



BIOLOGICAL CONTROL MEASURES AGAINST ROOT DISEASES IN LAVENDER (*LAVANDULA ANGUSTIFOLIA*)

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Abstract: The research identifies root diseases in *Lavandula angustifolia* (lavender) while evaluating natural biological controls instead of traditional chemical fungicides. The availability of essential oils from Lavender along with its medicinal properties makes the plant vulnerable to *Fusarium* spp., *Rhizoctonia solani*, *Pythium* spp., and *Verticillium* spp. soil-borne pathogens. Soil-borne pathogens result in root rot, growth impairment, and plant death and this leads to substantial yield decrease with concurrently diminished quality. This research examines *Trichoderma harzianum* along with *Bacillus subtilis* and *Pseudomonas fluorescens* biological agents since these microorganisms demonstrate their pathogenic inhibition abilities through antibiosis and parasitic and competitive exclusion methods in order to prevent environmental chemical treatment risks. The paper discusses three complementary agricultural methods including compost application along with crop rotation and bio-fumigation within integrated disease control systems. The investigation combines literature review with data collected from lavender farming areas of Uzbekistan to showcase how biological techniques function in their native agroecological environment. Multiple trials conducted by researchers reveal disease incidents reduce substantially along with an enhanced plant health condition following biological control implementation. The article demonstrates how biological control strategies contribute to enhanced lavender crop sustainability by adopting environmentally friendly agricultural practices globally. Scientific studies and the local development of biological control agents should continue to support successful large-scale adoption within the Uzbekistan lavender sector.

Keywords: *Lavandula angustifolia*, root diseases, biological control, *Trichoderma harzianum*, *Bacillus subtilis*, *Pseudomonas fluorescens*, *Fusarium* wilt, eco-friendly plant protection, rhizosphere microbiology, sustainable agriculture

Introduction

The aromatic and medicinal plant *Lavandula angustifolia* receives high importance in cultivation because its essential oil extracts serve the perfume industry and cosmetics and traditional healing applications. The cultivation of lavender has become more popular in Uzbekistan since it tolerates dry environments and produces economic benefits and shows suitability across different soil and climate zones. The cultivation of lavender faces economic threats because several soil-borne pathogens infect roots which causes serious agronomic problems and economic losses. The major root diseases which affect lavender include fusarium wilt from *Fusarium* spp. and the root rot infections caused by *Rhizoctonia solani* and *Pythium* spp. and verticillium wilt from *Verticillium* spp. The pathogens show challenging control characteristics as they exist in the soil long-term and easily spread when environmental conditions support their growth. Short-term control strategies that use fungicides create environmental risks and harm soil sustainability as well as native organisms

within the surrounding areas. Biological control represents an attractive alternative because present global agricultural movements focus on sustainable eco-friendly farming methods. Beneficial microorganisms apply natural suppression mechanisms to plants to protect them over time while retaining a friendly impact on the environment. The research investigates root diseases in Uzbekistan lavender crops to evaluate biological control agents and sustainable techniques for managing such infections.

Literature Review

“*Fusarium oxysporum* and *Fusarium solani* are among the most destructive pathogens responsible for wilt and root rot in lavender plants, particularly in warm and moist soil conditions” [1], which poses a significant threat to irrigated lavender fields in southern Uzbekistan. These infections flourish in humid conditions, and considering the seasonal irrigation methods prevalent in Uzbekistan's agriculture, their spread might significantly jeopardise lavender yield.

Chemical fungicides help mitigate root infections; nevertheless, they may induce soil toxicity and diminish beneficial bacteria.[2] This concern is particularly significant in Uzbekistan, where soils are frequently calcareous and biologically inert. The application of synthetic fungicides may further compromise the microbial composition of the soil, resulting in diminished fertility and crop resilience over time.

“Biological agents like *Trichoderma harzianum* markedly diminish the prevalence of root rot in aromatic plants via competitive and parasitic mechanisms” [3], rendering them exceptionally appropriate for sustainable disease management. Their implementation in Uzbekistan may prove especially efficacious if native strains are isolated and utilised since they would be more suitably adapted to the local soil and climatic circumstances.

The application of *Bacillus subtilis* enhanced the resistance of lavender plants and augmented root biomass under pathogen stress, which is crucial for lavender grown in salty or semi-arid regions of Uzbekistan.[4] Improved root development enables the plant to better endure environmental shocks and naturally fend off pathogenic invasion.

“Integrated biological methods, such as compost and biofertilizers, establish an antagonistic soil environment that restricts pathogen proliferation” [5], which corresponds with Uzbekistan's objective to restore damaged soils and enhance organic matter content. Advocating for such actions can alleviate disease prevalence while enhancing soil vitality.

Local adaptation of biocontrol agents is crucial for efficacy in field circumstances, especially in areas with severe temperatures, a point that must be underscored while formulating biopreparations for Uzbekistan's continental environment.[6] Choosing microbial strains that are robust to both heat and cold will be essential for maintaining consistent field performance in various locales.

Methodology

This study sought to evaluate the efficacy of biological control techniques in the management of root diseases affecting *Lavandula angustifolia* within the agro-climatic context of Uzbekistan. The study entailed the gathering of symptomatic lavender specimens from designated plantations in the Samarkand and Kashkadarya regions throughout the 2023 growing season. These regions were selected for their growing engagement in lavender farming and their diverse soil and climate characteristics. Plant specimens displaying symptoms of root rot, wilting, and chlorosis were gathered in conjunction with healthy controls for laboratory examination. Root and rhizosphere soil samples were transported to



the laboratory for the isolation of prospective fungal pathogens. Isolation was performed utilising potato dextrose agar (PDA) medium, with plates incubated at 25°C for seven days. Pathogenic fungi were detected using colony morphology, microscopic characteristics, and internal transcribed spacer (ITS) sequencing. The most commonly isolated fungi were *Fusarium oxysporum*, *Rhizoctonia solani*, and *Pythium* spp., recognised as principal causative agents of root disease in aromatic plants.

To assess the efficacy of biological management, indigenous strains of *Trichoderma harzianum*, *Bacillus subtilis*, and *Pseudomonas fluorescens* were chosen according to their established antagonistic characteristics. The biocontrol agents were cultured in a nutrient-dense medium, and standardised suspensions with concentrations of approximately 10^7 CFU/mL were generated for experimental application. Antagonistic interactions were evaluated *in vitro* by dual culture tests, wherein colonies of the pathogen and biocontrol agent were cultivated on the same plate. The suppression of mycelial growth was quantified and represented as a percentage to evaluate antagonistic efficacy. Healthy lavender seedlings were cultivated in sterile soil and infected with one of the identified pathogens for greenhouse testing. Following a 48-hour incubation, biocontrol treatments were administered via root drenching and compared to untreated controls. Growth metrics including plant height, leaf pigmentation, root biomass, and observable disease manifestations were documented throughout a 45-day observation interval.

A field trial was done at a lavender cultivation site in the Samarkand region, in addition to laboratory and greenhouse testing. Lavender plants were organised in randomised plots, and biocontrol chemicals were administered directly to the root zone at monthly intervals during the vegetative phase. The presence of pathogens and the severity of the disease were visually assessed and quantified using a standardised 0–5 disease index. The experimental design facilitated the comparison of individual treatments and a collective biocontrol consortium. Environmental variables, including soil temperature and humidity, were documented to evaluate their impact on treatment efficacy. All gathered data were statistically analysed utilising SPSS 26.0 software. Analysis of variance (ANOVA) was employed to assess the significance of treatment effects, with mean differences evaluated using Tukey's test at a 5% probability threshold. This thorough technique guarantees the assessment of each biological agent's performance in both controlled and practical environments, demonstrating the real-world relevance of biocontrol strategies for lavender cultivators in Uzbekistan.

Results and Discussion

This study's results indicate that biological control agents markedly diminished the occurrence of root illnesses in *Lavandula angustifolia* in both greenhouse and field settings. Of the infections examined, *Fusarium oxysporum* exhibited the most aggressiveness, resulting in observable wilting and root deterioration in untreated plants. The utilisation of biological agents shown differing levels of disease suppression and enhancement of plant development. In the *in vitro* dual culture assay, *Trichoderma harzianum* had the most significant antagonistic action, inhibiting *Fusarium oxysporum* by 68.5%, *Rhizoctonia solani* by 61.2%, and *Pythium* spp. by 58.4%. *Bacillus subtilis* exhibited modest suppression against all pathogens, whereas *Pseudomonas fluorescens* shown notable efficacy against *Pythium* spp. The findings are encapsulated in Table 1.

Table 1. Antagonistic activity of biocontrol agents against root pathogens *in vitro*



(Inhibition of mycelial growth in %)

Patogen	Trichoderma harzianum	Bacillus subtilis	Pseudomonas fluorescens
<i>Fusarium oxysporum</i>	68,5	52,3	44,8
<i>Rhizoctonia solani</i>	61,2	49,1	42,5
<i>Pythium spp.</i>	58,4	46,7	60,9

Greenhouse experiments validated the inhibitory effects found in vitro. Plants subjected to *Trichoderma harzianum* treatment had markedly reduced disease symptoms, preserved superior root architecture, and displayed increased biomass relative to untreated controls. The consortium treatment, comprising a combination of all three treatments, produced the most favourable outcomes for disease reduction and plant vitality. The severity of disease in untreated plants was 75%, but it diminished to 28% in *Trichoderma*-treated plants and further reduced to 19% in the consortium group. Field trials further corroborated these findings in natural growth circumstances in Uzbekistan. The consortium of biological agents diminished the disease severity index (DSI) to 22.4% in contrast to 68.7% in the untreated control group. Treated plants exhibited enhanced flowering and elevated essential oil content (results not presented in the table), indicating a potential indirect benefit on crop quality.

The uniformity of these findings across laboratory, greenhouse, and field settings underscores the potential for incorporating biological control into lavender disease management strategies. Given Uzbekistan's increasing interest in aromatic and medicinal plants, along with the environmental hazards associated with chemical fungicides, biological methods present a sustainable and efficacious alternative. The regional adaptation of biocontrol strains guarantees improved survival in the extreme climatic circumstances characteristic of Central Asia, hence augmenting the efficacy of these therapies. These findings further endorse the global trend of minimising chemical inputs in agriculture and advocating for environmentally sustainable options for plant health.

Conclusion and Recommendations

This research shows that biological control systems prove effective while being environment-friendly measures to fight root diseases in *Lavandula angustifolia*. Biological agents *Trichoderma harzianum* together with *Bacillus subtilis* and *Pseudomonas fluorescens* succeeded in controlling *Fusarium oxysporum* and *Rhizoctonia solani* alongside *Pythium spp.* pathogens. The applied agents showed substantial success in lowering disease occurrence and Disease intensity while operating both inside greenhouses and open fields. Plant health and disease control reached their best outcomes when all agents including *Trichoderma harzianum* in the biocontrol consortium were applied together due to their optimal antagonistic characteristics. The disease severity index decreased by more than 70% throughout treated plots which demonstrated better results against untreated controls. The biological agents enhanced the root development as well as plant vigor and improved flowering capacity of treated lavender plants therefore demonstrating both protective and growth-promoting abilities, and the study evidence points toward biocontrol strategies providing a beneficial alternative to chemical fungicides that cause damage to soils and environmental systems. Adaptation and production of local strains for extensive biological agent application are crucial because Uzbekistan faces a sharply continental climate together with a growing demand for sustainable agriculture. Farmer education programs combined



with technical training must be established to help lavender growers introduce biocontrol techniques into their current production systems. The establishment of biological disease management systems through a complete framework will sustain lavender productivity for the long-term while maintaining ecological stability in the regional environment.

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