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"Comprehensive Review of the Neem Plant's Attributes and Applications"

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Abstract.

The neem plant (*Azadirachta indica*) is an ancient and versatile botanical resource that has been revered for its numerous medicinal, agricultural, and industrial applications. This review article provides a comprehensive examination of the neem plant, covering its botanical description, traditional uses, chemical composition, and pharmacological properties. The introduction highlights the historical, cultural, and economic significance of the neem plant, emphasizing its widespread utilization in traditional medicine, agriculture, and various other domains. The botanical description and taxonomy section offer a detailed overview of the neem plant's characteristics, including its scientific classification and morphological features. Exploring the traditional and historical uses of the neem plant, this article presents its diverse applications in different cultures and regions. It discusses its role in traditional medicine, agricultural practices, pest control, cosmetic preparations, and cultural rituals, showcasing the long-standing cultural importance of the neem plant. The chemical composition section delves into the bioactive compounds found in the neem plant, such as nimbin, azadirachtin, nimbolide, and limonoids. Extraction methods for these compounds are also discussed, shedding light on their potential applications. The pharmacological properties section examines the extensive research on the neem plant's antimicrobial, antiviral, antifungal, antidiabetic, anti-inflammatory, and antioxidant activities. It explores the mechanisms of action and the therapeutic potential of neem-derived compounds, offering insights into their biomedical applications.

Keywords: *Azadirachta indica*, modern medicine, agriculture, bioactive compounds, sustainable development.

Introduction: The neem plant (*Azadirachta indica*) holds a significant place in traditional medicine, agriculture, and various industries due to its remarkable properties and diverse

applications. With a rich history spanning thousands of years, this versatile plant has been utilized in different cultures across the globe [1].

The neem tree, native to the Indian subcontinent, belongs to the Meliaceae family and has garnered attention for its various bioactive compounds, making it a valuable botanical resource. The neem plant has been extensively used in traditional medicine systems such as Ayurveda, Siddha, and Unani, where it is considered a panacea for various ailments. Its leaves, bark, seeds, and oil have been utilized to treat conditions ranging from skin disorders to gastrointestinal issues [2].

The antibacterial, antiviral, antifungal, and anti-inflammatory properties of neem have been recognized for centuries, leading to its widespread use in traditional remedies. In addition to its medicinal uses, the neem plant has found applications in agriculture & pest control. Neem-based products have been employed as natural pesticides, insect repellents, and soil conditioners, offering eco-friendly alternative to synthetic chemicals. Its efficacy against a wide range of pests, including insects, mites, and nematodes, has made it a valuable asset in integrated pest management strategies [3].

Moreover, neem products have been explored for their potential in improving soil fertility, enhancing crop yield, and promoting

sustainable agricultural practices. The chemical composition of the neem plant is of immense interest due to its bioactive compounds [4].

Key constituents such as nimbin, azadirachtin, nimbolide, and limonoids have been extensively studied for their pharmacological properties. Researchers have investigated their potential as anticancer agents, antidiabetic agents, immune modulators, and more. The unique combination of bioactive compounds in the neem plant contributes to its diverse pharmacological activities, making it a subject of scientific inquiry and exploration [5].

Moreover, the neem plant has gained attention in the industrial sector. Its derivatives have been utilized in the production of pharmaceuticals, personal care products, and biopesticides. Neem-based formulations have shown promise in combating various diseases and have found applications in cosmetics, dental care, and veterinary products. The increasing demand for natural and sustainable alternatives has contributed to the growing commercial value of neem-derived products [6].

Given the vast potential and diverse applications of the neem plant, this review article aims to provide a comprehensive overview of its botanical description, traditional uses, chemical composition, pharmacological properties, and potential

future perspectives. By examining the existing body of knowledge, this review seeks to contribute to our understanding of the neem plant's significance and explore its untapped potential in various fields [7].

Botanical Description and Taxonomy of Neem Plant:

The neem plant, scientifically known as *Azadirachta indica*, is an evergreen tree belonging to the Meliaceae family. It is native to Indian subcontinent & is widely distributed in tropical and subtropical regions across Asia, Africa, & Americas [8].

The neem tree is known for its resilience and ability to adapt to various climatic conditions, including arid and semi-arid environments. Morphologically, the neem plant exhibits several distinguishing features. It typically reaches a height of 15-20 meters, although some specimens can grow up to 40 meters tall. The tree has a straight trunk with a greyish-brown bark that is deeply furrowed. Its crown is characterized by a dense arrangement of branches and leaves. The leaves of the neem plant are pinnate and alternate in arrangement. Each leaf is composed of numerous leaflets, usually 8-19 in number [9].

The leaflets are lanceolate in shape, with serrated margins & a pointed tip. The leaf surface is glossy, & color ranges from light green to dark green, depending on age of foliage. During the flowering season, neem

plant produces small, fragrant white flowers. The flowers are arranged in drooping panicles, & each flower has a five-lobed calyx & five petals. The male and female flowers are borne on the same tree, but they are usually found on separate inflorescences. After pollination, the neem tree produces ellipsoid or ovoid fruits, commonly known as neem fruits or neem seeds. These fruits have a thin outer skin that turns from green to yellow as they ripen. Inside the fruit, there is a single seed, which is enclosed in a hard, fibrous husk. The seed is roughly triangular in shape, with a brown color & a bitter taste [10].

Taxonomically, the neem plant is classified as follows:

Kingdom: Plantae.

Subkingdom: Tracheobionta.

Superdivision: Spermatophyta.

Division: Magnoliophyta.

Class: Magnoliopsida.

Subclass: Rosidae

Order: Sapindales

Family: Meliaceae.

Genus: *Azadirachta*

Species: *Azadirachta indica*

The neem plant is the sole species within the *Azadirachta* genus & it has several common names in different languages, including neem,

nimtree, Indian lilac, margosa tree, and veppam in various parts of the world [11].

Traditional and Historical Uses of the Neem Plant:

The neem plant (*Azadirachta indica*) has a rich history of traditional uses across cultures and regions. For centuries, it has been highly regarded for its diverse therapeutic properties and has found applications in traditional medicine, agriculture, pest control, personal care, and cultural practices [12].

Here are some of the traditional and historical uses of the neem plant:

1. Traditional Medicine:

In traditional medicine systems such as Ayurveda, Siddha & Unani, neem has been extensively used to treat various ailments. Different parts of neem plant, including leaves, bark, seeds, and oil, are utilized for their medicinal properties. Neem has been employed to treat skin disorders, such as eczema, acne & psoriasis, due to its anti-bacterial & anti-inflammatory effects. It has also been used to address digestive issues, promote oral health, support liver function & boost the immune system [13].

Neem has a long history of use in agriculture, particularly in pest control & soil improvement. Neem-based formulations, such as neem oil and neem cake, have been employed as natural insecticides and insect

repellents. They have shown efficacy against a wide range of pests, including insects, mites & nematodes, while posing minimal harm to beneficial organisms & environment. Neem has also been used as a soil conditioner, enhancing fertility, improving water retention & inhibiting the growth of soil-borne pathogens [14].

3. Pest Control:

In addition to agricultural applications, neem has been traditionally used for pest control in stored grains and other commodities. Neem leaves or powdered neem have been placed with stored grains to repel insects and prevent infestations. The bitter taste and odor of neem act as natural deterrents for pests, helping to protect stored food from damage.

4. Cosmetics and Personal Care:

Neem has been incorporated into various cosmetic and personal care products due to its beneficial effects on the skin and hair. Neem oil has been used in soaps, shampoos, creams, and lotions for its antimicrobial and moisturizing properties. It is believed to help in treating dandruff, scalp conditions, and skin infections. Neem-based preparations are also employed in traditional beauty treatments to improve complexion and promote healthy skin [15].

5. Cultural and Ritual Practices:

The neem plant holds cultural and ritualistic significance in many communities. In certain traditions, neem leaves are used in religious ceremonies and auspicious occasions. They are believed to ward off evil spirits and bring prosperity. Neem twigs have been used as natural toothbrushes in some cultures, promoting oral hygiene & dental health. The neem plant, *Azadirachta indica*, has a wide range of bioactive substances that contribute to its medicinal benefits & prospective uses. These chemical components have been identified & isolated by studies on various neem plant parts, including as leaves, bark, seeds & oil [16].

Here are some of the major bioactive compounds found in the neem plant:

Chemical Composition:

1. Nimbin:

It is a sulfur-containing compound present in the neem plant, particularly in the leaves and seeds. It is known for its antipyretic, analgesic, anti-inflammatory, and antifungal properties.

2. Azadirachtin:

Azadirachtin is one of most well-known & extensively studied compounds in neem. It is primarily found in seeds and acts as a potent insecticide and insect growth regulator. Azadirachtin exhibits anti-feedant, repellent, and ovicidal properties, making it effective against a wide range of pests.

3. Nimbolide:

Nimbolide is a terpenoid compound present in neem leaves & seeds. It has shown anticancer, antidiabetic, anti-inflammatory & antioxidant activities in various studies.

4. Limonoids:

Neem contains a group of compounds known as limonoids, which are characterized by their triterpenoid structure. Some of prominent limonoids found in neem include gedunin, azadiradione, & salannin. Limonoids exhibit a broad spectrum of biological activities, including anti-malarial, anti-fungal, antitumor & insecticidal properties [17].

5. Quercetin:

Quercetin is a flavonoids compound found in neem leaves. It possesses antioxidant, anti-inflammatory, and antiproliferative properties. Quercetin is known for its ability to scavenge free radicals & protect against oxidative stress.

6. Beta-sitosterol:

Beta-sitosterol is a phytosterol present in the neem plant. It exhibits cholesterol-lowering effects and has been studied for its potential in managing cardiovascular health.

7. Gallic acid:

Gallic acid is a phenolic compound found in neem leaves. It possesses antioxidant, anti-inflammatory, and antimicrobial properties. Gallic acid has been investigated for its

potential in wound healing and dermatological applications [18].

8. Triterpenoids:

Neem contains various triterpenoid compounds, including azadirachtol, azadirachol, and nimocinol. These compounds exhibit anti-microbial, anti-viral & anti-cancer activities.

Pharmacological Properties:

The neem plant (*Azadirachta indica*) possesses a wide range of pharmacological properties, which have been extensively studied & documented. The bio-active compounds present in different parts of neem plant contribute to its diverse therapeutic potential [19].

Here are some of the major pharmacological properties associated with the neem plant:

1. Antimicrobial Activity:

Neem exhibits broad-spectrum antimicrobial activity against various bacteria, fungi, and viruses. Its bioactive compounds, such as nimbin, azadirachtin, and nimbolide, have shown significant antibacterial and antifungal effects. Neem has been explored for its potential in treating infections, including skin infections, oral infections, and urinary tract infections.

2. Antiviral Activity:

The neem plant has demonstrated anti-viral activity against several viruses, including herpes simplex virus, (HIV), & dengue virus. Compounds like nimbidin & nimbolide have been studied for their anti-viral properties, inhibiting viral replication and infectivity.

3. Antifungal Activity:

Neem has been found to be effective against various fungal pathogens, including *Candida* species, *Aspergillus* species, and dermatophytes. Its antifungal properties are attributed to the presence of azadirachtin and other bioactive compounds, which inhibit fungal growth and development [20].

4. Antidiabetic Activity:

The neem plant has been traditionally used for managing diabetes, and scientific studies support its antidiabetic properties. Neem extracts and compounds like nimbin and nimbolide have shown antihyperglycemic effects, promoting glucose uptake and improving insulin sensitivity.

5. Anti-inflammatory Activity:

Neem possesses potent anti-inflammatory properties, which have been attributed to its compounds, including nimbidin & nimbolide. These compounds inhibit inflammatory mediators, such as cytokines & prostaglandins, thereby reducing inflammation. Neem has been studied for its potential in managing

inflammatory conditions, including arthritis, skin inflammation & GI inflammation [21].

6. Antioxidant Activity:

The neem plant exhibits strong antioxidant activity, attributed to its phenolic compounds like quercetin and gallic acid. Antioxidants help neutralize harmful free radicals and protect cells from oxidative damage. Neem's antioxidant properties have implications for various health conditions, including aging, cardiovascular diseases, and neurodegenerative disorders [22].

7. Anticancer Activity:

Several bioactive compounds in neem, such as nimbolide, gedunin, and azadiradione, have shown anticancer properties. They exhibit cytotoxic effects, induce apoptosis (programmed cell death), inhibit tumor growth & suppress cancer cell proliferation. Neem has been studied for its potential as an adjunct therapy in cancer treatment.

8. Immunomodulatory Activity:

Neem has been found to modulate immune system, enhancing immune response and promoting immune regulation. It stimulates the production of immune cells & enhances the activity of natural killer cells, macrophages, & T cells. This immunomodulatory effect has implications for various immune-related disorders & overall immune health.

Agricultural Applications of neem plant:

The neem plant (*Azadirachta indica*) has been widely utilized in agriculture due to its numerous benefits and eco-friendly nature. Its various parts, including leaves, seeds, oil, and cake, have found applications in agricultural practices. Here are some of the key agricultural applications of the neem plant [23].

1. Natural Pesticide:

Neem-based products are widely used as natural pesticides in integrated pest management (IPM) strategies. Neem oil and neem extracts contain compounds like azadirachtin, which act as potent insecticides. They disrupt the life cycle of pests, inhibit feeding, and reduce their reproductive capacity. Neem-based pesticides have been effective against a wide range of pests, including insects, mites, and nematodes.

2. Insect Repellent:

Neem products also serve as effective insect repellents. They repel insects and prevent them from feeding on crops, thereby reducing damage and infestations. Neem oil and neem extracts can be applied to crops to deter pests and protect against insect-borne diseases [24].

3. Soil Conditioner:

Neem cake, a byproduct obtained after extracting oil from neem seeds, is used as a soil conditioner. It is rich in organic matter,

nitrogen, and other essential nutrients. Neem cake helps improve soil fertility, enhances microbial activity, and promotes nutrient availability for plants. It also acts as a natural nematicide, inhibiting the growth of plant-parasitic nematodes.

4. Seed Treatment:

Neem-based seed treatments are used to protect seeds from fungal and insect attacks. Treating seeds with neem products helps prevent seed-borne diseases and enhances germination. It provides a protective coating around the seeds, ensuring healthy seedlings and increased crop yield.

5. Plant Growth Promoter:

Neem products, particularly neem oil, have been found to promote plant growth. They enhance root development, improve nutrient uptake, and increase plant vigor. Neem oil also has growth-regulating properties, which help in achieving balanced growth and development of plants [25].

6. Post-Harvest Preservation:

Neem-based formulations are employed in post-harvest preservation to prevent spoilage and extend the shelf life of agricultural produce. Neem oil and extracts have antifungal and antimicrobial properties, inhibiting the growth of post-harvest pathogens and maintaining the quality of stored crops [26].

7. Environmentally Friendly Approach:

One of the significant advantages of using neem in agriculture is its environmentally friendly nature. Neem-based products are biodegradable, non-toxic to humans & beneficial organisms, and have minimal impact on environment compared to synthetic pesticides & chemical fertilizers. They support sustainable agricultural practices & contribute to the preservation of ecological balance [27].

Commercial and Industrial Applications:

The neem plant (*Azadirachta indica*) offers a wide range of commercial & industrial applications due to its valuable properties & versatile components. Here are some of key commercial and industrial applications of neem plant:

1. Pharmaceutical & Cosmetics Industries:

Neem extracts & neem-derived compounds are extensively used in pharmaceutical and cosmetics industries. Neem oil, neem leaf extracts, & neem-based formulations are incorporated into various skincare products, including soaps, creams, lotions, & shampoos. The antimicrobial, anti-inflammatory, & antioxidant properties of neem make it beneficial for treating skin disorders, promoting healthy hair, and improving overall skin health [28-29].

2. Agriculture and Horticulture:

Neem-based products are widely used in agricultural practices, as discussed earlier. In addition to its natural pesticide & soil conditioning properties, neem is utilized in foliar sprays, bio-fertilizers, & bio stimulants' extracts & formulations can enhance crop yield, improve plant health, & protect plants from pests and diseases.

3. Animal Care and Veterinary Products:

Neem oil and neem-based products have applications in animal care and veterinary industries. They are used for pest control, treating skin conditions in animals, repelling ticks and fleas, and promoting overall animal health.

4. Biopesticides & Insect Repellents:

Neem-based bio-pesticides & insect repellents have gained popularity as environmentally friendly alternatives to synthetic chemicals. They are used in agricultural settings, households & public health programs to control insects, pests & vectors of diseases [30].

5. Neem Oil-based Formulations:

Neem oil is processed to create various formulations, such as emulsifiable concentrates, wettable powders & granules. These formulations are used for effective application, storage stability, & controlled release of neem's bioactive compounds. Neem oil formulations find applications in

agriculture, horticulture, pest control & personal care products [31].

6. Industrial Lubricants and Biofuels:

Neem oil has been explored as a potential source for industrial lubricants due to its low volatility, high viscosity index, and thermal stability. Additionally, neem oil has been considered as a feedstock for the production of biodiesel and other biofuels, offering a renewable and sustainable alternative to fossil fuels [32].

7. Paper and Textile Industries:

Neem bark contains fibers that can be utilized in the paper and textile industries. The fibers are used for producing handmade papers, packaging materials, textiles with natural antimicrobial properties [33].

8. Soap and Detergent Manufacturing:

Neem oil and neem extracts are incorporated into soaps and detergents for their cleansing and antibacterial properties. Neem-based soaps are known for their skin-friendly nature & beneficial effects on various skin conditions.

Safety:

The neem plant (*Azadirachta indica*) is generally considered safe for various applications, but it is important to note that some precautions should be taken into account [34].

Here are some key points regarding the safety and potential toxicity of neem plant:

1. Generally Recognized as Safe (GRAS):

Neem has a long history of traditional use in various cultures, & its safety has been recognized by regulatory authorities. Neem oil & neem-based products are generally considered safe when used as directed.

2. Skin Sensitivity:

Some individuals may experience skin irritation or allergic reactions when directly applying neem oil or neem-based products. It is advisable to perform a patch test before applying neem products topically and discontinue use if any adverse reactions occur.

3. Eye Irritation:

Neem oil should be kept away from the eyes, as it can cause irritation and discomfort if it comes into contact with eyes. In case of accidental eye exposure, rinse thoroughly with water & seek medical attention if necessary [35].

4. Oral Consumption:

Neem oil & neem extracts should not be consumed orally in large quantities, as they can be toxic. Neem oil contains compounds that can cause stomach upset, vomiting, and other gastrointestinal symptoms. It is important to use neem-based products

according to the recommended dosage and guidelines.

5. Pregnancy and Lactation:

Pregnant and lactating women should exercise caution when using neem products. Limited studies are available on safety of neem during pregnancy & breast-feeding, so it is advisable to consult a healthcare professional before using neem products in these situations.

6. Interactions with Medications:

Neem may interact with certain medications, particularly those metabolized by the liver. Neem compounds can affect activity of liver enzymes responsible for drug metabolism, potentially altering effectiveness & safety of certain medications. It is important to consult a healthcare professional if you are taking any medications & considering use of neem products [36].

7. Environmental Impact:

Neem is generally considered environmentally friendly due to its biodegradability and minimal impact on non-target organisms. However, concentrated neem-based products can still have adverse effects on beneficial insects, such as bees & butterflies, if used inappropriately or excessively. It is important to follow the instructions and guidelines for neem-based products to minimize potential environmental risks.

8. Quality and Purity:

When using neem-based products, it is essential to ensure their quality & purity. Choosing products from reputable manufacturers and following recommended storage & usage guidelines can help ensure the safety and effectiveness of neem products.

Future Perspectives & Conclusion

Future Perspectives:

The neem plant (*Azadirachta indica*) continues to hold great promise for various fields and industries. Ongoing research and exploration are likely to uncover new applications and further enhance our understanding of its potential.

Here are some future perspectives for the neem plant:

1. Development of Novel Formulations:

Continued research into neem's bioactive compounds may lead to the development of innovative formulations with improved stability, controlled release, and enhanced efficacy. These advancements could further optimize neem-based products for agriculture, healthcare, and other industries.

2. Biotechnology and Genetic Improvement:

Advances in biotechnology, including genetic engineering and biotechnological approaches, offer opportunities to enhance the properties and yield of neem. Genetic improvement may

lead to the development of neem varieties with higher concentrations of desired bioactive compounds, increased resistance to pests and diseases, and improved agronomic traits.

3. Standardization and Quality Control:

Standardization of neem-based products, including the identification and quantification of bioactive compounds, will be crucial for ensuring consistent quality and efficacy. Development of standardized protocols and quality control measures will enable reliable and reproducible use of neem in various applications.

4. Combination Therapies:

Neem's multifaceted pharmacological properties open avenues for exploring combination therapies. Combining neem extracts or compounds with conventional drugs or other natural products may enhance efficacy, reduce side effects, and combat drug resistance.

5. Industrial Applications:

Neem's potential in industrial sectors, such as biofuels, lubricants, textiles, and paper, may be further explored and optimized. Research efforts can focus on refining extraction methods, maximizing yield, and developing efficient processes for utilizing neem's valuable components.

Conclusion: The neem plant, with its rich bioactive compounds and versatile

applications, continues to be an area of interest for researchers, industries, and communities worldwide. Its pharmacological properties, agricultural benefits, and commercial potential make it a valuable resource for sustainable practices and eco-friendly solutions. As we deepen our understanding of neem's chemical composition, biological activities, and mechanisms of action, we can further harness its potential in medicine, agriculture, and various industries. The ongoing exploration of neem's untapped potential, coupled with advancements in technology and research methodologies, holds promise for unlocking new applications and optimizing existing ones. However, it is important to continue research into the safety, efficacy, and sustainability aspects of neem-based products. Collaboration among researchers, industry stakeholders, and regulatory authorities will be crucial in establishing guidelines, standards, and best practices for the responsible and effective use of neem. In conclusion, the neem plant stands as a versatile and valuable resource with a vast range of applications. Its traditional uses, coupled with ongoing scientific research, present opportunities for sustainable agriculture, healthcare, and eco-friendly industries. With further exploration, innovation, and collaboration, the neem plant holds great potential for addressing global challenges and promoting a greener and healthier future.

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