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ECOLOGICAL ASSESSMENT OF THE IMPACT OF FUNGICIDES USED TO PROTECT VEGETABLE CROPS IN GREENHOUSES ON SOIL AND AQUATIC ECOSYSTEMS

Savriddinov Ibratjon Ikrom o'g'li
Email: savriddinovibratjon@gmail.com

Annotation

This review-based thesis examines the environmental pathways and potential ecological consequences of fungicides applied to greenhouse vegetables. Emphasis is placed on the persistence and movement of residues in cultivated substrates, effects on soil microbial functions, contamination of drainage and irrigation-return water, and toxicity to non-target aquatic organisms. A practical risk-assessment framework combining application records, residue monitoring and biological indicators is proposed. The analysis demonstrates that ecological risk depends on active ingredient, formulation, treatment frequency, substrate characteristics and wastewater management. Integrated disease management and monitoring are recommended to reduce off-site exposure.

Keywords: greenhouse vegetables; fungicides; soil microbiota; aquatic ecosystems; pesticide residues; ecological risk assessment.

SABZAVOT EKINLARINI HIMOYA QILISHDA QO‘LLANILADIGAN FUNGITSIDLARNING TUPROQ VA SUV EKOTIZIMLARIGA TA’SIRINI EKOLOGIK BAHOLASH

Annotatsiya

Ushbu adabiyotlar tahliliga asoslangan tezisda issiqxona sabzavotlarini himoya qilishda ishlatiladigan fungitsidlarning atrof-muhitga tarqalish yo‘llari va mumkin bo‘lgan ekologik oqibatlari ko‘rib chiqiladi. Tuproqda qoldiqlarning saqlanishi, mikroorganizmlar faoliyatiga ta’siri, drenaj suvlari orqali ko‘chishi hamda suv organizmlari uchun xavf alohida tahlil qilinadi. Qo‘llash jurnali, qoldiq tahlili va biologik indikatorlarni birlashtiruvchi baholash yondashuvi taklif etiladi. Xavfni kamaytirish uchun integratsiyalashgan himoya va oqova suv monitoringi tavsiya qilinadi.

Kalit so‘zlar: issiqxona sabzavotlari; fungitsidlar; tuproq mikrobiotasi; suv ekotizimlari; pestitsid qoldiqlari; ekologik xavf.

Аннотация

В тезисе на основе анализа научной литературы рассматриваются пути распространения и потенциальные экологические последствия применения фунгицидов при выращивании овощей в теплицах. Проанализированы остаточные количества в почве, влияние на микробные процессы, перенос веществ с дренажными водами и риск для водных организмов. Предложен подход к экологической оценке, объединяющий учет обработок, химический мониторинг и биологические индикаторы. Для снижения воздействия рекомендованы интегрированная защита растений и контроль сточных вод.

Ключевые слова: тепличные овощи; фунгициды; почвенная микробиота; водные экосистемы; остатки пестицидов; экологический риск.

INTRODUCTION

Greenhouse vegetable production improves the continuity and productivity of food supply, yet the humid microclimate and dense planting can favor fungal diseases. Fungicides are therefore applied against diseases affecting tomato, cucumber, pepper and other crops. A protected structure does not create an environmentally closed system: spray deposits, spilled concentrates, contaminated substrates and nutrient solutions may eventually enter drainage channels and receiving waters. Fungicides have

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been documented in agricultural surface waters and can affect organisms beyond the target pathogens (Zubrod et al., 2019).

The purpose of this thesis is to synthesize published evidence and outline a feasible ecological assessment of soil and water risks associated with greenhouse fungicide use. It does not report original field measurements; the proposed indicators and diagram are conceptual rather than experimental results.

MAIN PART

1. Environmental transport and soil-level effects

Environmental behavior varies greatly among active ingredients. Sorption to organic matter and clay, solubility, hydrolysis, microbial degradation and temperature jointly determine whether a fungicide remains in the root zone or moves with drainage water (Arias-Estévez et al., 2008). Repeated use may create recurring exposures even where an individual compound degrades relatively quickly. Metal-containing products, including copper-based fungicides, warrant special attention because copper is an element and cannot be biodegraded; accumulation is influenced by total historical loading and soil chemistry (Komárek et al., 2010).

Potential soil-level endpoints include microbial biomass carbon, basal respiration, dehydrogenase activity, phosphatase activity, nitrification rate, earthworm survival and changes in fungal-to-bacterial community structure. These indicators should be interpreted alongside soil pH, organic carbon, texture and salinity. An observed change in one enzyme assay is not by itself proof of ecosystem-level harm; replicated reference comparisons and exposure data are needed.

2. Aquatic exposure and ecological endpoints

In hydroponic and substrate-based greenhouses, discarded nutrient solutions and filter backwash can convey dissolved fungicides to drainage infrastructure. In soil-based houses, leaching, runoff from adjacent washing areas and improper disposal are relevant pathways. Exposure may be episodic after spraying or sustained where water is recirculated without suitable treatment. Aquatic fungi, algae, invertebrates and fish may exhibit different sensitivities; indirect food-web effects must also be considered (Zubrod et al., 2019).

Chemical analyses should sample irrigation intake, collection drains, storage tanks and any discharge point, ideally before treatment and at predefined intervals after application. Ecological interpretation should combine measured environmental concentrations (MEC) with substance-specific predicted no-effect concentrations (PNEC) or regulatory assessment values, while acknowledging uncertainties and mixture effects. A screening risk quotient may be expressed as RQ = MEC/PNEC; values greater than 1 identify a need for closer investigation, not automatic proof of damage.

3. Monitoring and decision-support framework

Table 1 presents a practical measurement framework. Sampling should reflect application history, greenhouse type and season, and record detection limits and quality-control procedures. High-performance liquid chromatography with tandem mass spectrometry is commonly suitable for targeted organic residues; metals require appropriate elemental analysis. Biological indicators supplement chemical measurements because concentrations alone cannot describe ecosystem function.

Table 1. Proposed ecological monitoring framework for greenhouse fungicides

Compartment / pathway	Core indicators	Interpretation / management use
Greenhouse soil/substrate	Residue concentration; pH; organic carbon; microbial respiration	Detect accumulation and altered soil functions
Drainage and runoff	Active ingredient concentration; discharge volume; sampling date	Quantify off-site exposure and peak releases

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Receiving surface water	MEC; PNEC; screening RQ; seasonal pattern	Prioritize compounds for detailed aquatic assessment
Biological response	Algal growth; invertebrate endpoints; soil enzyme assays	Cross-check chemical risk with ecological function

A tiered approach can reduce unnecessary laboratory expenditure: (i) map use and discharge pathways; (ii) screen residues and basic soil-water indicators; (iii) calculate substance-specific screening RQs; and (iv) investigate priority locations using ecotoxicological tests. Preventive interventions include resistant cultivars, pathogen diagnosis before spraying, sanitation, biological control, dose compliance and segregation or treatment of contaminated drainage.

Figure 1. Conceptual transport pathway of fungicide residues (schematic; not measured concentrations).



Figure 1 illustrates the screening sequence rather than a universal fate model. Actual losses depend on the formulation, drainage capture, environmental conditions and local disposal practices. Greenhouse-specific empirical datasets are needed before quantitative mitigation benefits can be claimed.

CONCLUSION

Fungicides protect greenhouse vegetable crops but can create ecological pressures when residues accumulate in soil or escape through drainage and wastewater. Environmental impacts are compound- and context-specific, so risk evaluation should not rely solely on application rate or a single residue measurement. Combining chemical monitoring, soil-function indicators and aquatic risk screening provides a more defensible basis for action. The highest practical priorities are documented pesticide use, safe handling and disposal, drainage-water containment, targeted application based on disease monitoring and periodic verification of soil and water quality. Future investigations should compare greenhouse systems through repeated paired sampling and ecotoxicological testing.

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