ISUBU
Journal of Agriculture Faculty
Ziraat Fakültesi Dergisi
ISSN 1304-9984 e-ISSN 2687-3419
https://dergipark.org.tr/tr/pub/sduzfd
Vol. 20, Issue. 1, pp. 1-7, June 2025 Araştırma Makalesi/Research Article

# Fungal Diseases in Lavender Fields of the Lakes Region of Turkey

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## Abstract

*Lavender (Lavandula spp.) is an economically significant aromatic plant widely cultivated in the Lakes Region of Turkey. This study aimed to determine fungal diseases affecting lavender cultivation in the region and to assess disease severity. A total of 277 fungal isolates were obtained from 98 symptomatic lavender plants collected from Isparta, Afyonkarahisar, Denizli, and Burdur. The most frequently isolated fungal genera were Fusarium (5.92–17.38%), Epicoccum (3.78–7.03%), Alternaria (3.00–5.40%), Rhizoctonia (0.80–1.20%), and Macrophomina (2.30%). Pathogenicity tests on Lavandula x intermedia 'Super A' seedlings revealed that Rhizoctonia spp. (80.0%), Epicoccum spp. (77.7–83.3%), and Fusarium spp. (66.6–88.8%) caused varying levels of disease severity. Since the Lakes Region accounts for 42% of Turkey's total lavender production, the findings of this study provide data that can reflect fungal pathogens and disease severity in lavender cultivation nationwide.*

## Article Info

Received:12.03.2025
Accepted:16.04.2025

## Keywords

*Lavandula* spp.
Lavender pathogenic fungi
Lakes region

## Türkiye'deki Göller Bölgesi Lavanta Alanlarında Fungal Hastalıklar

## Öz

*Lavanta (Lavandula spp.), Türkiye'de özellikle Göller Bölgesi'nde yaygın olarak yetiştirilen ekonomik değeri yüksek aromatik bir bitkidir. Bu çalışma, bölgede lavanta tarımını etkileyen fungal hastalıkların belirlenmesi ve hastalık şiddetlerinin değerlendirilmesi amacıyla gerçekleştirilmiştir. Çalışma kapsamında, Isparta, Afyonkarahisar, Denizli ve Burdur illerinde hastalık belirtisi gösteren 98 lavanta bitkisinden toplam 277 fungal izolat elde edilmiştir. En sık izole edilen cinsler Fusarium (%5.92–17.38), Epicoccum (%3.78–7.03), Alternaria (%3.00–5.40), Rhizoctonia (%0.80–1.20) ve Macrophomina (%2.30) olarak belirlenmiştir. Lavandula x intermedia 'Super A' fideleri üzerinde yapılan patojenite testlerinde, Rhizoctonia spp. (%80.0), Epicoccum spp. (%77.7–83.3) ve Fusarium spp. (%66.6–88.8) farklı seviyelerde hastalık şiddeti göstermiştir. Göller Bölgesi, Türkiye'deki toplam lavanta üretiminin %42'sini oluşturduğundan, bu çalışmada elde edilen bulgular lavanta tarımında görülen fungal patojenler ve hastalık şiddetleri açısından ülke geneline yansıyabilecek veriler sunmaktadır.*

## Anahtar Kelimeler

Göller bölgesi
Lavanta patojenik fungusları
*Lavandula* spp.

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## Introduction

Lavender (*Lavandula* spp.) is a widely cultivated aromatic plant with significant economic importance due to its applications in the cosmetics, pharmaceutical, and food industries (Lis-Balchin, 2002; Upson and Andrews, 2004). Its essential oil is highly valued for its antimicrobial and antioxidant properties, making it a key ingredient in perfumes, personal care products, and medicinal formulations (Beetham and Entwistle, 1982). The global demand for lavender and its derivatives has led to an expansion of cultivation areas, particularly in regions with suitable climatic conditions.

Turkey has emerged as a major lavender producer, with the Lakes Region playing a crucial role in national production. This region, encompassing the provinces of Isparta, Afyonkarahisar, Denizli, and Burdur, accounts for approximately 42% of Turkey's total lavender cultivation (Turkish Statistical Institute [TSI], 2023). The region's favorable climate and soil conditions have contributed to the rapid expansion of lavender farming, supporting both agricultural production and ecotourism activities (Baydar, 2021). However, the increasing cultivation area has also heightened the risk of plant diseases that threaten yield and quality.

Fungal pathogens are among the most significant biotic factors affecting lavender production, causing root rot, vascular wilt, and stem necrosis. Several fungal genera, including *Fusarium*, *Rhizoctonia*, *Epicoccum*, and *Macrophomina*, have been reported as major threats to lavender crops worldwide. *Fusarium oxysporum* has been identified as the causal agent of vascular wilt in lavender, leading to severe chlorosis, wilting, and plant death (Ortu et al., 2018). *Rhizoctonia solani* has been associated with black stem rot, a rapidly spreading disease resulting in complete plant collapse (Garibaldi et al., 2015). *Epicoccum sorghinum* has been reported as an emerging pathogen causing stem necrosis and plant decline (Gu et al., 2021), while *Macrophomina phaseolina* has been implicated in charcoal rot, a destructive root disease leading to substantial yield losses (Palacıoğlu et al., 2024). Despite these reports, studies on fungal diseases affecting lavender in Turkey remain limited, with most research focusing on first reports rather than comprehensive pathogen identification and disease severity assessments.

Despite the increasing interest in lavender cultivation, there has been no comprehensive study on fungal pathogens affecting lavender production in Turkey. The last available study on this subject, conducted in 1996, reported *Armillaria mellea*, *Rosellinia necatrix*, *Septoria lavandulae*, and *Ophiobolus brachystoma* as fungal pathogens associated with lavender (Ceylan, 1996). However, more recent research on this topic has been limited, with most studies focusing on first reports rather than providing a broader assessment of fungal prevalence and pathogenicity.

This study aimed to identify fungal pathogens affecting lavender cultivation in the Lakes Region of Turkey using morphological methods, determine their prevalence, and assess their pathogenicity. Given the region's significant contribution to national lavender production, the findings of this study are expected to provide valuable insights into the fungal diseases threatening lavender farming in Turkey.

## Material and Method

### *Survey and sample collection*

This study was conducted between May and October 2022 in major lavender-growing areas of the Lakes Region (Isparta, Afyonkarahisar, Denizli, and Burdur). A total of 98 symptomatic lavender plants were sampled, exhibiting root and crown browning, wilting, stem lesions, and vascular bundle discoloration. From these plants, a total of 277 fungal isolates were obtained. Purposive sampling was applied to ensure that only symptomatic plants were analyzed. The number of samples collected per province was determined based on the extent of lavender cultivation in each region (Table 1).

**Table 1.** Lavender production areas and number of samples by province (TSI, 2023).

| Provinces | Production Area (da) | | | Number of samples |
|---|---|---|---|---|
| | 2020 | 2022 | 2023 | |
| Isparta | 5596 | 8071 | 8262 | 37 |
| Afyonkarahisar | 3327 | 4625 | 4634 | 28 |
| Burdur | 2821 | 3443 | 3896 | 23 |
| Denizli | 1760 | 4143 | 5113 | 10 |
| Total | 13 504 | 20 282 | 21 905 | 98 |

Samples were obtained from six locations in Kuyucak Village (Isparta), five locations in Dinar District (Afyonkarahisar), five sites on the Burdur Mehmet Akif Ersoy University (MAKÜ) campus, and the Gündoğar lavender garden in Acıpayam (Denizli).

### *Fungal isolation and morphological identification*

Fungal isolation was performed using standard mycological techniques. Small (4–5 mm) tissue segments were excised from symptomatic plant regions, surface-sterilized with 2% sodium hypochlorite (NaClO) for 2 minutes, and rinsed three times with sterile distilled water. The samples were then dried on sterile filter paper and placed onto Potato Dextrose Agar (PDA, Merck) plates, with five tissue segments per plate. Emerging fungal colonies were subcultured to obtain pure isolates.



 DOI: 10.54975/isubuzfd.1656177

For morphological identification, slide cultures were prepared on PDA medium and incubated at 25 °C for 5–15 days (Booth, 1977). Microscopic examinations were conducted to assess hyphal branching, phialides, microconidia, macroconidia, chlamydospores, and sporodochium structures. The sizes of conidia were measured under a Nikon Eclipse E100 microscope at 10x and 40x magnifications, with 30–50 macroconidia and 25 microconidia measured per species.

*Fusarium* species were identified based on their characteristic phialides, microconidia, macroconidia, and chlamydospores (Barnett and Hunter, 1972; Samson et al., 1995). *Rhizoctonia* species were determined according to vegetative hyphal characteristics and the number of nuclei per cell (Ogoshi, 1975; Bandoni, 1979). *Macrophomina* species were identified by colony morphology, mycelial structure, and microsclerotium formation (Ashby, 1927; Goidanich, 1947). *Epicoccum* species were classified based on their distinctive sporulation patterns and colony characteristics (Schol-Schwarz, 1959).

### *Pathogenicity tests and disease severity assessment*

Pathogenicity tests were conducted using the most prevalent fungal isolates from each location. The pathogens were cultured on PDA medium supplemented with wheat substrate and incubated at 24 °C for 28 days, then stored at +4 °C for later use (Atakan, 2014).

*Lavandula* x *intermedia* 'Super A' seedlings (n=40) were planted in sterilized soil and arranged in a randomized block design, with three replicates per treatment. Sterile wheat culture portions (3 g each) were placed at the root collar of each seedling and covered with soil. Plants were irrigated as needed.

Disease severity was assessed using standard 1–5 and 0–3 rating scales for *Fusarium*, *Rhizoctonia*, and *Epicoccum* spp.:

*Fusarium* spp. disease severity scale (Prados-Ligero et al., 2007), (1–5 scale):

1 = Healthy plant

2 = Chlorosis in the lower part of the plant

3 = Chlorosis or wilting in the lower part and 1/3 of the plant

4 = Wilting symptoms observed in several leaves in the upper part of the plant

5 = Dead plant

*Rhizoctonia* spp. disease severity scale (Cartwright, 1995), (1–5 scale):

1 = No disease symptoms

2 = Less than 25% of the stem covered with lesions

3 = 26–50% of the stem covered with lesions

4 = 51–75% of the stem covered with lesions

5 = Stem completely surrounded by lesions or dead plant

*Epicoccum* spp. disease severity scale (Ambang et al., 2023), (0–4 scale):

0 = No disease symptoms

1 = Mild infection (1–25% of leaf area affected)

2 = Moderate infection (26–50% of leaf area affected)

3 = Severe infection (51–75% of leaf area affected)

4 = Very severe infection or plant death (76–100% of leaf area affected)



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Disease severity percentages were calculated following Townsend and Heuberger (1943) using the formula:

$$\% \text{ Disease severity} = \frac{\sum(n.v)}{(N.V)}\ x\ 100 \quad (1)$$

Where; n: scale value, v: number of plants corresponding to that scale value, N: highest scale value, V: total number of plants assessed.

*Frequency of fungal pathogen isolation*

The frequency of fungal pathogen isolation was calculated as the percentage of isolates belonging to each fungal genus among all collected samples (Spurr and Welty, 1972):

$$\% \text{ Frequency} = \frac{\text{Total number of isolates belonging to the genus}}{\text{Total number of isolates}}\ x\ 100 \quad (2)$$

This calculation allowed for the determination of the most dominant fungal pathogens in each region.

## Results and Discussion

Fungal isolates obtained from symptomatic lavender plants varied significantly across the surveyed provinces. *Fusarium* spp. was the most frequently isolated genus, particularly in Burdur (17.38%) and Isparta (11.58%), indicating that this pathogen may play a significant role in lavender decline in these regions. The frequency of *Fusarium* spp. was lower in Afyonkarahisar (5.92%) and Denizli (3.88%), suggesting possible environmental or host-related factors limiting its spread.

*Epicoccum* spp. was predominantly found in Denizli (7.03%) and Afyonkarahisar (6.47%), while *Alternaria* spp. showed the highest occurrence in Denizli (5.4%). The presence of *Rhizoctonia* spp. was confirmed only in Isparta (0.80%) and Afyonkarahisar (1.20%), whereas *Macrophomina* spp. was detected exclusively in Burdur (2.3%), suggesting a region-specific distribution pattern (Table 2).

**Table 2.** Genus-level frequency (%) of fungi isolated from survey areas.

| Provinces | Frequency (%) | | | | | |
|---|---|---|---|---|---|---|
| | *Fusarium* spp. | *Rhizoctonia* spp. | *Epicoccum* spp. | *Macrophomina* spp. | *Alternaria* spp. | The others* |
| Isparta | 11.58 | 0.80 | 4.22 | - | 3.00 | 6.18 |
| Afyonkarahisar | 5.92 | 1.20 | 6.47 | - | 5.30 | 4.34 |
| Burdur | 17.38 | - | 3.78 | 2.30 | 4.12 | 5.57 |
| Denizli | 3.88 | - | 7.03 | - | 5.40 | 2.75 |

*The "others" includes fungal genera requiring molecular confirmation for precise identification, which are not among those listed in Table 2.

The disease severity of fungal isolates was assessed on the 10$^{th}$ day of the pathogenicity tests using fungus-specific disease severity scales. The results are summarized in Table 3.

**Table 3.** Disease severity of fungal isolates in pathogenicity tests (%).

| No | Isolate code | Fungus | Disease severity |
|---|---|---|---|
| 1 | T5-3-2p-2 | *Fusarium* spp. | 73.3 |
| 2 | KU6221 | *Fusarium* spp. | 73.3 |
| 3 | D1321 | *Epicoccum* spp. | 77.7 |
| 4 | AF3623 | *Rhizoctonia* spp. | 80.0 |
| 5 | KU1311 | *Fusarium* spp. | 66.6 |
| 6 | AF2311 | *Fusarium* spp. | 70.0 |
| 7 | D1811 | *Fusarium* spp. | 80.0 |
| 8 | AF1321 | *Fusarium* spp. | 88.8 |
| 9 | AF2411 | *Epicoccum* spp. | 83.3 |

Among the *Fusarium* spp. isolates, disease severity ranged from 88.8% to 66.6%, with the highest severity recorded for AF1321 (88.8%). *Epicoccum* spp. isolates caused disease severity of 77.7% (D1321) and 83.3% (AF2411), while *Rhizoctonia* spp. (AF3623) exhibited a severity of 80.0%.



 DOI: 10.54975/isubuzfd.1656177

These results suggest that *Fusarium* spp. isolates generally exhibited high pathogenicity on lavender plants, while *Epicoccum* spp. and *Rhizoctonia* spp. were also associated with significant disease severity. The observed symptoms, including stem lesions, vascular discoloration, and wilting, align with previous reports on fungal infections in lavender.

The fungal isolates obtained from symptomatic lavender plants in this study were identified as belonging to *Fusarium* spp., *Rhizoctonia* spp., and *Epicoccum* spp., all of which are known to be associated with plant diseases. Pathogenicity tests revealed that these fungal isolates caused significant disease severity on lavender, with *Fusarium* spp. generally exhibiting the highest levels of pathogenicity. The symptoms observed, including stem lesions, vascular discoloration, and wilting, align with previous reports of fungal infections affecting lavender and other medicinal plants.

Several studies have reported *Fusarium* spp. as a major pathogen in lavender cultivation. Ortu et al. (2018) identified *F. oxysporum* as the causal agent of vascular wilt in *Lavandula* × *allardii*, demonstrating its host specificity and ability to induce severe disease symptoms. Similarly, Wei et al. (2023) reported an outbreak of root rot caused by *F. foetens* in *L. angustifolia* fields in China, where the disease rapidly spread, affecting 80% of the cultivated area. The high disease severity observed in our study further supports the role of *Fusarium* spp. as an important pathogen in lavender, warranting further investigation into its epidemiology and management.

*Rhizoctonia* spp., another significant genus detected in this study, has also been previously reported as a destructive pathogen in lavender. Garibaldi et al. (2015) identified *R. solani* AG 1-IB as the causal agent of black stem rot in *L. stoechas* in Italy, where the disease led to rapid plant death. The ability of *R. solani* to spread aggressively and colonize plant tissues suggests that it could pose a similar threat to lavender production in Turkey. The observed 80% disease severity caused by *Rhizoctonia* spp. in this study indicates that this pathogen may contribute significantly to lavender decline in the surveyed regions.

*Epicoccum* spp., while often considered a secondary pathogen or endophyte, has recently been recognized for its potential to cause plant diseases under certain conditions. Gu et al. (2021) reported *E. sorghinum* as the causal agent of charcoal rot disease in *L. angustifolia* in China, where it was associated with widespread wilting and necrosis. In our study, *Epicoccum* spp. isolates caused disease severity levels of 83.3% and 77.7%, suggesting that these fungi may also have pathogenic potential in Turkish lavender fields.

The presence of these fungal pathogens in symptomatic lavender plants highlights the complex nature of fungal infections in lavender cultivation. The varying levels of disease severity among isolates suggest that multiple factors, including environmental conditions, host susceptibility, and fungal virulence, may influence disease development. Further research, particularly molecular characterization of isolates and field-based epidemiological studies, is necessary to understand the full extent of fungal threats to lavender production.

## Conclusion

This study identified *Fusarium* spp., *Rhizoctonia* spp., and *Epicoccum* spp. as fungal pathogens associated with symptomatic lavender plants in Turkey. Pathogenicity tests revealed that *Fusarium* spp. isolates exhibited the highest disease severity, followed by *Epicoccum* spp. and *Rhizoctonia* spp.. The observed symptoms, including vascular discoloration, stem lesions, and wilting, indicate that these fungi may play a significant role in lavender decline.

Given the economic importance of lavender as a medicinal and aromatic crop, effective disease management strategies should be prioritized. These strategies may include: a) early detection and monitoring through fungal identification and pathogenicity screening, b) crop rotation and soil health management to reduce soilborne pathogen loads, c) use of resistant lavender cultivars, d) exploration of biological control agents to minimize fungal infections sustainably.

Future studies should focus on the epidemiology of these fungal pathogens, potential host resistance mechanisms, and sustainable disease management approaches. Implementing integrated disease management strategies will be essential to protect lavender production and ensure the sustainability of this economically valuable crop.

*Acknowledgement*

The authors would like to express their gratitude to Isparta University of Applied Sciences, Faculty of Agriculture, Department of Plant Protection for their valuable contributions during the research and manuscript preparation. This study was supported by the TÜBİTAK 2211-C National Ph.D. Scholarship Program for Priority Fields in Science and Technology as part of doctoral research conducted at the Institute of Graduate Education.

*Author Contributions*

The authors equally contributed to the preparation of this paper.

*Conflict of Interest*

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

*Ethics Committee Approval*

As the authors of this study, we confirm that we do not have any ethics committee approval.

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