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Antibacterial and antioxidant activities of endophytic fungi isolated from *Hyptis suaveolens* L.

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ABSTRACT

Fungal endophytes are a diverse group of fungi that thrive inside healthy plant tissues and provide several benefits to their host plants. They are known to be an excellent source of active secondary metabolites. The aim of the present study was the isolation of fungal endophytes from the stem and leaf tissues of *Hyptis suaveolens* and the evaluation of their secondary metabolites for antibacterial and antioxidant activities. Eleven fungal endophytes were recovered from both the leaf and stem tissues of *Hyptis suaveolens*. Fungal identification was carried out using a combination of microscopy and ITS rRNA sequencing techniques. We observed that *Alternaria* sp. (HL3) exhibited the highest colonisation frequency (24%) in the leaf tissue, while *Talaromyces muroii* (HS1) was predominant in the stem tissue with a colonisation frequency of 12%. Out of eleven fungal endophytes, crude extracts of eight showed positive antibacterial activity against at least one pathogenic bacterium tested, including *Klebsiella pneumoniae*, *Enterococcus faecalis* and MRSA. To define antibacterial activity, we adopted the following inhibition zone scale: (+) = 6 mm, (++) = 6–10 mm, (+++) = more than 10 mm, and (–) = no activity. *Talaromyces muroii* (HS1) demonstrated the best antibacterial efficacy over all three tested pathogenic bacteria, with an inhibition zone greater than 10 mm for each of the tested pathogens. Furthermore, crude extracts of eight fungal isolates exhibited positive antioxidant activity. These findings indicate that the endophytic fungi obtained from *Hyptis suaveolens* exhibit considerable potential as a reservoir of antioxidant and antibacterial compounds.

Keywords: Fungal endophytes, Secondary metabolites, Medicinal plant, Bioactive compounds

INTRODUCTION

Humanity faces significant challenges from emerging new life-threatening diseases and developing resistance in pathogenic bacteria against existing treatments. To tackle this pressing issue, research efforts are crucial in the quest for effective bioactive molecules (Singh *et al.,* 2021). Endophytic fungi, residing within healthy plants, have emerged as a potential source of bioactive compounds of diverse activities, including antibacterial, antiviral, antioxidant, and anticancer (Gautam *et al.,* 2022; Kharwar *et al.,* 2011; Mishra *et al.,* 2019; Verma *et al.,* 2014). Studies indicate that fungal endophytes play a critical role in defending their host plants from both pathogens and environmental stresses (Ma *et al.,* 2025; Pal *et al.,* 2023). Additionally, it has been established that endophytic fungi can produce metabolites originating from their host plants (Singh *et al.,* 2021; Stierle *et al.,* 1993). For example, taxol, an important anticancer drug originally produced from the bark of the *Taxus brevifolia* tree, has also been found in its fungal endophyte *Taxomyces andreanae* (Stierle *et al.,* 1993). Subsequently, other significant compounds, including vincristine, vinblastine, piperine, and azadirachtin, have been identified in endophytic fungi associated with the same host plant (Singh *et al.,* 2021; Varghese *et al.,* 2025; Verma *et al.,* 2011).

Endophytic fungi occupy a unique ecological niche that may stimulate the biosynthesis of novel bioactive metabolites (Abd-Elsalam *et al.*, 2025). The purpose of the current study was to characterise the endophytic fungi from *Hyptis suaveolens*. *H. suaveolens*, a renowned medicinal plant from the Lamiaceae family, is well

recognised for its medicinal properties. The leaves of *H. suaveolens* are known for their diverse medicinal activities, including antibacterial, antifungal, antiulcerogenic, antistress, anticancer, analgesic, antipyretic, anti-inflammatory, and antitumour properties (Mishra *et al.,* 2021). Recent studies have demonstrated the pharmaceutical potential of fungal endophytes, with multi-omics approaches revealing diverse metabolites such as polyketides, alkaloids, and terpenoids that contribute to antimicrobial and antioxidant activities (Varghese *et al.,* 2025). These metabolites act through mechanisms including disruption of bacterial cell walls, alteration of membrane permeability, inhibition of quorum sensing, and scavenging of reactive oxygen species (Bhattacharya *et al.,* 2025). Although *H. suaveolens* is a medicinally important plant with diverse ethnopharmacological uses, no prior studies have reported the isolation or bioactivity assessment of its fungal endophytes. Given the established therapeutic value of *H. suaveolens*, the present study was undertaken to isolate its fungal endophytes from stem and leaf tissues, evaluate their antibacterial and antioxidant activities, and provide preliminary insights into their potential as sources of bioactive metabolites.

MATERIALS AND METHODS

Plant samples

Healthy stem and leaf samples were collected randomly from *H. suaveolens* growing in the campus garden of Banaras Hindu University, Varanasi, India. The samples were immediately brought to the laboratory and stored at 4 ºC for further processing.

Surface sterilisation

Surface sterilisation was performed with slight modifications to a previously outlined method (Petrini *et al.,* 1993; Sahu *et al.,* 2022). Briefly, tissue samples were cleaned under running tap water and then rinsed with double-distilled water (DDW) to eliminate surface-adhered soil and debris. Then, the stems were sectioned into 0.2 to 0.25 cm thick pieces and the leaves were segmented into 0.5×0.5 cm^2 segments using an aseptic pinch cutter. The segments were first subjected to 4% aqueous NaOCl for 3 min, followed by 70% ethanol for 2 min. Subsequently, the tissue sections were washed multiple times using sterile water and dried under a laminar hood before plating. The final wash solution was plated onto PDA and LBA plates to confirm the absence of microbial contamination.

Isolation and identification of fungal endophytes

A total of 100 surface-sterilised tissue segments (50 each from stem and leaf) were transferred onto a PDA plate containing the antibiotic streptomycin sulphate (100 µg ml^{-1}) (4 to 6 segments on each plate) and incubated at 27 ± 2^0C for 15 days. Emerging fungal mycelium surrounding the tissues was transferred onto fresh plates of PDA and subsequently purified. Morphological characterisation of endophytic fungi was based on colony colour and texture, hyphal morphology, and structures of fruiting bodies and conidia. Fungal genera were identified by referring to established taxonomic manuals including Ainsworth et al. (1973), Arx and Schipper (1978), Barnett and Hunter (1999), and Ellis (1976).

Sequencing and molecular identification of endophytic fungal isolates

Following the procedure described by Sim et al. (2010), genomic DNA was isolated from pure fungal isolates. The primers ITS1:5′-TCCGT AGGTGAACCTGCGG-3′ and ITS4:5′-TCCTCC GCTTATTGATAGC-3′ were used to amplify the ITS rRNA region using standard methods described in our previous studies (Mishra *et al.,* 2019; Verma *et al.,* 2014). PCR amplification was carried out in a Bio-Rad T100 Thermal Cycler with an initial denaturation at 95 ºC for 5 min; 34 cycles of 95 ºC for 60 s, annealing at 52 ºC for 60 s, and extension at 72 ºC for 90 s; and a final extension at 72 ºC for 10 min. The resulting PCR products were run on a 1.2% (w/v) agarose gel and visualised. Purification and sequencing of amplified products were performed by AgriGenome Laboratories Pvt. Ltd. (Kerala, India). The ITS rRNA sequences were BLAST searched against the NCBI GenBank sequence database to identify their best matches. All sequences were submitted to NCBI GenBank, and accession numbers were assigned upon deposition. Each sequence was aligned using the ClustalW function in MEGA11 (Tamura *et al*., 2021). A maximum-likelihood phylogenetic tree was then constructed under the GTR+G model with 1000 bootstrap replicates, using two to three

closely related reference sequences retrieved from the NCBI database.

Colonization frequency (%CF) of fungal endophytes

Colonization frequency (%CF) of fungal endophytes was determined employing the formula proposed by Hata and Futai (1995): %CF = (Ncol/Nt) x 100, where Ncol represents the count of plant tissue segments each fungus has colonised and Nt denotes the overall number of tissue segments examined.

Cultivation of fungi and secondary metabolites extraction

Mycelial discs from all actively growing fungal isolates were inoculated into potato dextrose broth (PDB) and incubated for 21 days at 27 ± 2 ºC in a B.O.D. incubator (Supertech, India). After incubation, the fungal mycelia were removed by filtration through four-layered muslin cloth. Secondary metabolites from the filtrate were extracted using ethyl acetate as the organic solvent. The ethyl acetate extracts were concentrated using a vacuum evaporator (IKA, Germany) and collected individually in glass vials. The concentrated metabolites were then allowed to evaporate slowly at room temperature and stored at 4 ºC until further use.

Antimicrobial activity against human pathogenic bacteria

Antibacterial activity of the fungal crude secondary metabolites was evaluated against three human pathogenic bacterial strains, including *Klebsiella pneumoniae* (KP), *Enterococcus faecalis* (EF), and methicillin-resistant *Staphylococcus aureus* (MRSA) with the procedure of disc diffusion described earlier by Hudzicki (2009). These strains were obtained from the Institute of Medical Sciences, BHU, Varanasi, India. Briefly, 20 µl of methanolic extract containing 0.2 mg of crude metabolite was impregnated onto sterilised paper discs (5 mm diameter, Whatman filter paper # 1) and dried for 20 minutes under a laminar hood. These paper discs were individually placed onto NA plates previously seeded with cultures of pathogenic bacteria. For the control disc, 20 µl of only methanol was used. Culture plates were incubated at 27 ± 2 ºC and the inhibition zones surrounding the discs were assessed after 24 h. All the experiments were conducted in triplicate. Antibacterial activity was categorised as (+) = 6 mm, (++) = 6–10 mm, (+++) = >10 mm and (–) = no activity. The assay was performed as a preliminary screening, without inclusion of antibiotic positive controls or statistical validation.

Assessment of antioxidant property

The DPPH (2, 2-di phenyl 2-picryl hydrazyl) free radical scavenging activity was used to analyse the antioxidant property of crude secondary metabolites of fungal isolates. 0.1 ml of methanol-dissolved crude extract (1 mg ml^{-1}) was mixed with 2.9 ml of 100 µM DPPH methanolic solution and incubated for 30 minutes in the dark. The colour change of the DPPH solution from purple to yellow indicated the positive antioxidant activity. The assay was performed qualitatively as a preliminary screening for antioxidant activity.

RESULTS

Isolation, identification and phylogenetic analysis of endophytic fungi

A total of 11 fungal endophytes were recovered from the completely surface-sterilised stem and leaf tissues from five randomly selected *Hyptis suaveolens* plants. The absence of microbial growth in the final wash solution confirmed that surface sterilisation was effective. Based on microscopic examination and ITS rRNA sequencing, the isolates were identified as *Talaromyces muroii* (HS1), *Alternaria angustiovoidea* (HS2), *Alternaria* sp. (HS3), *Alternaria alstroemeriae* (HS4), and *Aspergillus sclerotiorum* (HS5) from stem tissues, and *Cercospora gomphrenigena* (HL1), *Alternaria alstroemeriae* (HL2), *Alternaria* sp. (HL3), *Corynespora* sp. (HL4), *Alternaria pogostemonis* (HL5), and *Alternaria angustiovoidea* (HL6) from leaf tissues (**Table 1**).

Accession numbers and percentage similarity with closest matches were obtained from NCBI GenBank (**Table 1**). Phylogenetic analysis using the maximum-likelihood method clustered all eleven isolates into strongly supported nodes with their respective groups (**Figure 1**).

Table 1: Molecular identification of endophytic fungal isolates of *Hyptis suaveolens* with their closest match from GenBank along with their accession number and total colonisation frequency (%CF).

Plant tissues	Isolates	GenBank accession No.	Closest match from GenBank	(%) Identity	Accession No. of reference species	%CF
Stems	HS1	OR257576	*Talaromyces muroii*	100%	MK450747	12%
	HS2	OR257577	*Alternaria angustiovoidea*	99.43%	MH861939	8%
	HS3	OR257578	*Alternaria* sp.	91.17%	OP341770	4%
	HS4	OR257579	*Alternaria alstroemeriae*	100%	NR163686	4%
	HS5	OR257580	*Aspergillus sclerotiorum*	99.78%	NR131294	12%
Leaves	HL1	OR257570	*Cercospora gomphrenigena*	99.25%	MK442573	16%
	HL2	OR257571	*Alternaria alstroemeriae*	100%	NR163686	12%
	HL3	OR257572	*Alternaria angustiovoidea*	96.24%	MH861939	24%
	HL4	OR257573	*Corynespora torulosa*	96.69%	NR145181	4%
	HL5	OR257574	*Alternaria pogostemonis*	99.43%	OP120855	10%
	HL6	OR257575	*Alternaria angustiovoidea*	97.11%	MH861939	12%

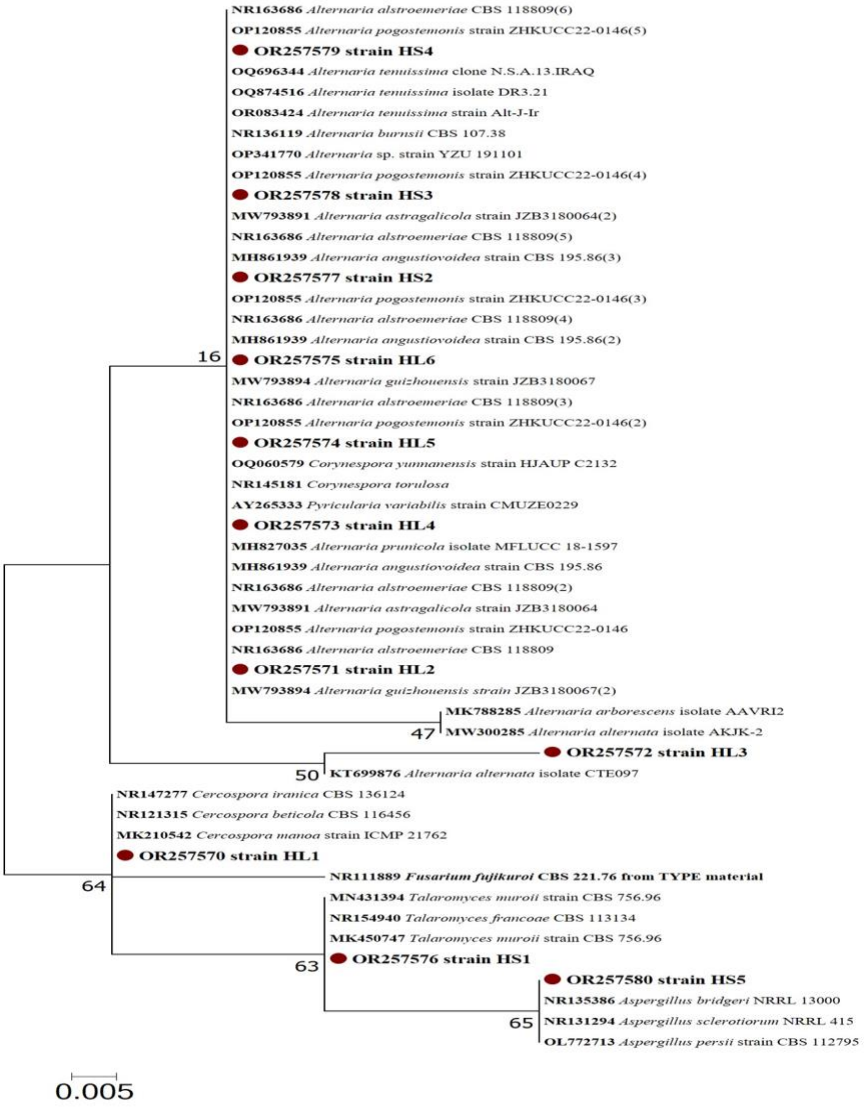


Figure 1: Phylogenetic tree was constructed using the maximum-likelihood method based on 18S rRNA ITS sequences of fungal isolates (highlighted with a red dot) and closest reference sequences retrieved from GenBank (accession numbers indicated). The tree was constructed using GTR+G substitution model with 1000 bootstrap replicates in MEGA11. The tree is rooted with *Fusarium fujikuroi* CBS 221.76 as outgroup.

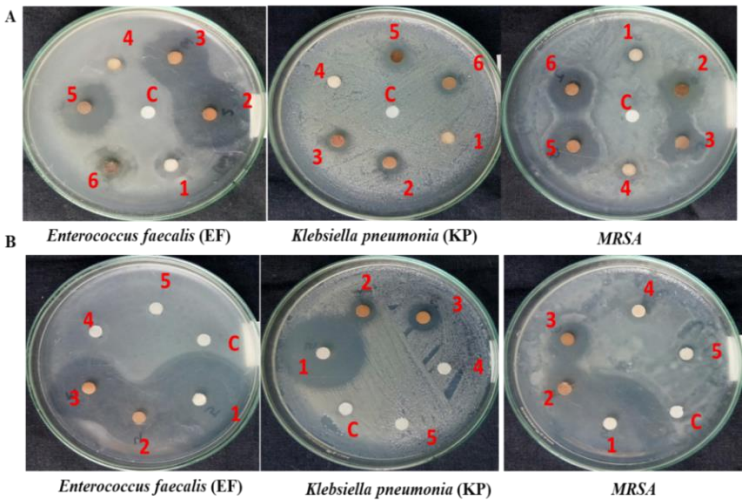


Figure 2: Antibacterial activity of secondary metabolites from endophytic fungi isolated from *Hyptis suaveolens*, evaluated using the disc diffusion assay. A: Endophytic fungi isolated from leaves: 1-*Cercospora gomphrenigena* (HL1), 2-*Alternaria alstroemeriae* (HL2), 3-*Alternaria* sp. (HL3), 4-*Corynespora* sp. (HL4), 5-*Alternaria pogostemonis* (HL5), 6-*Alternaria angustiovoidea* (HL6); B- Endophytic fungi isolated from the stem where: 1-*Talaromyces muroii* (HS1), 2-*Alternaria angustiovoidea* (HS2), 3-*Alternaria* sp. (HS3), 4- *Alternaria alstroemeriae* (HS4), 5-*Aspergillus sclerotiorum* (HS5) and c-control.

Table 2: Antibacterial activity of secondary metabolites of fungal endophytes of *Hyptis suaveolens* using the disc diffusion assay

Isolates	Fungal endophytes	Activity		
		EF	KP	MRSA
HS1	*Talaromyces muroii*	+++	+++	+++
HS2	*Alternaria angustiovoidea*	+	+	+
HS3	*Alternaria* sp.	+	+	+
HS4	*Alternaria alstroemeriae*	-	-	-
HS5	*Aspergillus sclerotiorum*	-	-	-
HL1	*Cercospora gomphrenigena*	+	-	-
HL2	*Alternaria alstroemeriae*	+	+	+
HL3	*Alternaria* sp.	++	+	+
HL4	*Corynespora* sp.	-	-	-
HL5	*Alternaria pogostemonis*	++	+	++
HL6	*Alternaria angustiovoidea*	+	+	++

Where, KP is *Klebsiella pneumoniae,* EF is *Enterococcus faecalis* and MRSA is Methicillin-resistant *Staphylococcus aureus*. Diameter of inhibition zone (+) = 6 mm, (++) = 6–10 mm, (+++) = more than 10 mm and (–) = no activity**.**

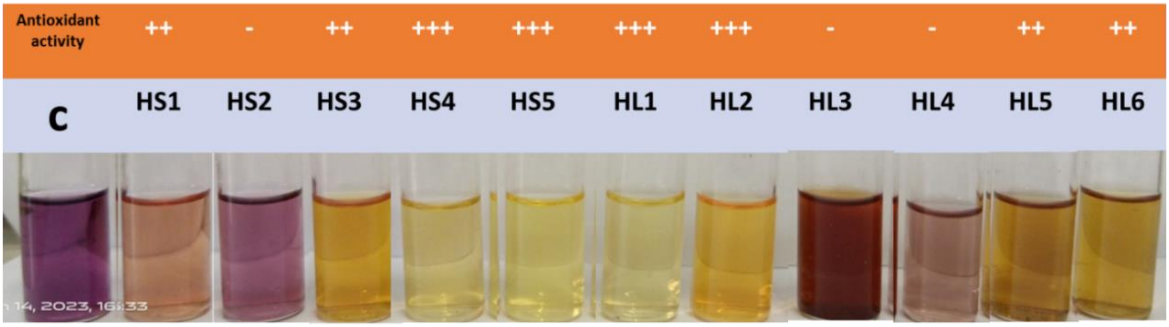


Figure 3: Antioxidant activity of secondary metabolites produced by endophytic fungi isolated from *Hyptis suaveolens.* The activity was evaluated using DPPH radical scavenging assay. Isolates from stem tissues: HS1- *Talaromyces muroii,* HS2-*Alternaria angustiovoidea* HS3-*Alternaria* sp., HS4-*Alternaria alstroemeriae*, HS5-*Aspergillus sclerotiorum*, HL1-*Cercospora gomphrenigena*, HL2-*Alternaria alstroemeriae*, HL3-*Alternaria* sp., HL4- *Corynespora* sp., HL5- *Alternaria pogostemonis*, HL6-*Alternaria angustiovoidea* and C- control. Antioxidant activity is represented categorically: (+) strong activity, (++) stronger activity, (+++) strongest activity with maximum decolourisation of the radical solution.

Colonisation frequency analysis revealed *Alternaria* sp. (HL3) as the most dominant in leaf tissues (24%), followed by *Cercospora gomphrenigena* (HL1) (16%) and *Alternaria angustiovoidea* (HL6) (12%). In stem tissues, *Talaromyces muroii* (HS1) and *Aspergillus sclerotiorum* (HS5) showed the highest colonisation frequency (12% each).

Extraction of crude metabolites, and antibacterial and antioxidant activities

Crude metabolites were extracted from 21-day PDB cultures using ethyl acetate. Antibacterial activity was tested against *Enterococcus faecalis* (EF), *Klebsiella pneumoniae* (KP), and MRSA using the disc diffusion assay. Eight out of eleven isolates inhibited at least one pathogen. Notably, *Talaromyces muroii* (HS1) exhibited strong activity against all three pathogens, with inhibition zones exceeding 10 mm. Isolates HL4 and HS5 showed no antibacterial activity.

Antioxidant activity was assessed using DPPH assay. Positive results were observed in eight isolates, with *Talaromyces muroii* (HS1) showing the highest radical scavenging activity. Extracts of *Alternaria* sp. (HS3), *Alternaria alstroemeriae* (HS4), *Aspergillus sclerotiorum* (HS5), *Cercospora gomphrenigena* (HL1), and *Alternaria alstroemeriae* (HL2) also demonstrated significant antioxidant activity. In contrast, *Alternaria angustiovoidea* and *Alternaria* sp. (HS2, HL3) and *Corynespora* sp. (HL4) did not exhibit antioxidant property (**Figure 3**).

DISCUSSION

Isolation, identification and phylogenetic analysis of endophytic fungi

In this study, 11 fungal endophytes were successfully isolated from the surface-sterilised stem and leaf tissues of five randomly selected *Hyptis suaveolens* plants, thereby ensuring biological replication at the plant level in addition to technical replication through multiple tissue segments plated per PDA plate. The efficacy of the sterilisation procedure in the present work was validated by inoculating the last wash solution of the stems and leaves, which showed no microbial growth. Previous studies have demonstrated that a combination of 70% ethanol and 4% sodium hypochlorite is effective for sterilising plant tissues prior to endophyte isolation (Gautam *et al.,* 2022; Gond *et al.,* 2011; Kharwar *et al.,* 2011; Mishra *et al.,* 2019; Verma *et al.,* 2014). Based on microscopic examination and gene sequencing of the ITS region of rRNA, the fungal isolates were identified as *Talaromyces muroii* (HS1), *Alternaria angustiovoidea* (HS2), *Alternaria* sp. (HS3), *Alternaria alstroemeriae* (HS4), and *Aspergillus sclerotiorum* (HS5) from the stem and *Cercospora gomphrenigena* (HL1), *Alternaria alstroemeria* (HL2), *Alternaria* sp. (HL3), *Corynespora* sp. (HL4), *Alternaria pogostemonis* (HL5), and *Alternaria angustiovoidea* (HL6) from the samples of leaf (**Table 1**). The combination of microscopic structures along with sequencing of the ITS rRNA region has been considered a reliable approach for the characterisation of fungi at the species level (Gautam *et al.,* 2022; Singh *et al.,* 2019; Verma *et al.,* 2014). Accession numbers obtained from NCBI GenBank of each isolate along with their percentage similarity with closest match are given in **Table 1**. A maximum-likelihood phylogenetic tree was constructed, with all eleven strains clustering at strongly supported nodes within their respective clades (Figure 1). Among the eleven isolates, *Alternaria* sp. (HL3) exhibited the highest colonisation frequency (24%), followed by *Cercospora gomphrenigena* (HL1) (16%) and *Alternaria angustiovoidea* (HL6) (12%) within the tissues of leaves. In the stem samples, the highest colonisation frequency was observed for *Talaromyces muroii* (HS1) (12%) and *Aspergillus sclerotiorum* (HS5) (12%) (**Table 1**). In this study, we analysed only culturable endophytic fungi. However, recent sequencing technologies, including next-generation sequencing, have made possible exploration of non-culturable endophytic fungi and their functional prediction (Roy *et al.,* 2025).

Extraction of crude metabolites and antibacterial and antioxidant activities

Endophytic fungi, residing in unique niches within plants, can be a source of various biologically active molecules with antimicrobial, antimalarial, anticancer, antioxidant, immunosuppressive, and anti-inflammatory activities (Gautam *et al.,* 2022; Kharwar *et al.,* 2011; Mishra *et al.,* 2021; Verma *et al.,* 2014). In this study, crude metabolites were extracted using ethyl acetate as an organic solvent

from 21-day PDB cultures of all eleven fungal isolates. Ethyl acetate, a commonly used organic solvent, was selected for its higher extraction efficiency of fungal metabolites compared to chloroform or hexane. Mishra *et al.* (2019) reported ethyl acetate as the most effective solvent for extracting secondary metabolites from the liquid culture of endophytic fungi. Their findings further highlight PDB as preferred medium for secondary metabolites production. The antibacterial property of the crude metabolites was examined against the three standard bacterial pathogens - *Enterococcus faecalis* (EF), *Klebsiella pneumoniae* (KP), and MRSA - applying the disc diffusion assay. Secondary metabolites from over 70% of endophytic fungal isolates (8 out of 11) inhibited one or more tested bacterial pathogens in the disc diffusion assay. Notably, the extract from *Talaromyces muroii* (HS1) was the most effective against all three bacterial strains, showing inhibition zones of over 10 mm. However, isolates HL4 and HS5 demonstrated no activity against the tested pathogens. Gong and Guo (2009) reported antibacterial activity in only 8.3 % of endophytic fungi of *Aquilaria sinensis* and *Dracaena cambodiana*. In another study, Lin *et al.* (2007) observed 27.6% fungal endophytes of *Camptotheca acuminata* with antibacterial activities. However, 58.33% of fungal endophytes of *Madhuca indica* and 75% from *Adenocalymma alliaecium* showed antibacterial activity against tested bacterial pathogens (Kharwar *et al.,* 2011; Verma *et al.,* 2014). The antibacterial activity observed in this study was broadly consistent with findings reported in previous studies on endophytic fungi (Gautam *et al.,* 2022; Gond *et al.,* 2011; Mishra *et al.,* 2019; Kharwar *et al.,* 2011; Verma *et al.,* 2014; Verma *et al.,* 2024).

Reactive oxygen species (ROS: O_2^- and OH^-) and free radicals play significant roles in cell-to-cell communication, signal transduction, apoptosis, and gene expression. However, unregulated excess production of these ROS and free radical molecules may cause serious oxidative damage to key functional biomolecules including lipids, proteins, and DNA which leads to the development of diseases like cancer, atherosclerosis, Alzheimer's, and other neurodegenerative disorders (Finkel and Holbrook, 2000). Natural products derived from plants and microbes have been utilised in the development of antioxidant drugs. Fungal endophyte's metabolites have been reported to contain flavonoids, phenolics and quinones which are well known antioxidant molecules (Gautam *et al.,* 2022). DPPH test was employed for assessing antioxidant properties of metabolites. The DPPH method is well established and accurate, and has been used previously to assess antioxidant activity (Gautam *et al.,* 2022; Mishra *et al.,* 2021; Verma *et al.,* 2014; Verma *et al.* 2024). In this study, positive antioxidant results were observed for the metabolite extracts of eight out of eleven endophytic fungal isolates. In particular, the extract of *Talaromyces muroii* (HS1) exhibited the highest decolourisation of the DPPH radical. Crude extract of *Alternaria* sp. (HS3), *Alternaria alstroemeriae* (HS4), *Aspergillus sclerotiorum* (HS5), *Cercospora gomphrenigena* (HL1), *Alternaria alstroemeriae* (HL2) also showed significant antioxidant activity. However, *Alternaria angustiovoidea* (HS2), *Alternaria* sp. (HL3) and *Corynespora* sp. (HL4) did not display any antioxidant activity **(Figure 3)**. Mishra *et al*. (2019) reported that crude extracts from 20% of fungal endophytes of *Tinospora cordifolia* showed strong antioxidant activity. The findings of the current investigation suggest that endophytic fungi are an excellent source of bioactive compounds having antibacterial and antioxidant activities and further efforts are needed to characterise the pure compounds, which will contribute to the discovery of antioxidant and antimicrobial drugs.

CONCLUSIONS

This study highlights the diversity and bioactive potential of endophytic fungi isolated from *Hyptis suaveolens.* Eleven culturable fungal endophytes were identified through ITS rRNA sequencing and phylogenetic analysis, where *Alternaria angustiovoidea* and *Talaromyces muroii* emerged as dominant species in leaf and stem tissues, respectively. Several isolates exhibited antibacterial activity against clinical pathogens, while multiple demonstrated very strong antioxidant activity. Among all the endophytes, *Talaromyces muroii* produced metabolites that exhibited both antibacterial and antioxidant activity, suggesting that it may produce broad-spectrum metabolites of therapeutic relevance. The findings provide valuable preliminary insights. However, future

studies should focus on structural characterisation of active compounds and mechanistic studies to confirm their functional roles. Incorporation of these experiments will strengthen the potential of endophytic fungi from *Hyptis suaveolens* as promising sources for novel drug discovery.

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Conflict of Interest

Authors do not have any conflict of interest to declare.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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