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A study on root fungal endophytes and antibacterial activity of *Fusarium cf. foetens* dominant endophyte isolated from *Uvaria narum* Wall

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ABSTRACT

***Uvaria narum* Wall. (*Annonaceae*) is a woody climber widely used in traditional medicine to treat allergic reactions, rheumatism, and hemorrhoids. Despite its medicinal value, limited research exists on its associated endophytic fungi and their therapeutic potential. This study identified 154 fungal isolates from root tissues of *U. narum*, belonging to nine different endophytic species. The dominant isolate, *Fusarium* cf. *foetens*, along with the host root extract, was evaluated for antibacterial activity. The *Fusarium* cf. *foetens* extract showed strong inhibition against *Staphylococcus aureus* (30.8 mm ± 1.17) and moderate inhibition against *Klebsiella pneumoniae* (26.4 mm ± 3.72) at 40 µL. In contrast, the root extract exhibited weaker activity, with inhibition zones of 11 mm ± 6.32 for *S. aureus* and 6 mm ± 4.19 for *K. pneumoniae* at the same concentration. The endophyte extract demonstrated greater antibacterial efficacy than the host. These findings highlight the potential of endophytic fungi from *U. narum* as novel sources of antibacterial agents, linking traditional knowledge with modern drug discovery.**

Keywords: Endophytes, *Klebsiella pneumoniae*, *Staphylococcus aureus*, Woody climber

INTRODUCTION

Fungal endophytes are microorganisms that colonize internal plant tissues without causing any apparent symptoms (Carroll, 1986; 1988). They are ubiquitous, occurring in nearly all plant families across diverse ecological and climatic zones (Sieber et al., 1988; Bussaban *et al*., 2001). It is estimated that at least one million fungal endophyte species exist (Dreyfuss and Chapela, 1994). These fungi are of considerable biotechnological interest due to their potential applications as genetic vectors (Murray *et al*., 1992), sources of novel secondary metabolites (Fisher *et al.*, 1986), and agents of biological control (Bacon, 1990; Clay, 1989). Endophytic fungi have been isolated from various plant parts, including leaves, stems, roots, and seeds. Studies have reported root-associated endophytes from different ecological systems, such as the coastal halophyte *Sesuvium portulacastrum* (Wang *et al*., 2022; 2025), alpine medicinal plants (Hou *et al*., 2025), and desert halophytes (Li *et al*., 2020). Colonization of barley roots by *Fusarium equiseti* and *Pochonia chlamydosporia* has also been documented (Maciá-Vicente *et al*., 2009). Recent research has focused on the ability of these endophytes to synthesize a wide array of bioactive compounds with significant pharmacological and agricultural potential. *Uvaria narum* Wall (Annonaceae) is a woody climber widely used in traditional medicine for the treatment of various inflammatory conditions, including rheumatism, acute allergic reactions, catarrhal

inflammation, hemorrhoids, and liver disorders. Phytochemical studies have identified a variety of active constituents in *Uvaria* species, including phenolic compounds, flavones, tannins, saponins, and polyoxygenated cyclohexenes (Jalil *et al*., 2020). However, despite the medicinal importance of this genus, the diversity and potential of its associated endophytic fungi remain largely unexplored. Notably, little to no research has been conducted on endophytic fungi in *Uvaria narum,* particularly in South India. Given the therapeutic relevance of both the host plant and its likely fungal symbionts, this study aimed to (1) isolate and identify fungal endophytes from the root tissues of *U. narum*, and (2) evaluate the antibacterial activity of crude extracts from the host root and a dominant fungal endophyte, *Fusarium* cf. *foetens.*

MATERIALS AND METHODS

Isolation of Fungal Endophytes

The host plant *Uvaria narum* Wall. (Annonaceae), a woody climber, was screened for root fungal endophytes. Roots were collected from a medium-sized tree in the Javadhu Hills, Eastern Ghats, Tamil Nadu. The local Tamil name for the plant is Puliccan. Healthy, undamaged, and uninfected root samples were processed within 24 h of collection (Fisher and Petrini, 1987). Media and glassware other than Petri dishes were sterilized by autoclaving at 121°C and 103 kPa for 20 min. Petri dishes were sterilized in hot air oven at 160 °C for 3 h (Lakshmanan, 2024). For fungal endophyte isolation, Potato Dextrose Agar (PDA) was used, supplemented with chloramphenicol as a bacterial inhibitor. Root segments (0.5 cm), cut from healthy roots (Cabral *et al*., 1993), were surface sterilized following the modified method of Dobranic *et al.* (1995), by immersion in 70% ethanol for 2 minutes, followed by 4% NaOCl for 90 seconds, and rinsing in sterile water for 1 minute. One hundred surface-sterilized root segments were placed on PDA medium (12 mL per Petri dish, 9 cm diameter) amended with chloramphenicol (150 mg/L) and incubated in a light chamber for 21 days (Bills and Polishook, 1992; Suryanarayanan, 1992). The light regimen was 8 hrs of light followed by 16 hrs of darkness. The temperature was 27 °C ± 1 °C. Petri dishes were observed periodically, and fungal endophytes that grew out of the root tissues were transferred to fresh PDA slant. To prevent rapidly growing fungi from inhibiting slow-growing species, the former were removed following isolation (Bills, 1996; Lakshmanan, 2024).

Morphology And Molecular Identification

Fungal Endophytes were identified morphologically using standard keys; Ellis and Ellis 1988; Onion *et al*., 1981; Deepak *et al*., 2025). The non sporulating sterile forms sterile isolates that could not be assigned to any taxonomic group were given codes using culture characteristics such as growth rate, colony surface texture and margin shape, and hyphal pigmentation (Bills and Polishook, 1994; Dobranic *et al*., 1995; Rajagopal, 1999). Genomic DNA was extracted from fungal isolates using the HiPurA Fungal DNA Purification Spin Column Kit (HiMedia, India) and confirmed on a 1% agarose gel. The internal transcribed spacer (ITS) region (~600 bp) of fungal rDNA was amplified using fungal-specific primers ITS1 (5′-TCCGTAGGTGA ACCTGCGG-3′) and ITS4 (5′-TCCTCCGCTTATT GATATGC-3′), as described by (White et al., 1990). PCR was carried out in a 25 µL reaction containing EmeraldAmp GT PCR Master Mix (Takara Bio, USA), 50–100 ng of DNA, 10 µM of each primer, and nuclease-free water. Thermocycling conditions on an Applied Biosystems Veriti Thermal Cycler were as follows: initial denaturation at 95°C for 5 min; 36 cycles of denaturation at 94°C for 2 min, annealing at 52°C for 1 min, and extension at 72°C for 2 min; followed by a final extension at 72°C for 7 min. PCR products were verified by electrophoresis on a 1% agarose gel stained with GelRed and visualized using a UV transilluminator (ProteinSimple Red Imager SA-1000). Amplicons were purified using Exonuclease I and Shrimp Alkaline Phosphatase (New England Biolabs, USA), and subjected to cycle sequencing with the BigDye Terminator v3.1 Kit (Applied Biosystems, USA). Sequencing reactions were cleaned using the sodium acetate–ethanol precipitation method (Thermo Fisher Scientific) and run on a 3500xL Genetic Analyzer (Applied Biosystems, USA). Resulting sequence files (ab1) were edited using CHROMAS Lite v1.5 and analyzed via the NCBI BLASTN algorithm (Altschul *et al*., 1990; Gertz, 2005), using the rRNA/ITS database to identify the closest type strains. Pairwise sequence similarity was calculated (States *et al*., 1991), and the first 5–10 best BLAST hits were recorded. Multiple sequence alignment and

phylogenetic analysis were conducted using MEGA11 (Tamura *et al*., 2021). The evolutionary tree was constructed using the Neighbor-Joining method (Saitou and Nei, 1987), with evolutionary distances calculated using the Kimura 2-parameter model (Kimura, 1980), and bootstrap analysis with 1000 replicates to assess branch support (Felsenstein, 1985).

DATA ANALYSIS

Colony frequency (CF %) was calculated for each fungal endophytes following the method of Kumaresan and Suryanarayanan (2002). The fungal diversity was also calculated using Shannon Diversity Index (Pielou, 1966).

COLONY FREQUENCY

The Colony Frequency (CF), expressed as percentage, was calculated as follows:

CF%= No. of isolates for a species x 100/Total Isolates

SHANNON DIVERSITY INDEX

The Shannon Diversity Index (H') was used to assess the diversity of fungal endophytes in the collected samples. This index provides a comprehensive measure of community structure by accounting for both species richness and evenness (Shannon and Weaver, 1949; Magurran, 2004; Pielou, 1966). It is calculated using the following formula:

$$H= -\sum [(pi) \times \log (pi)]$$

PREPARATION OF ROOT EXTRACT

Ten grams of roots were immersed in 100 mL of ethyl acetate and kept on a shaker overnight. The immersed roots were then crushed in a mortar and pestle and centrifuged at 8000 rpm for 6 minutes. The supernatant was collected and transferred to fresh vials for further study (Suresh *et al*., 1997; Apoorva *et al*., 2021). The fungal endophyte *Fusarium* cf. *foetens* was grown in liquid PDA medium for 7 days. After incubation, the mycelium was ground in a mortar and pestle with 10 mL of medium and filtered through Whatman No. 1 filter paper. The filtrate was mixed with an equal volume of ethyl acetate and left overnight. The organic layer was carefully separated, evaporated, and the residue was used for further study (Nurhadi *et al*., 2025).

ASSAY FOR ANTIBACTERIAL ACTIVITY

The antibacterial activity of the root extract of *Uvaria narum* and its dominant fungal endophyte, *Fusarium cf. foetens*, was evaluated against *Staphylococcus aureus* (MTCC 3160), a Gram-positive bacterium, and *Klebsiella pneumoniae* (MTCC 3040), a Gram-negative bacterium. Both bacterial strains were procured from the Microbial Type Culture Collection (MTCC) and maintained on Nutrient Agar slants at 37°C. Fresh bacterial suspensions were prepared from 15 h-old cultures, and the inoculum density was adjusted to approximately 1×10^8 CFU mL^{-1} using the 0.5 McFarland turbidity standard. The bacterial suspensions were uniformly spread on Mueller–Hinton Agar (MHA) plates using sterile cotton swabs. Crude ethyl acetate extracts of the root and *Fusarium cf. foetens* were concentrated under reduced pressure and re-dissolved in ethyl acetate to obtain a stock concentration of 1 mg mL^{-1}. Sterile paper discs (6 mm diameter) were impregnated with 10, 25, and 40 µL of the extract solution, corresponding to 10, 25, and 40 µg $disc^{-1}$, respectively. Discs loaded with ethyl acetate alone served as the negative control, while Rifampicin (30 µg $disc^{-1}$) was used as the positive control. Antibacterial activity was determined using the disc diffusion method. The plates were incubated at 37°C for 24 h, after which the zones of inhibition were measured in millimetres (mm). All experiments were performed in triplicate, and the results were expressed as mean ± standard deviation (SD). Statistical analysis was carried out using one-way analysis of variance (ANOVA) followed by Tukey's HSD post hoc test, and differences were considered statistically significant at $P < 0.05$ (Quinto and Santos, 2005; Torres and Dela Cruz, 2015; Jamith Basha, 2019; Zar, 2010)

RESULTS

Isolation of fungal Endophytes from the Root of *Uvaria Narum* Wall.

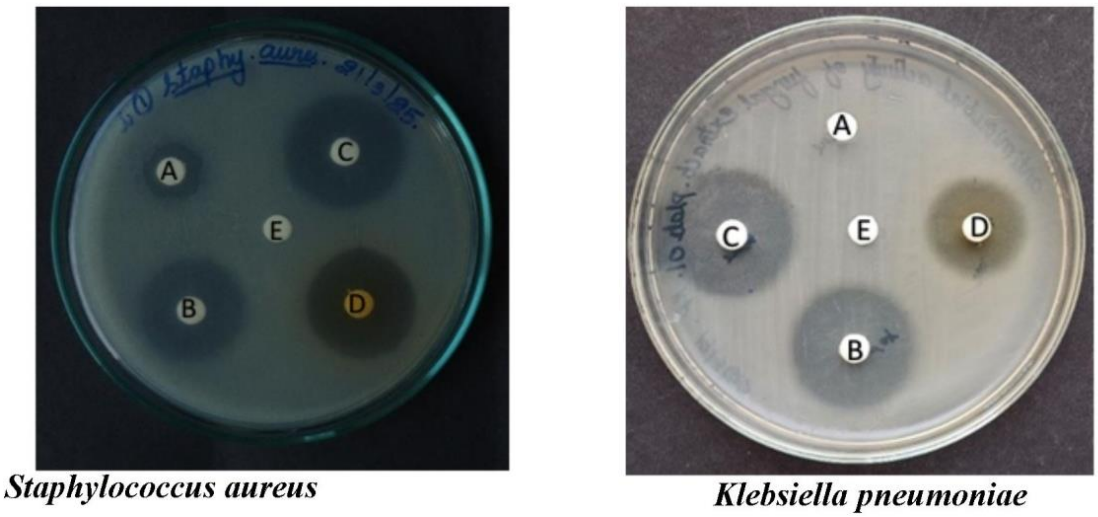
Fungal endophytes were isolated from the root tissues of *Uvaria narum* Wall. A total of 154 fungal endophyte isolates were recovered from surface-sterilized root tissues. Based on morphological characteristics, nine fungal endophyte taxa were identified (**Table 1, Plate 1**). Among them, seven were sporulating forms, whereas two were sterile

forms and were assigned code numbers. The colonization frequency of each fungal endophyte was calculated and is presented in **Table 1**.

Table 1: Fungal endophytes isolated from the roots of *Uvaia narum* Wall. With number of isolates (N) and Colonization frequency (CF%).

Fungal Endophytes	Number of Isolates (N)	Colonization Frequency (%)	Proportion (p_i)	Natural Logarithm (ln(p_i))	p_i * ln(p_i)
Fusarium cf. foetens	66	42.8%	0.4286	-0.8473	-0.3625
Fusarium oxysporum	36	23.4%	0.2338	-1.4481	-0.3383
Torula sp.	22	14.3%	0.1429	-1.9459	-0.2779
Fusarium sp.	8	5.2%	0.0519	-2.9516	-0.1532
Nodulisporium sp.	6	3.9%	0.039	-3.2333	-0.1261
Cladosporium sp.	6	3.9%	0.039	-3.2333	-0.1261
Sterile form I	4	2.6%	0.026	-3.6445	-0.0949
Trichoderma sp.	4	2.6%	0.026	-3.6445	-0.0949
Sterile form II	2	1.3%	0.013	-4.3428	-0.0565
Total	**154**	**100%**	**-**	**-**	**-1.6304**

The colonization frequency (CF%) and total calculations indicate that *Fusarium foetens* was the most dominant endophyte. The Shannon-Wiener Diversity Index (H) was 1.6304, reflecting a moderate level of fungal diversity, with major dominance by Fusarium foetens but contributions to diversity from several less common taxa.



Staphylococcus aureus ***Klebsiella pneumoniae***

Plate1. The antibacterial activity of *Fusarium foetens* extract was tested against *Staphylococcus aureus* and *Klebsiella pneumoniae* using the agar well diffusion methods. Wells A. B, and C contained 10 µL, 25 µL, and 40 µL of extract, respectively, well D had 30 µL of positive control, and well E has 30 µL of negative control. Clear inhibition zones around the wells show the extract's antimicrobial effect at different concentrations for both bacteria.

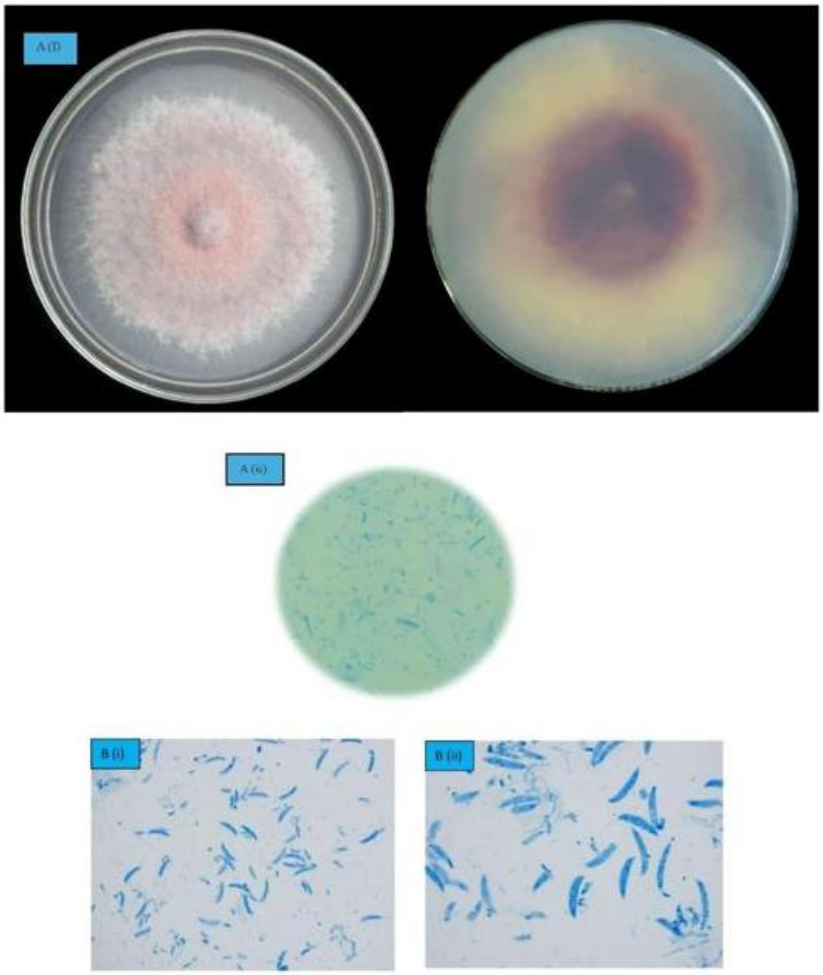


Figure 1. Morphological characteristics of *Fusarium foetens* **(a)** colony morphology on Potato Dexose Agar (PDA) after 7 days of incubation at 25°C, showing white to pale pink, cottony and fluffy mycelial growth with salmon-pink reverse pigmentations. **(Bi)** Microscopic views of conidiophores bearing monophialides producing abundant microconidia in false heads (400x, lactophenol cotton blue) **(Bii)** Falcate, multicellular macroconidia produced form sporodochia, 3-5 septate, slightly curved with pointed apical cells and characteristic foot shaped basal cells.

The endophytic fungal community comprised *Fusarium cf. foetens* (66 isolates, 42.8%), *Fusarium oxysporum* (36 isolates, 23.4%), *Torula* sp. (22 isolates, 14.3%), *Fusarium* sp. (8 isolates, 5.2%), *Nodulisporium* sp. (6 isolates, 3.9%), *Cladosporium* sp. (6 isolates, 3.9%), Sterile form I (4 isolates, 2.6%), *Trichoderma* sp. (4 isolates, 2.6%), and Sterile form II (2 isolates, 1.3%) (**Table 1**; **Figure 1 A(i), A(ii), B(i), and B(ii)).** The endophytic community was dominated by *Fusarium cf. foetens*, followed by *F. oxysporum* and *Torula* sp. Together, these three taxa accounted for more than 80% of the total isolates, indicating their predominance within the root tissues of the host plant. The amplified ITS sequence (538 bp) showed high similarity to reference sequences available in the NCBI database. BLAST analysis revealed the closest matches to *Fusarium cf. foetens* (NR_159865.1; 99.41% identity) and *Fusarium inflexum* (NR_152941.1; 99.03% identity), indicating that the isolate is closely related to these species. Phylogenetic analysis based on the Neighbor-Joining method supported this identification, with the isolate clustering within the *Fusarium* clade near *F. cf. foetens* and *F. inflexum* with strong bootstrap support (**Figure 2**). The analysis included 12 ITS sequences and 464 aligned positions after pairwise deletion of ambiguous bases, and evolutionary distances were computed using the Kimura 2-parameter model. In the current study, the proportion (pi) and natural logarithm of each proportion were computed; the results are presented in **Table 1**. The study indicates the natural logarithm of the proportion for *Fusarium foetens (*0.4286) is -0.8473, while for *Fusarium oxysporum* (0.2338), it is

-1.4481, *Torula* sp (0.1429), it is -1.9459, *Fusarium* sp. (0.0519), it is -2.9516, *Nodulisporium* sp. (0.039) it is -3.2333, *Cladosporium* sp. (0.039), it is -3.2333, Sterile form I (0.026), it is -3.6445, *Trichoderma* sp. (0.026), it is -3.6445, Sterile form II (0.013), it is -4.3428. The Shannon Index value of 1.6304 indicates a moderate level of diversity in the fungal sample. A higher Shannon Index suggests greater diversity, while a lower value indicates a more homogenous sample with fewer distinct categories. In this case, the index suggests that the fungal endophyte samples contain a moderate degree of diversity, with some categories being more dominant, such as *Fusarium foetens*, but with several other categories of fungal endophytes also contributing to the overall diversity.

Antibacterial Activity of Crude Extracts of *Uvaria Narum* Root and *Fusarium cf. foetens*

A study was conducted to evaluate the antibacterial activity of the root extract of *Uvaria narum* and the dominant fungal endophyte, *Fusarium cf. foetens*, selected based on its high colonization frequency (CF%), using organic extracts. The antibacterial activity of both the root and fungal extracts showed varied results (**Table 2; Figure 3**). The test organisms used in the present investigation were *Staphylococcus aureus* (MTCC 3160), a Gram-positive bacterium, and *Klebsiella pneumoniae* (MTCC 3040), a Gram-negative bacterium. The *Fusarium cf. foetens* extract exhibited antibacterial activity against both *S. aureus* and *K. pneumoniae* at all tested concentrations. The inhibition zones increased with increasing extract concentration, with the highest activity recorded at 40 µL, producing inhibition zones of 30.8 ± 1.17 mm against *S. aureus* and 26.4 ± 3.72 mm against *K. pneumoniae*. The inhibition observed against *K. pneumoniae* at 40 µL was comparable to that of the positive control (**Table 2; Figure 3**).

Table 2: Antibacterial activity of crude extracts of *Uvaria narum* root and *Fusarium cf. foetens* against *Staphylococcus aureus* and *Klebsiella pneumoniae*.

Extract Type	Concentration (µL)	*S. aureus* (mm ± SD)	*K. pneumoniae* (mm ± SD)
Fusarium cf. foetens	**10**	**13.8 ± 2.00**	**9.6 ± 5.89**
	25	**27.2 ± 2.32**	**19.8 ± 5.15**
	40	**30.8 ± 1.17**	**26.4 ± 3.72**
Rifampicin (+)	**30**	**26.4 ± 4.22**	**26.4 ± 4.22**
Root	**10**	**ND**	**1.8 ± 3.60**
	25	**7.4 ± 6.24**	**1.0 ± 2.26**
	40	**11.0 ± 6.32**	**6.0 ± 4.19**
Rifampicin (+)	**30**	**27.2 ± 4.49**	**29.2 ± 2.48**
Ethyl acetate (−)	**30**	**ND**	**ND**

ND = No detectable inhibition zone.
(+) = Positive control (Rifampicin).
(−) = Negative control (Ethyl acetate).



Figure 2. Phylogenetic tree based on ITS region sequences showing the relationship of *Fusarium foetus* (CBS 110286) with related *Fusarium* species. The analyzed isolate (highlighted), grouped closely with *Fusarium foetus* and neighbouring taxa, with *Aspergillus niger* as the outgroup for composition.

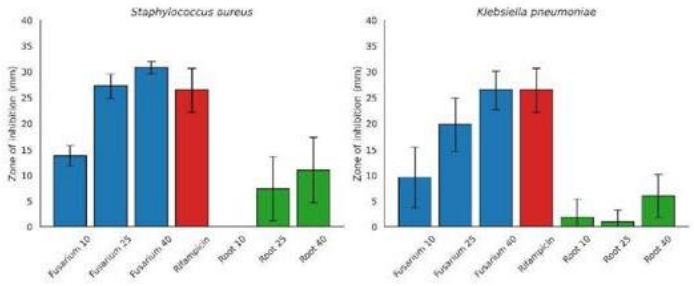


Figure 3. Antibacterial activity of *Fusarium foetus* extract and *U. narum* root extract against *Staphylococcus aureus* and *Klebsiella pneumoniae*. Zones of inhibition (mm) at varying extract concentrations (10, 25, 40 µl) are compared, with rifampicin used as the control.

In contrast, the root extract showed weak or no inhibitory activity against the tested bacterial pathogens. The negative control (ethyl acetate) did not exhibit any inhibitory activity against either of the test organisms. Statistical analysis using one-way ANOVA revealed significant differences in the antibacterial activity of *Fusarium cf. foetens* extract against *Staphylococcus aureus* ($F = 32.06$, $P < 0.001$). However, differences among concentrations against *Klebsiella pneumoniae* were not statistically significant ($F = 3.32$, $P = 0.078$). Significant differences were also observed among the concentrations of the root extract against *S. aureus* ($F = 8.06$, $P = 0.008$) and *K. pneumoniae* ($F = 36.18$, $P < 0.001$). Tukey's HSD test indicated that the 40 µL fungal extract treatment produced significantly greater inhibition against *S. aureus* than the lower concentrations, whereas no significant differences were detected among fungal extract concentrations against *K. pneumoniae*.

DISCUSSION

Endophytes include bacteria, viruses, and fungi; however, fungal endophytes have received greater attention in the literature for their ability to synthesize diverse bioactive secondary metabolites within host plants. The incidence of endophytic associations is found in nearly all plant species, and their roles are well established. This relationship exists in roots, stems, and leaves; these microbial endophytes enhance growth, yield, and stress tolerance, and contribute to the natural control of plant pathogens and diseases. Only a few lianas or climbers have been screened for the presence of fungal endophytes (Bagchi, 2021; Bagchi and Saradar, 2021; Lakshmanan, 2024; Ashwini, 2019). The endomycobiomes (fungal microbiomes) impact plants from seed germination to full maturation (Geisen *et al*., 2021). The present study revealed that the roots of *Uvaria narum* harboured diverse fungal endophytes. One hundred root segments harbored 154 isolates belonging to 9 different endophytic species (**Table 1**). Of which *Fusarium* cf. *foetens* showed the CF% of (66 isolates, 42.8%) (Table 1). Although 9 endophytic fungi were present, only three taxa (*Fusarium* cf. *foetens, Fusarium oxysporum*, and *Torula* sp.) accounted for more than 80% of the total isolates. This finding is consistent with Petrini (1986), who reported that only one or a few endophytic fungal taxa typically dominate a single host plant. Suryanarayanan *et al*., (1998) reported that during the endophyte screening study, Basidiomycetes and Zygomycetes were absent or reported in low numbers; in the current study, a similar observation was made. *Fusarium, Trichoderma* sp., and *Cladosporium* sp. generally occur as epiphytic or plant pathogenic fungi but are capable of penetrating superficial epidermal layers and surviving surface sterilization procedures, thereby appearing as fungal endophytes in culture plates (Palaez *et al*., 1998). The present study also suggests that epiphytic, saprophytic, and pathogenic fungi may exist as endophytic associates within plant tissues. Although standard surface sterilization procedures were followed, additional validation was performed: imprint controls and final rinse water were plated, and no fungal growth was observed, confirming the efficacy of the sterilization process.

Plant fungal endophytes are a significant and unique reservoir of natural bioactive compounds with potential applications in medicine, industry, and agriculture. Through co-evolution, a mutualistic association is established between endophytes and their host plants, enabling some endophytes to produce the same or similar bioactive compounds as those synthesised by the host plant (Zhao *et al*., 2011). Malhadas *et al.* (2017) examined the

biological potential of fungal endophytes isolated from Olea europaea leaves and reported that phenylethyl alcohol and 3-methyl-1-butanol possessed strong antibacterial properties. Similarly, fungal endophyte-derived metabolites such as 5-hydroxymethylfurfural (HMF) and octadecanoic acid have also been reported to exhibit significant antibacterial activity (Hellwig *et al*., 2002). The comparatively higher antibacterial activity exhibited by the crude extract of *Fusarium* cf. *foetens* in the present study may be attributed to its ability to synthesize diverse secondary metabolites with antimicrobial properties. Endophytic *Fusarium* species are known to produce biologically active compounds such as alkaloids, polyketides, terpenoids, peptides, and phenolic derivatives that contribute to their antimicrobial potential (Toghueo, 2020). The stronger inhibitory activity observed against *Staphylococcus aureus* than against *Klebsiella pneumoniae* may be related to differences in cell wall architecture between Gram-positive and Gram-negative bacteria. The outer membrane present in Gram-negative bacteria often acts as an additional permeability barrier, thereby reducing susceptibility to antimicrobial metabolites. Similar antibacterial activities have been reported from endophytic *Fusarium* species isolated from medicinal plants, supporting the view that endophytic fungi represent an important reservoir of bioactive natural products with potential pharmaceutical applications (Ratnaweera *et al*., 2015). Since the present study was performed using crude extracts, the observed antibacterial activity may have been influenced by factors such as metabolite concentration, extract composition, diffusion characteristics, and the presence of multiple compounds. Therefore, further purification, characterization, and identification of the active metabolites are required to determine the specific compounds responsible for the observed antibacterial activity. Future studies should focus on the determination of MIC and MBC values, purification of bioactive compounds, and characterization of the metabolites responsible for the observed antibacterial activity.

CONCLUSION

The increasing problem of antimicrobial resistance has created an urgent need to discover new therapeutic agents from natural sources. In the present study, the ethyl acetate extract of *Fusarium cf. foetens* isolated from the root of *Uvaria narum* exhibited notable antibacterial activity against the tested bacterial pathogens and showed greater efficacy than the corresponding root extract. The findings suggest that the dominant fungal endophyte may contribute significantly to the bioactive potential of the host plant. However, this study was based on crude extracts, and further investigations involving purification, characterization of active metabolites, and determination of MIC and MBC values are required to validate its pharmaceutical potential.

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CONFLICTS OF INTEREST

The authors confirm that they have no competing interests to disclose.

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