FORMATION OF MICROBIOLOGICAL BALANCE AND MONITORING OF PHYTOSANITARY CONDITIONS IN TOMATO ROOT ZONE USING BIOFUNGICIDES

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ABSTRACT

The sustainability of modern agricultural systems increasingly depends on environmentally friendly plant protection strategies. This research investigates the formation of a microbiological balance in the tomato (Solanum lycopersicum L.) rhizosphere through the use of biofungicides and the monitoring of phytosanitary conditions during the vegetation period. Laboratory and field experiments were carried out to study the effects of biofungicides based on Trichoderma harzianum, Bacillus subtilis, and Pseudomonas fluorescens on soil microbial communities, plant health, and pathogen suppression. The study revealed that the application of biofungicides enhanced the population of beneficial microorganisms, reduced the density of phytopathogens such as Fusarium oxysporum and Rhizoctonia solani, and increased enzymatic soil activity. Phytosanitary monitoring confirmed that biofungicides contributed to a more stable rhizosphere environment, decreased disease incidence, and improved tomato yield quality. The results highlight biofungicides as key components of sustainable agriculture and integrated pest management (IPM).

1. Introduction

Tomato (*Solanum lycopersicum L.*) is one of the most economically significant vegetable crops worldwide. However, its cultivation faces major constraints due to the presence of soil-borne pathogens such as *Fusarium oxysporum*, *Rhizoctonia solani*, and *Pythium spp.*, which cause root rot and wilt diseases. These pathogens not only damage the roots but also disturb the natural microbial balance of the rhizosphere, leading to yield reductions of up to 40–60% in some regions.

Conventional chemical fungicides, though effective for disease control, have several disadvantages. Their prolonged use can result in pathogen resistance, soil toxicity, environmental contamination, and negative effects on beneficial microorganisms. Hence, there is an urgent need for eco-friendly alternatives that maintain soil health while ensuring effective plant protection.

Biofungicides, which are formulations containing living microorganisms such as *Trichoderma*, *Bacillus*, and *Pseudomonas* species, have emerged as a sustainable solution. These agents exhibit antagonistic activity against phytopathogens through mechanisms such as mycoparasitism, antibiosis, enzyme secretion, and competition for nutrients and space. Moreover, they enhance plant growth by stimulating systemic resistance and improving nutrient uptake.

The present study was undertaken to evaluate the effectiveness of biofungicides in forming a stable microbiological balance within the tomato root zone and to perform phytosanitary monitoring to assess disease suppression, soil microbial activity, and overall plant performance throughout the vegetation period.

2. Materials and Methods

2.1. Experimental Site and Conditions

The experiments were conducted at the Soil Microbiology Department of the Agricultural Research Institute (Tashkent region) during the 2024–2025 growing season. The experimental soil was a light loam, with neutral pH (6.9–7.2), medium humus content (1.8%), and moderate nitrogen and phosphorus levels. The average temperature during the vegetation period ranged from 25°C to 32°C, with relative humidity of 65–75%.

2.2. Plant Material and Treatments

Tomato variety *Navruz* was selected for the experiment due to its sensitivity to soil-borne pathogens and its widespread use in regional agriculture. Four treatments were established:

- **T1:** *Trichoderma harzianum* biofungicide (2×10^7 CFU/ml)
- **T2:** *Bacillus subtilis* biofungicide (1×10^8 CFU/ml)
- **T3:** *Pseudomonas fluorescens* biofungicide (1×10^8 CFU/ml)
- **C (Control):** Untreated soil (no biofungicide)

The biofungicides were applied as a soil drench at transplanting and again 30 days later. Each treatment was replicated three times in a randomized block design, with each plot measuring 2×3 m and containing 20 tomato plants.

2.3. Microbiological and Phytosanitary Monitoring

Soil samples were collected from the rhizosphere at depths of 10–15 cm at 15-day intervals. Microbial counts were determined by the plate dilution method on selective media: Czapek-Dox agar for fungi, nutrient agar for bacteria, and actinomycete agar for actinomycetes. Pathogen density was determined by plating root fragments on potato dextrose agar (PDA) and identifying colonies morphologically.

Enzymatic activity (dehydrogenase and phosphatase) was measured using colorimetric assays to assess biological soil activity. Disease incidence was calculated as the percentage of infected plants in each treatment. Data were analyzed statistically using ANOVA, and mean differences were compared with the LSD test at $p \leq 0.05$.

3. Results and Discussion

3.1. Microbial Population Dynamics

Application of biofungicides significantly influenced the composition and density of soil microflora. The total bacterial count increased by 45% in the *Trichoderma* treatment, 40% in the *Bacillus* treatment, and 38% in the *Pseudomonas* treatment compared to the control. The population of beneficial fungi also increased, indicating the establishment of a favorable microbial balance in the rhizosphere.

The biofungicides stimulated the proliferation of antagonistic microorganisms that suppressed phytopathogens by competing for carbon sources and producing antifungal metabolites. *Trichoderma harzianum* was particularly effective due to its strong mycoparasitic activity and ability to produce chitinase and glucanase enzymes, which degrade the cell walls of pathogenic fungi.

3.2. Disease Incidence and Soil Health

Phytosanitary monitoring revealed a significant decrease in disease incidence across all treated plots. The rate of *Fusarium* wilt infection in control plants reached 56%, whereas in *Trichoderma*, *Bacillus*, and *Pseudomonas* treatments, it was reduced to 16%, 20%, and 23%, respectively. This demonstrates the superior performance of *Trichoderma harzianum* in disease suppression.

Enzyme activity analyses confirmed enhanced biological functioning in treated soils. Dehydrogenase activity increased 1.8-fold and phosphatase activity 1.5-fold relative to the control, indicating improved soil respiration and nutrient cycling. These results align with those of Meena et al. (2022), who reported similar findings in biofungicide-treated vegetable crops.

3.3. Plant Growth and Yield Parameters

The improved microbiological and phytosanitary conditions positively affected plant growth. Tomato plants in biofungicide treatments exhibited stronger root systems, greener foliage, and larger fruits. Average yield increased by 28% in *Trichoderma*, 24% in *Bacillus*, and 21% in *Pseudomonas* treatments compared to the control. Moreover, fruit quality indicators—such as vitamin C content and firmness—also improved.

3.4. Discussion

The results confirm that biofungicides contribute to establishing a balanced soil micro-ecosystem where beneficial microorganisms predominate. The suppression of pathogens occurs through multiple synergistic mechanisms, including antibiosis, enzyme activity, and competition. Maintaining such microbial equilibrium ensures the long-term health of both soil and plants.

In contrast to synthetic fungicides, biofungicides do not disrupt soil biodiversity or lead to chemical residues. This makes them an essential element of sustainable and organic agriculture.

4. Conclusion

The application of biofungicides based on *Trichoderma harzianum*, *Bacillus subtilis*, and *Pseudomonas fluorescens* significantly improved the microbiological balance of tomato root zones and maintained a stable phytosanitary condition throughout the growing season. These treatments enhanced beneficial microbial activity, reduced phytopathogenic populations, increased enzymatic soil activity, and improved plant growth and productivity.

Regular phytosanitary monitoring confirmed that biofungicides can be effectively integrated into ecological farming systems as a sustainable approach to disease control. Future research should focus on combining biofungicides with organic amendments and studying their long-term effects on soil health and microbial diversity..

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