

Original Research Article

<https://doi.org/10.20546/ijcmas.2026.sp13.014>

Isolation, Extraction and Characterization of Volatile compound from *Trichoderma harzianum* by GC-MS Analysis and Its Potential Antimicrobial Activity

B. Roshini and K. Nithya 

Department of Microbiology, Valliammal College for Women, Chennai, Tamil Nadu, India

*Corresponding author

ABSTRACT

In the present study, *Trichoderma harzianum* was isolated from the 1/Biopesticide on PDA agar and tested for its antagonistic property against different fungal species using dual culture technique. Its crude extract obtained was used to carry out different antimicrobial activities by dissolving in DMSO solution. The antagonistic activity of *T.harzianum* was tested against fungal species was isolated from two soil samples (raddish and tomato) in which all fungal species were significantly inhibited the mycelial growth of *Aspergillus niger* with 65.9%, *A.terreus* with 83.33% and *penicillium sp.* 78.65% by the crude extract of *T.harzianum* with zone inhibition of 33mm, 40mm and 34mm respectively. Antimicrobial assay was done for *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa* and Multidrug-resistant strains of *Pseudomonas aeruginosa* and *Klebsiella Pneumoniae* were tested and its shown significant activity. The crude extract of *Trichoderma harzianum* was subjected to FT-IR and Gas chromatography-Mass spectrometry (GC-MS) for the analysis of volatile constituents. GC-MS analysis revealed two peaks in which Diethyl phthalate was found to be Propanol, 2,2-dimethyl- oxime. These findings indicate that Diethyl phthalate could be responsible for the antimicrobial activity of *Trichoderma harzianum* against bacterial and fungal species. Propanol, 2,2-dimethyl-, oxime might be responsible for the activity against Multidrug-resistant bacteria. Hence, further studies could be carried out in future to explore the properties of these potential compounds of *Trichoderma harzianum* in agricultural and pharmaceutical sectors.

Keywords

GC-MS, *T.harzianum*, MDR, FT-IR, DMSO, Propanol, 2,2-dimethyl- oxime.

Article Info

Received:

20 August 2026

Accepted:

22 September 2026

Available Online:

10 October 2026

Introduction

Environmental perspective, *Trichoderma* species are highly resistant to a range of toxicants such as to heavy metals, organometallic compounds, tannery effluents and

harmful chemicals like cyanide (CN) and are thus employed in bioremediation of toxic pollutants present in the environment (Pratibha Tripathi *et al.*, 2013). The present study was attempted to isolate, extract and characterize the volatile compounds of *T.harzianum* and

its potential antimicrobial activity against various organisms. One among *Trichoderma* is a fast-growing filamentous fungus which belongs to Hypocreaceae family and comes under Ascomycota division. They reproduce asexually and most of the strains have no sexual stages (teleomorph-bearing filamentous fungi). *Trichoderma* species mature in 3-5 days of incubation, which grow as fluffy white tufts and later on give rise to greenish colonies (due to the production of conidia). The reverse of the colony is whitish yellow or light tan to yellow. They show characteristic branched conidiophores and phialides under microscope.

Trichoderma harzianum is one of those species in *Trichoderma* family which is ubiquitous and cosmopolitan in nature and are effective against several airborne and soilborne plant fungal pathogens. They are considered as most potential agent commercially available as biofungicides and are being used recently. In general *T. harzianum* have been isolated from soil, rotting plant materials, sapwood of tropical trees (common endophytes) and other fungi. They are known to secrete higher concentration of cell wall degrading enzymes such as α -1,3-glucanases (involved in mycoparasitism), chitinolytic enzymes (involved in mycoparasitism), peroxidases, β -1,3 and β -1,4 glucanases and capable of producing various secondary metabolites.

Secondary metabolites are bioactive compounds produced by fungal and bacterial species that are not essential for their growth, development and reproduction but acts as a part of their defense mechanism. *Trichoderma* species are known to produce a wide range of secondary metabolites such as peptaibols, polyketides, pyrones, terpenes and diketopiperazine-like compounds. Among these secondary metabolites peptaibols, polyketides and terpenes are mainly produced by different species of *Trichoderma*.

Materials and Methods

Collection of Materials

A *Trichoderma harzianum* containing pesticide is bought from Leaf and Clay Garden store. Multidrug resistant (MDR) bacteria namely *Pseudomonas aeruginosa* (MDR-PA) and *Klebsiella pneumoniae* (MDR-KP) were obtained from the Biolim lab, Ayanavaram. Strains include Gram positive bacteria (*Staphylococcus aureus* MTCC 6908) and 2 Gram negative bacteria (*Escherichia*

coli MTCC 1574 and *Pseudomonas aeruginosa* MTCC 2582) from Microbial Type Culture Collection and GeneBank (MTCC).

Isolation of *Trichoderma harzianum* from biopesticide

Under sterilized condition, 1 gram of biopesticide was taken from the pack and it was serially diluted. 0.1ml of sample from above dilution factors were taken and it was transferred aseptically to respective cooled PDA plates for spread plate technique and the plates were incubated at room temperature (28°C) for 2-4 days.

Isolation of fungal species from tomato and raddish soil sample

A gram of raddish and tomato soil sample was taken from the garden. It was serially diluted in two sets of test tubes and the dilution factors selected for fungi isolation was 10⁻¹, 10⁻², 10⁻³ & 10⁻⁴. Two sets of PDA plates, one for raddish soil sample and other for tomato soil sample was assigned for the spread plate technique. 0.1ml of sample was taken from the selected dilution factors and it was transferred aseptically to respective sets of PDA plates and spread completely on the agar. The plates were then incubated at room temperature for 3-10 days. After incubation, morphologically different colonies were selected, purified and subculture periodically.

Identification of *Trichoderma* and fungal species (from soil) by slide culture technique

The PDA plates were checked for the growth of *Trichoderma* and fungal species after incubation. They were identified based on their colony morphology such as color, texture and background of the colony. Based on their microscopical characteristics such as hyphal, conidiophore and conidial arrangement.

Antagonistic activity

Trichoderma harzianum isolate was tested for its antagonistic property against three fungal species by using dual culture technique. Three PDA plates were prepared and labelled according to the fungal species to be tested for the determination of antagonistic property of *T. harzianum*. In each plate, half of the plate was inoculated with mycelial disc of *T. harzianum* and other

half of the plate with mycelial disc of fungal species. Control plates were maintained for each fungal species. The plates were then incubated at room/1temperature for 3-10 days. After incubation, mycelial growth was measured on the control and test plates of each fungus and percentage inhibition (PI) was calculated as per the formula (Monika jangir *et al.*, 2018).

$$\text{Percentage Inhibition (PI)} = \frac{C - 1C - 1}{C - C} \times 100$$

Extraction of secondary metabolites from *Trichoderma harzianum*

The master plates and antagonistic plates of *T.harzianum* was chosen for the extraction of secondary metabolites. The plates containing the growth of *T.harzianum* was cut into small cubes and added in sterile plastic beaker. It was frozen at -20°C for overnight for loosening the cell membrane and for easy penetration of the solvent (Methanol) into membrane and for efficient extraction. After overnight incubation, the preparation was kept in stirrer for about 2 hours. Then it was poured in sterile centrifugal tubes and were centrifuged at 3500 rpm for 15 minutes. The supernatant obtained was carefully transferred into clean crucible and kept in hot air oven for overnight at 40°C for solvent evaporation. The next day crude extract obtained was dissolved in DMSO/Methanol and other procedures were carried out.

Antimicrobial activity of crude extract of *T.harzianum* by agar well diffusion/1method

The antimicrobial activities were carried out by dissolving crude extract of *T.harzianum* in DMSO. Crude extract of *Trichoderma harzianum* as Sample and DMSO as negative control.

Antifungal activity of crude extract of *T.harzianum*

Antifungal activity of crude extract was carried out by agar well diffusion method against *Aspergillus niger*, *A.terreus* and *Penicillium sp.* 1ml of sample from each subculture broth of fungal species were added in respectively labelled plates and sterile PDA was poured over the sample and mixed gently. After solidification two wells (5mm in diameter) were punctured on the agar media and labelled one as control and other as test. 50µl

of DMSO and 50µl of crude extract was added in control and test wells respectively. The plates were then incubated at room temperature for 2-3 days. After 24 hours of incubation, the diameter of the zones was measured.

Antibacterial activity of crude extract of *T.harzianum*

Antibacterial activity of crude extract was performed against three test bacterial pathogens namely *Staphylococcus aureus* MTCC 6908, *Escherichia coli* MTCC 1574 and *Pseudomonas aeruginosa* MTCC 2582 by agar well diffusion method. Three sterile plates were taken and labelled with required information. 1ml of sample from each bacterial suspension were transferred to respectively labelled plates, well was in 1 diameter of 5mm and labelled one as control and other as test. The control well was filled with 50µl of DMSO and the test well with 50µl of crude extract. The plates were then incubated at 37°C for 1-2 days. After incubation, the plates were examined for the Zone of inhibition.

Antimicrobial activity of crude extract of *T.harzianum* against Multidrug-Resistant (MDR) bacteria

Antimicrobial activity of crude extract of *T.harzianum* was evaluated against two MDR bacteria using agar well diffusion method. For this, two sterilized petriplates were taken and labelled one plate as Multidrug resistant *Pseudomonas aeruginosa* (MDR-PA) and other plate as Multidrug resistant *Klebsiella pneumonia* (MDR-KP). A loopful of culture was taken from the plate maintained for Multi drug resistant (MDR) bacteria and it was diluted in Sterile saline. 1ml of each MDR bacterial suspension was taken and transferred aseptically to sterile petriplates labelled. 50µl of crude extract was added in wells labelled as sample in each plate followed by the addition of DMSO in negative control and erythromycin and amoxicillin in positive controls. The plates were then incubated at 37°C for 24 hours. After incubation, the results were interpreted.

Characterization of crude extract of *T.harzianum* by FT-IR

Fourier Transform Infrared Spectroscopy (FT-IR) is widely used for the identification of chemical residues such as amine, carbonyl and hydroxyl functional groups

in a molecule. The dry extract of *T.harzianum* was dissolved in methanol for proceeding the FT-IR analysis by Shimadzu, Japan instrument with diffuse reflectance mode attachment. All measurements were carried out in the range of 400-4000 cm⁻¹ at a resolution of 4 cm⁻¹. (Pavithra. R and Lalitha. S 2020)

Characterization of crude extract by GC-MS

The dry extract of *T.harzianum* was dissolved in methanol and subjected to GC-MS analysis in Shimadzu instrument. It was carried out in the specific parameters such as column oven temperature -70°C, injector temperature 240°C, split injection mode, split ratio 10 and flow control in linear velocity mode. The column flow rate was maintained at 1.55ml/min and 1µl of sample was loaded for the analysis. Helium was used as the carrier gas.

The mass spectrometric experiment was carried out with the specifications including ion source temperature 200°C, interface temperature 240°C, EI (70ev) was the ionization level. The scan range was set from 40-1000 m/z and the solvent cut time was 3 minutes. Structure prediction was carried out using the NIST08s mass spec library.

Results and Discussion

Identification of *Trichoderma* species

The *Trichoderma* species was successfully isolated from the biopesticide and identified to be as *Trichoderma harzianum* based on their colony morphology and microscopical observations after 3-5 days of incubation. (Figure 3 & 4)

Identification of fungal species from soil sample

Fungal species namely *Aspergillus niger*, *Aspergillus terreus* and *Penicillium sp.* were isolated from the raddish and tomato soil sample after 3-10 days of incubation and identified based on their cultural and microscopical characteristics (Figure.5 and Figure.6). The colony morphology of fungal species was determined based on their colony color, texture and reverse appearance as given in the Table.1 and the microscopical characteristics were studied through conidiophore, vesicle, phialides/sterigmata and conidial arrangement (Table.2).

Antagonistic property of *Trichoderma harzianum*

Antagonistic effect of *T.harzianum* against three fungal species were determined and compared As *T.harzianum* significantly inhibited the mycelial growth of *A.terreus* with 83.33% and *Penicillium sp.* with 78.65% and *A.niger* with 65.9% as shown in Figure.7&8.

Antimicrobial activity of crude extract of *Trichoderma harzianum*

Antifungal activity of crude extract of *T.harzianum*

Antifungal activity of crude extract of *T.harzianum* was studied against *Aspergillus niger*, *Aspergillus terreus* and *Penicillium sp.* and their zone of inhibition were recorded and the results obtained were very effective against *A.terreus* as compared to *A.niger* and *Penicillium sp.* (Figure.10). No zones were observed around control well in each plate (Figure.9)

Antibacterial activity of crude extract of *T.harzianum*

Antibacterial activity of crude extract of *T.harzianum* was analyzed against *Staphylococcus aureus* MTCC 6908, *Escherichia coli* MTCC 1574 and *Pseudomonas aeruginosa* MTCC 2582 (Figure.11&13) and their zone of inhibition were recorded and compared. Almost all bacterial species tested was effectively inhibited by crude extract of *T.harzianum*.

Antimicrobial activity of crude extract of *T.harzianum* against Multi drug-resistant (MDR) bacteria

The crude extract of *T.harzianum* was significant growth of inhibition of Multidrug-resistant (MDR) strains of *Pseudomonas aeruginosa* and *Klebsiella pneumonia* (Figure.12 &13).

Identification of volatile compounds from *T.harzianum* by FT-IR and GC-MS

Identification of volatile compounds by FT-IR

FT-IR spectroscopy analysis was performed for the structural identification of *T.harzianum* using

interpretation of the characteristic functional groups present. FT-IR spectrum of the active fraction (Crude extract) contained the following characteristic bands: a strong, broad band at 3200-3500 indicating the presence of intermolecular bonded alcohol group with O-H stretching, a medium band at 1647 corresponding to the functional group of oxime group with C=N stretching. The bond in the region 1350-1450 corresponding to vibrations of the carboxylic acid functional group as shown in the (Figure.14).

Identification of volatile compounds by GC-MS (Mahadevi *et al.*, 2018)

The crude extract of *T.harzianum* was analyzed for the presence of volatile compounds by GC-MS revealed two peaks depicted in (Figure.15) representing major compound as Diethyl phthalate with 90.27% of peak area and other compound as propanol, 2,2-dimethyl-, oxime with 9.73% of peak area (Table.3).

The volatile compounds with their retention time, peak area percentage, molecular formula and structure were mentioned in the table

Among *Trichoderma* species, *Trichoderma harzianum* was considered as the most potent biocontrol agent. Its volatile and non-volatile secondary metabolites possess many beneficial properties such as biofungicidal, bioinsecticidal, biopesticidal in the field of agriculture whereas in the field of pharmaceutical they might be used as an alternative drug of choice due to increasing Multidrug-resistant strains worldwide.

In the present study, *Trichoderma harzianum* was isolated from the biopesticide and identified based on colony morphology and microscopical observations. Similarity Pavithra.R and Lalitha.S 2020. The secondary metabolites from *Trichoderma harzianum* were extracted with the methanol solvent, same to that of Nayara C. Saldan *et al.*, 2018.

Antagonism is the main property of *Trichoderma harzianum*. Many studies were reported the antagonistic property of *Trichoderma harzianum* against wide range of Fungal pathogens. In the present study antagonistic activity of *Trichoderma harzianum* were shown against *Aspergillus terreus*, *Aspergillus niger* and *Penicillium sp.* at strong inhibitory percentage of 83.33%, 65.9% and 78.65% respectively. This same phenomenon was observed by Mahadevi *et al.*, 2018 reported strong

antagonism of *Trichoderma harzianum* against *Phytophthora palmivora* with the maximum percentage inhibition of 73.85% followed by percentage inhibition of 72.31%, 70.77%, 69.23% and 67.69% by *Trichoderma viride*, *Trichoderma koningii*, *Trichoderma polysporum* and *Trichoderma hamatum* reported Yasser S. A. Mazrou *et al.*, 2020.

The antifungal activity of *Trichoderma harzianum* shown significant results against *Aspergillus niger*, *Aspergillus terreus* and *Penicillium sp.* with zone inhibition of 33mm, 40mm and 34mm respectively at 50µl of crude extract. In contrast Leelavathi *et al.*, 2014.

The antibacterial activity of *Trichoderma harzianum* was carried out against *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa* at 50µl of crude extract had shown promising results with maximum Zone inhibition of 35mm, 33mm and 31mm respectively. In contrast, Leelavathi *et al.*, 2014.

In this study antimicrobial activity of *Trichoderma harzianum* (from biopesticide) wastested against Multidrug-resistant strains of *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* and were reported with significant and promising results than the other species of *Trichoderma*. Hence, *Trichoderma harzianum* and its volatile compounds reported in the present study could have significant antimicrobial property against both plant and human pathogens, Sri Sedjati *et al.*, 2021

The finding of present study, crude extract of *Trichoderma harzianum* was analyzed using GC-MS technique revealed the presence of two compounds, Diethyl phthalate with 90.27% of peak area and Propanol, 2, 2-dimethyl-, Oxime with 9.73% of peak area (Pivalaldehyde oxime) were reported Mahadevi *et al.*, 2018. In the present study, the major compound identified was Diethyl phthalate and has been reported to have an antimicrobial activity (Premjanu N and Jaynthy C *et al.*, 2014).

As in the present study, the crude extract of *Trichoderma harzianum* against various organisms (bacteria, fungi and MDR bacteria) showed encouraging antimicrobial results. From the FT-IR and GC-MS analysis, two compounds were identified namely Diethyl phthalate and Propanol, 2,2-dimethyl-, oxime, in which second compound was found to be novel. The reported antimicrobial activity of *Trichoderma harzianum* could be due to the presence of these compounds.



Figure.1 Biopesticide of *T.harzianum*

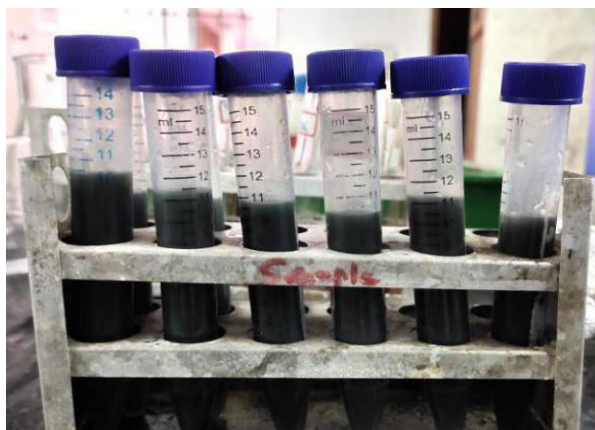


Figure.2a Extract of *Trichoderma harzianum* before centrifugation



Figure.2b Supernatant from the extract after centrifugation

Figure.3 Cultural characteristics of *T. harzianum*



3rd day of incubation



4th day of incubation



5th day of incubation

Figure.4 Microscopic appearance of *T.harzianum* showing characteristic phialides and phialospores on conidiophores.

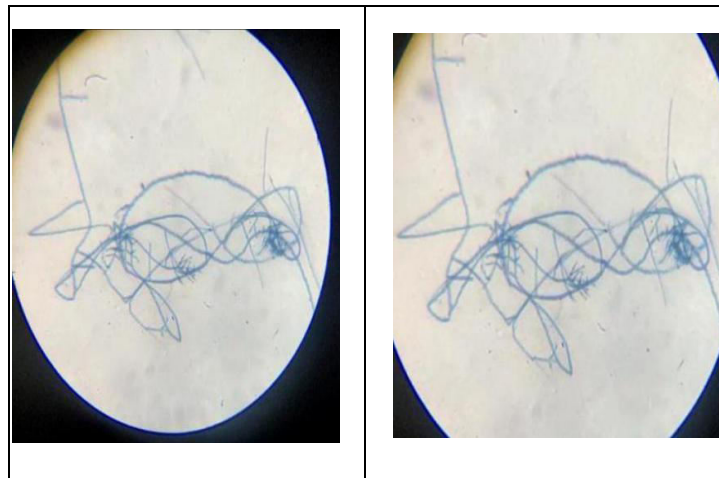


Figure.5 Macroscopic appearance of fungi

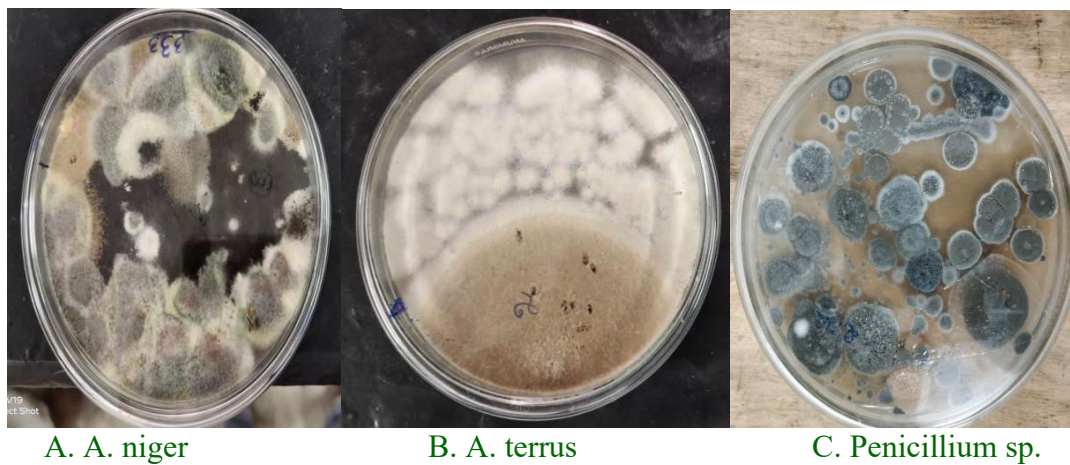


Figure.6 Microscopic appearance of fungi

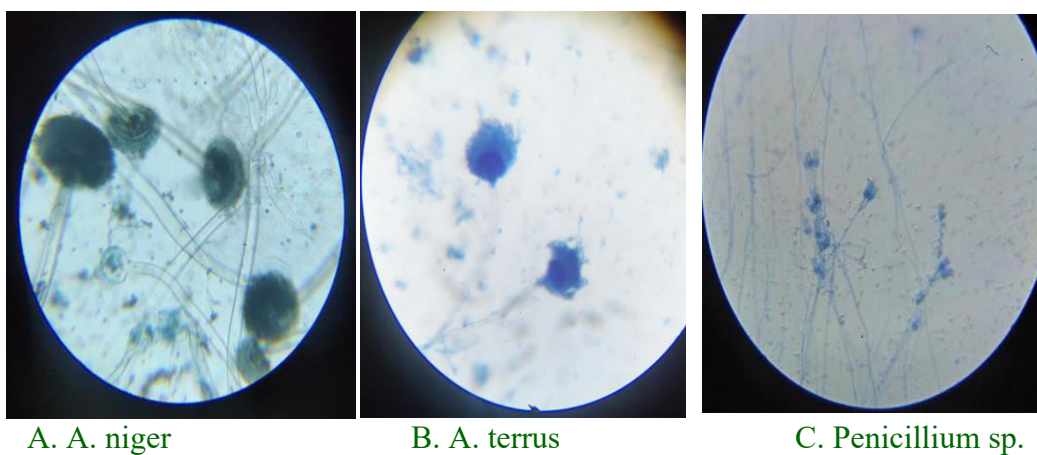


Figure.7 Antagonistic activity of *T.harzianum* against *Aspergillus niger* (A); *A.terreus* (B); *Pencillium sp.*, (C)

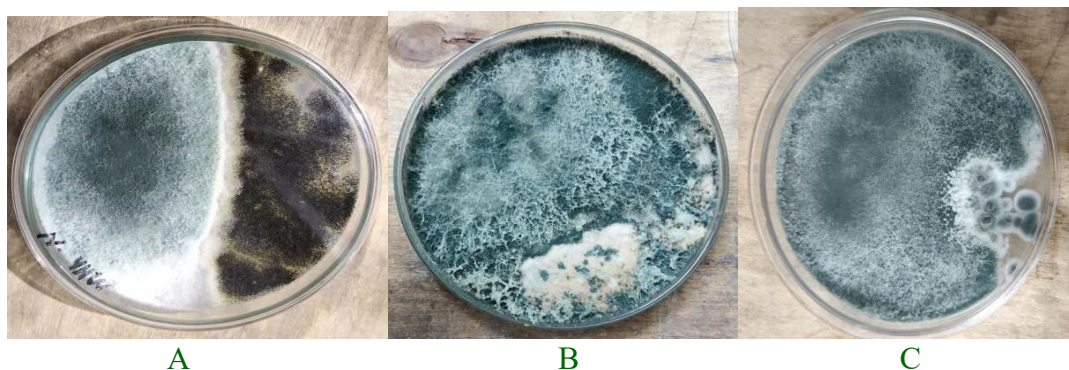


Fig.8 Antagonistic property of *T.harzianum* against fungal species

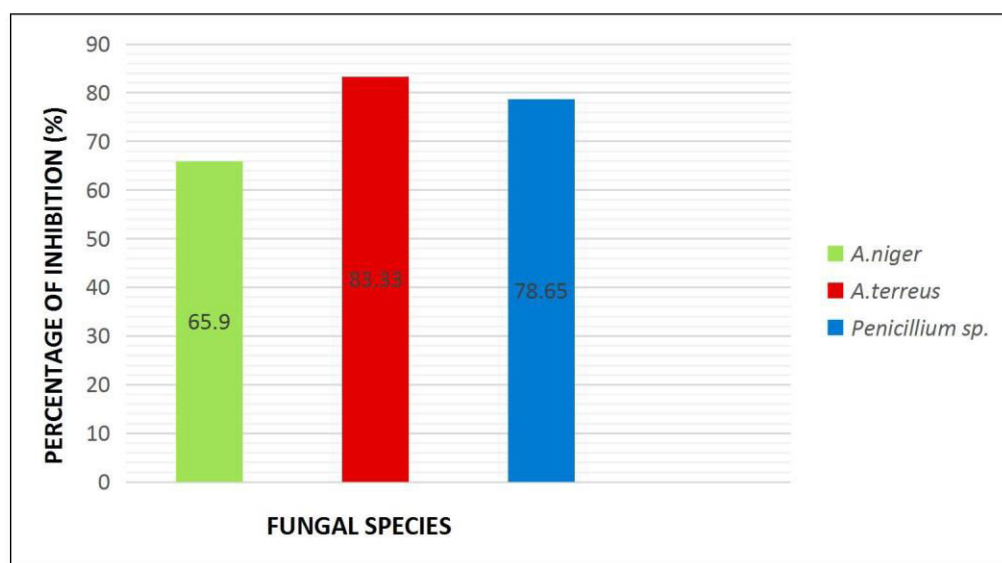


Figure.9 Antifungal activity of *T.harzianum* against fungal species

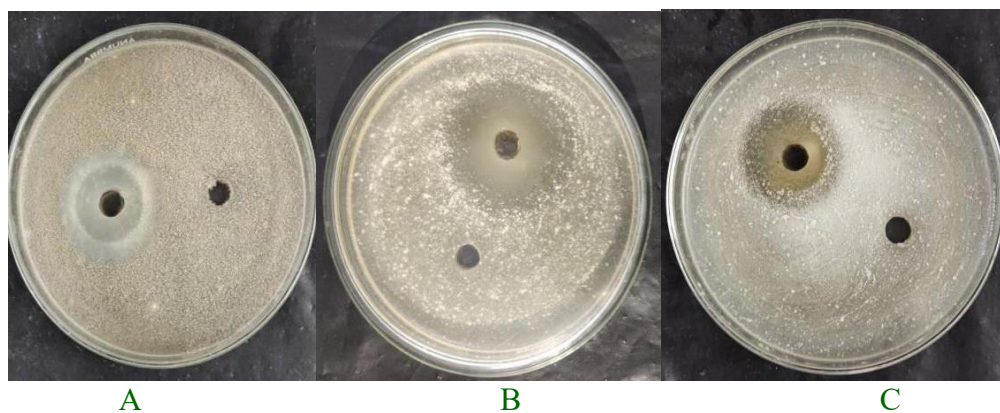


Fig.10 Antifungal activity of *T.harzianum* against fungal species at 50µl of crude extract

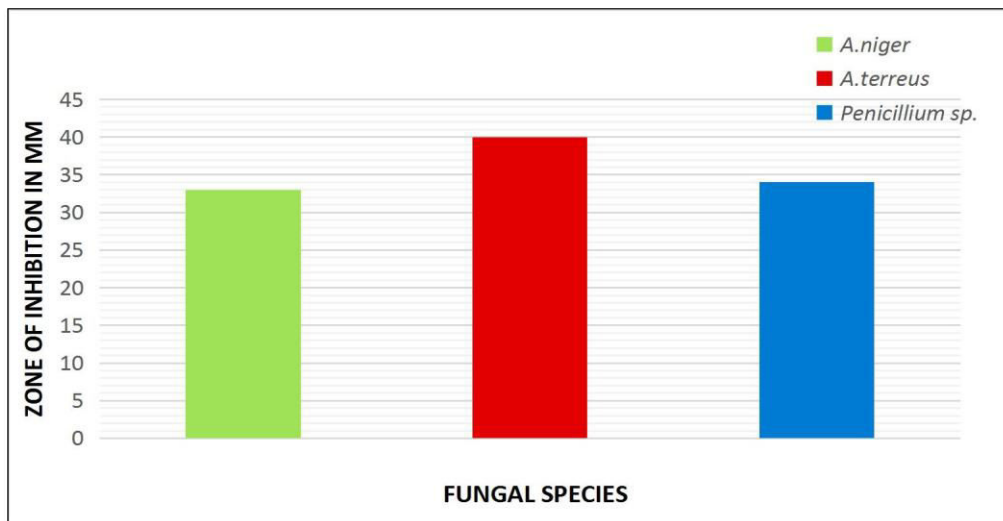


Figure.11 Antibacterial activity of *T.harzianum* against *S.aureus* (A), *E.coli* (B) and *P.aeruginosa* (C)

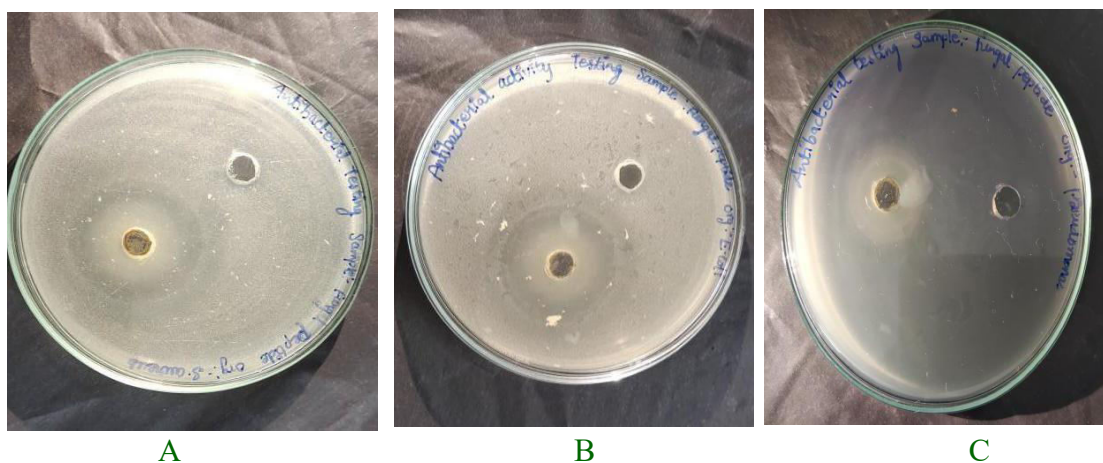


Figure.12 Antimicrobial activity of activity of *T.harzianum* against against MDR-KP (A) and MDR-PA (B)

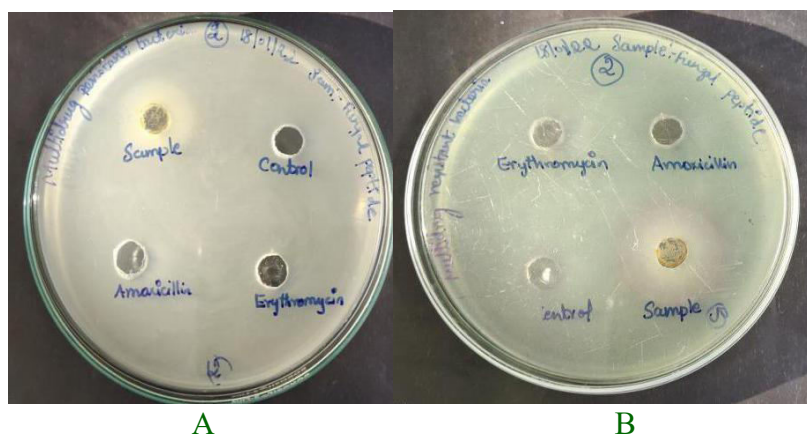


Figure.13 Antimicrobial activity of *T.harzianum* against bacterial strains and two Multi drug-resistant (MDR) bacteria at 50 μ l of crude extract

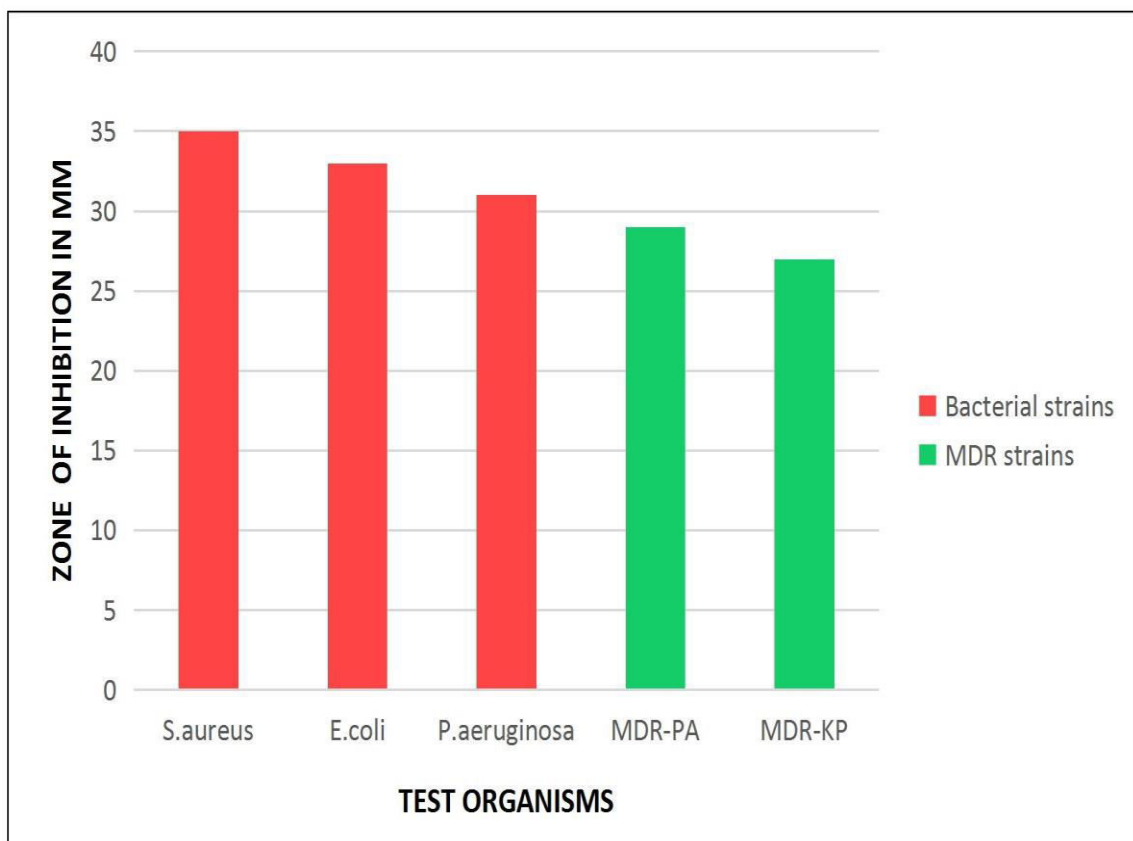


Figure.14 FT-IR analysis of crude extract of *Trichoderma harzianum*

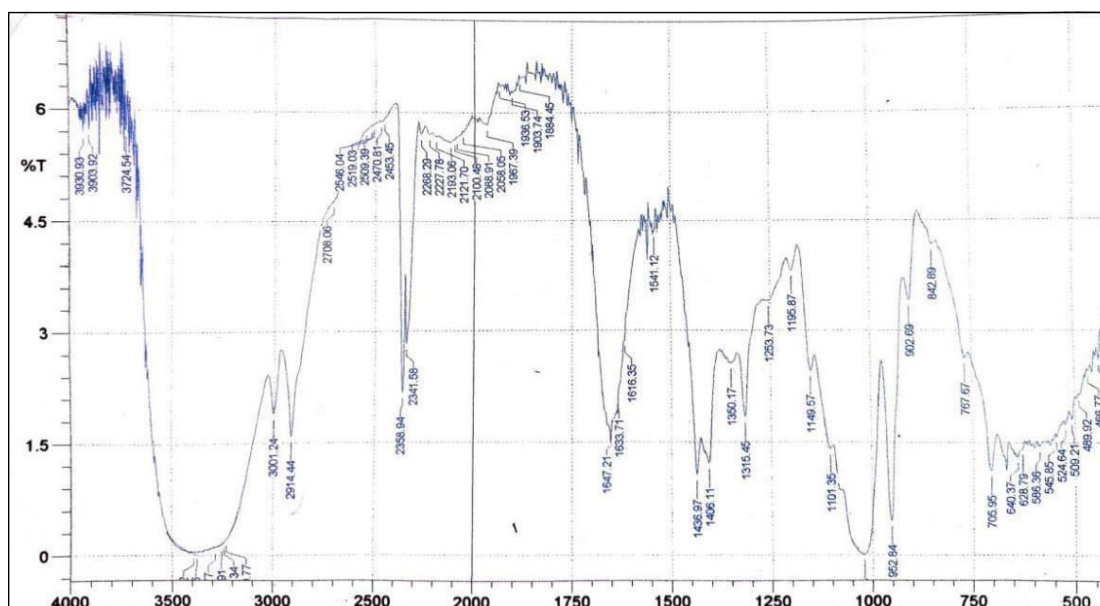


Figure.15 GC-MS analysis of crude extract of *Trichoderma harzianum*

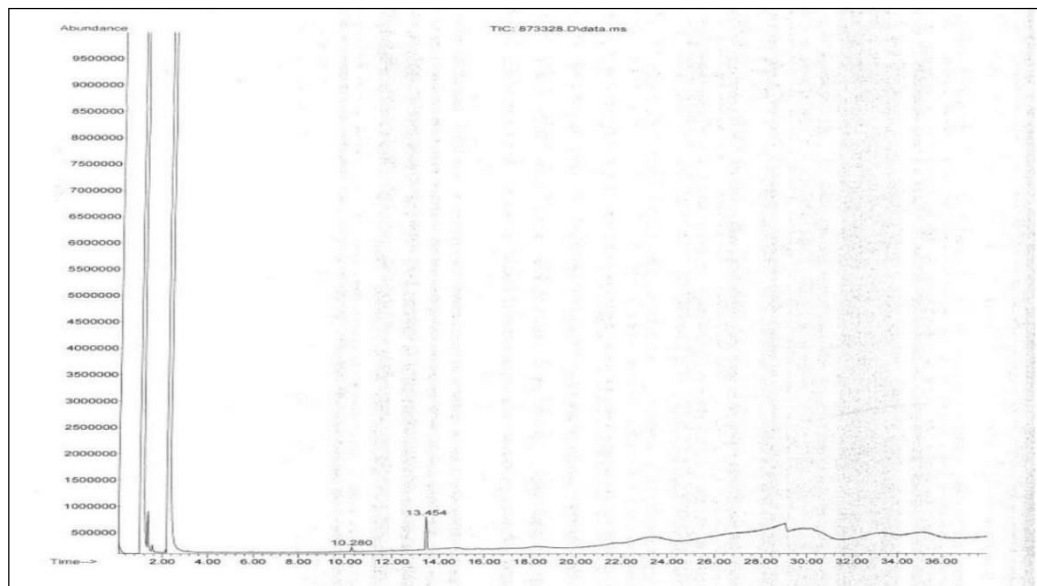


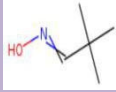
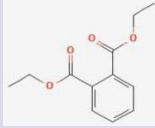
Table.1 Cultural characteristics of fungal species

Macroscopic observation		Fungal species		
S. no	Colony morphology/cultural characteristics	<i>Aspergillus niger</i>	<i>Aspergillus terreus</i>	<i>Penicillium sp.</i>
1.	Colony appearance	Brown-black colored colonies	Smooth, Cinnamon colored colonies encircled by white border	Velutinous, sulcate green colored colonies with white border covering upto 2-3cm from the periphery of the colony with watery droplets in the centre.
2.	Reverse colony appearance	White-yellow	Reddish orange	White-creamy yellow grooves

Table.2 Microscopical characteristics of fungal species

Microscopic observation		Fungal species		
S. no	Microscopical Characteristics	<i>Aspergillus Niger</i>	<i>Aspergillus terreus</i>	<i>Penicillium sp.</i>
1.	Hyphae	Septate	Septate	Filamentous hyphae
2.	Conidiophore	Thick walled, Smooth and Colorless	Thin and Smooth	Long thin tubes
3.	Sterigmata/phialides	Biseriate	Biseriate	Flask-shaped phialides
4.	Vesicle	Globose and radiate	Globose	-
5.	Conidia	Globose and echinulate	Globose	Globose

Table.3 Volatile compounds profile of *T.harzianum* identified in GC-MS analysis

S. no	Retention time	Area%	Compound name	Molecular Formula	Structure
1.	10.279	9.73	Propanol, 2,2-dimethyl-, oxime	C ₅ H ₁₁ NO	
2.	13.454	90.27	Diethyl phthalate	C ₁₂ H ₁₄ O ₄	

Hence, volatile compounds of *Trichoderma harzianum* could have significant applications in agricultural and pharmaceutical areas.

Author Contributions

Roshini Balamurugan: Conceived the original idea and designed the model and wrote the manuscript. K. Nithya: Designed the model and the computational framework and analysed the data.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

References

Agnes Keszler, Esther Forgacs and Laszlo Koyai, Juan Antonio Vizcaino, Enrique Monte and Isabel Garcia-Acha. Separation and identification of volatile components in the fermentation broth of *Trichoderma atroviride* by solid-phase extraction and Gas Chromatography-Mass

Spectrometry. Journal of Chromatographic science 2000; 38.

<https://doi.org/10.1093/chromsci/38.10.421>

Alfi Inayati, Liliek Sulistyowati, Luqman Qurata Aini and Eriyarto Yusnawan. Antifungal activity of volatile organic compounds from *Trichoderma virens*. International conference on Biology and Applied Science (ICOBAS) 2019.

<https://doi.org/10.1063/1.5115750>

Gavryushina I A, Georgieva M L, Kuvarina A E, Sadykova V S. Peptaibols as potential antifungal and anticancer antibiotics: Current and Foreseeable Development. Applied Biochemistry and Microbiology 2021; 57(5): 556-563.

<https://doi.org/10.1134/S0003683821050070>

Mada Triandala Sibero, Ocky Karna Radjasa, Agus Sabdono, Agus Trianto, Desy Wulan Triningsih, Ingrid Debora Hutagaol. Antibacterial activity of Indonesian Sponge associated fungi against clinical pathogenic Multidrug resistant bacteria. Journal of Applied Pharmaceutical Science 2018; 8(02): 088-094.

<https://dx.doi.org/10.7324/japs.2018.8214>

Marwa Gamal, Mohamed Abou Zaid, Iman Kamel Abou Mourad, Hussein AbdeI Kareem, Ola M. Gomma. *Trichoderma viride* bioactive peptaibol induces apoptosis in *Aspergillus niger* infecting tilapia in fish farms. Aquaculture 2022; 547.

<https://doi.org/10.1016/j.aquaculture.2021.737474>

Monika Jangir, Ritika pathak, Abhishek sharma, Shilpi sharma, Satyawati sharma. Volatiles as strong markers for antifungal activity against *Fusarium oxysporum* f. sp. cycopersici. Indian Phytopathology 2018.

<https://doi.org/10.1007/s42360-018-0073-4>

- Nagwa E. Awad, Hanaa A. Kassem, Manal A. Hamed, Amal M. El-Feky, Mohamed A. A. Elnaggar, Khaled Mohmoud and Mohamed A. Ali. Isolation and characterization of the biocative metabolites from soil derived fungus *Trichoderma viride*. Mycology 2018; 9(1): 70-80.
<https://doi.org/10.1080/21501203.2017.1423126>
- Richa Salwan, Nidhi Rialchand, Vivek Sharma. Bioactive volatile metabolites of *Trichoderma*: An overview. Springer Nature Singapore Pte Ltd.2019. https://doi.org/10.1007/978-981-13-5862-3_5
- Roshani Shrestha, Sujit Shah and Bijiya Pant. Identification of endophytic fungi from roots of two *Dendrobium* species and evaluation of their antibacterial property. African Journal of Microbiology Research 2018; 12(29): 697-704.
<https://doi.org/10.5897/AJMR2018.8924>
- Ruocco, Stefania Lanzuise, Gelsomina Manganiello and Matteo Lorito. *Trichoderma* secondary metabolites active on plants and fungal pathogens. The Open Mycology Journal 2014; 8: 127-139.
<http://dx.doi.org/10.2174/1874437001408010127>
- Shafiquzzaman Siddiquee, Bo Eng Cheong, Khanam Taslima, Hossain Kausar, Md Mainul Hasan. Separation and identification of Volatile compounds from Liquid cultures of *Trichoderma harzianum* by GC-MS using three different capillary columns. Journal of Chromatographic Science 2012; 50(4): 358-367.
<https://doi.org/10.1093/chromsci/bms012>
- Shazia Shafique, Sobiya Shafique, Alina Javed, Naureen Akhtar and Shumaila bibi. Analysis of antagonistic potential of secondary metabolites and oragnic fractions of *Trichoderma* species agianst *Alternariaalternata*. Biocontrol Science 2019; 24(2): 81-88.
<https://doi.org/10.4265/bio.24.81>
- Sri sedjati, Ambariyanto Ambariyanto, Agus Trianto, Ali Ridlo, Endang Supriyantini, Agus Sabdono, Ocky Karna Radjasa, Teguh Firmansyah. Antibacterial activity of the fungal metabolites of *Trichoderma longibrachiatum* against Multidrug-Resistant *Klebsiella pneumoniae* and Methicillin-Resistant *Staphylococcusaureus*. Jordan Journal of Biological sciences 2022; 15(1): 107-113.
<https://doi.org/10.54319/jjbs/150114>
- Vinale R, Marra R, Scala F, Ghisalberti E L, Lorito M and Sivasithamparam K. Major secondary metabolites produced by two commercial *Trichoderma* strains active against different phytopathogens. Letters in Applied Microbiology 2006; 43: 143-148.
<https://doi.org/10.1111/j.1472-765X.2006.01939.x>
- Yasser S. A. Mazrou, Abeer H. Makhoulouf, Mona M. Elseehy, Mohamed F. Awad and Mohamed M. Hassan. Antagonistic activity and molecular characterization of biological control agent *Trichoderma harzianum* fom Saudi Arabia. Egyptian Journal of Biological Pest Control 2020; 30: 4. <https://doi.org/10.1186/s41938-020-0207-8>

How to cite this article:

Roshini B. and Nithya K. 2026. Isolation, Extraction and Characterization of Volatile compound from *Trichoderma harzianum* by GC-MS Analysis and Its Potential Antimicrobial Activity. *Int.J.Curr.Microbiol.App.Sci*. Special Issue-13: 112-124. doi: <https://doi.org/10.20546/ijemas.2026.sp13.014>