Pharmedico Publishers
International Journal of Pharmaceutical Science and Medicine
Volume 4, Issue 1 (2026): 1-12
DOI: 10.70199/IJPSM.4.1.1-12

REVIEW ARTICLE

ISSN: 2584-1610 (Online)

PLANT-DERIVED THERAPEUTICS FOR DERMATOPHYTOSIS: FOCUS ON *AZADIRACHTA INDICA*

Preeti Yadav[*1], Vibha[2], Ramsurat Yadav[2], Avinash Kumar Rao[3]

Research Scholar[1], Assistant Professor[2], Rishi Ram Naresh College of Pharmacy, Mau, Uttar Pradesh, India.
Principal[3], Sharda Devi Mahavidyalay Badlapur Jaunpur, Uttar Pradesh, India.

Article History
Received: 09 December 2025
Revised: 23 January 2026
Accepted: 15 February 2026
Published: 25 March 2026

Correspondence should be addressed to
Preeti Yadav,
Research Scholar,
Rishi Ram Naresh College of Pharmacy, Mau, Uttar Pradesh, India.

Email- preetiyadav222109@gmail.com

ABSTRACT: Dermatophytosis is among the most widespread fungal infections worldwide, affecting the keratinized tissues of the skin, hair, and nails and posing a persistent challenge to public health. Despite the availability of conventional antifungal drugs, treatment outcomes are often compromised by prolonged therapy, recurrence, adverse effects, and the growing threat of antifungal resistance. These limitations have accelerated the search for novel, nature-inspired therapeutics capable of offering safer and more effective disease management. In this context, medicinal plants have emerged as valuable sources of multifunctional bioactive compounds with significant antifungal potential. *Azadirachta indica* A. Juss. (Neem), a cornerstone of traditional medicine, has gained increasing scientific attention as a promising plant-derived therapeutic against dermatophytosis. Its pharmacological efficacy is attributed to a diverse array of phytochemicals, including azadirachtin, nimbidin, nimbin, gedunin, salannin, quercetin, and other limonoids, which collectively exhibit antifungal, anti-inflammatory, antioxidant, and skin-protective activities. Unlike conventional agents that primarily target fungal growth, neem-derived compounds offer a multi-target approach by inhibiting dermatophyte proliferation, reducing oxidative stress, modulating inflammatory responses, and promoting tissue regeneration. Recent in vitro and in vivo studies have demonstrated significant activity of neem extracts and formulations against major dermatophytes, including *Trichophyton*, *Microsporum*, and *Epidermophyton* species. Furthermore, advances in herbal nanotechnology, such as nanoemulsions and nanogels, have enhanced the delivery and therapeutic performance of neem bioactives. This review comprehensively examines the phytochemistry, antifungal mechanisms, experimental evidence, and future translational prospects of *Azadirachta indica*, highlighting its potential as a next-generation botanical strategy for the sustainable management of dermatophytosis.

Keywords: Dermatophytosis, *Azadirachta indica*, Neem, Antifungal activity, Phytochemicals, Plant-derived therapeutics

I. INTRODUCTION

Inflammation is a necessary physiological reaction which Dermatophytosis is one of the most prevalent superficial fungal infections and is a public health problem that millions of people suffer every year in the world. These infections are caused by a special class of keratinophilic fungi, meaning that they invade and use keratinized tissues (such as the skin, hair and nails) as a nutrient source [1]. Depending on the site of infection, tinea infections are the most common forms of dermatophytosis, including tinea corporis, tinea capitis, tinea pedis, tinea cruris and tinea unguium. Although not often life threatening, these infections can cause significant cosmetic issues, psychological stress, and discomfort, and can decrease quality of life, especially in warm, humid tropical and subtropical climates where fungi can thrive [2].

However, the prevalence of dermatophytosis is significantly elevated in recent years over the last decade, among many reasons, due to the increasing urbanization, overcrowding, lack of hygiene, immunosuppression, diabetes and the general use of immunomodulatory drugs. In humans the species of genera Trichophyton, Microsporum and Epidermophyton are the most common causative agents. Although synthetic antifungal agents such as the azoles, allylamines and polyenes are available, treatment is still difficult due to the length of treatment, recurrence, adverse drug reactions, high cost of treatment and the alarming problem of antifungal drug resistance [3].

Such restrictions have encouraged increased interest in the use of medicinal plants as alternative and complementary medicine. Herbal medicines have many bioactive components that can act as an antifungal, anti-inflammatory, antioxidant and wound-healing agent by several different mechanisms. Of the above, *Azadirachta indica* A. Juss. Neem has been the subject of many scientific investigations because of its wide range of pharmacological properties and its traditional medicinal applications [4]. Neem is rich in bioactive compounds such as limonoids, flavonoids, and other compounds, which have shown potential in controlling fungal pathogens like dermatophytes. Hence, the current review attempts to comprehensively review the therapeutic potential of *A. indica* for dermatophytosis, especially its

phytochemistry, antifungal mechanisms, experimental evidence and future prospects for clinical application [5].

2. Literature Search Methodology

An extensive literature survey was done to gather and analyze scientific data on the therapeutic use of *Azadirachta indica* for the treatment of dermatophytosis. Major electronic databases, such as PubMed, Scopus, Google Scholar and ScienceDirect were searched for relevant studies. This search aimed to locate original research articles, review articles and experimental research which focused on the phytochemistry, antifungal activity, mechanism of action, and formulation of Azadirachta indica for dermatophyte infection in English [6].

A literature search was done using different key words and their combinations namely "*Azadirachta indica*", "Neem", "Dermatophytosis", "Dermatophytes", "Antifungal activity", "Trichophyton", "Microsporum", "Epidermophyton", "Medicinal plants", "Phytochemicals", "Antifungal agents", "Herbal antifungal agents" and "Antifungal therapeutics from plants". Boolean operators (AND, OR) were used to narrow down the search strategy to get more focused and relevant studies. Review of the reference lists of selected articles was also done manually to find relevant articles [7].

Studies were selected if they mentioned the phytochemical composition, in vitro antifungal activity, in vivo efficacy, mechanism of action, safety profile or pharmaceutical formulation of *Azadirachta indica* in relation to dermatophytosis and fungal skin infections. Both experimental and review studies providing substantial scientific evidence were considered. The articles published in other than English language, studies with inadequate methodological details, duplicate records, conference abstracts and publications that were not included in the review of dermatophyte infections were discarded [8].

The articles selected for the review were thoroughly scrutinized for relevance, quality and scientific value. Systemic extraction and organization of important information such as objectives of study, parts used, extraction methods, phytochemical constituents, antifungal screening, dermatophyte species tested, key findings and formulation approach was done. The collected data was then analyzed and synthesized to give the holistic and evidence-based review of the therapeutic activity of *Azadirachta indica* as a plant derived drug for dermatophytosis [9].

3. Dermatophytosis: An Overview

Dermatophytosis is a superficial fungal infection that is caused by a specialized group of fungi, called dermatophytes. These fungi invade keratinized tissues, such as skin, hair and nails, causing a range of clinical forms known as tinea infections. Dermatophytosis is an important public health problem, endemic in almost all parts of the world, and more prevalent in tropical and sub-tropical areas where the environment is conducive to fungal growth and spread. The disease occurs in all age groups, has a high morbidity, can be recurrent and impacting on quality of life [10].

3.1 Etiology

Dermatophyte Fungi

The dermatophytes are fungi of three genera, *Trichophyton*, *Microsporum* and *Epidermophyton*, which are the main causes of dermatophytosis. These organisms have the power to produce keratinolytic enzymes that facilitate them to colonize and survive on keratin-rich tissues. Trichophyton rubrum is the most common species isolated from all over the world followed by Trichophyton mentagrophytes, *Microsporum canis*, *Microsporum gypseum* and *Epidermophyton floccosum*. Individual species vary in prevalence based on geographical region, climate and host related factors [11].

Sources of Infection

Dermatophytes can be divided into anthropophilic, zoophilic and geophilic species, depending on which environment they are most likely to inhabit. Anthropophilic species are transmitted person to person and cause most human infections. Zoophilic dermatophytes can be obtained from infected animals like cats, dogs, cattle and rodents, while geophilic species are picked up from contaminated soil [12]. Transmission is typically by direct contact with the infected person, animal or contaminated articles like bedding, footwear, towels, combs or clothing. Excessive sweating, poor hygiene, tight fitting clothing, immunosuppression and overcrowding make people more susceptible to infection [13].

3.2 Clinical Manifestations

The clinical presentation of dermatophytosis depends on the anatomical site affected and the causative fungal species.

Tinea Corporis: Tinea corporis, commonly known as ringworm of the body, is characterized by circular or annular erythematous lesions with elevated, scaly borders and central clearing. It commonly affects the trunk, arms, and legs and is often associated with itching and irritation [14].

Tinea Capitis: Tinea capitis is a fungal infection of the scalp and hair shafts, predominantly affecting children. Clinical features include scalp scaling, hair breakage, patchy alopecia, inflammation, and in severe cases, the formation of kerion lesions [15].

Tinea Pedis: Tinea pedis, or athlete's foot, is one of the most prevalent dermatophytic infections. It typically involves the interdigital spaces and soles of the feet, presenting with scaling, fissuring, erythema, burning sensation, and pruritus [16].

Tinea Cruris: Tinea cruris, commonly referred to as jock itch, affects the groin, inner thighs, and adjacent skin folds. It manifests as itchy, erythematous, well-demarcated lesions that may gradually expand to surrounding areas [17].

Tinea Unguium: Tinea unguium, also known as onychomycosis, involves fungal infection of the nails. The condition is characterized by nail discoloration, thickening, brittleness, deformation, and eventual destruction of the nail plate, often requiring prolonged treatment [18].

3.3 Current Treatment Strategies

Topical Antifungals

Topical antifungal agents are generally considered the first-line treatment for localized dermatophytic infections. Commonly used drugs include clotrimazole, miconazole, ketoconazole, terbinafine, and luliconazole. These agents act by disrupting fungal cell membrane synthesis and are effective when applied consistently for the recommended duration [19].

Oral Antifungals

Systemic antifungal therapy is indicated for extensive, recurrent, or resistant infections as well as infections involving the scalp and nails. Frequently prescribed oral agents include terbinafine, itraconazole, fluconazole, and griseofulvin. Although effective, systemic therapy may be associated with adverse effects, drug interactions, and the need for prolonged treatment periods [20].

Emerging Resistance Issues

The resistance of fungi to antifungal drugs is a new concern in dermatophytosis management in recent years. The emergence of reduced susceptibility within dermatophyte species has been attributed to the widespread and inappropriate use of antifungal drugs, self-medication practices, incomplete treatment and misuse of corticosteroid containing combinations. Due to this acquired resistance, higher recurrence and treatment failures are observed, thus emphasizing the need to look for other therapeutic strategies that include plant-based antifungal agents like *Azadirachta indica* [21].

Table 1: Common Dermatophytes and Associated Clinical Infections [22]

S. No.	*Dermatophyte Species*	*Genus*	*Primary Source*	*Common Clinical Infection*	*Site Affected*
1	*Trichophyton rubrum*	Trichophyton	Anthropophilic	Tinea corporis	Skin
2	*Trichophyton rubrum*	Trichophyton	Anthropophilic	Tinea unguium	Nails
3	*Trichophyton mentagrophytes*	Trichophyton	Anthropophilic/Zoophilic	Tinea pedis	Feet
4	*Trichophyton mentagrophytes*	Trichophyton	Anthropophilic/Zoophilic	Tinea corporis	Skin
5	*Trichophyton tonsurans*	Trichophyton	Anthropophilic	Tinea capitis	Scalp
6	*Trichophyton violaceum*	Trichophyton	Anthropophilic	Tinea capitis	Hair and Scalp
7	*Trichophyton schoenleinii*	Trichophyton	Anthropophilic	Favus (severe tinea capitis)	Scalp
8	*Trichophyton verrucosum*	Trichophyton	Zoophilic	Tinea barbae	Beard Area
9	*Trichophyton verrucosum*	Trichophyton	Zoophilic	Tinea corporis	Skin
10	*Microsporum canis*	Microsporum	Zoophilic	Tinea capitis	Scalp
11	*Microsporum canis*	Microsporum	Zoophilic	Tinea corporis	Skin
12	*Microsporum gypseum*	Microsporum	Geophilic	Tinea corporis	Skin

4. Botanical Description and Ethnomedicinal Uses of *Azadirachta indica*

The tree *Azadirachta indica* A. Juss. commonly known as Neem is one of the most valued medicinal plants known for its wide range of medicinal uses in traditional and modern health care systems. Neem belongs to the family Meliaceae and has been greatly used in Ayurveda, Unani, Siddha and folk medicine for many centuries against various infectious and inflammatory diseases [23]. With its powerful antimicrobial, antifungal, anti-inflammatory, antioxidant and wound healing effects, neem is dubbed as "Village Pharmacy" in numerous Asian countries. The plant is also known for its potential in treating skin disorders and microbial infections, among other things, and is a potential source of treatment for dermatophytosis [24].

4.1 Taxonomy

The taxonomical classification of *Azadirachta indica* is presented below:

- **Kingdom:** Plantae
- **Division:** Magnoliophyta
- **Class:** Magnoliopsida
- **Order:** Sapindales
- **Family:** Meliaceae
- **Genus:** *Azadirachta*
- **Species:** *Azadirachta indica* A. Juss.
- **Common Names:** Neem, Indian Lilac, Margosa Tree

Neem belongs to the family Meliaceae, which comprises several species known for their medicinal and pesticidal properties. Among them, *Azadirachta indica* is the most extensively studied species owing to its rich phytochemical composition and diverse pharmacological activities [25].

4.2 Botanical Characteristics

Azadirachta indica is an evergreen fast-growing tree which can reach 15-30 m tall in favorable environmental conditions. The tree has a straight trunk, foursided, rough, and fissured, and the color of the bark is grayish-brown to dark brown. Its leaves are alternate, pinnately compound, and with numerous serrated leaflets, which have a very bitter taste [26].

Neem flowers are small, fragrant, white, in the axillary panicles. Its fruits are oval-shaped smooth drupes (stone fruits) that ripen to yellow and have one seed that is rich in biologically active compounds. All parts of the plant (leaf, bark, seed, flower, fruit and seed oil) have been reported to have medicinal properties. The leaves and seed oil are

significant because of the high number of bioactive phytochemicals, which appear to possess antimicrobial and antifungal properties [27].

4.3 Geographic Distribution

Neem is native to the Indian subcontinent, particularly India, Pakistan, Bangladesh, Nepal, and Sri Lanka. Owing to its adaptability and drought tolerance, the plant has been successfully introduced into many tropical and subtropical regions across the world, including Africa, Southeast Asia, Australia, Central America, South America, and the Middle East [28].

The tree thrives in warm climates with temperatures ranging from 21–32°C and can grow in a wide variety of soil types. Its ability to survive under harsh environmental conditions has contributed to its widespread cultivation for medicinal, agricultural, and environmental purposes. India remains the largest producer and cultivator of neem, where it is extensively utilized in traditional medicine and pharmaceutical research [29].

4.4 Traditional Uses in Skin Diseases

Neem has been extensively employed in traditional medicine for the prevention and treatment of numerous skin disorders. Its therapeutic effectiveness is primarily attributed to its antimicrobial, antifungal, anti-inflammatory, and wound-healing properties [30].

Ringworm: Neem leaves and seed oil have traditionally been applied topically to treat ringworm infections. The antifungal constituents present in neem help inhibit the growth of dermatophytes responsible for the infection while reducing associated itching and inflammation [31].

Eczema: Neem preparations have long been used to relieve symptoms of eczema, including redness, irritation, dryness, and itching. Its anti-inflammatory and antioxidant properties contribute to improved skin health and symptom management [32].

Scabies: In traditional medicine, neem leaf extracts and neem oil are commonly used for the treatment of scabies caused by *Sarcoptes scabiei*. The plant helps reduce skin irritation and supports the elimination of mites responsible for the condition [33].

Wounds: Fresh neem leaf pastes and neem-based formulations have been traditionally applied to cuts, wounds, ulcers, and burns to prevent microbial infection and accelerate tissue repair. The wound-healing properties of neem are supported by its ability to reduce inflammation and promote skin regeneration [34].

Other Fungal Infections: Apart from dermatophytosis, neem has been widely used for the management of various fungal skin infections, including candidiasis and other superficial mycoses. Its broad-spectrum antifungal activity has made it an important herbal remedy in traditional healthcare practices and a subject of growing scientific interest for the development of plant-based antifungal therapeutics [35].

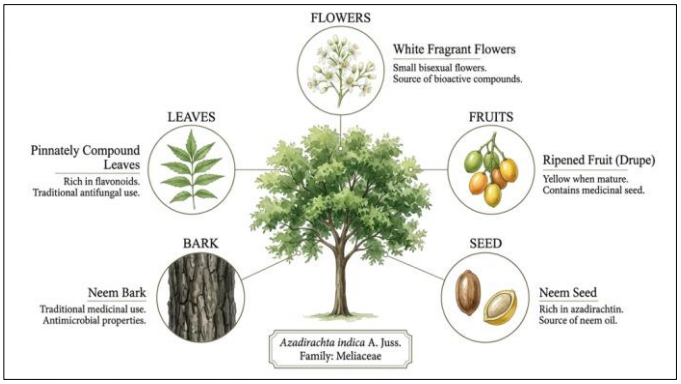

Figure 1: Botanical Illustration of Azadirachta indica [**36**]

5. Phytochemical Profile of *Azadirachta indica*

The remarkable therapeutic potential of *Azadirachta indica* is largely attributed to its rich and diverse phytochemical composition. Various parts of the plant, including leaves, bark, seeds, flowers, fruits, and seed oil, contain numerous biologically active compounds that contribute to its antimicrobial, antifungal, antioxidant, anti-inflammatory, and wound-healing properties. Phytochemical investigations have identified both primary and secondary metabolites that play important roles in the pharmacological activities of neem. The presence of these compounds has made *Azadirachta indica* one of the most extensively studied medicinal plants for the management of infectious and dermatological disorders [37].

5.1 Primary Metabolites

Primary metabolites are essential compounds involved in the normal growth, development, and metabolic functions of plants. In *Azadirachta indica*, these metabolites include carbohydrates, proteins, amino acids, lipids, and fatty acids. Carbohydrates serve as energy reserves and structural components, while proteins and amino acids participate in various physiological and biochemical processes. Neem seeds are particularly rich in lipids and fatty acids, which contribute to the medicinal value of neem oil. Although primary metabolites are not directly responsible for the plant's therapeutic effects, they provide the biochemical foundation necessary for the synthesis of pharmacologically active secondary metabolites [38].

5.2 Secondary Metabolites

Secondary metabolites represent the major bioactive constituents of *Azadirachta indica* and are primarily responsible for its medicinal properties. These compounds exhibit a wide range of biological activities, including antifungal, antibacterial, antiviral, antioxidant, anti-inflammatory, and immunomodulatory effects [39].

Azadirachtin: Azadirachtin is one of the most important limonoids isolated from neem seeds. It is widely recognized for its biological activity and has demonstrated significant antimicrobial and antifungal properties. In addition to its well-known pesticidal activity, azadirachtin contributes to the inhibition of fungal growth and colonization [40].

Nimbin: Nimbin is a triterpenoid compound predominantly found in neem seed kernels and leaves. It possesses antimicrobial, anti-inflammatory, and antifungal activities, making it an important constituent involved in the treatment of skin infections and inflammatory conditions [41].

Nimbidin: Nimbidin is a major bitter principle isolated from neem seed oil. It has been reported to exhibit potent antifungal, antibacterial, anti-inflammatory, and antioxidant activities. Several studies have suggested that nimbidin plays a significant role in the therapeutic effectiveness of neem against dermatological disorders [42].

Gedunin: Gedunin is a naturally occurring limonoid known for its antimicrobial and antifungal properties. It has shown promising biological activity against various pathogenic microorganisms and contributes to the overall medicinal potential of neem [43].

Quercetin: Quercetin is a flavonoid widely distributed in neem leaves and flowers. It is recognized for its strong antioxidant activity and its ability to reduce oxidative stress and inflammation. Quercetin also exhibits antimicrobial effects and may contribute to skin protection and healing during fungal infections [44].

Salannin: Salannin is another important limonoid compound found in neem. It possesses antimicrobial and antifungal properties and acts synergistically with other phytochemicals to enhance the overall therapeutic activity of the plant [45].

Limonoids: Limonoids constitute a major class of tetranortriterpenoids characteristic of the Meliaceae family. These compounds are considered key bioactive constituents of neem and are responsible for many of its pharmacological properties. Limonoids exhibit significant antifungal, anti-inflammatory, antioxidant, and immunomodulatory activities, making them valuable therapeutic agents in the management of dermatophytosis and other infectious diseases [46].

5.3 Analytical Techniques

Advanced analytical techniques have been extensively employed to identify, characterize, and quantify the phytochemical constituents of *Azadirachta indica*. These techniques provide valuable information regarding the chemical composition and quality of neem extracts.

High-Performance Thin-Layer Chromatography (HPTLC)

HPTLC is widely used for phytochemical fingerprinting and quality control of neem extracts. The technique enables rapid identification and comparative analysis of multiple bioactive compounds present in different plant parts [47].

High-Performance Liquid Chromatography (HPLC)

HPLC is one of the most commonly used analytical methods for the separation, identification, and quantification of phytochemicals such as azadirachtin, nimbin, and quercetin. It provides high accuracy, sensitivity, and reproducibility [48].

Gas Chromatography–Mass Spectrometry (GC–MS)

GC–MS is primarily employed for the analysis of volatile and semi-volatile compounds present in neem oil and extracts. The technique allows precise identification of numerous bioactive constituents based on their mass spectra [49].

Liquid Chromatography–Tandem Mass Spectrometry (LC–MS/MS)

LC–MS/MS is an advanced analytical tool used for detailed characterization and quantification of complex phytochemicals. Its high sensitivity and specificity make it particularly useful for detecting trace bioactive compounds and validating phytochemical profiles in neem-based formulations.

The diverse phytochemical composition of *Azadirachta indica* provides a strong scientific basis for its traditional medicinal use and supports its growing application as a plant-derived therapeutic agent for dermatophytosis and other fungal infections [50].

Table 2: Major Bioactive Compounds of *Azadirachta indica* and Their Pharmacological Roles [51]

S. No.	*Bioactive Compound*	*Chemical Class*	*Plant Part Source*	*Pharmacological Role*
1	Azadirachtin	Limonoid	Seeds	Antifungal, antimicrobial, insecticidal
2	Nimbin	Triterpenoid	Seeds, Leaves	Antifungal, anti-inflammatory
3	Nimbidin	Bitter principle (Triterpenoid)	Seed Oil	Antifungal, antibacterial, antioxidant
4	Gedunin	Limonoid	Seeds	Antifungal, antiparasitic, anti-inflammatory
5	Salannin	Limonoid	Seeds	Antimicrobial, antifungal
6	Quercetin	Flavonoid	Leaves, Flowers	Antioxidant, antifungal, anti-inflammatory
7	Nimbolide	Limonoid	Leaves, Flowers	Antimicrobial, antioxidant
8	Sodium Nimbidate	Terpenoid Derivative	Seed Oil	Antifungal, anti-inflammatory
9	Gallic Acid	Phenolic Compound	Leaves	Antioxidant, antimicrobial
10	Catechin	Flavonoid	Leaves	Free radical scavenging, skin protection
11	Epicatechin	Flavonoid	Leaves	Antioxidant, anti-inflammatory
12	β-Sitosterol	Phytosterol	Leaves, Bark	Anti-inflammatory, wound healing

6. Antifungal Activity Against Dermatophytes

The antifungal potential of *Azadirachta indica* has been extensively investigated against various dermatophyte species responsible for superficial fungal infections. Numerous studies have demonstrated that different neem-derived preparations, including leaf extracts, seed extracts, bark extracts, and neem oil, possess significant inhibitory activity against dermatophytes [52]. The antifungal efficacy of neem is primarily attributed to its rich phytochemical composition, particularly limonoids, flavonoids, triterpenoids, and phenolic compounds. These bioactive constituents act through multiple mechanisms to suppress fungal growth, reduce fungal colonization, and prevent the progression of infection. Consequently, *Azadirachta indica* has emerged as a promising natural alternative for the management of dermatophytosis [53].

6.1 *In Vitro* Studies

Several in vitro investigations have evaluated the antifungal activity of *Azadirachta indica* against clinically important dermatophytes such as *Trichophyton rubrum*, *Trichophyton mentagrophytes*, *Microsporum canis*, and *Epidermophyton floccosum*. Different laboratory methods have been employed to assess its efficacy [54].

Agar Well Diffusion Assay

The agar well diffusion method is one of the most commonly used techniques for evaluating the antifungal activity of neem extracts. In this assay, wells containing neem extracts are introduced into agar plates inoculated with dermatophytes. Numerous studies have reported significant zones of inhibition around the wells, indicating effective suppression of fungal growth. Ethanolic and methanolic extracts of neem leaves generally exhibit greater antifungal activity than aqueous extracts due to their higher concentration of bioactive phytochemicals [55].

Disc Diffusion Assay

The disc diffusion technique has also been widely utilized to determine the susceptibility of dermatophytes to neem extracts. Filter paper discs impregnated with neem-derived preparations are placed on fungal culture media, and the resulting inhibition zones are measured after incubation. Several investigations have demonstrated strong inhibitory effects against *Trichophyton* and *Microsporum* species, supporting the traditional use of neem in fungal skin infections [56].

Minimum Inhibitory Concentration (MIC) Studies

MIC studies provide quantitative evidence regarding the antifungal potency of neem extracts. Various researchers have reported low MIC values for neem-derived formulations against dermatophytes, suggesting significant antifungal activity even at relatively low concentrations. These findings indicate that neem possesses broad-spectrum antifungal properties and may serve as an effective source for the development of plant-based antifungal agents [57].

6.2 *In Vivo* Studies

Although *in vitro* studies provide valuable preliminary evidence, *in vivo* investigations are essential for evaluating therapeutic efficacy under physiological conditions.

Animal Infection Models

Experimental animal models have been employed to assess the antifungal activity of neem against dermatophytic infections. Infected animals treated with neem extracts or neem-based formulations have shown reductions in fungal burden, lesion size, erythema, and inflammation [58]. Histopathological examinations have further demonstrated improved skin architecture and accelerated healing in treated groups compared to untreated controls. These findings suggest that neem possesses both antifungal and skin-protective properties.

Clinical Observations

Traditional and preliminary clinical studies have reported beneficial effects of neem-based preparations in the management of fungal skin infections. Topical application of neem extracts, neem oil, and herbal formulations has been associated with reduced itching, scaling, redness, and lesion severity. While these observations support the therapeutic value of neem, well-designed randomized clinical trials are still required to establish its efficacy, safety, and optimal dosage regimens in human subjects [59].

6.3 Mechanisms of Antifungal Action

The antifungal activity of *Azadirachta indica* is mediated through multiple complementary mechanisms that collectively inhibit fungal growth and survival.

Cell Wall Disruption

Bioactive compounds present in neem interfere with the synthesis and structural integrity of fungal cell walls. Disruption of cell wall components weakens fungal cells and increases their susceptibility to environmental stress, ultimately leading to growth inhibition and cell death [60].

Membrane Damage

Neem phytochemicals have been reported to alter fungal cell membrane permeability by affecting membrane lipids and associated proteins. This disruption results in leakage of intracellular contents, loss of cellular homeostasis, and impairment of essential metabolic processes required for fungal survival [61].

Inhibition of Fungal Growth

Neem-derived compounds suppress fungal growth through interference with spore germination, mycelial development,

and cellular metabolism. In addition, the antioxidant and anti-inflammatory properties of neem help reduce tissue damage associated with infection and create an unfavorable environment for fungal proliferation. The synergistic action of these mechanisms contributes to the broad-spectrum antifungal activity of *Azadirachta indica* against dermatophytes and supports its potential application as a natural therapeutic agent for dermatophytosis [62].

7. Anti-Inflammatory and Antioxidant Contributions

The therapeutic effectiveness of *Azadirachta indica* against dermatophytosis extends beyond its direct antifungal activity. Fungal infections are often accompanied by excessive oxidative stress and inflammatory responses that contribute to tissue damage, delayed healing, erythema, itching, and disease recurrence. Neem possesses potent antioxidant and anti-inflammatory properties owing to the presence of bioactive phytochemicals such as quercetin, nimbin, nimbidin, nimbolide, gedunin, flavonoids, and phenolic compounds. These constituents work synergistically to neutralize reactive oxygen species (ROS), regulate inflammatory mediators, protect skin tissues, and promote recovery of infected areas. Consequently, neem offers a multifaceted therapeutic approach for the management of dermatophytosis and other skin disorders [63].

7.1 Antioxidant Mechanisms
ROS Scavenging

Oxidative stress plays a crucial role in the pathogenesis of dermatophytic infections. During fungal invasion, excessive production of reactive oxygen species (ROS) can damage cellular proteins, lipids, and nucleic acids, resulting in impaired skin integrity and delayed healing. *Azadirachta indica* contains several antioxidant compounds, particularly quercetin, catechins, limonoids, and phenolic acids, which possess strong free radical scavenging activity.

These phytochemicals neutralize ROS and reduce oxidative stress, thereby preventing cellular damage and maintaining normal physiological functions within the skin [64].

Protection of Skin Cells

The antioxidant constituents of neem provide protective effects against oxidative injury in keratinocytes, fibroblasts, and other skin cells. By minimizing lipid peroxidation and preserving cellular membrane integrity, neem helps maintain healthy skin architecture during fungal infections. Furthermore, antioxidant activity supports collagen synthesis and tissue regeneration, which are essential processes for restoring damaged skin and preventing chronic infection [65].

7.2 Anti-inflammatory Effects
Cytokine Modulation

Inflammation is a natural defense mechanism against fungal pathogens; however, excessive or prolonged inflammation may contribute to tissue damage and delayed recovery. Neem phytochemicals have been reported to modulate the production of pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α), interleukin-1β (IL-1β), and interleukin-6 (IL-6). By regulating these inflammatory mediators, neem helps control the inflammatory response while preserving host defense mechanisms. This immunomodulatory action contributes significantly to the therapeutic benefits of neem in dermatological conditions [66].

Reduction of Erythema and Itching

Clinical and experimental studies have demonstrated that neem extracts can alleviate common symptoms associated with fungal skin infections, including erythema, irritation, burning sensation, and pruritus. The anti-inflammatory activity of neem reduces vascular congestion and inflammatory cell infiltration, thereby minimizing redness and discomfort. These effects enhance patient comfort and improve the overall healing process [67].

7.3 Role in Skin Healing

In addition to its antifungal and anti-inflammatory properties, *Azadirachta indica* plays an important role in skin repair and regeneration. Neem bioactive compounds promote fibroblast proliferation, collagen synthesis, and re-epithelialization, which are critical stages of wound healing. The plant also exhibits antimicrobial activity that helps prevent secondary bacterial infections commonly associated with damaged skin. By reducing oxidative stress, controlling inflammation, and stimulating tissue regeneration, neem accelerates the restoration of normal skin structure and function [68].

The combined antioxidant, anti-inflammatory, and wound-healing properties of *Azadirachta indica* provide a strong scientific basis for its traditional use in the treatment of dermatophytosis and other skin disorders. These complementary mechanisms not only assist in eliminating fungal pathogens but also contribute to faster recovery and improved skin health [69].

8. Formulation Approaches for Dermatophytosis

The therapeutic efficacy of *Azadirachta indica* in dermatophytosis can be significantly enhanced through suitable pharmaceutical formulations. Although crude extracts possess considerable antifungal activity, formulation-based approaches improve the stability, bioavailability, skin penetration, and patient acceptability of neem-derived bioactive compounds. Recent advances in topical drug delivery systems have facilitated the development of innovative neem-based formulations designed to provide sustained antifungal activity, reduce irritation, and accelerate skin recovery. These approaches have attracted considerable attention for the management of dermatophytic infections and other fungal skin disorders [70].

8.1 Neem-Based Creams

Neem-based creams are among the most widely used topical formulations for the treatment of fungal skin infections. These creams incorporate neem leaf extracts, seed extracts, or neem oil into suitable cream bases to facilitate easy application and prolonged contact with the infected skin. The antifungal constituents present in neem help inhibit the growth of dermatophytes while simultaneously reducing inflammation and itching. Several experimental studies have demonstrated that neem creams effectively alleviate symptoms associated with dermatophytosis, including erythema, scaling, and irritation. Furthermore, creams offer good patient compliance due to their non-greasy texture, ease of application, and ability to provide localized therapeutic effects [71].

8.2 Herbal Gels

Herbal gels have emerged as promising alternatives to conventional creams because of their superior spreadability, cooling effect, and enhanced drug release characteristics. Neem-based gels are typically formulated using gelling agents such as Carbopol, hydroxypropyl methylcellulose (HPMC), or natural polymers. These formulations allow efficient delivery of bioactive phytochemicals directly to the site of infection while minimizing systemic exposure. In addition to their antifungal activity, neem gels contribute to skin hydration and improved wound healing. Studies have reported that herbal gels containing neem extracts exhibit significant inhibitory effects against dermatophytes and provide faster symptomatic relief compared to some conventional topical preparations [72].

8.3 Nanoformulations

Recent developments in nanotechnology have opened new avenues for improving the therapeutic performance of plant-derived antifungal agents. Nanoformulations enhance the solubility, stability, skin penetration, and controlled release of neem phytochemicals, thereby increasing their overall effectiveness against dermatophytic infections.

Nanogels

Nanogels are nanoscale hydrogel systems capable of encapsulating bioactive compounds and delivering them in a controlled manner. Neem-loaded nanogels provide enhanced skin retention, prolonged drug release, and improved penetration into infected tissues. These characteristics contribute to greater antifungal efficacy and reduced frequency of application [73].

Nanoemulsions

Nanoemulsions are thermodynamically stable colloidal systems composed of oil, water, surfactants, and bioactive agents. Neem oil-based nanoemulsions possess small droplet sizes that facilitate deeper penetration into the skin and improved interaction with fungal cells. Studies have demonstrated that nanoemulsion formulations enhance the antifungal activity of neem while improving formulation stability and patient acceptability [74].

Lipid Nanoparticles

Solid lipid nanoparticles (SLNs) and nanostructured lipid carriers (NLCs) have gained considerable attention as advanced drug delivery systems. These carriers protect neem bioactive compounds from degradation and enable sustained drug release at the site of infection. Lipid nanoparticles also improve skin permeation and increase the residence time of active constituents, thereby enhancing therapeutic outcomes in dermatophytosis management [75].

8.4 Combination Herbal Formulations

Combination herbal formulations represent an emerging strategy for maximizing therapeutic efficacy through synergistic interactions among medicinal plants. Neem is frequently combined with other herbal extracts such as *Curcuma longa* (turmeric), *Ocimum sanctum* (holy basil), *Aloe vera*, and *Cassia alata* to develop multifunctional antifungal formulations. Such combinations provide complementary antifungal, anti-inflammatory, antioxidant, and wound-healing effects, resulting in broader therapeutic coverage and enhanced clinical benefits [76]. Furthermore, combination formulations may reduce the risk of resistance development and improve overall treatment effectiveness. The integration of neem with other medicinal plants therefore offers a promising approach for the development of next-generation herbal therapies for dermatophytosis [77].

Overall, advances in formulation science have significantly expanded the therapeutic applications of *Azadirachta indica*. The development of creams, gels, nanoformulations, and combination herbal products has improved the delivery and efficacy of neem-derived phytochemicals, highlighting their potential as innovative and sustainable alternatives for the management of dermatophytic infections [78].

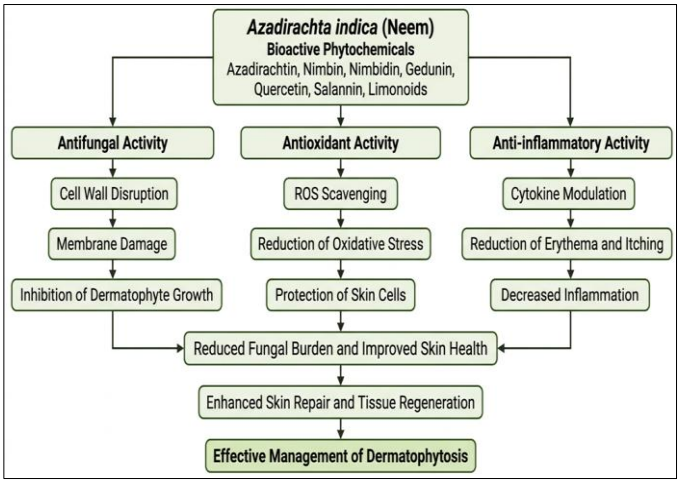

Figure 2: Proposed Mechanism of *Azadirachta indica* in Dermatophytosis Management [79]

9. Safety, Toxicity and Regulatory Considerations

The increasing application of *Azadirachta indica* in dermatological formulations has highlighted the importance of evaluating its safety and regulatory status. Although neem has been used traditionally for centuries, scientific studies are essential to ensure its safe and effective use in the management of dermatophytosis.

Acute Toxicity Studies

Acute toxicity studies have generally demonstrated that neem extracts possess a favorable safety profile when used within recommended therapeutic doses. Animal studies involving leaf, bark, and seed extracts have reported minimal toxicity and no significant adverse effects on major organs. However, toxicity may vary depending on the dose, extraction method, and route of administration [80].

Skin Irritation Studies

Since neem is commonly used in topical formulations, its dermatological safety is particularly important. Various studies on neem-based creams, gels, and oils have shown minimal skin irritation and good tolerability. Most formulations produce little or no erythema, edema, or allergic reactions, indicating their suitability for topical application. Nevertheless, patch testing is recommended for individuals with sensitive skin [81].

Human Safety Data

Traditional use and available clinical observations suggest that neem-based products are generally safe for human use. Reported adverse effects are uncommon and usually limited to mild skin irritation, dryness, or temporary burning sensations. Despite encouraging safety data, well-designed clinical studies are still needed to establish long-term safety and optimal therapeutic dosage [82].

Regulatory Status of Neem Products

Neem-derived products are widely marketed as herbal medicines, cosmetics, and personal care products in many countries. Their regulatory approval depends on product quality, safety, manufacturing standards, and intended use. Although neem enjoys broad acceptance in traditional medicine, further standardization and clinical validation are required to support its wider integration into evidence-based pharmaceutical and dermatological practice. Overall, available evidence indicates that *Azadirachta indica* is a relatively safe medicinal plant with significant therapeutic potential. Continued toxicological evaluation and regulatory standardization will further strengthen its application in dermatophytosis management [83].

10. Conclusion

Azadirachta indica A. Juss. (Neem) has emerged as a promising plant-derived therapeutic for the management of dermatophytosis due to its broad-spectrum antifungal activity and long history of traditional medicinal use. Numerous experimental studies have demonstrated the effectiveness of neem extracts and neem-based formulations against major dermatophyte species, including *Trichophyton*, *Microsporum*, and *Epidermophyton*. These findings support the potential of neem as a natural alternative or complementary approach to conventional antifungal therapy.

The therapeutic efficacy of neem is largely attributed to its rich phytochemical composition, particularly bioactive compounds such as azadirachtin, nimbin, nimbidin, gedunin, quercetin, salannin, and other limonoids. These phytochemicals exhibit antifungal, antioxidant, anti-inflammatory, and skin-protective properties that collectively contribute to the inhibition of fungal growth, reduction of infection-associated inflammation, and promotion of tissue repair. The multifaceted mechanisms of action of neem make it a valuable candidate for the treatment of dermatophytic infections.

Beyond its direct antifungal effects, neem offers additional therapeutic benefits by reducing oxidative stress, alleviating erythema and itching, and supporting skin healing. Recent advancements in pharmaceutical formulations, including creams, gels, nanoemulsions, nanogels, and lipid-based delivery systems, have further enhanced the stability, bioavailability, and therapeutic performance of neem-derived bioactive compounds.

Despite encouraging preclinical evidence, the clinical application of neem-based antifungal products remains limited by the lack of standardized formulations and well-designed human studies. Therefore, comprehensive clinical trials, long-term safety evaluations, and quality-control measures are required to establish their efficacy and reliability.

In conclusion, *Azadirachta indica* represents a promising natural resource for the development of innovative antifungal therapies. Continued research integrating phytochemistry, nanotechnology, and pharmaceutical sciences may facilitate the translation of neem-based products into effective and evidence-based treatments for dermatophytosis and other fungal skin infections.

ACKNOWLEDGEMENT: Author are thankful to his supervisor and co-supervisor for their valuable guidance throughout this study.

CONFLICT OF INTEREST: Nil

REFERENCES:

1. AL-Khikani FH. Dermatophytosis a worldwide contiguous fungal infection: Growing challenge and few solutions. Biomedical and Biotechnology Research Journal (BBRJ). 2020 Apr 1;4(2):117-22.
2. Shemer A, Babaev M. Fungal infections (onychomycosis, tinea pedis, tinea cruris, tinea capitis, tinea manuum, tinea corporis, different candida infections, and pityriasis

versicolor) and mycological laboratory analyses. InGender and dermatology 2018 May 8 (pp. 235-242). Cham: Springer International Publishing.
3. Maksimov AY, Balandina SY, Topanov PA, Mashevskaya IV, Chaudhary S. Organic antifungal drugs and targets of their action. Current Topics in Medicinal Chemistry. 2021 Mar 1;21(8):705-36.
4. Mohanasundaram P, Antoneyraj MS. A systematic review of neem flower (Azadirachta indica): a promising source of bioactive compounds with pharmacological and immunomodulating properties. Tradit Med Res. 2025;10(7):41.
5. Baby AR, Freire TB, Marques GD, Rijo P, Lima FV, Carvalho JC, Rojas J, Magalhães WV, Velasco MV, Morocho-Jácome AL. Azadirachta indica (Neem) as a potential natural active for dermocosmetic and topical products: A narrative review. Cosmetics. 2022 Jun 2;9(3):58.
6. Afzal S, Shoaib S, Jahan R, Shadab M, Alomary MN, Ansari MA. Medicinal and Nutritional Importance of Azadirachta indica in Human Health. InMedicinal Plants and their Bioactive Compounds in Human Health: Volume 2 2026 Jan 17 (pp. 1-15). Singapore: Springer Nature Singapore.
7. Baby AR, Freire TB, Marques GD, Rijo P, Lima FV, Carvalho JC, Rojas J, Magalhães WV, Velasco MV, Morocho-Jácome AL. Azadirachta indica (Neem) as a potential natural active for dermocosmetic and topical products: A narrative review. Cosmetics. 2022 Jun 2;9(3):58.
8. Saleem S, Muhammad G, Hussain MA, Bukhari SN. A comprehensive review of phytochemical profile, bioactives for pharmaceuticals, and pharmacological attributes of Azadirachta indica. Phytotherapy research. 2018 Jul;32(7):1241-72.
9. Rajabiyan A, Bakhshi D, Hosseini SA. A methodological review of extraction, purification, and identification techniques for natural bioactive compounds. Organic Process Research & Development. 2025 Jul 23;29(8):1885-915.
10. Chanyachailert P, Leeyaphan C, Bunyaratavej S. Cutaneous fungal infections caused by dermatophytes and non-dermatophytes: an updated comprehensive review of epidemiology, clinical presentations, and diagnostic testing. Journal of Fungi. 2023 Jun 14;9(6):669.
11. Weitzman I, Summerbell RC. The dermatophytes. Clinical microbiology reviews. 1995 Apr;8(2):240-59.
12. Kindo AJ, Danni MK. Dermatophytoses. InTextbook of Fungal Zoonoses and Sapronoses 2024 Sep 25 (pp. 125-136). Singapore: Springer Nature Singapore.
13. Rawat S, Parul, Sharma N, Sharma B, Jain U, Thakur V. Transmission, Maintenance of Infection, and Consequences of Disease. Epidemiology and Environmental Hygiene in Veterinary Public Health. 2025 Apr 6:67-79.
14. Patel P, Bhatt R. Tinea Corporis: A Comprehensive Review of Clinical Features and Homoeopathic Therapeutics. International Journal of Research and Innovation in Applied Science (IJRIAS). 2026 Mar 20;11(2).
15. Gupta AK, Polla Ravi S, Wang T, Faour S, Bamimore MA, Heath CR, Friedlander SF. An update on tinea capitis in children. Pediatric Dermatology. 2024 Nov;41(6):1030-9.
16. Leung AK, Barankin B, Lam JM, Leong KF, Hon KL. Tinea pedis: an updated review. Drugs in context. 2023 Jun 29;12.
17. Kaushik N, Pujalte GG, Reese ST. Superficial fungal infections. Primary care: clinics in office practice. 2015 Dec 1;42(4):501-16.
18. Narain U, Bajaj AK, Misra K. Onychomycosis. Indian Journal of Dermatology. 2002 Apr 1;47(2):68-75.
19. Sahni K, Singh S, Dogra S. Newer topical treatments in skin and nail dermatophyte infections. Indian dermatology online journal. 2018 May 1;9(3):149-58.
20. Gupta AK, MacLeod MA, Foley KA, Gupta G, Friedlander SF. Fungal skin infections. Pediatrics in review. 2017 Jan 1;38(1):8-22.
21. Sonego B, Corio A, Mazzoletti V, Zerbato V, Benini A, di Meo N, Zalaudek I, Stinco G, Errichetti E, Zelin E. Trichophyton indotineae, an emerging drug-resistant dermatophyte: a review of the treatment options. Journal of Clinical Medicine. 2024 Jun 18;13(12):3558.
22. Brasch J, Hipler UC. Clinical aspects of dermatophyte infections. InHuman and Animal Relationships 2008 (pp. 263-286). Berlin, Heidelberg: Springer Berlin Heidelberg.
23. Oli B, Gautam D. Medicinal value of Azadirachta indica: A review. Modern phytomorphology. 2022 Oct 29;15:161-7.
24. Debnath S, Das M, Mondal S, Sarkar BK, Babu G. Neem (Azadirachta indica A. Juss): a multifaceted tree & an elixir in the traditional system of Indian medicine. Discover Plants. 2025 May 26;2(1):156.
25. Wahjono TE, Suhatman A, Wihermanto W, Hadiyanto H. Neem (Azadirachta indica A. Juss; Meliaceae) as the source for plant-based pesticides as an effective and sustainable biocontrol alternative. Journal of Bioresources and Environmental Sciences. 2024 Dec 1;3(3):128-41.
26. Mursal M, Ahmad M, Badruddeen, Akhtar J. Azadirachta indica L. Medicinal and Aromatic Plants of India, Vol. 3. 2024 Dec 14:47-59.
27. Gupta S, Verma D, Tufchi N, Kamboj A, Bachheti A, Bachheti RK, Husen A. Food, fodder and fuelwoods from forest. InNon-Timber Forest Products: Food, Healthcare and Industrial Applications 2021 Jul 31 (pp. 383-425). Cham: Springer International Publishing.
28. Arunachalam B, Ganesan S, Natarajan HP, Suthandhirajan R, Muthuswamy S, Balaiyan S, Satheesan A. Advancing Neem's Role in Environmental Sustainability: Genetic Potential and Industrial Applications. Environmental Quality Management. 2025 Mar;34(3):e70041.
29. Pramova E, Locatelli B, Djoudi H, Somorin OA. Forests and trees for social adaptation to climate variability and change. Wiley Interdisciplinary Reviews: Climate Change. 2012 Nov;3(6):581-96.
30. Singh V, Roy M, Garg N, Kumar A, Arora S, Malik DS. An insight into the dermatological applications of neem: a review on traditional and modern aspect. Recent Advances in Anti-Infective Drug Discovery Formerly Recent Patents on Anti-Infective Drug Discovery. 2021 Aug 1;16(2):94-121.
31. Sahu P, Tamrakar N, Sri R, Wamankar S, Sahu G, Kaur C. Synergistic Combinations Of Natural Antifungals In The Management Of Dermatophytosis (Ringworm). International Journal of Scientific Research and Technology. 2026 Apr 21;3(4):788-800.
32. Srivastav A, Srivastav Y, Hameed A, Ahmad MI. Prevention and cure of dermatology disorders using herbal medications: summary. International Journal of Indigenous Herbs and Drugs. 2024 Feb 28:1-4.
33. Pasipanodya CN, Tekedza TT, Chatiza FP, Gororo E. Efficacy of neem (Azadirachta indica) aqueous fruit

extracts against Sarcoptes scabiei var. suis in grower pigs. Tropical animal health and production. 2021 Mar;53(1):135.
34. Prakash A, Malviya R, Sridhar SB, Wadhwa T, Shareef J. Physicochemical Properties, Drug Delivery, and Tissue Engineering Applications of Neem Gum and Its Derivatives: A Comprehensive Review. Mini-Reviews in Medicinal Chemistry. 2025 Nov 4.
35. Ojha S, Rana P, Tiwari R. A comprehensive review: the role of herbs in management offungal infection. Current Clinical and Medical Education. 2025 Mar 13;3(03):54-65.
36. Fernandes JB. Secondary metabolism as a measurement of efficacy of botanical extracts: The use of Azadirachta indica (Neem) as a model. Insecticides: Advances in Integrated Pest Management. 2012 Jan 5;367.
37. Bittner Fialová S, Rendeková K, Mučaji P, Nagy M, Slobodníková L. Antibacterial activity of medicinal plants and their constituents in the context of skin and wound infections, considering European legislation and folk medicine—a review. International Journal of Molecular Sciences. 2021 Oct 4;22(19):10746.
38. Ezin V, Chabi IB. Azadirachta indica: Its biological, pharmacological, antidiabetic potential, and omics applications. InAntidiabetic Plants for Drug Discovery 2022 Dec 29 (pp. 1-22). Apple Academic Press.
39. Loganathan T, Barathinivas A, Soorya C, Balamurugan S, Nagajothi TG, Jayakumararaj R. GCMS profile of bioactive secondary metabolites with therapeutic potential in the ethanolic leaf extracts of Azadirachta indica: A sacred traditional medicinal plant of india. Journal of Drug Delivery and Therapeutics. 2021 Jul 2;11(4-S):119-26.
40. Su X, Liang Z, Xue Q, Liu J, Hao X, Wang C. A comprehensive review of azadirachtin: physicochemical properties, bioactivities, production, and biosynthesis. Acupuncture and Herbal Medicine. 2023 Dec 1;3(4):256-70.
41. Guchhait KC, Dey S, Das A, Manna T, Jana D, Karmakar M, Majumder S, Panda AK, Ghosh C. Bioactive Alkaloids in Azadirachta indica Seed and Their Biological Activities. InNatural Products: Phytochemistry, Botany, Metabolism of Alkaloids, Phenolics and Terpenes 2025 Mar 13 (pp. 1-25). Berlin, Heidelberg: Springer Berlin Heidelberg.
42. Lim TK. Azadirachta indica. InEdible Medicinal and Non Medicinal Plants: Volume 8, Flowers 2014 Mar 3 (pp. 409-455). Dordrecht: Springer Netherlands.
43. Jolanta P, Daniel Jan S, Agata K, Stanislaw L. Variability of biological activities of limonoids derived from plant sources. Mini-Reviews in Organic Chemistry. 2014 Aug 1;11(3):269-79.
44. Vollmannová A, Bojňanská T, Musilová J, Lidiková J, Cifrová M. Quercetin as one of the most abundant represented biological valuable plant components with remarkable chemoprotective effects-A review. Heliyon. 2024 Jun 30;10(12).
45. Govindachari TR, Narasimhan NS, Suresh G, Partho PD, Gopalakrishnan G. Insect antifeedant and growth-regulating activities of salannin and other C-seco limonoids from neem oil in relation to azadirachtin. Journal of chemical ecology. 1996 Aug;22(8):1453-61.
46. Roy A, Saraf S. Limonoids: overview of significant bioactive triterpenes distributed in plants kingdom. Biological and pharmaceutical bulletin. 2006;29(2):191-201.
47. Praveena K, Kashyap N, Sidar AS, Pandey S, Saha S. TLC and HPLC fingerprinting of medicinal plants used in Indian traditional medicine. International Journal of Pharmacognosy and Herbal Drug Technology. 2025 Jul 24:121-34.
48. Schaaf O, Jarvis AP, Van Der Esch SA, Giagnacovo G, Oldham NJ. Rapid and sensitive analysis of azadirachtin and related triterpenoids from neem (Azadirachta indica) by high-performance liquid chromatography–atmospheric pressure chemical ionization mass spectrometry. Journal of Chromatography A. 2000 Jul 21;886(1-2):89-97.
49. Muñoz-Nuñez E, Madrid-Villegas A, Alarcón-Enos J, Ferreira-Funes C, Valdés-Navarro F, Santander R, Norambuena-Morales J, Martínez-Lobos M. Insecticidal potential of Baccharis macraei essential oils: An ecological approach to their volatile composition in insect management. Agronomy. 2025 Feb 20;15(3):509.
50. Singh PK, Singh J, Medhi T, Kumar A. Phytochemical screening, quantification, FT-IR analysis, and in silico characterization of potential bio-active compounds identified in HR-LC/MS analysis of the polyherbal formulation from Northeast India. ACS omega. 2022 Sep 7;7(37):33067-78.
51. Alzohairy MA. Therapeutics role of Azadirachta indica (Neem) and their active constituents in diseases prevention and treatment. Evidence-Based Complementary and Alternative Medicine. 2016;2016(1):7382506.
52. Ospina Salazar DI, Hoyos Sánchez RA, Orozco Sanchez F, Arango Arteaga M, Gómez Londoño LF. Antifungal activity of neem (Azadirachta indica: Meliaceae) extracts against dermatophytes. Acta Biológica Colombiana. 2015 Sep;20(3):181-92.
53. Mudenda S, Banda M, Mohamed S, Chabalenge B. Phytochemical composition and antibacterial activities of Azadirachta indica (Neem): significance of traditional medicine in combating infectious diseases and antimicrobial resistance. J Pharmacogn Phytochem. 2023;12(5):256-63.
54. Pimple BP, Badole SL, Menaa F. Exploring Neem (Azadirachta indica) for antidermatophytic activity. InBioactive Dietary Factors and Plant Extracts in Dermatology 2012 Oct 28 (pp. 459-469). Totowa, NJ: Humana Press.
55. Mondall NK, Mojumdar A, Chatterje SK, Banerjee A, Datta JK, Gupta S. Antifungal activities and chemical characterization of Neem leaf extracts on the growth of some selected fungal species in vitro culture medium.
56. Tauseef S, Tauseef F, Siddiqui K. Antifungal Potential of Leaves and Barks of Azadirachta indica: Antifungal Potential of Neem Tree. Biological Sciences-PJSIR. 2024 Mar 4;67(1):8-14.
57. Alhussaini MS, Alyahya AA, Al-Ghanayem AA. TiO2-based nanomaterials as antimicrobial agents: Recent progress and trends (2020–2025). Main Group Chemistry. 2026 Jan 7:10241221251413990.
58. Malakar M, Mandal D. Neem-Drug Cabinet of Mother Nature. InAdvances in Medicinal and Aromatic Plants 2024 Jul 5 (pp. vol2-55). Apple Academic Press.
59. Yadav A, Gupta V, Malik JK, Singh G, Bhardwaj Y. PHARMACOLOGICAL POTENTIAL OF AZADIRACHTA INDICA LEAF EXTRACT IN DERMATOPHYTE INFECTIONS: A REVIEW.
60. Ali J, Bangash JA, Siddique M. Comparative bioactive compounds and fourier transform infrared spectroscopic evaluation of Azadirachta indica extracts and its potential as bio-fungicides against plant pathogenic fungi. Int J Eng Sci Technol. 2023;15(1):1-2.

61. Sultana R, Nayem RI, Islam Masum MM. In Silico Screening of Neem-Derived Phytochemicals Targeting the Avr1 (SIX4) Effector Protein of Fusarium oxysporum for Fusarium Wilt Management. bioRxiv. 2025 Dec 26:2025-12.
62. Daud SA, Simone Y, Zakaria L, Azuddin NF, Salikin NH, Jalil MT, Rashid SA, Tung WC. Endophytic Colletotrichum siamense from neem leaves: A novel source of antibacterial compounds against Staphylococcus aureus. Malaysian Journal of Microbiology. 2025 Oct 1;21(5).
63. Kumar R, Kumar S, Kanwar SS. Biomedical perspectives of herbal honey. InBiomedical Perspectives of Herbal Honey 2024 Apr 25 (pp. 89-167). Singapore: Springer Nature Singapore.
64. Jusuf S, Mansour MK. Catalase Deactivation Increases Dermatophyte Sensitivity to ROS Sources. Journal of Fungi. 2024 Jul 11;10(7):476.
65. Shareef M, Akhtar MS. Neem (Azadirachta indica) and its potential for safeguarding health, prevention and treatment of diseases. Matrix Science Medica. 2018;2(1):04-8.
66. Lionakis MS, Drummond RA, Hohl TM. Immune responses to human fungal pathogens and therapeutic prospects. Nature Reviews Immunology. 2023 Jul;23(7):433-52.
67. Ahuja A, Gupta J, Gupta R. Miracles of herbal phytomedicines in treatment of skin disorders: natural healthcare perspective. Infectious Disorders-Drug TargetsDisorders). 2021 May 1;21(3):328-38.
68. Satapathy T, Yadu H, Sahu P. Protective Role of Herbal Bioactive in Modulation of PDGF-VEGF-TGFβ-EGF Fibroblast Proliferation and Re-epithelialization for the Enhancement of Tissue Strength and Wound Healing. Regenerative Engineering and Translational Medicine. 2025 Sep 22:1-22.
69. Chew YL, Khor MA, Xu Z, Lee SK, Keng JW, Sang SH, Akowuah GA, Goh KW, Liew KB, Ming LC. Cassia alata, Coriandrum sativum, Curcuma longa and Azadirachta indica: food ingredients as complementary and alternative therapies for atopic dermatitis-a comprehensive review. Molecules. 2022 Aug 26;27(17):5475.
70. Tamrakar N, Sri R, Sahu P, Wamankar S, Sahu G, Kaur C. Synergistic Combinations Of Natural Antifungals In The Management Of Dermatophytosis (Ringworm). Int. J. Sci. R. Tech. 2026;3(4).
71. Osahon OV, Oshiokhayamhe IK, Esther EE, Oshoke EE. Production and Antimicrobial Properties of Neem Based Herbal Soap against Selected Skin Pathogens.
72. Prakash A, Malviya R, Sridhar SB, Wadhwa T, Shareef J. Physicochemical Properties, Drug Delivery, and Tissue Engineering Applications of Neem Gum and Its Derivatives: A Comprehensive Review. Mini-Reviews in Medicinal Chemistry. 2025 Nov 4.
73. Silva MP, Fabi JP. Food biopolymers-derived nanogels for encapsulation and delivery of biologically active compounds: A perspective review. Food hydrocolloids for health. 2022 Dec 1;2:100079.
74. Kumar H, Suryawanshi B, Jaiswal Y, Aravindbhai AJ, Bhupatbhai CV. Azadirachtin based sustainable nano-emulsion: formulation, parametric study and modeling. Journal of Molecular Liquids. 2025 Oct 15;436:128254.
75. Müller RH, Radtke M, Wissing SA. Solid lipid nanoparticles (SLN) and nanostructured lipid carriers (NLC) in cosmetic and dermatological preparations. Advanced drug delivery reviews. 2002 Nov 1;54:S131-55.
76. Jayaraman L, Lakshitha D, Sivaji S, Vasantharekha R, Seetharaman B, Mudgal G. Future Directions in Herbal Synergy Research: Emerging Trends and Prospective Areas. Exploring Herbal Synergies for Optimal Human Health.:411-35.
77. Deshpande A, Bali S, Shukla AK, Mairal T, Kadoo N. Regulatory and Legal Frameworks in Bioprospecting and Application of Medicinal Plant-Derived Antifungal Agents. InIntegrative Approach to Fungal Infections and Bioprospecting for Drug Discovery (pp. 228-256). CRC Press.
78. Dutt Y, Pandey RP, Dutt M, Gupta A, Vibhuti A, Raj VS, Chang CM, Priyadarshini A. Silver nanoparticles phytofabricated through Azadirachta indica: anticancer, apoptotic, and wound-healing properties. Antibiotics. 2023 Jan 9;12(1):121.
79. Sarkar S, Singh RP, Bhattacharya G. Exploring the role of Azadirachta indica (neem) and its active compounds in the regulation of biological pathways: an update on molecular approach. 3 Biotech. 2021 Apr;11(4):178.
80. Baligar NS, Aladakatti RH, Ahmed M, Hiremath MB. Evaluation of acute toxicity of neem active constituent, nimbolide and its hepatoprotective activity against acute dose of carbon tetrachloride treated albino rats. International Journal of Pharmaceutical Sciences and Research. 2014 Aug 1;5(8):3455.
81. Johansen JD, Aalto-Korte K, Agner T, Andersen KE, Bircher A, Bruze M, Cannavó A, Giménez-Arnau A, Gonçalo M, Goossens A, John SM. European Society of Contact Dermatitis guideline for diagnostic patch testing–recommendations on best practice. Contact dermatitis. 2015 Oct;73(4):195-221.
82. Wylie MR, Merrell DS. The antimicrobial potential of the neem tree Azadirachta indica. Frontiers in pharmacology. 2022 May 30;13:891535.
83. Shyamsunder B. Veterinary and Agricultural Perspectives. Herbal Medicine Approaches to Antimicrobial Resistance and One Health. 2026 Jun 4:247.

How to cite this article:
Yadav P, Vibha, Yadav R, Rao AK. Plant-derived therapeutics for dermatophytosis: focus on *Azadirachta indica*. International Journal of Pharmaceutical Science and Medicine 2026; 4(1): 1-12.