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Wrightia tinctoria And It's Therapeutic Potential A Review

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Abstract

Objective:

The present review aims to explore the therapeutic potential of *Wrightia tinctoria* (Roxb.) R. Br., emphasizing its traditional applications, phytochemical profile, pharmacological activities, mechanisms of action, safety aspects, and recent advancements in formulation strategies for improved clinical utility.

Methodology:

Relevant literature was collected from scientific databases including PubMed, Scopus, ScienceDirect, and Google Scholar, covering ethnopharmacological reports, phytochemical analyses, pharmacological investigations, and formulation studies up to 2024. Keywords used were "*Wrightia tinctoria*," "psoriasis," "flavonoids," "anti-inflammatory," "phytoconstituents," and "formulations." Articles focusing on traditional uses, bioactive compounds, pharmacological mechanisms, toxicity studies, and modern drug delivery systems were critically reviewed and analyzed.

Results:

Wrightia tinctoria was found to be traditionally employed in the treatment of dermatological, gastrointestinal, musculoskeletal, and infectious disorders. Phytochemical studies revealed the presence of flavonoids (quercetin, rutin, kaempferol), triterpenoids (lupeol, amyrin), sterols, alkaloids, glycosides, tannins, and fatty acids. Experimental evidence supports its anti-psoriatic, anti-inflammatory, antioxidant, antimicrobial, hepatoprotective, anticancer, and wound-healing activities. Mechanisms of action involve modulation of oxidative stress, inhibition of pro-inflammatory cytokines, normalization of keratinocyte proliferation, and regulation of immune pathways. Novel delivery systems such as nanoemulsions, liposomes, and phytosomes demonstrated improved bioavailability and therapeutic efficacy. Toxicological assessments indicated general safety at therapeutic doses, though comprehensive clinical validation is limited.

Conclusion:

Wrightia tinctoria integrates traditional knowledge with modern pharmacological evidence and represents a promising candidate for safe and effective herbal therapeutics, particularly in dermatological conditions such as psoriasis. However, large-scale clinical trials, standardization of extracts, and detailed mechanistic studies are necessary to establish its therapeutic reliability and facilitate regulatory acceptance.

Keywords: *Wrightia tinctoria*, anti-psoriatic, phytochemistry, pharmacology, traditional medicine, formulation.

1.Introduction

Medicinal plants have been regarded as valuable therapeutic resources for centuries, forming the basis of traditional healing systems and continuing to contribute to modern drug discovery. According to the World Health Organization (WHO), nearly 80% of the global population relies on herbal medicines for primary health care, underscoring the importance of plant-derived products in global health care strategies [1]. Among these medicinal plants, *Wrightia tinctoria* (Roxb.) R. Br., commonly referred to as Sweet Indrajao, Pala Indigo Plant, or Dyer's Oleander, is a small deciduous tree belonging to the family *Apocynaceae*. It is widely distributed in the dry deciduous forests of India, Sri Lanka, Myanmar, and other parts of Southeast Asia [2,3].

Wrightia tinctoria has long been employed in traditional medicinal systems such as Ayurveda, Siddha, and Unani. Different parts of the plant exhibit distinct therapeutic applications. The seeds and seed oil are most notably used for the management of psoriasis, eczema, and chronic non-healing skin conditions [4]. The leaves are traditionally applied to wounds, insect bites, and boils, whereas the bark has been prescribed for gastrointestinal problems such as dysentery and diarrhea [5]. The latex and root extracts have been employed to alleviate rheumatism, fever, and dental pain [6]. These ethnopharmacological uses indicate the plant's versatility in targeting diverse ailments.

The pharmacological potential of *Wrightia tinctoria* is primarily attributed to its rich phytochemical profile. Phytochemical investigations have revealed the presence of diverse classes of compounds, including indole alkaloids (wrightial, isowrightial), flavonoids (quercetin, rutin, kaempferol), terpenoids (lupeol, amyrin), steroids (β-sitosterol), glycosides (iridoid glycosides, indican), tannins, and phenolic compounds [7–9]. These metabolites are believed to act singly or synergistically, conferring a wide range of pharmacological properties.

Among its reported biological activities, the anti-psoriatic property has attracted significant attention. Psoriasis is a chronic autoimmune-mediated inflammatory disorder characterized by rapid keratinocyte proliferation, scaling, and erythema. Conventional therapies such as corticosteroids, methotrexate, and biologics, although effective, often pose risks of side effects and relapse [10]. In this context, topical formulations of *Wrightia tinctoria* seed oil have demonstrated considerable efficacy in reducing psoriatic lesions, scaling, and itching, while showing a favorable safety profile [11,12]. Experimental findings suggest that its therapeutic effects may involve downregulation of pro-inflammatory cytokines such as TNF-α, IL-6, and IL-17, as well as normalization of keratinocyte differentiation pathways [13].

Beyond its dermatological applications, *Wrightia tinctoria* exhibits a broad pharmacological spectrum. Extracts from its leaves, bark, and seeds have shown antimicrobial activity against various bacterial and fungal pathogens, validating its traditional use in treating infectious diseases [14]. Its antioxidant activity helps reduce oxidative stress, a major factor in chronic inflammatory conditions, metabolic disorders, and cancer progression [15]. Additionally, in vivo and in vitro studies support antidiabetic [16], hepatoprotective [17], anticancer [18], anti-inflammatory [19], and wound-healing [20] effects.

Despite its traditional use and emerging pharmacological validation, systematic studies on Wrightia tinctoria remain limited [10]. There is a need for more in-depth exploration of its molecular mechanisms, standardization of bioactive compounds, and clinical evaluations to establish evidence-based therapeutic applications [11]. This review aims to provide a comprehensive overview of the botanical aspects, ethnomedicinal relevance, phytochemical constituents, pharmacological activities, formulations, toxicological safety, and future research prospects of Wrightia tinctoria, highlighting its potential role as a promising candidate in the development of novel therapeutics [12].

2. Botany, Distribution and Ethnobotanical Uses

2.1 Botanical description and distribution

Wrightia tinctoria is a small, deciduous tree (up to ~10 m), with smooth grey bark, opposite lanceolate leaves, and white fragrant flowers. It is indigenous to India, Sri Lanka and parts of Southeast Asia and grows commonly in dry deciduous forests and wastelands. Different plant parts—seeds, leaves, bark, flowers and latex—are used in local pharmacopeias.

2.2 Traditional and Ethnomedicinal Uses

Wrightia tinctoria (Roxb.) R. Br. has been a cornerstone of traditional medicine in South Asia, particularly in Ayurveda, Siddha, and Unani systems, where it is highly valued for its versatile therapeutic properties. Local communities across India and neighboring countries have utilized different parts of the plant for treating a wide variety of ailments, ranging from skin diseases to gastrointestinal and musculoskeletal disorders. Its role in folk medicine continues to remain significant, reflecting deep cultural integration and long-standing empirical knowledge.

One of the most well-documented uses of *Wrightia tinctoria* is in the management of dermatological conditions. The seed oil, often prepared in the form of medicated extracts or ointments, is applied topically for psoriasis, eczema, chronic dermatitis, and non-healing wounds. In Ayurveda, it is considered effective in balancing the doshas, particularly pitta and kapha, which are believed to be responsible for inflammatory skin disorders. Village healers traditionally prescribe the oil for relieving scaling, itching, and erythema. In Siddha medicine, formulations of seed oil mixed with coconut oil are commonly prescribed for psoriasis and leprosy.

Apart from skin diseases, the bark and root of *Wrightia tinctoria* are used in folk medicine to treat gastrointestinal problems, such as diarrhea, dysentery, and worm infestations. Decoctions prepared from bark are administered orally to children suffering from intestinal disturbances. The bitter principle present in the bark is believed to stimulate digestion and act as an astringent. The leaves are externally applied as poultices for treating boils, abscesses, insect bites, and minor wounds. Traditional healers also use leaf juice as a remedy for toothache and ear pain.

The latex of *Wrightia tinctoria*, a characteristic milky exudate, has been utilized in traditional medicine as an anti-rheumatic agent. Applied externally, it is said to reduce inflammation and pain in conditions such as arthritis, joint stiffness, and sprains. Ethnomedicinal practices in rural India also record the use of latex for snakebite and scorpion sting, where it is either applied locally or given with herbal combinations.

In addition to its medicinal roles, *Wrightia tinctoria* has been valued for cultural and economic purposes. The leaves and bark were historically used as a source of natural blue dye (indigo substitute) for textiles, a practice that gave rise to its common name, “Pala Indigo Plant.” In tribal communities, its wood is used for small implements, toys, and religious rituals. Such non-medicinal applications have contributed to the widespread domestication and protection of the species in rural landscapes. Modern validation of these traditional claims has revealed pharmacological activities consistent with ethnomedicinal practices. For instance, seed oil’s efficacy in psoriasis has been confirmed by both clinical and experimental studies, while extracts from bark and leaves demonstrate antimicrobial and anti-inflammatory effects. These findings highlight the importance of bridging traditional knowledge with scientific research, ensuring the preservation and safe use of this medicinally rich plant.

3. Phytochemistry of *Wrightia tinctoria*

Wrightia tinctoria (Roxb.) R. Br., commonly known as “Pala Indigo Plant,” is rich in diverse secondary metabolites, which are responsible for its broad pharmacological activities. Phytochemical investigations

have revealed that almost all parts of the plant—seeds, bark, leaves, and latex—contain bioactive constituents belonging to multiple chemical classes, including alkaloids, flavonoids, triterpenoids, sterols, glycosides, and phenolic compounds. These phytoconstituents play a vital role in validating its ethnomedicinal applications, particularly in dermatological and anti-inflammatory therapies.

Among the major classes of compounds, indole alkaloids are characteristic of the plant and contribute to its medicinal significance. Wrightiadione, an isoflavone isolated from the stem bark, is one of the most studied bioactive compounds, exhibiting notable anti-cancer and anti-inflammatory activities. Other alkaloids such as tryptanthrin and indirubin, previously reported from related species, are also suggested to occur in *Wrightia tinctoria* and may account for its anti-psoriatic effects.

Flavonoids and phenolic compounds are another important group. Rutin, quercetin, kaempferol, and isorhamnetin derivatives have been reported from leaf and seed extracts. These flavonoids act as potent antioxidants, capable of scavenging free radicals and modulating inflammatory pathways. Their presence provides scientific support for the plant's use in skin disorders where oxidative stress plays a key role.

The triterpenoids and sterols identified in *Wrightia tinctoria* include compounds such as lupeol, β-sitosterol, and stigmasterol. These are commonly distributed in bark and latex and are known to exert anti-inflammatory, hepatoprotective, and immunomodulatory properties. Lupeol, in particular, has been associated with wound healing and anti-arthritic activity, which may justify the traditional external application of bark and latex for joint pain and wounds.

Seed oil of *Wrightia tinctoria* has received considerable attention due to its pharmacological relevance. Chemical analysis has shown the presence of fatty acids such as oleic acid, linoleic acid, and palmitic acid, along with unsaponifiable matter containing sterols and triterpenes. This lipid-rich composition contributes to the emollient, anti-psoriatic, and skin-soothing effects of the seed oil, which are well-documented in Ayurveda and supported by experimental models.

Another notable constituent is cycloartenol, a tetracyclic triterpenoid alcohol reported in the bark and latex. Cycloartenol is known for its role in sterol biosynthesis and has been linked to cytoprotective and immunomodulatory actions. Similarly, the presence of cardiac glycosides in the leaves suggests additional therapeutic roles, though their pharmacological activities are less explored.

The latex of *Wrightia tinctoria* contains proteolytic enzymes and sterol derivatives that contribute to its anti-rheumatic and wound-healing properties. In addition, the bark contains tannins and saponins, providing astringent and antimicrobial properties that align with its traditional gastrointestinal applications.

Overall, the phytochemical spectrum of *Wrightia tinctoria* underlines its therapeutic versatility. By combining alkaloids, flavonoids, triterpenoids, sterols, and fatty acids, the plant exerts multifaceted biological effects. These bioactive molecules justify its role in Ayurveda, Siddha, and Unani medicine, while also offering a foundation for modern pharmacological validation and potential drug development. Future studies on isolation, structural elucidation, and mechanism-based screening are essential to fully exploit the therapeutic potential of these phytochemicals.

4. Pharmacological Activities and Mechanisms of *Wrightia tinctoria*

Wrightia tinctoria (Roxb.) R. Br. has been extensively studied for its wide range of pharmacological activities that support its traditional uses. Modern pharmacology has confirmed that extracts, oils, and isolated compounds from the plant exert significant effects on dermatological, inflammatory, microbial, and metabolic conditions. These therapeutic effects can be attributed to the synergistic action of its phytochemicals, including flavonoids, alkaloids, triterpenoids, and fatty acids.

Anti-psoriatic activity

One of the most validated uses of *Wrightia tinctoria* is its efficacy against psoriasis. Seed oil formulations have shown promising results in both clinical and preclinical studies. The mechanism involves modulation of keratinocyte proliferation and differentiation, reduction of inflammatory cytokines, and normalization of epidermal turnover. Flavonoids such as quercetin and rutin provide antioxidant activity, reducing reactive oxygen species (ROS) that exacerbate psoriasis. Additionally, triterpenoids and sterols in seed oil act as emollients, restoring skin barrier function and reducing scaling.

Anti-inflammatory activity

The plant exhibits potent anti-inflammatory effects. Lupeol, β-sitosterol, and flavonoids suppress inflammatory mediators such as prostaglandins, nitric oxide, and tumor necrosis factor-alpha (TNF-α). Extracts inhibit cyclooxygenase (COX) and lipoxygenase (LOX) pathways, which are central to the biosynthesis of pro-inflammatory mediators. The latex, rich in triterpenoids, reduces joint swelling and tissue infiltration in experimental arthritis models, thereby supporting its traditional use in rheumatism.

Antimicrobial activity

Leaf and bark extracts of *Wrightia tinctoria* display broad-spectrum antimicrobial properties. The presence of tannins, saponins, and alkaloids contributes to antibacterial action against pathogens such as Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa. Antifungal activity has been reported against Candida albicans and dermatophytes, which aligns with its ethnomedicinal use in skin infections. The mechanism is primarily attributed to disruption of microbial cell walls, protein precipitation, and interference with microbial enzyme activity.

Hepatoprotective activity

Ethanolic extracts of bark and leaves demonstrate hepatoprotective effects in chemically induced liver injury models. Antioxidants like quercetin and isorhamnetin derivatives reduce lipid peroxidation, while triterpenoids stabilize hepatocyte membranes. The mechanism includes enhancement of endogenous antioxidant enzymes such as superoxide dismutase (SOD) and catalase, leading to improved hepatic function and protection against oxidative stress.

Anticancer activity

Wrightiadione and related flavonoids isolated from *Wrightia tinctoria* exhibit cytotoxic activity against various cancer cell lines, including breast and lung cancer models. The mechanism involves induction of apoptosis, inhibition of angiogenesis, and modulation of signaling pathways such as NF-κB and PI3K/Akt. These activities suggest the potential of the plant as a source of lead molecules for anticancer drug development.

Wound healing and immunomodulatory activity

Topical application of seed oil and latex accelerates wound contraction and epithelialization. The fatty acids provide a moist healing environment, while sterols stimulate collagen synthesis. Immunomodulatory properties are evident from studies showing regulation of lymphocyte proliferation and cytokine balance, which are crucial for tissue repair and immune defense.

The pharmacological evidence strongly supports the traditional uses of *Wrightia tinctoria*. Its bioactive compounds act through diverse mechanisms, including antioxidant defense, anti-inflammatory signaling modulation, microbial inhibition, and immune regulation. Standardization of extracts, development of novel formulations, and clinical validation are needed to fully integrate this plant into evidence-based medicine.

5. Formulation Science and Delivery Approaches

The therapeutic success of *Wrightia tinctoria* largely depends on its formulation strategies, which aim to optimize stability, enhance bioavailability, and ensure targeted delivery. Traditional preparations such as medicated oils and pastes have demonstrated effectiveness in dermatological disorders, but modern formulation science has enabled the development of novel delivery systems to overcome challenges such as poor solubility, variable absorption, and limited systemic bioavailability (7).

Conventional formulations

In Ayurveda and Siddha, *Wrightia tinctoria* seed oil has been used topically in its pure form or in combination with carrier oils like coconut oil for psoriasis, eczema, and leprosy (4). These conventional dosage forms act locally by providing emollient effects, reducing scaling, and restoring the barrier function of the skin. However, direct application of crude oil can result in inconsistent dosing, poor patient compliance, and issues related to rancidity.

Topical novel systems

To address these limitations, researchers have developed advanced topical formulations such as nanoemulsions, microemulsions, liposomes, and gels. Nanoemulsion-based systems provide improved solubility for lipophilic constituents like sterols and triterpenoids, while ensuring sustained drug release and enhanced skin penetration (11). Microemulsion gels incorporating seed oil have shown superior spreadability and stability compared to traditional ointments, thus improving therapeutic outcomes in psoriatic lesions. Liposomal formulations, owing to their bilayered phospholipid structure, enhance dermal absorption of phytoconstituents such as flavonoids and triterpenoids while reducing local irritation (21).

Oral and systemic delivery

Though topical delivery dominates, oral dosage forms have also been explored. Ethanolic extracts of bark and leaves, rich in flavonoids and alkaloids, have been incorporated into capsules and tablets for systemic conditions like diarrhea and helminthic infections (6). However, poor aqueous solubility and first-pass metabolism of these phytoconstituents limit their oral bioavailability. To overcome this, phytosome technology and solid lipid nanoparticles (SLNs) have been investigated, where bioactives are complexed with phospholipids or encapsulated within lipid matrices to improve gastrointestinal absorption and prolong circulation time.

Targeted delivery approaches

Given the plant's relevance in chronic inflammatory and autoimmune disorders, researchers have focused on targeted drug delivery systems. Polymeric nanoparticles and nanogels loaded with *Wrightia tinctoria* seed oil or extracts allow site-specific release of bioactives, minimizing systemic side effects (8). Such systems exploit controlled release mechanisms and enhanced tissue localization, which are crucial in treating persistent skin diseases. Moreover, transdermal patches incorporating *Wrightia tinctoria* oil are under experimental investigation for sustained dermal delivery, improving patient adherence.

Future perspectives

Formulation science has significantly transformed the therapeutic use of *Wrightia tinctoria*. By moving from crude traditional preparations to evidence-based delivery systems, researchers have enhanced pharmacological performance and patient compliance. Nevertheless, standardization of extracts, optimization of excipient compatibility, and clinical validation of advanced formulations remain essential for translational success. Future work may integrate nanotechnology, bioadhesive carriers, and hybrid drug delivery platforms to maximize the therapeutic impact of this multipurpose medicinal plant.

6. Safety, Toxicology and Regulatory Considerations

Preclinical Toxicology Studies

Acute toxicity

Animal studies suggest that *Wrightia tinctoria* extracts and seed oil are generally safe at therapeutic doses. Acute oral toxicity experiments using rodent models demonstrated that ethanolic and aqueous extracts did not produce significant mortality or behavioral abnormalities up to doses of 2000 mg/kg, indicating a high margin of safety (7). Similarly, topical application of seed oil produced no dermal irritation in standard patch tests, supporting its traditional external use in psoriasis and eczema (11).

Sub-chronic and chronic toxicity

Repeated dose studies over 28 to 90 days have shown no significant alterations in hematological, hepatic, or renal parameters when *Wrightia tinctoria* extracts were administered orally within therapeutic ranges (8). Histopathological evaluations of major organs such as liver, kidney, heart, and spleen showed normal architecture, suggesting minimal risk of organ-specific toxicity. However, at supra-therapeutic doses, mild hepatocellular changes and gastrointestinal disturbances have been noted, indicating the importance of dose standardization.

Reproductive and developmental toxicity

Data on reproductive toxicity are limited. Preliminary animal studies reported no teratogenic effects when extracts were administered during pregnancy, but comprehensive multigenerational studies are lacking. Until more evidence is available, use during pregnancy and lactation should be approached with caution (21).

Clinical Safety Evidence

Topical application of *Wrightia tinctoria* seed oil has been clinically validated in psoriasis, with minimal adverse effects reported. In most cases, mild irritation or transient itching was observed in a small percentage of patients, which subsided upon continued use or discontinuation (11). Oral administration of bark or leaf preparations in traditional medicine is considered safe at low doses; however, systematic clinical trials assessing safety are scarce.

Drug-herb interactions are a potential concern. Constituents such as flavonoids and sterols may influence cytochrome P450 enzyme activity, potentially altering the metabolism of conventional drugs. For example, concurrent use with immunosuppressants, anticoagulants, or hepatotoxic drugs requires caution due to possible synergistic or antagonistic effects (6).

Potential Adverse Effects

Although largely safe, certain risks exist:

Dermatological reactions: Rare cases of contact dermatitis have been documented after prolonged topical application. This may be due to individual hypersensitivity to seed oil components.

Gastrointestinal effects: At high oral doses, nausea, abdominal discomfort, and mild diarrhea have been reported. These effects are often reversible upon dose reduction.

Hepatotoxicity risk: Overuse of bark decoctions without dose monitoring may strain hepatic metabolism, though clinical evidence remains minimal.

Latex toxicity: The plant's latex, rich in proteolytic enzymes, may cause local irritation when applied in concentrated forms. Traditional medicine usually employs diluted or processed latex to mitigate this.

Safety in Special Populations

Children: Traditional use includes decoctions for intestinal disorders in children. However, lack of dose standardization raises concerns about overdosing. Controlled pediatric trials are needed.

Pregnant and lactating women: Safety data are insufficient. Due to potential uterotonic activity of certain phytoconstituents, use is generally discouraged in these groups unless prescribed under supervision.

Elderly patients: No specific adverse events have been reported, but comorbidities and polypharmacy increase the risk of herb-drug interactions

Regulatory Considerations

Indian regulatory framework

In India, *Wrightia tinctoria* is listed in the Ayurvedic Pharmacopoeia and approved for use in traditional medicine. The Central Council for Research in Ayurvedic Sciences (CCRAS) supports clinical validation of herbal formulations containing *Wrightia tinctoria*. However, the Drug and Cosmetics Act mandates standardization of raw materials, quality control of extracts, and toxicological evaluation before approval for large-scale commercialization (5).

International perspectives

Globally, regulatory acceptance of *Wrightia tinctoria* varies:

European Union (EU): The European Medicines Agency (EMA) requires evidence of quality, safety, and efficacy under the Traditional Herbal Medicinal Products Directive (THMPD). Currently, *Wrightia tinctoria* is not registered as an official herbal drug in Europe, mainly due to insufficient clinical trial data.

United States: The Food and Drug Administration (FDA) classifies herbal products like *Wrightia tinctoria* under dietary supplements, which must comply with Good Manufacturing Practices (GMP) but are not subject to pre-market approval. Claims related to disease treatment require rigorous clinical evidence, which is presently limited.

World Health Organization (WHO): WHO emphasizes standardization, toxicity evaluation, and pharmacovigilance for traditional herbal medicines. *Wrightia tinctoria* is recognized as an ethnomedicinal plant, but official monographs are still under preparation.

Standardization and Quality Control

One of the key regulatory challenges for *Wrightia tinctoria* formulations is quality variability. Differences in geographical origin, harvesting time, and processing methods lead to inconsistent phytochemical profiles. Adulteration with other species or poor storage practices further compromise safety. To address this, regulatory agencies recommend: Phytochemical fingerprinting using chromatographic techniques (HPLC, GC-MS) for marker-based standardization. Toxicological profiling of extracts through OECD-compliant studies. Batch-to-batch consistency in commercial formulations.

Risk-Benefit Assessment

The overall safety profile of *Wrightia tinctoria* is favorable when used in appropriate doses and formulations. Its traditional use in skin and gastrointestinal disorders is supported by modern pharmacology, while toxicological studies demonstrate minimal adverse effects under controlled conditions. However, limited clinical safety trials and lack of long-term toxicity data remain barriers for global acceptance. Regulatory authorities require robust evidence on dose safety, herb-drug interactions, and adverse event monitoring before granting wider approvals.

The toxicological and safety profile of *Wrightia tinctoria* supports its use as a therapeutic agent, particularly for dermatological disorders like psoriasis. Preclinical and clinical studies confirm a high safety margin, though caution is warranted in special populations and high-dose administration. Regulatory frameworks in India have integrated the plant into traditional medicine systems, but international recognition will depend on further clinical validation and standardization. Future research should focus on comprehensive toxicological evaluations, pharmacovigilance systems, and development of standardized formulations to ensure global regulatory acceptance.

Clinical safety signals and marketplace issues

Although many herbal oils containing Wrightia are marketed for psoriasis and other skin conditions, regulatory oversight varies by jurisdiction, and quality control in some commercial products is inconsistent. Case reports and reviews caution about variable potency and potential for contaminants in unregulated formulations—underscoring the need for standardized manufacturing, labeling and clinical testing.

Clinical Evidence and Human Studies

Clinical evidence is limited but promising: small clinical series and clinic-analytical studies report symptomatic improvement in psoriasis patients treated with standardized seed oil preparations or traditional oils containing Wrightia. However, most human studies suffer from small sample sizes, lack of randomization or blinding, heterogeneity of formulations and outcome measures. High-quality randomized controlled trials, with standardized extracts and objective endpoints (PASI score, physician global assessment), are necessary to confirm efficacy and safety.

Limitations, Knowledge Gaps and Research Priorities

Limitations

Despite the long-standing use of *Wrightia tinctoria* in traditional medicine and encouraging preclinical evidence, several limitations hinder its wider acceptance in modern therapeutics. Firstly, most pharmacological studies are preclinical, relying on in vitro assays or animal models, with very few controlled clinical trials available. This makes it difficult to establish dosage guidelines, efficacy ranges, or long-term safety in human populations (7). Secondly, variability in phytochemical composition due to geographical, seasonal, and extraction differences limits reproducibility of results. Without standardized formulations, therapeutic efficacy remains inconsistent. Another limitation is the lack of large-scale toxicological studies, especially concerning chronic use, reproductive safety, and herb–drug interactions. Regulatory restrictions further limit commercialization outside India due to the absence of globally recognized monographs and quality standards (6).

Knowledge Gaps

There remain significant gaps in the current understanding of *Wrightia tinctoria*. Although compounds such as wrightiadione, lupeol, and quercetin derivatives have been identified, comprehensive phytochemical profiling is incomplete. Metabolomic and proteomic studies are needed to map the full spectrum of active molecules. Similarly, the mechanistic pathways of action in conditions like psoriasis, cancer, and hepatic injury are not fully elucidated. For instance, while antioxidant and anti-inflammatory activities are established, molecular targets such as NF-κB, STAT3, or PI3K/Akt require deeper investigation (2). Another gap lies in formulation science; while novel systems like nanoemulsions and liposomes have been developed, their clinical performance has not been validated in multicenter trials. Finally, pharmacokinetics and pharmacodynamics of bioactive compounds remain poorly characterized, hindering accurate dose predictions.

Research Priorities

Future research should focus on three main areas:

1. Phytochemical standardization and quality control

Development of validated analytical methods (HPLC, LC-MS, NMR) for standardization of extracts and marker compounds is crucial. Establishing pharmacopeial monographs will ensure batch-to-batch consistency and enhance regulatory acceptance.

2. Mechanism-based pharmacological studies

Investigations should explore molecular targets and signaling pathways of bioactive constituents, particularly in skin, liver, and immune-related disorders. Omics-based approaches and network pharmacology can provide new insights into multi-target mechanisms (8).

3. Clinical trials and translational research

Well-designed, randomized, controlled clinical trials are urgently needed to validate traditional claims. These should include dose-response evaluations, safety monitoring, and herb–drug interaction studies. Advanced formulations such as nanoparticles and phytosomes should be tested clinically to confirm improved bioavailability and patient compliance (11).

4. Toxicology and safety studies

Chronic toxicity, reproductive safety, and genotoxicity studies should be prioritized. Post-marketing pharmacovigilance systems can monitor adverse events once standardized formulations are introduced.

Although *Wrightia tinctoria* holds significant therapeutic promise, its integration into evidence-based medicine requires addressing key limitations and research gaps. By prioritizing phytochemical standardization, mechanism-focused studies, and clinical validation, researchers can establish the plant as a safe, effective, and globally recognized medicinal resource.

Conclusion

Wrightia tinctoria (Roxb.) R. Br. is a medicinally significant plant with a long history of traditional use in Ayurveda, Siddha, and Unani systems of medicine. Ethnobotanical evidence highlights its application in the management of psoriasis, eczema, gastrointestinal disorders, microbial infections, and inflammatory conditions. Modern pharmacological studies have confirmed many of these traditional claims, attributing the therapeutic potential of the plant to its diverse phytoconstituents, including flavonoids, terpenoids, alkaloids, glycosides, and phenolic compounds. The presence of unique bioactive molecules such as wrightiadione, lupeol, and rutin provides a strong foundation for its pharmacological versatility.

Pharmacological investigations demonstrate that *Wrightia tinctoria* exhibits anti-psoriatic, anti-inflammatory, antimicrobial, hepatoprotective, antioxidant, antidiabetic, and anticancer activities. These effects are mediated through multiple mechanisms, including modulation of oxidative stress, inhibition of pro-inflammatory cytokines, suppression of microbial growth, and regulation of cellular signaling pathways. Seed oil of *Wrightia tinctoria*, in particular, has shown promising results in clinical management of psoriasis, offering a safer and more tolerable alternative to synthetic drugs.

Despite this encouraging evidence, the scientific development of *Wrightia tinctoria* as a modern therapeutic agent faces several limitations. The majority of studies are restricted to preclinical research, with limited controlled clinical trials to validate its safety and efficacy in human populations. Variability in phytochemical content, influenced by environmental and seasonal factors, poses challenges for reproducibility and standardization. Furthermore, gaps exist in the comprehensive understanding of its pharmacokinetics, molecular targets, long-term safety, and herb–drug interactions.

Advances in formulation science provide new opportunities to enhance the therapeutic application of *Wrightia tinctoria*. Development of nanoemulsions, liposomes, phytosomes, and gels has improved the solubility, bioavailability, and targeted delivery of plant extracts, particularly for topical and systemic applications. However, these novel delivery systems still require clinical validation and regulatory approval before they can be translated into widely accepted pharmaceutical products.

From a regulatory perspective, the absence of pharmacopeial monographs, standardized quality control measures, and global acceptance limits the plant's commercialization potential. Safety assessments remain insufficient, with only a few toxicological studies addressing chronic and reproductive safety concerns. Addressing these gaps is essential for gaining regulatory recognition and ensuring consumer confidence in herbal formulations derived from *Wrightia tinctoria*.

Wrightia tinctoria represents a valuable medicinal resource with significant therapeutic potential. Its ethnomedicinal legacy, coupled with modern pharmacological validation, positions it as a promising candidate for the development of safe and effective herbal drugs. However, progress will depend on multidisciplinary research efforts focusing on phytochemical standardization, mechanism-based pharmacological studies, well-designed clinical trials, and comprehensive toxicological assessments. Integrating traditional knowledge with modern scientific tools such as network pharmacology, molecular docking, and advanced formulation technologies will further enhance its clinical relevance. By addressing current limitations and knowledge gaps, *Wrightia tinctoria* can evolve from a traditional remedy into a scientifically validated therapeutic agent, contributing meaningfully to global healthcare.

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