

# A Systematic Bioactivity-Guided in-vitro approach for bioprospecting selected Medicinal Plants Targeting Dermatophytic Fungi

Tumakuru Nataraj Sowmya<sup>1&2\*</sup>, Kigga Kaadappa Sampath Kumara,<sup>3</sup> Monnanda Somaiah Nalini<sup>4</sup>, Koteswar Anandrao Raveesha<sup>2&5</sup>

<sup>1</sup>Department of Biotechnology and Bioinformatics, School of Life Sciences, JSS Academy of Higher Education and Research, Shivaratreeshwara Nagara, Mysuru 570015, Karnataka, India. Email: sowmyatn@jssuni.edu.in

<sup>2</sup>Center for Innovative Studies in Herbal Drug Technology, Department of Studies in Botany, University of Mysore, Manasagangotri, Mysuru 570006, Karnataka, India

<sup>3</sup>Government Pre-University College, Davangere, Karnataka, India.

<sup>4</sup>Department of Studies in Botany, University of Mysore, Manasagangotri, Mysore, Karnataka 570 006, India.

<sup>5</sup>School of Life Sciences, JSS Academy of Higher Education and Research, Shivaratreeshwara Nagara, Mysuru 570015, Karnataka, India. E mail:

\*Correspondence: sowmyatn@jssuni.edu.in

Received: 11<sup>th</sup> Sep, 2025; Revised: 26<sup>th</sup> Oct 2025; Accepted: 16<sup>th</sup> Nov, 2025; Available Online: 1<sup>st</sup> December, 2025

## ABSTRACT

**Background:** Dermatological infections are the fourth major leading cause of nonfatal ailment to human kind which are difficult to treat. Medicinal plants are a rich source for the discovery of novel antifungal compounds since they have long been used for their antifungal properties to treat superficial skin infections.

**Methods:** The present study evaluates the efficacy of 10 selected medicinal plants for anti- dermatophytic efficacy by disc diffusion assay, minimal inhibitory concentration (MIC), minimal fungicidal concentration (MFC) and Thin layer chromatography guided characterisation of the antifungal compound.

**Findings:** All the test plants exhibited anti-dermatophytic activity against one or the other test fungi except *Sauropus androgynus*, *Combretum indicum* and *Entada gigas*. *Terminalia catappa*, *Syzygium jambos* and *Terminalia arjuna* were seen significantly inhibiting *Microsporum canis*, *Microsporum gypseum*, *Trichophyton rubrum*, *Trichosporon asahii* and *Candida albicans* with significant zone of inhibition ranging from 12.9±0.2 to 42.8±0.2 mm. Anti- dermatophytic activity of *Catunaregum spinosa* and *Filicium decipiens* is been reported here for the first time with inhibition zone ranging from 10.5±0.17 to 22.7±0.4. The test plants also exhibited significant minimum inhibitory concentration (9- 1250 µg/ml) which posed both fungicidal and fungistatic effect against one or the other test fungi and *T. catappa* acetone extract (TCA) being the most effective extract against all the test fungi having MIC from 19 to 312 µg/ml. Further, TCA was evaluated for thin layer chromatography-bioautography assay, the eluted phytochemicals with Rf values 0.71 and 0.52 exhibited halo zone around the compound indicating inhibition of *M. gypseum* and *M. canis*. Band with Rf value 0.52 was characterised and was tentatively identified as triterpenoid compound. Further pure compound isolation and structure elucidation is required to confirm the said compound.

**Novelty:** The plants employed here could be candidate plants for bioprospecting anti- dermatophytic compounds especially from the plant *T. catappa*, *S. jambos*, *C. spinosa* and *F. decipiens*. Further studies including isolation, characterisation and toxicity evaluation of triterpenoid compounds from the plant *T. catappa* is warranted which could pave way in developing alternative drugs for anti- dermatophytic therapy.

**Keywords:** Dermatophytosis, Polyphenols, *Terminalia*, *Microsporum*, Thymoquinone, *Nigella sativa*, Antifungal activity, TLC-Bioautography, *Trichosporon asahii*, Antifungal activity.

**How to cite this article:** Sowmya TN, Kumara KKS, Nalini MS, Raveesha KA; A Systematic Bioactivity-Guided in-vitro approach for bioprospecting selected Medicinal Plants Targeting Dermatophytic Fungi. *Int J Drug Deliv Technol.* 2026;16(1): 251-262. DOI: 10.25258/ijddt.16.1.27

**Source of support:** Nil.

**Conflict of interest:** None

## 1. INTRODUCTION

Fungal infections have become more common in recent years and are also a major source of morbidity and mortality in those with impaired immune systems. 74.3% makes up cutaneous and subcutaneous dermal infections, 9.5% makes up *Oculomycosis*, and 8.1% makes up

invasive and non-invasive rhinosinusitis and onychomycosis, respectively<sup>[1]</sup>.

Nearly 1.7 million people die each year from invasive Candidiasis (*Candida* sp.), Aspergillosis (*Aspergillus* sp.), and Cryptococcosis (*Cryptococcus* sp.), which cause significant morbidity and mortality<sup>[2]</sup> which is far greater

\*Author for Correspondence: herdiani-s-p@fk.unair.ac.id

than the mortality rate from malaria (405,000 deaths annually) and tuberculosis (1.5 million deaths annually) [3,4]. Fungal exposure can result in superficial, systemic, and subcutaneous mycosis and tissue necrosis of the epidermal layers. *Trichophyton* species are primarily the cause of Tinea manuum, Tinea corporis (ringworm), Tinea pedis, Tinea faciei, Tinea cruris (jockle-itch) and Tinea barbae. *Microsporum canis* (*M. canis*) can cause Tinea capitis, which causes scalp itching, red, scaly papules surrounding their hair shafts, and hair loss [5].

Dermatomycosis can be treated with the antifungal drugs, there is a higher chance of re-infection, and it is unclear if this is a new infection or a relapse. Due to the fact that most dermatomycoses affect individuals with weakened immune systems, and are more susceptible to the negative side effects of antifungal medications, this therapeutic approach faces two significant obstacles. Furthermore, it is challenging to create a high safety profile for efficient antifungal medications due to the conservative physiological differences between fungal diseases and humans [6].

One possible source for drug discovery is nature. For many years, scientists have looked to the phytochemicals found in flora because of their abundance, lack of negative effects, and increased human acceptability [7]. Plants have been used for diverse therapeutic purposes, like the treatment of microbiological infections, all over the world because plants produce a wide range of secondary metabolites which play a crucial role against a variety of pathological conditions caused by microbes [8]. The majority of traditional therapeutics and modern pharmaceutical developments are derived from plant sources, and they employ active metabolites that are recognised for their low to negligible toxicity. Research projects focussing on medicinal plants have significantly increased in recent years, with a particular focus on exploring their efficacy for antimicrobial drugs [9].

A report of WHO states that from the 119 plant bioactive molecules derived from the plants, 74% are being used in modern medicine and are in line with their usage in traditional medicine [10]. The WHO has encouraged the use of medicinal plants for healthcare since the Declaration of Alma Ata in 1978, which acknowledged the use of herbal medicines and medicinal plants for preventative, therapeutic, and palliative reasons [11]. Nevertheless, until recently, fewer than 1% of plants were identified by their pharmacologically active secondary metabolites because of their ecological richness and varied chemical endowment within each species traditional medicinal plants are the most valuable source of bioactive compounds in this respect [12].

The global market for herbal medicines was estimated to be worth \$170 billion in 2022 and is expected to increase

at a compound annual growth rate (CAGR) of 15% from 2023 to 2033, reaching \$600 billion [13].

Despite the encouraging potential of plant-derived antifungal medicines, challenges still stand in the way of their complete development.

Further investigation is required to identify and define active compounds, establish their mechanisms of action, and confirm their effects in vivo [2].

The present study aimed to investigate bioactivity guided efficacy of different extracts of selected traditional medicinal plants against dermatophytes. Since ancient times, plants are being utilised for their therapeutic efficacies. With diverse forms of secondary metabolites, plants are one of the significant source of natural compounds which can be utilised for therapeutic purposes with low or negligible toxicity. This increased scientific interest is reflected in the ongoing investigation of plant-based metabolites as important sources for the discovery of effective drugs, specifically in the field of infectious diseases. In the present study total

of 10 medicinal plants were selected for bioprospecting the anti- dermatophytic compounds which are known to contain diverse therapeutic secondary metabolites presented in Table 1.

**Table 1.** Details of active compounds and reported bioactivity of the medicinal plants selected for the study

Sl no	Name of the Plant	Active compound/s	Bioactivity reported	Reference
1	<i>Terminalia catappa</i>	Gallic acid, kaempferol, chlorogenic acid, Ellagic acid, Catechin, Epicatechin, Quercitrin, Caffeic acid, Isoquercitrin, Quercetin, Ellagic acid and Rutin	antibacterial, anti-inflammatory, antidiabetic, antimetastasis, anthelmintic, anti-quorum sensing, antioxidant, hepatoprotective and antifungal	[14]
2	<i>Nigella sativa</i>	Thymoquinone, Thymol, $\alpha$ -thujene, $\alpha$ -pinene, Longifene and Terpinene, Nigellidine and Nigellicine	anti-inflammatory, anticancer, neuroprotective, immunomodulatory and antihypertensive	[15]
3	<i>Terminalia arjuna</i>	Terminoside A, Terminomic acid, Luteolin Baicalein, Kaempferol, Quercetin, Gallic acid, Ellagic acid, Arjunin, Arjungenin, Arjunic acid, Arjunolic acid	Antimicrobial, hepatoprotective, antipyretic, anti-dysentery and anti-inflammatory	[16, 17]
4	<i>Syzygium jambos</i>	Jambone A- G, Cinnamic acid, Gallic acid, betulinic	Anti-Inflammatory, anti-diabetic, antimicrobial,	[18]

		acid, Asiatic acid, Myricetin 3-O-glucoside, Quercitrin, Vescalagin Quercetin, rutin, castalagin	antioxidant, anticancer	
5	<i>Callistemon lanceolatus</i>	$\alpha$ -pinene, P-terpinene, P-cymene and 1,8-cineole, Thujene, $\beta$ -Caryophyllene, isopinocarveol, pinocarvone, eucalyptol, limonene, Callistemonone A, Catechol, Gallic acid, Casurin	Antimicrobial, Anthelmintic, Anti-inflammatory, Antidiabetic anticancer	[19]
6	<i>Catunaregum spinosa</i>	Catunaregins A-L, Catunaregin, Arjunetoside, Randiasaponin, Randialic acid B, Araliasaponin V, Randioside A, Randianin, oleanolic acid,	Antimicrobial, hepatoprotective, antioxidant, anti-inflammatory, anti-hyperglycemic, wound healing activities and anti-cataleptic	[20]
7	<i>Filicium decipiens</i>	Trifolin, Kaempferol 3-O-alpha-Rhamnopyrosyl, Kaempferol 3-O-rutinoside	Antimicrobial, Anti-inflammatory, and anti-tumor activity, antidiabetic property	[21, 22]
8	<i>Entada gigas</i>	Pjaseoloidin, 1,3,4-trihydroxy benzene glucoside, entamide A, Entamide C, Rheedioside A and Rheedioside B	Antibacterial, antifungal	[23]
9	<i>Sauropus androgynous</i>	Tetradecanoic acid, Hexadecenoic acid, Octadecadienoic acid, morpholine, L-Phenylalanine, $\alpha$ -tocopherol	Multivitamin plant used in treating eye diseases, obesity, diabetic treatment, gastrointestinal diseases and in aiding lactation	[24]
10	<i>Combratum indicum</i>	Quisqualic acid, Caffeic acid, Quercetin 3-O-rhamnoside, Vanillic acid, Chlorogenic acid, Kaempferol-3-O-pentose F, Rutin, Isorhamnetin 3-O-hexoside	Anthelmintic property, antirheumatic, antifungal, antiviral, antidiarrheal	[25]

## 2. MATERIALS AND METHODS

### 2.1. Collection of plant material

Table 1 depicts the medicinal plants selected for the study. Different parts of the plant were collected from in and around Mysuru, shade dried and washed with water and subjected for shade drying for 10 days and further subjected to sequential Soxhlet extraction. The crude extract was obtained after evaporation and stored at 4° C for further assays.

### 2.2. Dermatophytes and growth media

Freeze-dried cultures of *Microsporum gypseum* (MTCC 2830), *Microsporum canis* (MTCC 2820) *Trichophyton*

*rubrum* (MTCC 296), *Trichisporon asahii* (MTCC 6179) and *Candida albicans* (MTCC 183), were purchased from MTCC and cultured on Sabouraud dextrose agar. Inoculum of the were maintained on Sabouraud dextrose broth .

### 2.3. Antifungal susceptibility tests

#### 2.3.1. Evaluating efficacy of the extracts by disc diffusion assay

Anti- dermatophytic and anti-yeast potential of the test plant extracts was evaluated by disc diffusion assay following the protocol of CLSI protocol SDA plates were inoculated with standardized inoculum of the test fungi. Sterile discs were impregnated with 100  $\mu$ l the test plant extract and placed onto the inoculated plates and incubated at 28 °C for 4-6 days for filamentous fungi and 24 hrs at 28 °C for yeast like fungi. The diameter of the zone of inhibition (ZOI) was calculated and statistically analyzed.

#### 2.3.2 Determination of Minimum Inhibitory concentration (MIC) and Minimum fungicidal Concentration (MFC) against Dermatophytes.

MIC of the active extracts were tested against filamentous fungi and yeast like fungi following the protocol of CLSI protocol. Two fold serial dilution of the test extract was tested against the dermatophytes to check the efficacy of the extracts. 0.5 McFarland standard inoculum was introduced into the wells and incubated at 28° C for 4-6 days for filamentous fungi and 24 hours at 28 °C for yeast like fungi. After the incubation period 20 $\mu$ l of aqueous solution of Iodonitro tetrazolium chloride (INT, 0.05mg/ml) was added to the wells. The well not exhibiting the colour change was designated as MIC. Aliquot of sample from the MIC well was inoculated to the previously solidified SDA plates and incubated at optimum temperature for 4-6 days. The well which did not show growth of any viable colony was designated as MFC.

The MFC/MIC ratio was computed in order to evaluate the extract's fungicidal or fungistatic potential. If the MFC/MIC ratio is  $\leq 4$  the extract is fungicidal and if the MFC/MIC ratio is  $> 4$  it is called fungistatic.<sup>[28]</sup> Sterility controls and standard antifungal agent were maintained.

#### 2.3.2. TLC-bioautography method to detect the antifungal activity of the separated phytochemicals from *T. catappa* acetone extract.

TLC-Bioautography is a quick and easiest tool to find the antimicrobial property of the eluted analytes. The acetone extract of *T. catappa* was subjected to TLC characterisation for separation of phytochemicals which was already done by our research group to test the antibacterial activity.

In the current investigation we employed the acetone extract to detect the anti-dermatophytic activity of the compounds present in the extract. After the elution the chromatogram was subjected to agar overlay bioautography with slight modifications [29]. The molten SDA was mixed with aliquot of standardized fungal inoculum and was poured on the developed chromatograms and incubated at 38 °C for 48-72h and the chromatograms were examined for zone of inhibition surrounding the eluted compounds. The *R<sub>f</sub>* value of the band exhibiting the antifungal activity was recorded.

#### 2.3.4. HRLCMS based compound identification of antifungal active bands (*R<sub>f</sub>* 0.52) from *T. catappa*.

The band *R<sub>f</sub>* 0.52 was analyzed by HRLCMS employing agilent (6550 ifunnel Q-TOF's) system. Chromatographic separation was carried out with hypersil gold column (C18X 2.1mm-3Micron) with flow rate 0.3ml/minute with injection volume of 5µl. Q-TOF mass spectrometer was operated with dual AJS ESI as ion source and scan range of 150-1000 M/Z for mass detection.

### 3. STATISTICAL ANALYSIS

All statistical analysis was done using Origin Pro 2017 graphing software.

Triplicate values were subjected to ANOVA followed by Tukey's post hoc test at 0.05 significance level.

## 4. RESULTS

### 4.1. Disc diffusion assay

The plants were tested for anti-dermatophytic potency and anti-yeast potency against *M. gypseum*, *M. canis*, *T. rubrum*, *C. albicans* and *T. asahii*. Out of 10 plants evaluated 7 plants resulted in significant inhibition of the test fungi with inhibition ranging from 15.0 mm to 42.8 mm. The plants exhibited antifungal activity against one or the other test fungi with varying zone of inhibition. The most potent plant extracts inhibiting test fungi were *T. catappa* > *S.jambos* >, *C. spinosa* >, *T. arjuna* >, *F. decipiens* >, *C. lanceolatus* > and *N. sativa*.

Among the test plants acetone and methanol extract of *Terminalia catappa* was the most potent extract exhibiting remarkable zone of inhibition against dermatophytes. Acetone extract inhibited the test fungi significantly (Table 2). Most susceptible fungi found inhibited was *M. gypseum* at 42.8±0.2 mm > *M. canis* which was inhibited at 39.7±1.1 mm and *T. rubrum* was inhibited at 35.2±0.3 mm. *C. albicans* and *T. asahii* was inhibited at 14.1±0.2 and 17.1±0.3 mm. On the contrary methanol extract was slightly less efficient compared to acetone extract. *M. canis* > *T. rubrum* > *M. gypseum* was highly susceptible to methanol extract exhibiting 36.2±1.0 mm, 29.1±0.6 mm and 26.7±0.2 mm zone of inhibition respectively. *C.*

*albicans* and *T. asahii* was inhibited at 12.9±0.2 mm and 15.0 mm respectively.

Acetone and methanol extract of *S. jambos* inhibited *M. canis* significantly exhibiting the zone of inhibition 26.91±1 mm and 28.58±1 mm respectively.

Methanol extract of *C. spinosa* inhibited *C. albicans* exhibiting significant zone of inhibition of 22.7±0.4 mm which was reported for the first time in our study.

Acetone and methanol extract of *T. arjuna* was seen significantly inhibiting all the test fungi with zone of inhibition ranging from 14.41±0.2 to 10.00 mm with *M. canis* being the most susceptible fungi. Moderate inhibition was observed by *T. arjuna* extracts. It was interesting to note that leaf acetone extract of *F. decipiens* inhibited *M. gypseum* and *M. canis* with 12.1±0.2 mm and 14.5±0.5 mm zone of inhibition respectively. The leaf extract of *F. decipiens* has not been evaluated for anti-dermatophytic activity earlier and our study stands as first report in inhibiting the dermatophytes by *F. decipiens*. *C. lanceolatus* and *N. sativa* exhibited least inhibitory activity only against *C. albicans* with zone of inhibition 12.08±0.2 and 11.03±0.2 mm respectively.

### 4.2. Efficacy of plant extracts evaluate by MIC and MFC.

MIC was carried out employing the standard broth microdilution test against dermatophytes. MIC determination is a significant step in antimicrobial drug discovery which helps in determining the minimum concentration required to inhibit/ kill the test organism.

In the present study all the test plants exhibited significant inhibition of one or the other test fungi. The MIC concentration of the test plants ranged from 9 µg/ml to 1250 µg/ml for the plants tested. Most of the plants tested exhibited fungicidal effect (Figure 1 and Table 3).

Among the test plants acetone and methanol extract of *T. catappa* exhibited significantly lesser inhibitory concentration and fungicidal effect against all the test fungi except *C. albicans* which exhibited fungistatic effect. The MIC of both acetone and methanol extract was found to be ranged between 19 µg/ml and 625 µg/ml. *M. gypseum* was the highly susceptible fungi with MIC and MFC of 19 µg/ml.

It must be noted here that antifungal activity of *T. catappa* against *T. asahii* is been carried out for the first time in our study and also the extract exhibited fungicidal effect.

Leaf acetone extract of *T. arjuna* exhibited inhibition of test fungi ranging from 78- 625 µg/ml and the most susceptible test fungi was found to be *M. gypseum* (78 µg/ml).

Acetone and methanol extract of *S. jambos* inhibited *T. asahii* and *C. albicans* significantly (156 µg/ml respectively). It was interesting to note that both the extract of *S. jambos* exhibited fungicidal effect.

*C. spinosa* methanol extract inhibited *T. rubrum* and *C. albicans* significantly at 39 µg/ml and 9 µg/ml respectively with fungicidal effect.

*M. gypseum* (78 µg/ml) and *T. asashii* (9 µg/ml) were significantly inhibited by acetone extract of *F. dicipiens* and the extract exhibited fungicidal effect against *M. gypseum*.

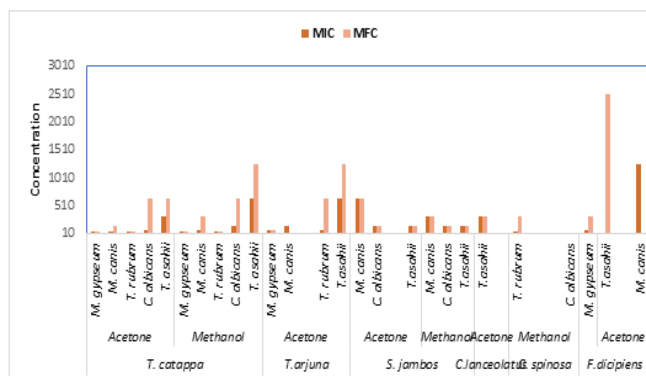


Figure 1. Efficacy of plant extracts exhibiting MIC and MFC against the dermatophytes

#### 4.3. Agar overlay bioautography and TLC characterization of leaf acetone extract of *T. catappa*.

TLC separation of the acetone extract was carried out by our research group previously which was evaluated for antibacterial activity but not for anti-dermatophytic activity. (Figure not shown and it is been published elsewhere by our research group). The TLC separation of the acetone extract exhibited clear elution of 9 bands having *R<sub>f</sub>* value 0.88, 0.79, 0.71, 0.59, 0.52, 0.47, 0.39, 0.20 and 0.07. Hence the acetone extract was further employed to detect the anti-dermatophytic activity of the eluted compounds.

The eluted compounds of *T. catappa* when subjected to agar overlay bioautography exhibited significant inhibition of *M. gypseum* and *M. canis*. *C. albicans* and *T. asahii* was not inhibited by the extract. The band with *R<sub>f</sub>* value 0.71, 0.59 and 0.52 exhibited antifungal activity by forming a clear zone around the eluted compound where there is no growth of the fungi which confirms the antifungal activity of the phytocompounds from acetone extract (Figure 2A and 2B).

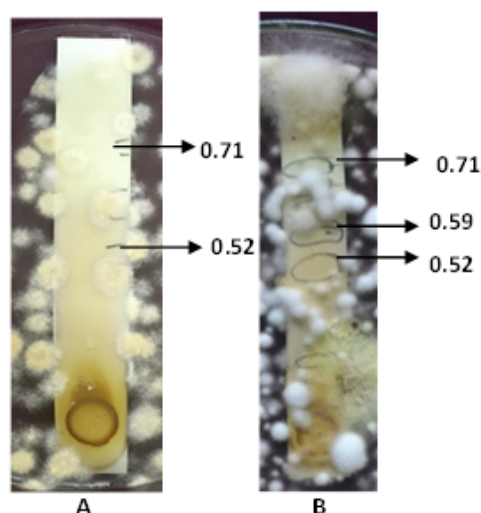
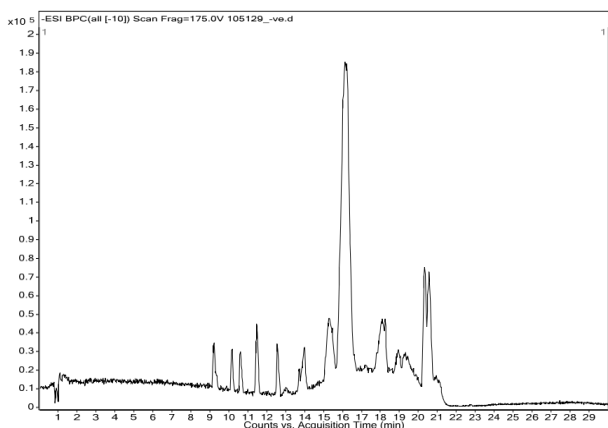


Figure 2. TLC- Bioautography assay of eluted phytocompounds to detect the antifungal activity against dermatophytes.

A: Bioautography assay showing antifungal activity against *M. canis* and B: Antifungal activity *M. gypseum*.

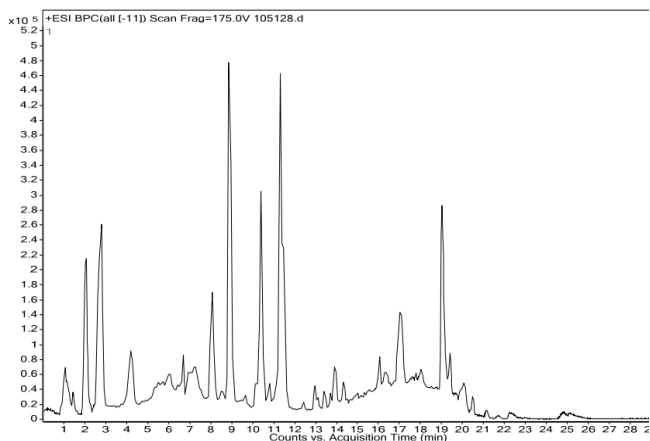
#### 4.4. HRLCMS characterization of the antifungal (*R<sub>f</sub>* 0.52)

The band with *R<sub>f</sub>* value 0.52 which exhibited clear ZOI against *M. gypseum* and *M. canis* were scrapped from the TLC plates and subjected to HRLCMS characterization for tentative detection of the antifungal compounds. Table 4 and 5 depicts the compounds tentatively identified by HRLCMS method in both negative and positive ionization mode. The liquid chromatogram of the antifungal band with *R<sub>f</sub>* value 0.52 showed varied concentration of metabolites (Figure 3 and 4). The compounds were identified by Metlin database. The HRLCMS data suggest that the plant has considerably high concentration of triterpenoids detected in the negative ionization mode. The compounds especially triterpenoid Ursolic acid and Malsinic acid is well documented in the plant *T. catappa*. This suggests that the negative ionization mode is more suitable for detection of triterpenoids from the plant *T. catappa*. Also, the extract exhibited the presence of flavonoids and alkaloids in the positive ionization mode.



**Figure 3.** Liquid chromatogram of the antifungal active band (R<sub>f</sub>0.52) showing abundance of compounds at different retention times in positive ionisation mode.

**Note.** The numbers on the chromatogram correlate with the compounds identified in the Table 4.



**Figure 4.** Liquid chromatogram of the antifungal active band (R<sub>f</sub>0.52) showing abundance of compounds at different retention times in negative ionisation mode.

**Note:** Numbers on the chromatogram correlate with the compounds identified in Table 5.

**Table 2.** Table depicting the antifungal activity of different extracts of selected medicinal plants against test fungi

Sl. no	Plant name	Part investigated	Extract	<i>M. gypseum</i>	<i>M. canis</i>	<i>T. rubrum</i>	<i>C. albicans</i>	<i>T. asahii</i>
--------	------------	-------------------	---------	-------------------	-----------------	------------------	--------------------	------------------

				Diameter of Zone of Inhibition (mm)				
1	<i>T. catappa</i>	Leaves	Acetone	42.8 ±0.2 <sup>c</sup>	39.7 ±1.2 <sup>g</sup>	35.2 ±0.3 <sup>a</sup>	14.1 ±0.2	17.1 ±0.3
			Methanol	26.7 ±0.2 <sup>b</sup>	36.2 ±1.0 <sup>f</sup>	29.2 ±0.6 <sup>e</sup>	12.9 ±0.2	15.0 ±0.0
2	<i>Nigella sativa</i>	Seeds	Hexane	0 ±0.00	0 ±0.00	0 ±0.00	0 ±0.00	11.0 ±0.22
3	<i>Callistemon lanolatus</i>	Leaves	Acetone	0 ±0.00	0 ±0.00	0 ±0.00	0 ±0.00	12.0 ±0.2
4	<i>Catunaregum spinosa</i>	Seeds	Methanol	0 ±0.00	0 ±0.00	22.7 ±0.4 <sup>a</sup>	15.0 ±0.0 <sup>b</sup>	0 ±0.00
5	<i>Tarjuna</i>	Leaves	Acetone	14.4 ±0.2 <sup>a</sup>	15 ±0.00 <sup>c</sup>	11.8 ±0.1 <sup>bd</sup>	15.0 ±0.0 <sup>e</sup>	10 ±0.00 <sup>f</sup>
			Methanol	0 ±0.00	0 ±0.00	0 ±0.00	10 ±0.0 <sup>c</sup>	0 ±0.00
6	<i>Syzygium jambos</i>	Leaves	Acetone	0 ±0.00	26.9 ±1.3 <sup>a</sup>	0 ±0.00	11 ±0.00	11 ±0.00
			Methanol	0 ±0.00	28.5 ±1.45 <sup>c</sup>	0 ±0.00	0 ±0.00	0 ±0.00
7	<i>Filicium decipiens</i>	Leaves	Acetone	12.1 ±0.2	14.5 ±0.5 <sup>a</sup>	0 ±0.00	0 ±0.00	10.5 ±0.17 <sup>b</sup>
	Reference antibiotics	Miconazole 50µg		32 ±0.00	35 ±0.00	27 ±0.8	19 ±0.00	29 ±0.00

**Note:** Values are presented in means ± Standard Error of Mean of three independent experiments. Superscript letters annotated after the mean values indicate statistical difference analyzed by One way ANOVA followed by tukey's LSD post hoc test at  $p \leq 0.05$ .

**Table 3.** MIC and MFC exerted against dermatophytes and yeast- like fungi by the test extracts

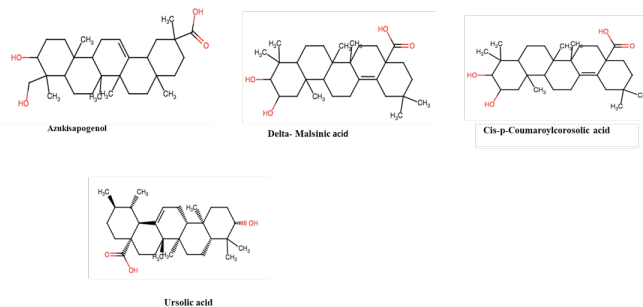
Sl. no	Plant name	Extract used	Test Organism	MIC (µg/ml)	MFC (µg/ml)	MIC: MFC Index	Effect	Reference Antibiotics (µg/ml)
1	<i>T. catappa</i>	Acetone	<i>M. gypseum</i>	19	19	1	Fungicidal	9
			<i>M. canis</i>	39	156	4	Fungicidal	9
			<i>T. rubrum</i>	19	39	2	Fungicidal	9
			<i>C. albicans</i>	78	625	8	Fungistatic	9
			<i>T. asahii</i>	312	625	2	Fungicidal	312
		Methanol	<i>M. gypseum</i>	39	39	1	Fungicidal	9
			<i>M. canis</i>	78	312	4	Fungicidal	9
			<i>T. rubrum</i>	39	39	1	Fungicidal	9
			<i>C. albicans</i>	156	625	4	Fungicidal	9
			<i>T. asahii</i>	625	1250	2	Fungicidal	312
2	<i>Tarjuna</i>	Acetone	<i>M. gypseum</i>	78	78	1	Fungicidal	9
			<i>M. canis</i>	156	*	No index achieved	No MBC Established	9
			<i>T. rubrum</i>	78	625	8	Fungistatic	9
			<i>T. asahii</i>	625	1250	2	Fungicidal	312
			<i>M. canis</i>	625	625	1	Fungicidal	9
3	<i>S. jambos</i>	Acetone	<i>M. canis</i>	625	625	1	Fungicidal	9
			<i>C. albicans</i>	156	156	1	Fungicidal	9
			<i>T. asahii</i>	156	156	1	Fungicidal	312
			<i>M. canis</i>	312	312	1	Fungicidal	9
			<i>C. albicans</i>	156	156	1	Fungicidal	9
4	<i>C. lanceolatus</i>	Acetone	<i>T. asahii</i>	312	312	1	Fungicidal	312
			<i>T. rubrum</i>	39	312	8	Fungistatic	9
5	<i>Catunaregam spinosa</i>	Methanol	<i>C. albicans</i>	9	9	1	Fungicidal	9
			<i>M. gypseum</i>	78	312	4	Fungicidal	9
6	<i>F. dicapsiens</i>	Acetone	<i>T. asahii</i>	9	2500	>8	Fungistatic	312
			<i>M. canis</i>	1250	*	Index not achieved	No MBC established	9

**Table 4.** HRLCMS analysis of antifungal active band (Rf 0.52) from leaf acetone extract of *T. catappa* depicting the identified compounds in negative ionization mode

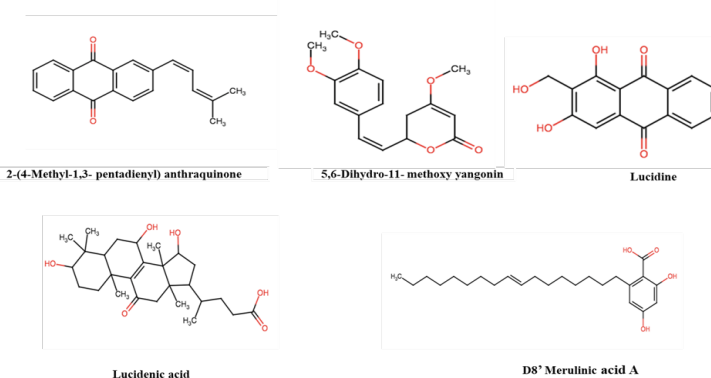
Sl. no	Compound name	Class of compound	Retention time	Mass	Molecular formula	Biological activity reported	Reference
1	Arukisapogenol	Triterpenoid saponin	12.627	462.35	C <sub>30</sub> H <sub>48</sub> O <sub>4</sub>	Anti-inflammatory	[30]
2	Delta-Maslimic acid	Triterpenoid	13.8	4732	C <sub>30</sub> H <sub>48</sub> O <sub>4</sub>	Anti-inflammatory and anticancer	[31]
3	Cis-p-Coumaroylcorsolic acid	Triterpenoid	15.2	618.3	C <sub>39</sub> H <sub>54</sub> O <sub>8</sub>	Immunomodulatory effect	[32]
4	Ursolic acid	Triterpenoid	16.0	456.3	C <sub>30</sub> H <sub>48</sub> O <sub>3</sub>	Anti-inflammatory, anticancer, Immunomodulatory, hepatoprotective	[33]

**Table 5.** HRLCMS analysis of antifungal active band (Rf 0.52) from leaf acetone extract of *T. catappa* depicting the identified compounds in positive ionization mode

Sl. no	Compound name	Class of compound	Retention time	Mass	Molecular formula	Biological activity	Reference
1	2-(4-Methyl-1,3-pentadienyl) anthraquinone	Anthraquinone	2.55	288.1	C <sub>20</sub> H <sub>16</sub> O <sub>2</sub>	Used as food colorant	[34]
2	5,6-Dihydro-11-methoxy yangonin	Kavalactone	13.6	290.1	C <sub>16</sub> H <sub>18</sub> O <sub>5</sub>	anti-anxiolytic	[35]
3	Lucidme B	Alkaloid	15.47	467.3	C <sub>20</sub> H <sub>49</sub> N <sub>3</sub> O	Anticancer and Acetylcholine esterase activity	[36]
4	Lucidenic acid M	Triterpenoid	16.04	462.6	C <sub>27</sub> H <sub>42</sub> O <sub>8</sub>	Anticancer agent	[37]
5	D8-Merulimic acid A	Hydroxybenzoic acid	19.4	390.2	C <sub>24</sub> H <sub>38</sub> O <sub>4</sub>	Anti-diabetic activity	[38]



**Figure 5.** Structures of the compounds identified by HRLCMS as depicted in Table 4.



**Figure 6.** Structures of the compounds identified by HRLCMS as depicted in Table 5.

## 5. DISCUSSION

Infections caused by fungi are currently a major cause of morbidity and mortality worldwide, making them a major health concern [39]. To effectively address the human fungal diseases that are resistant to the antifungal therapies, more efficacious antifungal drugs must be developed [40]. Therefore, bioprospecting medicinal plants for their antifungal efficacy should be given precedence and also the mechanism of action of the phytochemicals should be prioritised in order to develop efficacious phytotherapeutics [4].

Our study presents a comprehensive study of ten medicinal plants belonging to different taxonomical families evaluated for the bioactivity guided anti-dermatophytic activity against *M. gypseum*, *M. canis*, *T. rubrum*, *C. albicans* and *T. asahii*.

Among the test plants *T. catappa* was most effective in inhibiting the dermatophytes with significant zone of inhibition and less MIC values.

Antifungal activity of *T. catappa* was reported with significant inhibition against different *Candida* species and *Trichosporon beigelii* with zone of inhibition ranging from 21- 28 mm [41]. N-butanol fraction of *T. catappa* has reported good anti-candida activity which can be corroborated with our study [42, 43]. Anti- dermatophytic

activity of aqueous and ethanol extract of *T. catappa* was reported which revealed significantly high zone of inhibition against fungi [44,45]. The present study also reports promising inhibition and remarkably less MIC values which indicates that the plant *T. catappa* is a candidate plant in developing anti- dermatophytic drugs.

Stronger antifungal activity reported in our study may be attributed to the occurrence of therapeutic botanicals in the extract of *T. catappa*. The plant is known to have high polyphenolic content which supports the antifungal activity of the selected plant [46]. Various study showed that the polar extracts of *T. catappa* encompasses alkaloids, cardiac glycosides, tannins, steroids, phenols, flavonoids, saponins, coumarins, and terpenoids which may be attributed to the antifungal activity of the extracts because the mentioned phytochemicals are known to have antimicrobial potential [47]. Drug discovery scientists typically target plants with high phenolic content to treat infections [4]. Plant-derived phenolic chemicals are known for their antioxidant properties, which may be directly linked with their biological activity [48].

TLC-Bioautography is one of the versatile and simplest technique in drug discovery process which gives us the first hand information about the antimicrobial property of the separated compound/s [49].

In the present work it is noteworthy that TLC-bioautography assay of TCA exhibited inhibition of the dermatophytes thus confirming the antifungal property of the separated phytocompounds. However *C. albicans* and *T. asahii* were not inhibited in TLC-bioautography which proves that the antifungal activity of the acetone extract in disc diffusion assay is due to the synergistic action of the compounds present in the extract.

Methanol and acetone extract of *S. jambos* reported significant inhibition against *M. canis* in the present study. Anti- dermatophytic potential of *S. jambos* documented by various researchers showed inhibiting *Microsporum audouinii*, *Trichophyton mentagrophytes* and *T. soudanense* (MIC: 12.5 to 100 µg/ml) [18,50]. The plant is reported to have (E)-caryophyllene; n-heneicosane; α-humulene; thujopsan-2-α-ol, α-humulene as major phytoconstituents which have contributed to the anti-dermatophytic activity [50]. There are reports of antifungal activity of *S. jambos*, however anti- dermatophytic potential of the said plant is scarce. our study is in corroboration with the previous reports of anti-dermatophytic activity but our study shows remarkably high zone of inhibition and less MIC values.

*C. lanceolatus* and *N. sativa* extracts exhibited their potency towards only against *C. albicans*. As already reported the extracts of the plant contains essential oils which might be the cause of anti-candida activity. GC-MS data of *C. lanceolatus* revealed the extract contained 1,8-cineole, α-pinene, limonene and α-terpeniol as major phytoconstituents which have exhibited different bioactivities including anticancer potential [51].

*N. sativa* extracts has also been proven to be having antifungal efficacy because the essential oil contains Thymoquinone, Thymol, Thymohydroquinone, Nigellone, Nigellidine and Carvacrol as active constituents. Anti-candida activity of diethyl ether extract in animal infection model is also been proven [52]. Thymoquinone, an active ingredient of *N.sativa* seeds showed inhibitory action against *Trichophyton*, *Epidermophyton* and *Microsporum* species with MIC of 0.125mg/ml- 0.25mg/ml [53].

It is interesting to observe in the present study is that we report the anti-dermatophytic potential of *C. spinosa* and *F. dicipiens* for the first time and has not been evaluated earlier. *C. spinosa* is reported to contain iridoids (Morindolide), triterpenoid saponins (Randioside A, Randialic acid B, Catunoroside A-H, Araliasaponin, Randianin) and lignans (Catunaregin and Epicatunaregin) which has pharmacological activities like antimicrobial, hepatoprotective, anti-inflammatory and anti-hyperglycemic activities [20]. The leaves of *F. dicipiens* contains glycosides and saponins [54] which may be the cause for anti-dermatophytic activity in the present study.

In the present study the antifungal active band was characterized by HRLCMS to primarily identify the active compound. *T. catappa* is an ethnopharmacologically significant plant used in traditional Indian, Chinese and Tibetan medicine and are extensively used to treat infectious diseases. Different species of *Terminalia* including *Terminalia catappa* are known to have rich source of flavonoids, phenolic acids, triterpenoids, phenols, tannins and alkaloids. [46] [55-59].

From the HRLCMS result it was found that the antifungal active band may be a triterpenoid which was detected in the negative ionization mode and the positive ionization mode detected the presence of alkaloids, anthraquinone and flavonoids. The result is consistent with other researchers who found the presence of ursolic acid and Malsinic acid triterpenoid compounds in the extract of the plant *T. catappa* [56, 58, 59] [60,61]

Ursolic acid and triterpenoid compounds are known for their therapeutic effects. There are several reports suggesting the antifungal activity of triterpenoids against *C. albicans* and *Cryptococcus neoformans* [62,63]. Ursolic acid isolated have been isolated from different sources like *Piper beetle* leaves, *Oreganum vulgare*, and *Thymus vulgaris* have shown to possess antifungal activity [64].

Though the triterpenoids and flavonoids are reported to have various therapeutic activities, compounds like Malsinic acid, Lucidenic acid, Merulinic acid and Coumaroylcorosolic acid identified in our study has not studied for anti-dermatophytic activity. Hence the compounds identified in our study paves way for isolation the compounds in pure form which remains as the further scope of the study in the development of novel anti-dermatophytic drugs.

## 5. CONCLUSION

The study presents a systematic scientific investigation of anti-dermatophytic activity of 10 selected medicinal plant extracts. Among the 10 plants *T. catappa*, *T. arjuna* and *S. jambos* found to be the promising plants with significant anti-dermatophytic activity. Further, TLC- bioautography assay of acetone extract of *T. catappa* confirms the anti-dermatophytic potential and TLC characterisation of the antifungal band revealed that the antifungal active band may be triterpenoid compound hence making *T. catappa* a candidate plant in development of antifungal drugs. The anti-dermatophytic potential of *T. catappa* presented in our work also proves the traditional usage of the plant for treating skin disorders. The anti-dermatophytic potential of *C. spinosa* and *F. decipiens* is reported for the first time hence paving a significant scope in bioprospecting the said plants for antifungal compounds. The present study provides a compelling evidence to the bioactivity guided identification of the triterpenoid compounds which is an economical and faster process in bioprospecting the small molecules in antifungal drug discovery process.

Moving further, isolation, characterisation and structure elucidation of the phytocompounds responsible for the anti-dermatophytic activity from the active extracts of the plant/s, their pharmacological and toxicological evaluation in-vivo might lead to the development of the antifungal drugs which could help in combating skin infection causing dermatophytes.

**Acknowledgements:** The authors are thankful to ICMR-New Delhi and VGST-CISEE, Government of Karnataka for the financial assistance. The authors also thank SAIF-IIT Bombay for providing the HRLCMS analytical facility.

**Conflict of interest:** There are no potential conflict of interest

**Consent for publication:** All authors provide consent for publication of the manuscript

## REFERENCES

1. Abirami S, Edwin Raj B, Soundarya T, Kannan M, Sugapriya D, Al-Dayyan N. Exploring antifungal activities of acetone extract of selected Indian medicinal plants against human dermal fungal pathogens. *Saudi Journal of Biological Sciences*. 2021; 28(4): 2180- 2187. [10.1016/j.sjbs.2021.01.046](https://doi.org/10.1016/j.sjbs.2021.01.046).
2. Hosee YN, Farhan MS, Shaban SA. The potential of medicinal plants in antifungal and future directions. *Journal of Mycology and Infection*; 2025; 30:1–17. [10.17966/JMI.2025.30.1.1](https://doi.org/10.17966/JMI.2025.30.1.1)
3. Esmacili A, Saleh I, Abu-Dieyeh MH. Antifungal potential of plant-based extracts against *Candida* species: Values, safety concerns, and possible applications. *Phytochemistry Reviews*. 2025; <https://doi.org/10.1007/s11101-025-10093-x>.
4. Kaur N, Bains A, Kaushik R, Dhull SB, Melinda F, Chawla PA. Review on antifungal efficiency of plant extracts entrenched polysaccharide-based nanohydrogels. *Nutrients*; 2021; 13 (6):1–26. <https://doi.org/10.3390/nu13062055>
5. Aljuhani S, Rizwana H, Aloufi AS, Alkahtani S, Albasher G, Almasoud H, Elsayim R. Antifungal activity of *Carica papaya* fruit extract against *Microsporum canis*: in vitro and in vivo study. *Frontiers in Microbiology*. 2024; 15:1–12. <https://doi.org/10.3389/fmicb.2024.1399671>.
6. Chepkwony JK, Mwitari PG, Kipsumbai PK, Bii C, Twei VC. Anti-dermatophytic activity of *Salvia nilotica* methanolic crude leaf extract against *Trichophyton mentagrophytes*. *Journal of Phytopharmacology*. 2021; 10(6): 433-438. [10.31254/phyto.2021.10602](https://doi.org/10.31254/phyto.2021.10602).
7. Jubair N, Rajagopal M, Chinnappan S, Abdullah NB, Fatima A. Review on the Antibacterial Mechanism of Plant-Derived Compounds against Multidrug-Resistant Bacteria (MDR). *Evidence-based Complementary and Alternative Medicine*; 2021; 1-30. <https://doi.org/10.1155/2021/3663315>
8. Gou J, Lu Y, Xie M, Tang X, Chen L, Zhao J, Li G, Wang H. Antimicrobial activity in *Asterceae*: The selected genera characterization and against multidrug resistance bacteria. *Heliyon*; 2023; 9:e14985. <https://doi.org/10.1016/j.heliyon.2023.e14985>.
9. Salah EM, Issa MY, Mohamed TA, Hegazy M-EF, Tadros SH, Fathallah N. Chemical composition and antifungal activity of *Teucrium Leucocladum* Boiss. essential oils growing in Egypt using two different techniques. *Future Journal of Pharmaceutical Sciences*. 2024; 10: 1-14. <https://doi.org/10.1186/s43094-024-00621-5>
10. Manilal A, Raghavanpillai K, Shewangizaw M, Aklilu A, Seid M, Merdikios B, Tsegaye B. In vitro

- antibacterial activity of medicinal plants against bio film-forming methicillin-resistant *Staphylococcus aureus*: Efficacy of *Moringa stenopetala* and *Rosmarinus officinalis* extracts. *Heliyon*; 2020; 6:e03303.  
<https://doi.org/10.1016/j.heliyon.2020.e03303>
11. Mendes PM, Martins G, Fontoura G, Rodrigues S, Souza AS, Pereira J, Dutra RP, Ferreira AGN, Neto MS, Reis AS, Berretta AA, Monteiro-neto V, Maciel, MCG. Therapeutic Potential of *Punica granatum* and Isolated Compounds: Evidence-Based Advances to Treat Bacterial Infections. *International journal of Microbiology*. 2023; 1-15.  
<https://doi.org/10.1155/2023/4026440>
  12. Kebede T, Gadisa E, Tufa A. Antimicrobial activities evaluation and phytochemical screening of some selected medicinal plants: A possible alternative in the treatment of multidrug-resistant microbes. *PLoS One*; 2021; 16:  
<https://doi.org/10.1371/journal.pone.0249253>
  13. Silveira D, Boylan F. Medicinal Plants: Advances in Phytochemistry and Ethnobotany. *Plants*. 2023; 12: 1682.  
<https://doi.org/10.3390/plants12081682>
  14. Sneha D, Bhat R. *Terminalia catappa*: A Review of Its Botanical Identity, Phytochemistry, and Clinical Potential. *International Journal of Pharmaceutical Sciences*. 2025; 7: 2892-2900.  
[10.5281/zenodo.16274532](https://zenodo.org/record/16274532).
  15. Hannan A, Saleem S, Chaudhary S, Barkaat M, Arshad MU. Anti-bacterial activity of *Nigella sativa* against clinical isolates of Methicillin resistant *Staphylococcus aureus*. *Journal of Ayub Medical College abottabad*. 2008; 20:72-4.
  16. Tahsin MR, Sultana A, Mohtasim Khan MS, Jahan I, Mim SR, Tithi TI, Ananta MF, Afrin S, Ali M, Sajjad Hussain M, Chowdhury JA, Kabir S, Chowdury AA, Amran Md S, Aktar F. An evaluation of pharmacological healing potentialities of *Terminalia Arjuna* against several ailments on experimental rat models with an in-silico approach. *Heliyon*; 2021; 7:e08225.  
<https://doi.org/10.1016/j.heliyon.2021.e08225>
  17. Amalraj A, Gopi S. Medicinal properties of *Terminalia arjuna* (Roxb.) Wight & Arn.: A review. *Journal of Traditional and Complementary Medicine*; 2017; 7:65-78.  
<https://doi.org/10.1016/j.jtcme.2016.02.003>
  18. Ochieng MA, Ben Bakrim W, Bitchagno GTM, Mahmoud MF, Sobeh M. *Syzygium jambos* L. Alston: An Insight Into its Phytochemistry, Traditional Uses, and Pharmacological Properties. *Frontiers in Pharmacology*. 2022; 13:1-15.  
<https://doi.org/10.3389/fphar.2022.786712>
  19. Larayetan R, Ololade ZS, Ogunmola OO, Ladokun A. Phytochemical Constituents, Antioxidant, Cytotoxicity, Antimicrobial, Antitrypanosomal, and Antimalarial Potentials of the Crude Extracts of *Callistemon citrinus*. *Evidence-Based Complementary and Alternative Medicine*. 2019; 5410923. <https://doi.org/10.1155/2019/5410923>
  20. Timalcina D, Devkota HP, Bhusal D, Sharma KR. *Catunaregam spinosa* (Thunb.) Tirveng: A Review of Traditional Uses, Phytochemistry, Pharmacological Activities, and Toxicological Aspects. *Evidence-based Complementary and Alternative Medicine*. 2021; 1-10 <https://doi.org/10.1155/2021/3257732>
  21. Basarikatti AI, Mishra S, Uppar V, Padmashali B. Antimicrobial, anti-inflammatory, and anticancer activities of leaves extracts of *Filicium decipiens*. *Journal of Applied Biology and Biotechnology*; 2021; 9:83-7. 10.7324/JABB.2021.9111
  22. Sherin Monichan P, Mosae Selvakumar, Christine Thevamithra MSA, Nadar M, Joel J. Green Synthesis of Silver Nanoparticles using the Leaves Extract of *Filicium decipiens* and its Anti- Microbial Activity. *Journal of Environmental Nanotechnology*. 2021;10:16-24.  
<https://doi.org/10.13074/jent.2021.09.213442>
  23. Okba MM, Matheeussen A, Abdel-Sattar E, Yousif MF, El Deeb KS, Soliman FM. *Entada rheedii* phaseoloidin, protocatechuic acid and entadamide A against protozoal diseases: Trypanosomiasis and leishmaniasis. *Jordan Journal of Pharmaceutical Sciences*. 2020; 13:283-90. 10.7324/JAPS.2018.8513
  24. Fikri F, Purnama MTE. Pharmacology and phytochemistry overview on *Sauropus androgynous*. *Systematic Reviews in Pharmacy*. 2020; 11:124-8. 10.31838/srp.2020.6.20.
  25. Abd Elkarim AS, Taie HAA. Characterization of Flavonoids From *Combretum indicum* L. Growing in Egypt As Antioxidant and Antitumor Agents. *Egyptian Journal of Chemistry*. 2023; 66:1519-43.
  26. Espinel-Ingroff, S.; Canton, E. Antifungal susceptibility testing for filamentous fungi. In *Antimicrobial Susceptibility Testing Protocols*, 9th ed.; Schwalbe, R., Steele-moore, L., Goodwin, C., Eds.; CRC Press: London, UK, 2012; pp. 209-241.
  27. Qaiyumi, S. Macro and Microdilution methods of antimicrobial susceptibility testing. In *Antimicrobial Susceptibility Testing Protocols*, 9th ed.; Schwalbe, R., Steele-moore, L., Goodwin, C., Eds.; CRC Press: London, UK, 2012; pp. 75-79.
  28. Ganam M, Lorentzen SB, Agger JW, Heyward CA, Bakke O, Knutsen SH, Aam BB, Eijssink VGH, Gaustad P, Sørli M. Antifungal activity of well-defined chito-oligosaccharide preparations against

- medically relevant yeasts. *PLoS One*; 2019; 14(1), 1–14.
29. Ristivojević P, Dimkić I, Trifković J, Berić T, Vovk I, Milojković-Opšenica D, Stanković S. Antimicrobial activity of Serbian propolis evaluated by means of MIC, HPTLC, bioautography and chemometrics. *PLoS One*. 2016;1:1–15. <https://doi.org/10.1371/journal.pone.0157097>
  30. Wang, J., Yang, H., Liu, Y., Norbo, K., Zeng, K., Zhao, M., & Zhang, Q. Azukisapogenol triterpene glycosides from *Oxytropis Chiliophylla roylei*. *Molecules*. 2018; 23(10), 2448. <https://doi.org/10.3390/molecules23102448>
  31. Choudhary N, Singh N, Singh A P, & Singh A. P. Medicinal Uses of Maslinic Acid: A Review. *Journal of Drug Delivery & Therapeutics*. 2021; 11(2). <https://doi.org/10.22270/jddt.v11i2.4588>
  32. Nhu, T Q, Dam N P, Hang B T B, Bach L T, Huong D T T, Hue B T B, Kestemont P. Immunomodulatory potential of extracts, fractions and pure compounds from *Phyllanthus amarus* and *Psidium guajava* on striped catfish (*Pangasianodon hypophthalmus*) head kidney leukocytes. *Fish & shellfish immunology*. 2020; 104, 289-303. <https://doi.org/10.1016/j.fsi.2020.05.051>
  33. Liu G, Qin P, Cheng X, Wu L, Wang R, Gao W. Ursolic acid: biological functions and application in animal husbandry. *Frontiers in Veterinary Science*. 2023;10, 1251248. <https://doi.org/10.3389/fvets.2023.1251248>
  34. Furumoto, T., & Jindai, A. Isolation and photoisomerization of a new anthraquinone from hairy root cultures of *Sesamum indicum*. *Bioscience Biotechnology Biochemistry*. 2008; 72(10), 2788-2790. <https://doi.org/10.1271/bbb.80373>
  35. Dharmaratne, H. R. W., Nanayakkara, N. D., & Khan, I. A. Kavalactones from *Piper methysticum*, and their <sup>13</sup>C NMR spectroscopic analyses. *Phytochemistry*. 2002; 59(4), 429-433. [https://doi.org/10.1016/S0031-9422\(01\)00443-5](https://doi.org/10.1016/S0031-9422(01)00443-5)
  36. Dymek, A., Widelski, J., Wojtanowski, K. K., Vivcharenko, V., Przekora, A., & Mroczek, T. (2021). Fractionation of Lycopodiaceae alkaloids and evaluation of their anticholinesterase and cytotoxic activities. *Molecules*. 26(21), 6379. <https://doi.org/10.3390/molecules26216379>
  37. Zheng, C., Rangsinth, P., Shiu, P. H., Wang, W., Li, R., Li, J., & Leung, G. P. (2023). A review on the sources, structures, and pharmacological activities of Lucidenic acids. *Molecules*. 28(4), 1756. <https://doi.org/10.3390/molecules28041756>
  38. Nallapaty, S., Malothu, N., Konidala, S. K., & Areti, A. R. Evaluation of in vitro antidiabetic and antioxidant activity of leaf extracts of *Ecbolium linneanum* kurz.: GC-MS and HR-LCMS based metabolite profiling and an in silico approach. *Journal of Applied Pharmaceutical Science*. 2024. 14(1), 247-260. <https://doi.org/10.7324/JAPS.2024.155513>
  39. Savarirajan D, Ramesh VM, Muthaiyan. In vitro antidermatophytic activity of bioactive compounds from selected medicinal plants. *Journal of Analytical Science and Technology*. 2021; 12:1-13. <https://doi.org/10.1186/s40543-021-00304-3>
  40. Chahal R, Nanda A, Akkol EK, Sobarzo-sánchez E, Arya A, Kaushik D, Dutt R, Bharadwaj R, Rehman Md H, Mittal V. *Ageratum conyzoides* L. And its secondary metabolites in the management of different fungal pathogens. *Molecules*. 2021; 26: 2933. <https://doi.org/10.3390/molecules26102933>
  41. Chanda S, Rakholiya K, Nair R. Antimicrobial Activity of *Terminalia catappa* L. Leaf Extracts against Some Clinically Important Pathogenic Microbial Strains. *Chinese Medicine*. 2011; 2:171–177. <https://doi.org/10.4236/cm.2011.24027>
  42. Rocha FMG, Rocha CHL, Silva LCN, Pinheiro AJMCR, Mendonça AMS, Cantanhede Filho AJ, Sousa EM, Rocha CQ, Assuncao Holanda R, Santos JRA, Monteiro CA. N-Butanol Fraction of *Terminalia Catappa* Possesses Anti-*Candida Albicans* Properties and in Vivo Action on Tenebrio Molitor Alternative Infection Model. *Microbial Pathogenesis*. 2025; 198, 107133. <https://doi.org/10.1016/j.micpath.2024.107133>
  43. Terças AG, Monteiro A de S, Moffa EB, dos Santos JRA, de Sousa EM, Pinto ARB, C da Silva Costa P, Borges ACR, Torres LMB, Barros Filho AKD, Fernandes ES, De Andrade Monteiro C. Phytochemical characterization of *Terminalia catappa* Linn. extracts and their antifungal activities against *Candida* spp. *Frontiers in Microbiology*. 2017; 8:1–13. <https://doi.org/10.3389/fmicb.2017.00595>
  44. Sakander H, Akhilesh B, Koteswara AR. Evaluation of antifungal potential of selected medicinal plants against human pathogenic fungi. *International Journal of Green Pharmacy*. 2015; 9:110-117. <https://doi.org/10.4103/0973-8258.155058>
  45. Colendres RJ, Pradera CL. In vitro activity of Indian almond (*Terminalia catappa*) leaf crude extracts against selected dermatophytes. *Annals of Tropical Research*. 2021; 43:55–66. <https://doi.org/10.32945/atr4.4.202311>
  46. Sowmya TN, Raveesha KA. Polyphenol-rich purified bioactive fraction isolated from *Terminalia catappa* L.: UHPLC MS/MS-based metabolite identification and evaluation of their antimicrobial potential. *Coatings*. 2021; 11. <https://doi.org/10.3390/coatings11101210>

47. Mwangi WC, Waudo W, Shigwenya ME, Gichuki J. Phytochemical characterization, antimicrobial and antioxidant activities of *Terminalia catappa* methanol and aqueous extracts. *BMC Complementary Medicine and Therpies*. 2024; 24:1–11. 24:137 <https://doi.org/10.1186/s12906-024-04449-7>
48. Araújo SA de, Lima A da S, Rocha CQ da, Previtalli-Silva H, Hardoim D de J, Taniwaki NN, Da silva calabrese K, Almeida -Souza F, Abreu -Silva AL. In Vitro Antioxidant and Antitrypanosomal Activities of Extract and Fractions of *Terminalia catappa*. *Biology*. 2023; 12: 895.
49. Choma IM, Grzelak EM. Bioautography detection in thin-layer chromatography. *Journal of Chromatography A*; 2011; 1218:2684–91.
50. Uddin ABMN, Hossain F, Reza ASMA, Nasrin MS, Alam AHMK. Traditional uses, pharmacological activities, and phytochemical constituents of the genus *Syzygium*: A review. *Food Science and Nutrition*. 2022; 10(6):1789–819. <https://doi.org/10.1002/fsn3.2797>
51. Sampath S, Veeramani V, Krishnakumar GS, Sivalingam U, Madurai SL, Chellan R. Evaluation of in vitro anticancer activity of 1,8-Cineole–containing n-hexane extract of *Callistemon citrinus* (Curtis) Skeels plant and its apoptotic potential. *Biomedicine and Pharmacotherapy*. 2017; 93:296–307. <https://doi.org/10.3390/biology12070895>
52. Shokri H. A review on the inhibitory potential of *Nigella sativa* against pathogenic and toxigenic fungi. *Avicenna J Phytomedicine*. 2026; 6(1): 21–33.
53. Aljabre SHM, Alakloby OM, Randhawa MA. Dermatological effects of *Nigella sativa*. *Journal of Dermatology Dermatologic Surgery*. 2015; 19:92–98.
54. Sharmila G, Farzana Fathima M, Haries S, Geetha S, Manoj Kumar N, Muthukumaran C. Green synthesis, characterization and antibacterial efficacy of palladium nanoparticles synthesized using *Filicium decipiens* leaf extract. *Journal of Molecular Structure*. 2017; 1138:35–40. <https://doi.org/10.1016/j.molstruc.2017.02.097>
55. Ravi L, Jindam D, Kumaresan S, Selvaraj V, Reddy J. Anti-methicillin resistant *staphylococcus aureus* potential of phytochemicals in *Terminalia catappa* and their proposed *in silico* mechanism of action. *Asian Journal of Pharmaceutical and Clinical Research*. 2019; 12:133-137. [10.22159/ajpcr.2019.v12i10.34705](https://doi.org/10.22159/ajpcr.2019.v12i10.34705)
56. Cock I E. The medicinal properties and phytochemistry of plants of the genus *Terminalia* (Combretaceae). *Inflammopharmacology*. 2015; 203-229. [10.1007/s10787-015-0246-z](https://doi.org/10.1007/s10787-015-0246-z)
57. Fahmy NM, Al-Sayed E, Singab AN. Genus *Terminalia*: A phytochemical and Biological Review. (Montin.) Species. *Medicinal and Aromatic Plants*. 2015; 4: 218. [10.4172/2167-0412.1000218](https://doi.org/10.4172/2167-0412.1000218)
58. Zhang XR, Kaunda JS, Zhu HT, Wang D, Yang CR, , Zhang YJ. The Genus *Terminalia* (Combretaceae): An Ethnopharmacological, Phytochemical and Pharmacological Review. *Natural Product Bioprospecting*. 2019; 9:357–392. [10.1007/s13659-019-00222-3](https://doi.org/10.1007/s13659-019-00222-3).
59. Harita VANV, Dutta K, Banerjee A, Mondal S. Pharmacognostic, Phytochemical, and Multi-Analytical Profiling of the Leaves and Fruit of *Terminalia Catappa* L Integrated with In-Silico Docking Studies. *Journal of Pharmaceutical Innovation*. 2025; 20:192. <https://doi.org/10.1007/s12247-025-10103-7>
60. Chole P, Ravi L. A review on medicinal potential of *Terminalia catappa*. *International Journal of Green Pharmacy*. 2020; 14(3): 229-234
61. Sneha D and Bhat R. *Terminalia catappa*: A Review of Its Botanical Identity, Phytochemistry, And Clinical Potential. *International journal of Pharmaceutical Sciences*; 2025; 3(7); 2892-2900. [10.5281/zenodo.16274532](https://doi.org/10.5281/zenodo.16274532)
62. Pereira VV, Pereira NR, Pereira RCG, Duarte LP, Takahashi JA, Silva RR. Synthesis and antimicrobial activity of Ursolic acid ester derivatives. *Chemistry and Biodiversity*; 2022; 19, e202100566. [10.1002/cbdv.202100566](https://doi.org/10.1002/cbdv.202100566).
63. Wang WJ, Liu CC, Li YT, Li MQ, Fu YT, Li XC, Jie-Kang, Qian WD. Antifungal and Antibiofilm In Vitro Activities of Ursolic Acid on *Cryptococcus neoformans*. *Current Microbiology*. 2022 Aug 16;79(10):293. [10.1007/s00284-022-02992-5](https://doi.org/10.1007/s00284-022-02992-5).
64. Arulnangai R, Thabassoom HA, Banu HV, Thirugnanasambandham K, Ganesamoorthy R. Recent developments on Ursolic acid and its potential biological applications. *Toxicology Reports*. 2025 14; 101900. [10.1016/j.toxrep.2025.101900](https://doi.org/10.1016/j.toxrep.2025.101900).