. Phytochemical screening and antibacterial activity of *Taxus baccata* L. against *Pectobacterium* spp. and *Dickeya chrysanthemi*. *Horticulturae* **2023**, *9*, 201.

[12] Hull, R. Symptoms and Host Range. In *Plant Virology*; Elsevier: Amsterdam, The Netherlands, 2014; pp. 145–198.

[13] Mehetre, G.T.; Leo, V.V.; Singh, G.; Sorokan, A.; Maksimov, I.; Yadav, M.K.; Upadhyaya, K.; Hashem, A.; Alsaleh, A.N.; Dawoud, T.M.; et al. Current developments and challenges in plant viral diagnostics: A systematic review. *Viruses* 2021, *13*, 412.