Plant and Environment
https://journals.pagepal.org/index.php/PlantandEnvironement
ISSN (Online), 2788-7553; (Print), 2788-7545
https://doi.org/10.54219/plantenviron.06.02.2025.308

# Molecular Characterization of Collar Rot of *Aloe vera* caused by *Fusarium phaseoli* in Bahawalpur, Punjab, Pakistan

***Tayyaba Afzal[1*], Roshaan Ahmed[1*], Ikram-ul-haq[3], Muhammad Talha Ikram[2], Muneeb Anwer[2], Amber Javed[1], Laraib Zahid[8], Saima Naeem[8], Saima Jameel[8], Waqas Ahmed Khan[4], Zarmeen Manzoor[5], Sajid Hussain[6], Imran khalid[9] and Muhammad Ahmad Murtaza[8]***

[1]Department of Plant Pathology, Faculty of Agriculture and Environment, The Islamia University of Bahawalpur, 63100, Punjab, Pakistan
[2]Department of Plant Pathology, College of Agriculture, Guizhou University, Guiyang, 550025, China
[3]Department of Plant Breeding and Genetics, University of Sargodha, 40100, Punjab, Pakistan
[4]Department of Plant Pathology, University of Agriculture, Faisalabad, 38000, Punjab, Pakistan
[5]Institute of Microbiology, UVAS, Lahore, 54000, Punjab, Pakistan
[6]Department of Agronomy, Faculty of Agricultural Sciences and Technology (FAS&T) University of Layyah, 31200, Punjab, Pakistan
[7]Department of Plant Pathology, College of Agriculture University of Sargodha, 40100, Punjab, Pakistan
[8]National Agricultural Research Centre (NARC), Islamabad, 45500, Punjab, Pakistan
[9]Department of Agriculture Extension Education, Faculty of Agriculture and Environment, The Islamia University of Bahawalpur, 63100, Punjab, Pakistan

## Article Info

**Keywords:**
Collar rot; *A. vera*; Molecular characterization; Koch's postulate; *Fusarium phaseoli*
**Date:**
Received: 14 October 2023
Accepted: 13 March 2024
Published: 15 June 2024

Volume: 05(01), 2024

**Copyright:** © 2024 by the authors. This article is distributed under the Creative Commons Attribution (CC BY) license, allowing for open access and sharing under specified terms and conditions. (https://creativecommons.org/licenses/by/4.0/).

## Abstract

*Aloe vera is a perennial, succulent, drought-tolerant plant that grows to a height of 60–100 cm. Its leaves are made up of rind, juice, and gel. During the winter and rainy seasons of 2022 and 2023, typical symptoms of collar rot were observed on A. vera plants in selected botanical gardens and commercial nurseries across Bahawalpur, Punjab, Pakistan. Infected plants exhibited light to dark brown necrotic lesions at the collar region, with lesion diameters ranging from 0.2 to 3.0 cm. Hundred infected leaves from 100 different plants with the same symptoms were collected and processed for isolation. Infected leaves were cut into 4 mm and surface sterilized with 1% NaOCl and rinsed thrice with distilled water. These pieces were placed on potato dextrose agar (PDA) medium and incubated for five days at 25 °C ± 2. The resulting colonies of fungus appeared white in color and spores were crescent in shape. Pathogen that consistently isolated from symptomatic tissues and identified as Fusarium phaseoli based on morphological characteristics and molecular characterization of the internal transcribed spacer (ITS) region and β-tubulin of ribosomal DNA. Pathogenicity was confirmed through controlled inoculation assays, fulfilling Koch's postulates. To the best of our knowledge, this represents the first report of F. phaseoli causing collar rot on A. vera in Bahawalpur, Punjab, Pakistan.*

## 1. Introduction

*Aloe vera* (L.) is a perennial succulent, monocot, non woody, drought resistant plant capable of growing in dry areas that grows normally to a height of 60–100 cm (Afrin, 2017). Aloe is a plant genus, belonging to family Aloeaceae (Tiwari et al., 2018), native to tropical and subtropical

Corresponding Author: Roshaan Ahmed* Email: hroshaana98@gmail.com
Tayyaba Afzal* tayyabaafzal254@gmail.com

climates of the world including Africa, India, Asia and China (Riaz et al., 2021). This species, memorably referred to as the "plant of immortality" of the ancient Egyptians (Avasthi et al., 2017) was formally described by Carl Linnaeus in the year 1753. A. vera belongs to xerophytic plant types for its ability to close stomata completely to prevent water loss and to store great amounts of water in its tissues (Silva et al., 2014). Commonly dubbed as a "wonder plant," it has been used for thousands of years for its therapeutic and economic purposes (Durge et al., 2021). Despite being often confused by a cactus, *A. vera* is only one of the more than 550 species of the genus Aloe found across the world (Ogidi et al., 2023). This has established that it plays a prominent role in the global herbal and the nutraceutical industry due to its long-fascinated utilizations in the traditional medicine system (Sen et al., 2017).

*Aloe vera* is a stemless plant that has leathery, triangular, and oblong-shaped leaves with serrated margins which are pale to bright green (Terefe et al., 2017). Morphologically, each leaf consists of three main parts including outer rind, inner juice with central mucilaginous gel, all of which contain most of the bioactive compounds (Saleem et al., 2022). The widely used gel from leaf parenchyma for formulation in pharmaceutical, cosmeceutical and nutraceutical (Martínez-Burgos et al., 2022). Its composition features a fascinating array of more than 200 biologically active compounds, including enzymes, vitamins, minerals, carbohydrates, amino acids, saponins, salicylic acid, and lignin (Saleem, 2021). This broad application throughout the world is diverse both in traditional as well as modern medicine systems and is mediated by its spectrum of phytochemicals (Jadhav et al., 2020). The gel is used topically for minor burns, wounds and skin irritations, and orally for constipation, cough, peptic ulcer, diabetes, migraine, arthritis and immune dysfunction (Tiwari et al., 2018).

*Aloe vera* is prone to multitude of biotic stresses despite its wider therapeutic prominence including fungal and bacterial diseases such as leaf spot, anthracnose, soft rot, dry leaf rot, collar rot, and root rot (Avasthi et al., 2018). Of these, collar rot is especially destructive, deeply changing the host morphological and biochemical characteristics (Meena et al., 2023). Plant pests affect the leaf gel quality and quantity thus reducing its market potential in herbal and cosmetic industry (Avasthi et al., 2019). Due to the great medicinal and ornamental significance of the plant; therefore, the present research work was aimed for isolation identification and characterization of fungal pathogen responsible for collar rot of *A. vera* plants grown in different nurseries and botanical gardens of Bahawalpur, Punjab, Pakistan.

## 2. Materials and Methods

### 2.1. Sample collection:

A survey of the incidence of collar rot of *A. vera* in several botanical gardens and nurseries (Table 1) in Bahawalpur,

**Table 1: Botanical Gardens and Plant Nurseries in Bahawalpur**

| Sr. No. | Garden/Nursery | Latitude (°N) | Longitude (°E) |
|---|---|---|---|
| **1** | Islamia University of Bahawalpur Botanical Garden | 29.3545 | 71.7616 |
| **2** | Noor Mahal Botanical Park | 29.3924 | 71.6752 |
| **3** | Central Park Bahawalpur (Model Town A) | 29.3641 | 71.7470 |
| **4** | Bahawalpur Zoo Garden (Mini Botanical Section) | 29.3978 | 71.6834 |
| **5** | Desert Research Centre – Cholistan Institute of Desert Studies (CIDS) | 29.1730 | 71.7602 |
| **6** | Horticulture Nursery (IUB) | 29.3558 | 71.7594 |
| **7** | Government Nursery Bahawalpur (Forest Department) | 29.4009 | 71.6785 |
| **8** | Private Aloe Vera Farms (Yazman Road Belt) | 29.1075 | 71.7423 |
| **9** | Model Farm Services Nursery | 29.3411 | 71.7288 |
| **10** | Regional Agricultural Research Institute (RARI) | 29.3633 | 71.7035 |



©PagePal. All Rights Reserved.

Punjab, Pakistan was conducted. Ten infected leaves at collar region were collected from each garden as well as nursery and kept in labeled zipper bags for transportation to the laboratory of Department of Plant Pathology. Symptoms morphology was examined using a hand lens and dissecting microscope (Ahmed et al., 2025).

### 2.2. Isolation and purification of pathogen:

The leaves of *A. vera* were collected in the lab and washed thoroughly with distilled water to remove superficial contaminants on the upper surface. The leaves were minced with sterile scalpel blades. Subsequently, the small pieces were surface sterilized with 1% sodium hypochlorite (NaOCl) for 1 min, washed three times with sterile distilled water. The surface sterilized pieces were aseptically inoculated (by sandwiching between blotting papers) unto potato dextrose agar media in petri dishes. The plates were then incubated at 25±2°C for five to seven days and the growth of fungal colonies checked each day (Ahmed et al., 2023).

### 2.3. Pathogenicity test

On healthy *A. vera* leaves pathogen's pathogenicity test was performed under controlled conditions. The fungal species that was isolated cultured on perti dishes containing Potato Dextrose Agar and incubated in incubator for seven to ten days at the temperature of 25±2°C. To make a spore suspension, the conidial concentration was adjusted to $1\times10^9$ per ml with a hemocytometer. Surface sterilization of healthy leaves with a 1 percent sodium hypochlorite (NaOCl) solution was performed for 1 minute. The test fungal organisms' spore suspension was applied using a sprayer and blotting paper that had been moistened. As a control, sterile distilled water was sprayed onto leaves. After 8-10 days, the leaves show typical symptoms of collar rot (Ikram et al., 2023; Ahmed et al., 2025).

### 2.4. Molecular analysis

CTAB (cetyl trimethyl ammonium bromide) method is used for the extraction of the genomic DNA of a fungal isolate (Ahmed et al., 2025). For seven days isolated fungus was allowed to grow on potato dextrose agar (PDA). After the growth of fungal mycelium three plugs were shifted into 250 ml of (PDB) Potato Dextrose Broth and incubated in a shaker incubator under shaking condition (200 rpm) at 28 ± 2°C for 4 days. The mycelium was shifted to a 50 ml of falcon tube and centrifuged to collect the actively growing mycelium. Three grams of mycelium were shifted in 1.5 ml micro tube and washed with double distilled water. This step was repeated three times. After fine washing, keep the mycelium in the tube and discard the water. 500 micro liters of CTAB was added in the tube and incubate it overnight at room temperature. Incubated mycelium was grounded in frozen sterilized pestle mortar. After fine grinding crushed

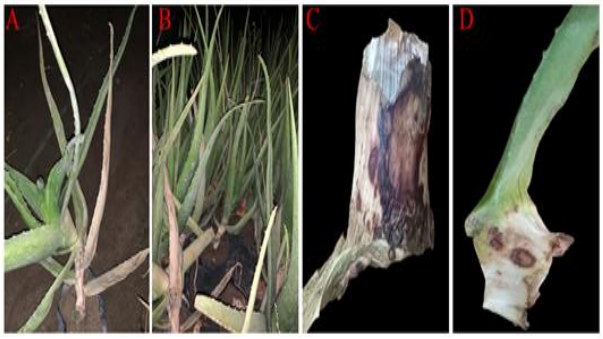



**Figure 1.** (A & B) shows plant having spots on collar region and the gelatinous material of respective leaves were dried, (C) shows the severe symptoms on collar region were spots are coalesce, (D) shows separate spots that vary in size.

mycelium and 400 micro liters of CTAB added in 1.5 ml micro tube and incubated at 65°C for 45 minutes. Tubes were centrifuged for 10 minutes at 12000 rpm. 700 micro liter supernatant was taken in new 2ml tube with 800 micro liters of PCI (Phenol:Chloroform:Isoamyl alcohol) (24:24:1) and centrifuge again at 14000 rpm for 10 minutes. In next step, 700 micro liters of supernatant was taken from the tube and added in 700 micro liters of (Chloroform: Isoamyl alcohol) (24:1). The tubes were centrifuged at 14000 rpm in 10 minutes. This step was repeated three times. The 400 micro liter transparent supernatant was collected in a tube with same amount of isopropanol and incubated for 1.5 hours at -20°C. After incubation the tubes were centrifuged, and DNA pallet was precipitated at the bottom of the tube. The DNA pallet was washed by 70 % ethanol. The washed DNA was suspended in 50 micro liters of double distilled water for gel electrophoresis. For confirmation of DNA, 1% gel was prepared by adding one gram of agarose in 100 ml of TAE buffer solution (Bakar et al., 2025; Ahmed et al., 2025).

### 2.5. Primers and amplification conditions

Using the primer pair ITS1, the internal transcribed spacer region ITSF (TCCGTAGGTGAACCTGCGG) and ITSR (TCCTCCGCTTATTGATATGC) and b-tubulin, b-tubF (GGTAACCAAATCGGTGCTGCTTTC) and b-tubR (ACCCTCAGTGTAGTGACCCTTGGC) of ribosomal DNA was amplified and sequenced. DNA samples were sequenced by Macrogen, Korea. The obtained sequences were submitted on NCBI for registration and after cross checking accession number was assigned against the respective sequences.

## 3. Results



©PagePal. All Rights Reserved.

The survey discovered that no nursery was devoid of collar rot infections. Every eight out of ten plants were associated with collar rot. Infected plant showed necrotic, circular to oval, and sunken dark brown spots and patches on the collar region, ranging in diameter from 0.1 cm to 1.5 cm (Figure 1). After the purification of pathogenic fungus by single spore technique, resulting colonies of fungus appeared white in

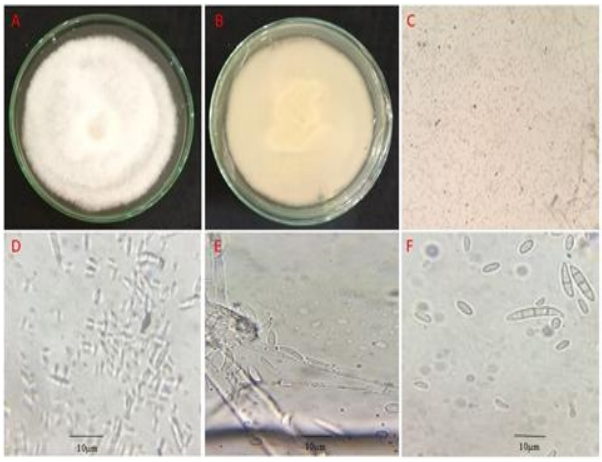



**Figure 2**. (A) shows the front side of pure fungal culture, (B) shows the back side of the culture, (C) shows the presence of tuft of fungal spore at 10X, (D) shows the fungal spores under light microscope at 40X, (E) shows the spore with mycelium at 100X, (F) shows the crescent like single spore of *F. phaseoli.*




**Figure 3**. (A) shows the pathogenicity of *A. vera* after 07 days to satisfy Koch's postulates, (B) shows the severe symptoms of collar rot caused by *F. phaseoli*, (C) shows pathogenicity on detached leaf of *A. vera*.

color and spores were crescent in shape. Based on morphological features, the fungus was identified as *F. phaseoli* (Figure 2). Disease symptoms induced by the fungus *F. phaseoli*, which developed full symptoms after eight days of inoculation, revealed minor changes. A disease of collar rot afflicted many plants, resulting in considerable losses. Necrotic, circular to oval, and sunken dark brown spots and patches on the collar region, ranging in diameter from 0.1 cm to 1.5 cm. The infected plant began to yellow and dry in the

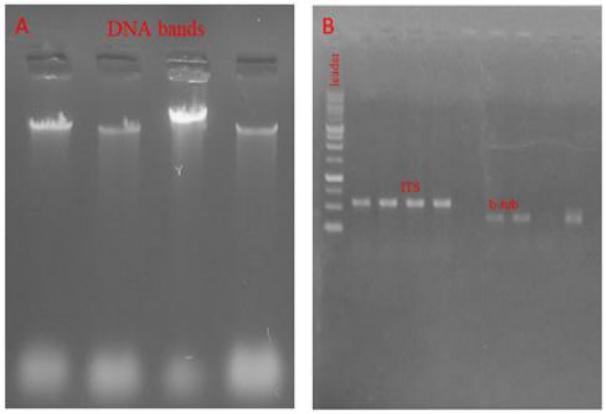



**Figure 4**. (A) Shows the DNA bands of isolated fungus, (B) Shows the bands of ITS and b-Tubulin

later stages of illness, losing their texture and mucilaginous jelly (Figure 3). Molecular identification was done by the extraction of DNA by following the protocol of (Ahmed et al., 2025) with minor modification. Polymerase chain reaction was performed for the amplification of DNA fragments and PCR products were sent to Macrogen (Korea) for sequencing (Figure 4). For amplification, internal transcribed spacer (ITS) and beta-Tubulin (b-Tubulin) primers were used. After getting the positive bands on gel samples were sent to Korea for sequencing. Based on sequencing and their submission in NCBI respective accession numbers were assigned for ITS and b-Tubulin primer OQ569155 and OQ067926 respectively which show 99.71% resemblance with KU180458 and DQ092469 respectively. These sequences were blast on NCBI to check the hierarchy of the fungus. Ten most resembling fungus sequences were downloaded, and their resemblance was found by using Mega 11 (Figure 4 and 5).

## 4. Discussion

The genus *Fusarium* represents one of the most important groups of economically relevant phytopathogenic fungi (Nikitin et al., 2023) with a broad host range of plants leading to various diseases, such as wilts, rots, blights and cankers (Zakaria, 2023) with most species functioning as both saprophytes and facultative parasites (Avasthi et al., 2018). Their presence in large numbers in soil and plant debris and



©PagePal. All Rights Reserved.

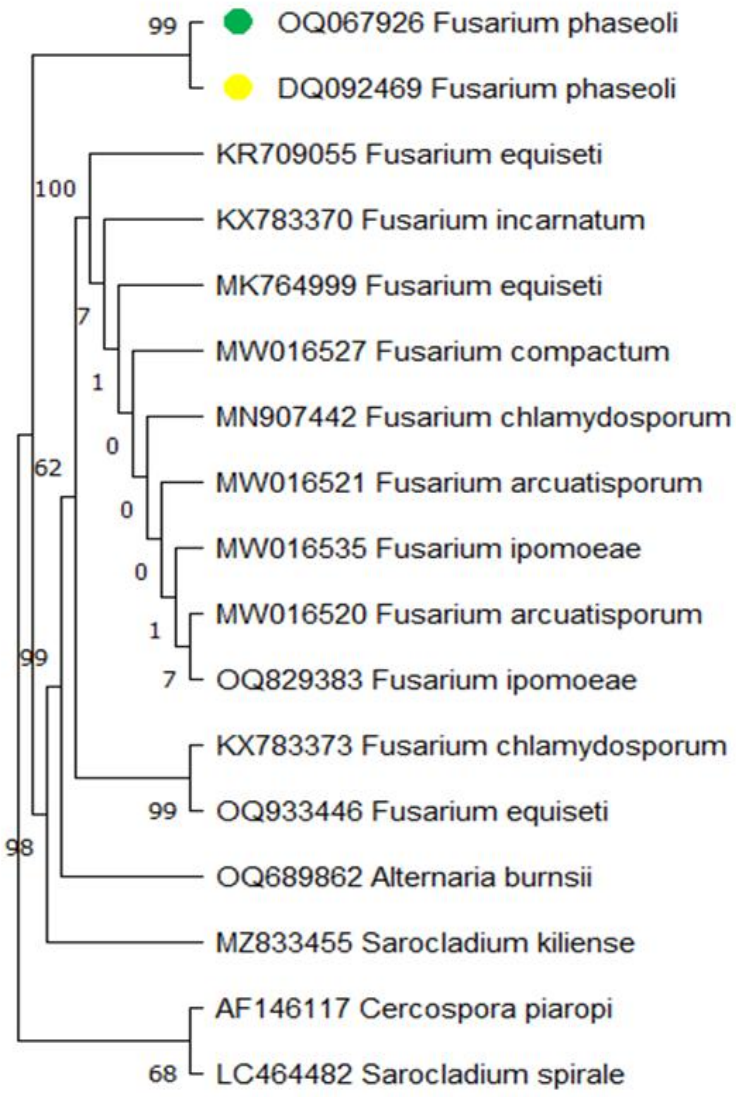



**Figure 5**. A maximum likelihood (ML) phylogenetic analysis was performed to determine the taxonomic placement of the *Fusarium* isolate associated with collar rot of *A. vera*, based on the β-tubulin (*TUB2*) gene sequence obtained in this study. The analysis was conducted using MEGA 11 software. A FASTA file comprising twelve β-tubulin gene sequences representing diverse species within the genus *Fusarium*, along with *Alternaria burnsii* as an outgroup, was retrieved from the National Center for Biotechnology Information (NCBI) GenBank database. These reference sequences, each identified by their respective accession numbers, were aligned with the query sequence (accession no. OQ067926) generated in this investigation. The alignment was compiled into a single dataset and analyzed using the maximum likelihood method in MEGA 11 under the best-fit nucleotide substitution model selected by the software. Branch support was assessed using nonparametric bootstrap (NPM) analysis with 1,000 replicates, and bootstrap values (expressed as percentages) are indicated at the corresponding nodes. The scale bar represents the number of nucleotide substitutions per site. The resulting phylogenetic tree revealed that the isolate OQ067926 clustered with high bootstrap support within a clade containing *F. phaseoli* (GenBank accession no. DQ092469), showing the highest sequence similarity to this reference strain. This close phylogenetic affinity strongly supports the identification of the causal pathogen as *F. phaseoli*.



©PagePal. All Rights Reserved.

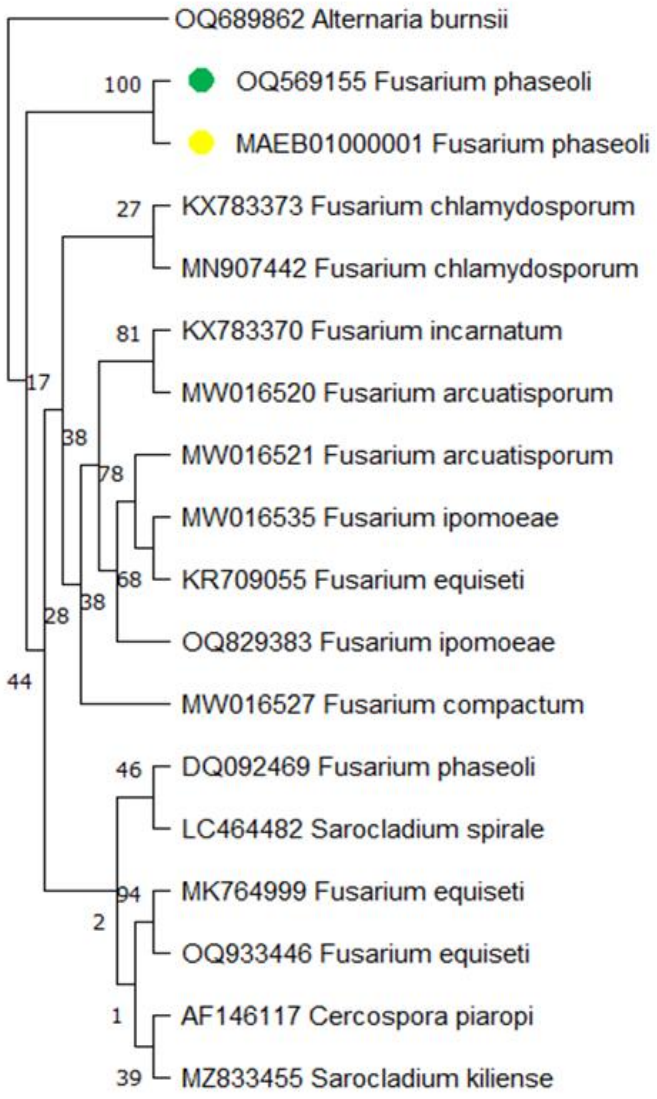



**Figure 6**. A maximum likelihood (ML) phylogenetic tree was constructed to infer the taxonomic identity of the *Fusarium* isolate associated with collar rot of *A. vera*, based on the internal transcribed spacer (ITS) region of ribosomal DNA. The analysis was performed using MEGA 11 software. A FASTA file containing eighteen ITS sequences representing various species within the genus *Fusarium*, along with an ITS sequence of *Alternaria burnsii* designated as the outgroup, was retrieved from the National Center for Biotechnology Information (NCBI) GenBank database. Each sequence was identified by its corresponding accession number. The query sequence generated in this study (accession no. OQ569155) was aligned with these reference sequences, and the combined dataset was imported into MEGA 11 for phylogenetic reconstruction. The ML tree was inferred using the best-fit nucleotide substitution model as determined by the software. Branch support was evaluated through nonparametric bootstrap (NPM) analysis with 1,000 replicates, and bootstrap values (expressed as percentages) are displayed at each node. The scale bar indicates the number of nucleotide substitutions per site. Phylogenetic analysis revealed that the isolate OQ569155 grouped with strong bootstrap support within a clade containing *F. phaseoli* (GenBank accession no. MAEB01000001), demonstrating the highest sequence similarity to this reference strain. This close clustering confirms the identification of the pathogenic isolate as *F. phaseoli.*



©PagePal. All Rights Reserved.

their ability to form highly resilient spores, known as chlamydospores, grants them capacity to survive in their environment for long periods of time and then for an even longer time to colonize the host if the conditions are favorable (Nikitin et al., 2023). In addition to crop losses, many of the Fusarium species are well known as producers of mycotoxins such as fumonisins, trichothecenes, and zearalenone exposing humans and animals to serious health risk via contaminated food and herbal products (Munkvold et al., 2021). Fusarium infections have particularly devastating consequences in medicinal and aromatic plants (Avan, 2021). One such plant widely utilized in the pharmaceutical, cosmetic, and nutraceutical industries as *A. vera* (Rahman et al., 2021). Earlier, *A. vera* has been reported to suffer from Fusarium diseases such root rot and leaf spot caused by *F. solani* (Bairwa et al., 2008), *F. moniliforme* (Avasthi et al., 2018), and *F. fusaroides* (Avasthi et al., 2019). Particularly, *F. solani* has been isolated from *A. vera* plants suffering from root rot in the Jaipur (Rajasthan) and Jabalpur (Madhya Pradesh) India (Avasthi et al., 2018), although foliar and root pathogens have been linked to diseases in other localities (Ji et al., 2007). In addition, *F. solani*, being the most polyphagous pathogen among the Fusarium sp. species under study, has also been found as a causal organism of root rot in many crops in India including pea (Gibert et al., 2022), tomato (Maurya et al., 2019), fennel (Khaleil et al., 2021), guar Yadav et al., 2022), and Salvia officinalis (Greff et al., 2023).

Fusarium species have broad diversity in cultural, morphological and molecular traits that frequently lead to difficulties in phenotypic identifications to species-level (Bugingo et al., 2025). A more complex taxonomy requires an integrative approach that combines morphological and multi-locus sequence analysis diagnostic capabilities. Though *F. moniliforme*, *F. verticillioides* has been obtained from broad range of hosts leading to malformation in mango (Summanwar et al., 1966; Abdurrehman et al., 2024), fruit rot in banana (Conti Taguali et al., 2024; Salem et al., 2020), wilt in sunflower (Wang et al., 2021; Yang et al., 2024) and stalk rot in sorghum (Raju et al., 1999; Ferrigo et al.,2022) and maize (Belisário et al., 2022; Ryley et al., 2021; Gai et al., 2018) no previous report is available on linking *A. vera* to *F. phaseoli*. To the best of our knowledge, this study represents the first documented case of collar rot in *A. vera* caused by *F. phaseoli*. Given the widespread use of *A. vera* in traditional remedies and commercial products often applied topically or consumed orally, the presence of a pathogenic *Fusarium* species in cultivated plants raises critical biosafety concerns. Fungal contamination may not only reduce gel yield and quality but also introduce mycotoxin residues into herbal preparations, potentially compromising consumer health. Therefore, this first report of *F. phaseoli* induced collar rot in *A. vera* underscores the urgent need for phytosanitary monitoring, disease-resistant cultivar development, and adoption of good agricultural practices in *A. vera* production systems. In conclusion, our findings expand the known host range of *F. phaseoli* and highlight an emerging threat to *A. vera* cultivation in Pakistan. This work provides a foundational reference for future diagnostics, epidemiological studies, and integrated disease management strategies targeting *Fusarium* collar rot in this high-value medicinal crop.

## 5. Conclusion

*Aloe vera* growth habit favor collar rot caused by *F. phaseoli*, because older, senescing leaves commonly droop to low hanging positions where they often contact short soil areas. The distance between these organs is very close and this leads to a favorable microenvironment for pathogen colonization, especially in humid or over-watered conditions. Fungal spores from infected soil splashed onto basal leaf axils and collar by rain splash or by overhead watering may be dislodged and spread from the soil and then infect the plant through natural openings or small wounds. Soil-to-plant transmission is a well-known pathway for many diseases caused by Fusarium and seems to be an important part of the epidemiology of collar rot in *A. vera*. In this context it raises serious broader concerns beyond the agronomic loss that pathogenic fungi such as *F. phaseoli* in *A. vera* tissues can cause. Because *A. vera* is commonly used topically and orally in traditional and commercial herbal preparations for a range of human diseases including digestive, dermal, and immune disorders, fungal contamination raises public health concerns. Mycotoxins and other secondary metabolites from the fungus threaten product safety and efficacy may be found in infected plant material. Thus, with regards to health and economic impact, the phytosanitary status of *A. vera* intended for medicinal and cosmetic use must be ensured to protect health from diseases related to this species and maintain the quality of herbal products sourced from this species of economic and therapeutic importance.

## 6. Funding

No funding was received for this study.

## 7. Acknowledgment

The authors are grateful to the University for providing seeds and chemicals for the research.

## 8. Conflict of Interest

The authors declare no conflict of interest.

## 9. Authors' Contribution

Roshaan Ahmed and Tayyaba Afzal supervise and write original draft, Amber Javed collect and analyze the data,



©PagePal. All Rights Reserved.

Ikram-ul-haq, Waqas Ahmed Khan and Zarmeen Manzoor conceptualize the article, Laraib Zahid, Saima Naeem and Saima Jameel optimize the methodology, Sajid Hussain, Awais Ahmed Khan, Muhammad Ahmad Murtaza, Muhammad Talha Ikram and Muneeb Anwer review & edit the article.

**10. SDGs Addressed**

This study supports SDG 2 (Zero Hunger) by improving molecular identification of *Fusarium phaseoli*, enabling effective management of collar rot in *Aloe vera* and reducing crop losses. It contributes to SDG 12 (Responsible Consumption and Production) by promoting targeted disease control and minimizing excessive fungicide use. The research also aligns with SDG 13 (Climate Action) and SDG 15 (Life on Land) by supporting climate-resilient plant disease management and sustainable soil health practices.

**References**


Abdurrehman, Mansoor, T., Subhani, M. N., Malik, M. T., Hasnain, A., Abbas, A., ... & Naqvi, S. A. H. (2024). Unveiling intricacies of mango malformation dynamics caused by Fusarium solani through extensive field surveys and laboratory, epidemiology, and model-based insights. *Applied Fruit Science*, *66*(2), 677-688.

Afrin, N. (2017). Antimicrobial activities of Aloe vera leaf and clove extracts, their comparison with commercial antibiotics and molecular analysis of genes involved with multidrug resistance in bacteria (Doctoral dissertation, BRAC University*).*

Ahmed, R., Aslam, M. N., Moosa, A., Shakeel, M. T., & Maqsood, A. (2023). First report of leaf spot of Aloe vera caused by Curvularia spicifera in Pakistan. *Journal of Plant Pathology, 105*(3), 1193-1193.

Ahmed, R., Raheel, M., Ali, L., Ashraf, W., Aslam, M.N., Faisal, M., Anwer, M., Ikram, M.T., Afzal, T., Iqbal, R. and Ditta, A., 2025. First Report of Leaf Spot of Conocarpus lancifolius Caused by Alternaria burnsii. *Polish Journal of Environmental Studies, 34(5),* pp.6017-6026.

Avan, M. (2021). Important fungal diseases in medicinal and aromatic plants and their control. *Turkish Journal of Agricultural Engineering Research*, *2*(1), 239-259.

Avasthi, S., Gautam, A. K., & Bhadauria, R. (2017). First report of leaf spot disease caused by Polyrostrata indica on Aloe vera from Madhya Pradesh, India. *Suan Sunandha Science and Technology Journal*, *4*(1), 14-18.

Avasthi, S., Gautam, A. K., & Bhaduaria, R. (2018). Isolation and characterization of Fusarium species causing leaf spot and root rot diseases on Aloe vera. *Journal on New Biological Reports*, *7*(1), 1-9.

Avasthi, S., Gautam, A. K., & Bhaduaria, R. (2018). Isolation and characterization of Fusarium species causing leaf spot and root rot diseases on Aloe vera. *Journal on New Biological Reports*, *7*(1), 1-9.

Avasthi, S., Gautam, A. K., & Bhaduaria, R. (2018). Isolation and characterization of Fusarium species causing leaf spot and root rot diseases on Aloe vera. *Journal on New Biological Reports*, *7*(1), 1-9.

Avasthi, S., Gautam, A. K., Vasu, D., & Bhadauria, R. (2019). Occurrence of fungal diseases on Aloe vera plants in Gwalior, Madhya Pradesh, India. *Int J Emer Technol*, *10*, 296-305.

Belisário, R., Robertson, A. E., & Vaillancourt, L. J. (2022). Maize anthracnose stalk rot in the genomic era. *Plant Disease, 106*(9), 2281-2298.

Bairwa, G. L. (2008). Studies on leaf spot of Aloe (Aloe vera) caused by Fusarium solani (Mart) Sacc. Department of plant pathology, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur College of Agriculture Jabalpur (MP)(M. Sc. Thesis).

Bakar, M. A., Ahmed, R., Maqsood, A., Aslam, M. N., & Shakeel, M. T. (2025). First report of leaf spot of Wodyetia bifurcata caused by Alternaria alternata in Pakistan. *Physiological and Molecular Plant Pathology, 136,* 102545.

Wang, D., Su, Z., Ning, D., Zhao, Y., Meng, H., Dong, B., ... & Zhou, H. (2021). Different appearance period of Verticillium wilt symptoms affects sunflower growth and production. *Journal of Plant Pathology, 103*(2), 513-517.

Bugingo, C., Infantino, A., Okello, P., Perez-Hernandez, O., Petrović, K., Turatsinze, A. N., & Moparthi, S. (2025). From Morphology to Multi-Omics: A New Age of Fusarium Research. *Pathogens*, *14*(8), 762.

Ryley, M., Gulya, T., Mathew, F., Thompson, S., Block, C., Markell, S., & Harveson, R. (2021). Sunflower wilt diseases: Charcoal rot, Phialophora yellows, and Verticillium wilt. *Plant Health Progress, 22(1), 75-85.*

Durge, A. A., & Moon, U. R. (2021). Vetiveria zizanioides l. Nash-a wonder plant: an industrial perspective. *Journal of Advanced Scientific Research*, *2021*(ICITNAS), 01-06.




©PagePal. All Rights Reserved.

Ferrigo, D., Mondin, M., & Raiola, A. (2022). Pathogenic and genetic characterization of Fusarium verticillioides strains collected from maize and sorghum kernels. *Agriculture*, *13*(1), 105.

Gai, X., Dong, H., Wang, S., Liu, B., Zhang, Z., Li, X., & Gao, Z. (2018). Infection cycle of maize stalk rot and ear rot caused by Fusarium verticillioides. *PloS one*, *13*(7), e0201588.

Gibert, S., Edel-Hermann, V., Gautheron, E., Gautheron, N., Sol, J. M., Capelle, G., ... & Steinberg, C. (2022). First report of Fusarium avenaceum, Fusarium oxysporum, Fusarium redolens, and Fusarium solani causing root rot in pea in France. *Plant Disease*, *106*(4), 1297.

Khaleil, M. M., Alnoman, M. M., Elrazik, E. S. A., Zagloul, H., & Khalil, A. M. A. (2021). Essential Oil of Foeniculum vulgare Mill. As a green fungicide and defense-inducing agent against fusarium root rot disease in Vicia faba L. *Biology*, *10*(8), 696.

Ikram, M.T., Aslam, M.N., Moosa, A., Zulfiqar, F., Shakeel, M.T., Ahmed, R., Anwer, M. and Khan, A.U.R., 2023. First report of Geotrichum candidum causing rose blight disease in Pakistan. *Journal of Plant Pathology, 105(4),* pp.1755-1756.

Jadhav, A. S., Patil, O. A., Kadam, S. V., & Bhutkar, M. A. (2020). Review on Aloe vera is used in medicinal plant. *Asian Journal of Research in Pharmaceutical Science*, *10*(1), 26-30.

Ji, G., Wei, L., He, Y., & Wu, Y. (2007). First report of aloe root and stem rot in China caused by Fusarium solani. *Plant Disease*, *91*(6), 768-768.

Conti Taguali, S., Riolo, M., Dopazo, V., Meca, G., & Cacciola, S. O. (2024). Characterization of mycotoxins produced by two Fusarium species responsible for postharvest rot of banana fruit. *Journal of Plant Pathology*, *106*(4), 1785-1800.

Greff, B., Sáhó, A., Lakatos, E., & Varga, L. (2023). Biocontrol activity of aromatic and medicinal plants and their bioactive components against soil-borne pathogens. Plants, 12(4), 706.

Martínez-Burgos, W. J., Serra, J. L., MarsigliaF, R. M., Montoya, P., Sarmiento-Vásquez, Z., Marin, O., ... & Paternina-Arboleda, C. D. (2022). Aloe vera: From ancient knowledge to the patent and innovation landscape–A review. *South African Journal of Botany*, *147*, 993-1006.

Maurya, S., Dubey, S., Kumari, R., & Verma, R. (2019). Management tactics for fusarium wilt of tomato caused by Fusarium oxysporum f. sp. lycopersici (Sacc.): A review. *Management*, *4*(5), 1-7.

Meena, R. P., Mandal, K., Patel, M. P., Minipara, D., & Samanta, J. N. (2023). Aetiology and molecular characterization of the pathogens associated with soft rot disease of Aloe vera (L.) Burm. f. *Journal of Applied Research on Medicinal and Aromatic Plants*, *35*, 100492.

Munkvold, G. P., Proctor, R. H., & Moretti, A. (2021). Mycotoxin production in Fusarium according to contemporary species concepts. *Annual Review of Phytopathology*, *59*(1), 373-402.

Nikitin, D. A., Ivanova, E. A., Semenov, M. V., Zhelezova, A. D., Ksenofontova, N. A., Tkhakakhova, A. K., & Kholodov, V. A. (2023). Diversity, ecological characteristics and identification of some problematic phytopathogenic Fusarium in soil: a review. *Diversity*, *15*(1), 49.

Ogidi, O. I., & Enenebeaku, U. E. (2023). Medicinal potentials of Aloe Vera (Aloe barbadensis Miller): technologies for the production of therapeutics. In Sustainable utilization and conservation of Africa's biological resources and environment (pp. 295-321). *Singapore: Springer Nature Singapore.*

Rahman, M. M., Amin, R., Afroz, T., & Das, J. (2021). Pharmaceutical, Therapeutically and nutraceutical potential of Aloe vera: a mini-review. *J Pharm Res Int*, *33*, 109-118.

Raju, N. S., Niranjana, S. R., Janardhana, G. R., Prakash, H. S., Shetty, H. S., & Mathur, S. B. (1999). Improvement of seed quality and field emergence of *Fusarium moniliforme* infected sorghum seeds using biological agents. *Journal of the Science of Food and Agriculture*, *79*(2), 206-212.

Riaz, U., Iqbal, S., Sohail, M. I., Samreen, T., Ashraf, M., Akmal, F., ... & Akhter, R. M. (2021). A comprehensive review on emerging importance and economical potential of medicinal and aromatic plants (MAPs) in current scenario.

Saleem, A., Naureen, I., Naeem, M., Murad, H. S., Maqsood, S., & Tasleem, G. (2022). *Aloe vera* gel effect on skin and pharmacological properties. *Scholars international journal of anatomy and physiology*, *5*(1), 1-8.



©PagePal. All Rights Reserved.

Saleem, M. J. P. J. O. S. (2021). Aloe Barbadensis Miller: a comprehensive review. *Pakistan Journal of Science*, *73*(4).

Salem, N. M., Almomany, A. M., Tahat, M. M., & Aldakil, H. (2020). First report of *Fusarium verticillioides* causing banana fruit rot in Jordan. *Plant Disease*, *104*(12), 3255.

Yadav, D., Jaisani, P., & Mawar, R. (2022). Guar diseases and Management: An Overview.*Current Agriculture*, *39*(2).

Sen, S., & Chakraborty, R. (2017). Revival, modernization and integration of Indian traditional herbal medicine in clinical practice: Importance, challenges and future. *Journal of traditional and complementary medicine*, *7*(2), 234-244.

Silva, H., Sagardia, S., Ortiz, M., Franck, N., Opazo, M., Quiroz, M., ... & Tapia, C. (2014). Relationships between leaf anatomy, morphology, and water use efficiency in *Aloe vera* (*L*) Burm f. as a function of water availability. *Revista chilena de historia natural*, *87*(1), 13.

Summanwar, A. S., Raychaudhuri, S. P., & Phatak, S. C. (1966). Association of the fungus *Fusarium moniliforme* Sheld. with the malformation in Mango (*Mangifera indica L.*).

Terefe, T., & Neges, T. (2017). Review on therapeutic and medicinal use of *Aloe vera*. *Cancer Biol*, *7*(4), 29-38.

Tiwari, M., & Upadhayay, M. (2018). The medicinal plant components and applications (*Aloe vera*). *Journal of Medicinal Plants Studies*, *6*(3), 89-95.

Yang, J., Wang, Y., Shi, S., Li, H., Zhang, W., Addrah, M. E., ... & Zhao, J. (2024). The Isolation and Identification of a New Pathogen Causing Sunflower Disk Rot in China. *Agronomy*, *14*(7), 1486.

Zakaria, L. (2023). Fusarium species associated with diseases of major tropical fruit crops. *Horticulturae*, *9*(3), 322.



©PagePal. All Rights Reserved.

**Disclaimer/Publisher's Note:** The views, opinions, and data presented in all publications are exclusively those of the respective author(s) and contributor(s) and do not reflect the stance of Pagepal or its editorial team. Pagepal and the editor(s) disclaim any responsibility for harm to individuals or damage to property resulting from the use of any ideas, techniques, instructions, or products mentioned in the content.



©PagePal. All Rights Reserved.