Current Pharmaceutical Research (CPR)
Vol 2, Issue 2, April-June 2026
Journal Homepage: https://cpr.org.in/

Flame of the Forest: A Review on the Traditional and Modern Uses of *Butea Monosperma*

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Keywords

Butea Monosperma; Phytochemicals; Pharmacological activities; Traditional medicine; Medicinal plants; Drug discovery.

Abstract

Butea Monosperma (Lam.) Taub., commonly known as Palash or the Flame of the Forest, is an important medicinal plant widely distributed across the Indian subcontinent and Southeast Asia. It has been extensively used in traditional systems of medicine, including Ayurveda, Unani, and folk medicine, for the management of various disorders such as inflammation, diabetes, gastrointestinal diseases, skin infections, parasitic infestations, and liver ailments. Different plant parts, including the flowers, leaves, bark, seeds, and gum, possess significant therapeutic value. Phytochemical investigations have identified numerous bioactive constituents, including flavonoids, chalcones, glycosides, tannins, phenolic compounds, terpenoids, and phytosterols, which contribute to its diverse pharmacological properties. Experimental studies have demonstrated that *Butea Monosperma* exhibits antioxidant, anti-inflammatory, antimicrobial, antidiabetic, hepatoprotective, anticancer, and anthelmintic activities, supporting many of its traditional medicinal uses. Toxicological investigations indicate a favorable safety profile at recommended therapeutic doses, although further long-term safety evaluations are warranted. The growing interest in plant-derived therapeutics has highlighted the potential of *Butea Monosperma* as a promising source of novel bioactive molecules for pharmaceutical, nutraceutical, and herbal medicine development. This review comprehensively summarizes the botanical characteristics, traditional uses, phytochemical composition, pharmacological activities, safety profile, and future therapeutic prospects of *Butea Monosperma*, emphasizing its importance as a valuable medicinal plant for future drug discovery and clinical research.

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Article Info
Received: 09 April 2026, Received in revised form: 28 July 2026, Accepted: 28 July 2026, Available online: 30 July 2026; Volume: 2; Issue: 2; Pages: 205–217.

ISSN: 3049-2955/The authors © 2026, under exclusive license to the Sprout Publication.
DOI: https://doi.org/10.63785/2026.2.2.205217

1. Introduction

Medicinal plants have been an integral component of traditional healthcare systems for thousands of years. Before the development of modern pharmaceutical drugs, plant-based remedies were widely used to treat a variety of diseases and health conditions. Even in the modern era, medicinal plants continue to play an important role in healthcare, particularly in developing countries where access to conventional medicines may be limited. A large proportion of the world's population continues to rely on traditional herbal medicines as a primary source of healthcare. Medicinal plants are rich sources of bioactive compounds such as alkaloids, flavonoids, glycosides, tannins, terpenoids, and phenolic compounds, which are responsible for their diverse therapeutic properties. These phytochemicals exhibit a broad spectrum of pharmacological activities, including antioxidant, antimicrobial, anti-inflammatory, antidiabetic, hepatoprotective, and anticancer effects. Consequently, medicinal plants remain valuable resources for drug discovery and the development of novel therapeutic agents [1].

Traditional systems of medicine such as Ayurveda, Unani, Siddha, and Traditional Chinese Medicine have extensively utilized medicinal plants for disease prevention and treatment. These systems emphasize the holistic use of plant materials, including roots,

leaves, bark, flowers, fruits, and seeds, to restore health and maintain physiological balance. Over the past few decades, increasing scientific interest has been directed toward validating the therapeutic potential of medicinal plants through phytochemical and pharmacological investigations. Many modern drugs used in clinical practice today are derived directly or indirectly from natural plant sources, highlighting the enduring importance of medicinal plants in pharmaceutical research [2].

Among the various medicinal plants used in traditional medicine, *Butea Monosperma* (Lam.) Taub., commonly known as Flame of the Forest, Palash, or Bastard Teak, is a highly valued species with significant medicinal and cultural importance. Belonging to the family Fabaceae (Leguminosae), the plant is widely recognized for its striking orange-red flowers that bloom during the spring season. *Butea Monosperma* has been extensively used in Ayurveda and various folk medicinal practices for the treatment of numerous health conditions. Different parts of the plant, including flowers, leaves, bark, seeds, and gum, possess therapeutic properties and have traditionally been used for the management of diarrhea, dysentery, inflammation, diabetes, skin disorders, and parasitic infections [3].

In Ayurvedic medicine, the seeds are commonly employed as an anthelmintic agent for intestinal worm infections, while the flowers are valued for their anti-inflammatory and antioxidant properties. The bark and gum, commonly referred to as Bengal kino, have been used as astringent agents in the treatment of diarrhea and bleeding disorders. Additionally, the leaves have been traditionally applied for wound healing and the management of various skin conditions. The broad spectrum of traditional applications has attracted considerable scientific interest in exploring the plant's pharmacological potential. From a botanical perspective, *Butea monosperma* is a medium-sized deciduous tree widely distributed throughout the Indian subcontinent and several regions of Southeast Asia. It commonly grows in dry forests and tropical environments and is naturally found in countries such as India, Nepal, Sri Lanka, Bangladesh, and Myanmar. The tree is characterized by its trifoliate leaves, thick bark, and brilliant orange or scarlet flowers that bloom in dense clusters during the flowering season, giving rise to its popular name, "Flame of the Forest." Beyond its medicinal significance, the plant also holds considerable cultural, economic, and ecological value in the regions where it is naturally distributed. In recent years, scientific investigations have increasingly focused on the phytochemical composition and pharmacological properties of *Butea monosperma*. Numerous bioactive constituents, including flavonoids, chalcones, glycosides, and phenolic compounds, have been isolated from different parts of the plant. These compounds have demonstrated a wide range of biological activities, including antimicrobial, anti-inflammatory, antioxidant, antidiabetic, hepatoprotective, and anticancer effects in experimental studies. Such findings provide scientific support for its traditional uses and underscore its potential as a promising source of natural therapeutic agents [4].

Therefore, the present review aims to provide a comprehensive overview of the traditional uses, phytochemical constituents, and pharmacological activities of *Butea monosperma*. The review further discusses its potential applications in modern medicine and highlights the need for continued research to fully elucidate its therapeutic potential and facilitate its development as a source of future pharmaceutical agents. By consolidating the available scientific evidence, this review seeks to enhance understanding of the medicinal significance of *Butea monosperma* and its contribution to both traditional and contemporary healthcare systems [5].

2. Botanical Description

Butea monosperma (Lam.) Taub. is a well-known medicinal plant belonging to the family Fabaceae (Leguminosae). It is widely recognized for its brilliant orange-red flowers and significant medicinal value in traditional medicine systems. The plant is commonly known by several vernacular names, including Palash, Flame of the Forest, Dhak, and Bastard Teak. Owing to its distinctive floral appearance and extensive medicinal applications, *B. monosperma* has attracted considerable attention in both traditional medicine and modern phytopharmacological research [6].

2.1 Taxonomy and Classification

Butea monosperma (Lam.) Taub. is a medicinally important deciduous tree belonging to the family Fabaceae (Leguminosae). It is taxonomically classified under the kingdom Plantae, subkingdom Tracheobionta (vascular plants), division Magnoliophyta (flowering plants), class Magnoliopsida (dicotyledons), and order Fabales. The plant belongs to the genus *Butea*, with *Butea monosperma* (Lam.) Taub. as the accepted species. Owing to its rich phytochemical composition and broad spectrum of pharmacological activities, *B. monosperma* has been widely used in traditional systems of medicine, particularly Ayurveda, for the management of various diseases. The genus *Butea* comprises only a few species distributed mainly in

tropical and subtropical regions of Asia, among which *B. monosperma* is the most extensively studied because of its diverse therapeutic potential. The species was first described by the French botanist Jean-Baptiste Lamarck, and its nomenclature was subsequently revised by the German botanist Paul Hermann Wilhelm Taubert [7].

2.2 Morphological Characteristics

Butea monosperma is a medium-sized deciduous tree that typically attains a height of 12–15 m. It possesses a crooked trunk with irregular branches and a thick, rough, fibrous bark that is greyish-brown in color. When injured, the bark exudes a reddish gum known as Bengal kino, which has long been valued in traditional medicine for its medicinal and astringent properties. The leaves are trifoliate, with each leaf comprising three large, leathery, broadly ovate leaflets having a smooth surface. They are arranged alternately on the branches and generally measure 10–20 cm in length. As a deciduous species, the tree sheds its leaves during the dry season. One of the most distinctive characteristics of *B. monosperma* is its brilliant orange-red flowers, which bloom in dense clusters during the spring season, typically from February to April. The flowers exhibit the papilionaceous structure characteristic of the Fabaceae family and are highly attractive to birds and insects that facilitate pollination. Their striking appearance has earned the tree the popular name "Flame of the Forest" [8].

The fruit is a flat, pale-brown, single-seeded pod measuring approximately 10–15 cm in length. The enclosed seeds are flat and kidney-shaped and are traditionally used as an anthelmintic agent for the treatment of intestinal helminthic infections [9].

2.3 Distribution and Habitat

Butea monosperma is widely distributed across the Indian subcontinent and several regions of Southeast Asia. The species occurs naturally in India, Nepal, Bangladesh, Sri Lanka, Myanmar, Thailand, and Pakistan. In India, it is abundant in tropical and subtropical regions, particularly in dry deciduous forests, open grasslands, wastelands, and cultivated landscapes. The plant is well adapted to warm and dry climatic conditions and grows in a wide range of soil types, including sandy, loamy, and lateritic soils. However, optimum growth is observed in well-drained soils receiving moderate rainfall. *B. monosperma* is commonly found from sea level up to an altitude of approximately 1,200 m. Its remarkable drought tolerance enables it to survive under harsh environmental conditions, making it an ecologically important component of forest ecosystems. Besides its ecological significance, *B. monosperma* possesses considerable cultural and economic importance. The brightly colored flowers are traditionally used for preparing natural dyes and are widely utilized during festivals such as Holi in India. The leaves are commonly fashioned into biodegradable plates and cups, while the wood is occasionally used as fuel and for small-scale construction and agricultural implements [10].

Figure 1 illustrates the botanical morphology of *Butea monosperma* (Lam.) Taub., including its medium-sized deciduous tree habit, trifoliate leaves, rough greyish-brown bark with Bengal kino gum exudation, bright orange-red papilionaceous flowers arranged in dense clusters, flat single-seeded pods, and kidney-shaped seeds, highlighting the key morphological characteristics of the species. [11]

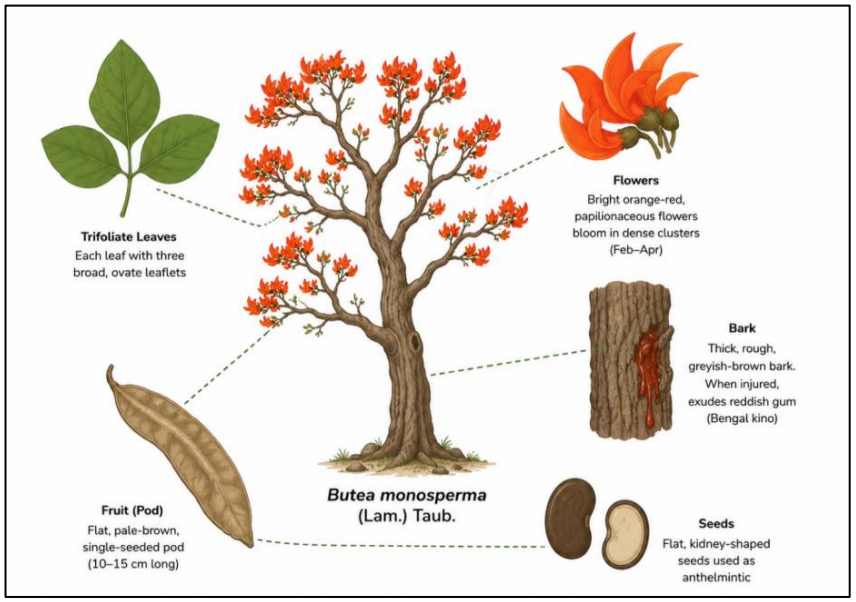

Figure 1: Botanical morphology of *Butea monosperma* (Lam.) Taub. illustrating the tree habit, trifoliate leaves, flowers, bark, fruit, and seeds.

3. Traditional and Ethnomedicinal Uses

Medicinal plants have long been an integral part of traditional healthcare systems worldwide. In the Indian subcontinent, they have been extensively utilized in Ayurveda, Unani, Siddha, and various folk medicinal traditions. *Butea monosperma* (Lam.) Taub., commonly known as Palash or Flame of the Forest, has been widely employed in these systems because of its diverse therapeutic properties. For centuries, it has been regarded as an important medicinal resource, with nearly every part of the plant—including the flowers, leaves, bark, seeds, and gum—being incorporated into traditional remedies for the treatment of a variety of ailments [12].

3.1 Use in Ayurveda, Unani, and Folk Medicine

In Ayurveda, *Butea monosperma* is considered an important medicinal plant and is frequently described in classical texts for its therapeutic benefits. It is traditionally recognized for its anthelmintic, anti-inflammatory, antimicrobial, and astringent properties. Different parts of the plant are used to manage intestinal worm infestations, diarrhea, dysentery, skin diseases, and inflammatory disorders. Among these, the seeds are particularly valued for their ability to expel intestinal parasites and are widely incorporated into Ayurvedic formulations as anthelmintic agents. In Unani medicine, *Butea monosperma* is appreciated for its astringent, tonic, and anti-inflammatory properties. It is traditionally prescribed to strengthen the digestive system and manage gastrointestinal disorders such as diarrhea, dysentery, and intestinal infections. The flowers are also used for their cooling properties and are included in herbal formulations intended to reduce inflammation and promote general well-being. Beyond the classical systems of medicine, *Butea monosperma* occupies an important place in the folk medicine of rural and tribal communities across India and neighboring countries. Traditional healers utilize various parts of the plant to treat fever, skin infections, wounds, urinary disorders, and inflammatory conditions. In certain tribal practices, the plant has also been employed in the management of snake bites and other toxic conditions. These ethnomedicinal applications underscore the cultural significance and longstanding therapeutic value of *Butea monosperma* in traditional healthcare [13].

3.2 Uses of Different Plant Parts

Different parts of *Butea monosperma* possess distinct medicinal properties and have been traditionally used for specific therapeutic purposes [14].

3.2.1 Flowers

The bright orange-red flowers are widely recognized for their anti-inflammatory, antioxidant, and antimicrobial properties. In Ayurvedic medicine, they are commonly used to manage urinary disorders, skin diseases, and inflammatory conditions. The dried flowers are prepared as decoctions, infusions, or powders and consumed as herbal remedies to promote general health. They are also traditionally utilized in the preparation of natural dyes and herbal beverages [15].

3.2.2 Leaves

The leaves have long been used for wound healing and the treatment of various skin disorders. Fresh leaves are commonly applied directly to wounds, ulcers, boils, and skin infections to accelerate healing and reduce inflammation. Besides their medicinal applications, the large leaves are widely used for manufacturing biodegradable plates and cups in many parts of India [16].

3.2.3 Bark

The bark is valued for its astringent and anti-inflammatory properties. Traditionally, bark decoctions are administered for the treatment of diarrhea, dysentery, and other gastrointestinal disorders. They are also used as mouth rinses for oral infections and gum diseases. The medicinal properties of the bark are largely attributed to its high content of tannins and other bioactive phytochemicals [17].

3.2.4 Seeds

The seeds are particularly renowned for their potent anthelmintic activity and have traditionally been used to eliminate intestinal worms in both humans and animals. Seed powders are commonly administered to treat parasitic infections. In addition, the seeds are believed to possess antimicrobial and anti-inflammatory activities, making them useful in the traditional management of certain skin diseases and infectious conditions [18].

3.2.5 Gum (Bengal Kino)

The reddish gum exuded from the trunk, commonly known as Bengal kino, is an important medicinal product. Owing to its strong astringent properties, it has traditionally been employed in the treatment of diarrhea, dysentery, and bleeding disorders. The gum is also incorporated into herbal formulations for wound healing and is considered beneficial as a digestive tonic in traditional medicine [18].

3.3 Traditional Therapeutic Applications

The rich diversity of bioactive constituents in *Butea*

monosperma has led to its widespread use in diseases and health conditions. It has been employed for the treatment of intestinal parasitic infections, gastrointestinal disorders, skin diseases, inflammation, diabetes, urinary disorders, fever, wounds, and microbial infections. Traditional healers have also utilized the plant to improve digestive health and relieve intestinal ailments through various herbal preparations. In addition, *Butea monosperma* has traditionally been used in the management of metabolic disorders, particularly diabetes, owing to its reputed blood glucose-lowering potential. The broad spectrum of ethnomedicinal applications reflects its importance as a versatile medicinal plant in indigenous healthcare systems. The extensive traditional use of *Butea monosperma* in Ayurveda, Unani, and folk medicine has established a strong foundation for contemporary scientific research. Modern phytochemical and pharmacological investigations continue to validate many of its traditional claims and support its potential as a promising source of novel therapeutic agents for modern medicine [19].

4. Phytochemical Constituents

Medicinal plants contain a wide array of bioactive compounds that are responsible for their therapeutic properties. These naturally occurring chemical constituents, commonly known as phytochemicals, are synthesized during plant metabolic processes and play crucial roles in defense against environmental stress, pathogens, and herbivores. Many of these compounds exhibit significant pharmacological activities in humans. The medicinal potential of *Butea monosperma* is largely attributed to its rich phytochemical composition, with bioactive constituents distributed throughout the flowers, leaves, bark, seeds, and gum. Phytochemical investigations have demonstrated that the plant contains diverse classes of secondary metabolites, including flavonoids, glycosides, tannins, terpenoids, phenolic compounds, sterols, and chalcones, which collectively contribute to its broad spectrum of biological activities [20].

4.1 Major Bioactive Compounds

Phytochemical studies of *Butea monosperma* have identified numerous biologically active compounds responsible for its medicinal properties. These constituents have been isolated from different plant parts and exhibit a variety of pharmacological activities, including antioxidant, antimicrobial, anti-inflammatory, antidiabetic, hepatoprotective, and anticancer effects. Among the identified phytochemicals, flavonoids represent the most abundant and extensively investigated group. These traditional medicine for managing numerous compounds are particularly concentrated in the flowers and bark and are recognized for their potent antioxidant activity, enabling them to scavenge free radicals and protect cells against oxidative damage. Besides flavonoids, the plant also contains glycosides, tannins, terpenoids, phenolic compounds, and sterols, all of which contribute to its therapeutic potential. The bark and seeds are especially rich in phenolic compounds and tannins that possess strong astringent, antimicrobial, and anti-inflammatory properties. Likewise, the flowers contain several flavonoid derivatives and chalcones that have demonstrated significant biological activities. The diversity and abundance of these phytochemicals provide scientific support for the traditional medicinal applications of *Butea monosperma* [21].

4.2 Flavonoids, Glycosides, Tannins, and Terpenoids

Flavonoids constitute one of the most important classes of phytochemicals present in *Butea monosperma*. These polyphenolic compounds are well known for their antioxidant, anti-inflammatory, antimicrobial, and cytoprotective properties. The flowers are particularly rich in flavonoids such as butein, butin, isobutrin, and coreopsin. These compounds possess remarkable free radical-scavenging activity and may contribute to the therapeutic management of oxidative stress-related disorders. Glycosides represent another important class of phytochemicals found in the plant. These compounds consist of a sugar moiety linked to a biologically active aglycone and exhibit diverse pharmacological activities. Glycosides isolated from *Butea monosperma* have been reported to possess antimicrobial, anti-inflammatory, cardioprotective, and antioxidant properties, thereby contributing to the medicinal value of the plant. Tannins are abundantly distributed in the bark and gum of *Butea monosperma*. These polyphenolic compounds exhibit strong astringent activity owing to their ability to precipitate proteins. Traditionally, tannins have been utilized for the management of diarrhea, dysentery, and other gastrointestinal disorders. Furthermore, their antimicrobial, antioxidant, and wound-healing properties significantly enhance the pharmacological profile of the plant. Terpenoids are another important group of secondary metabolites identified in *Butea monosperma*. Derived from isoprene units, these compounds possess a broad spectrum of biological activities, including antimicrobial, anti-inflammatory, hepatoprotective, and anticancer effects. Their presence in various plant parts further contributes to the therapeutic versatility of *Butea*

Monosperma [22].

4.3 Important Isolated Phytochemicals

Numerous individual phytochemical constituents have been isolated and characterized from *Butea monosperma* through extensive phytochemical investigations. The major isolated compounds include butein, butin, isobutrin, coreopsin, monospermoside, and several chalcone derivatives. These compounds belong predominantly to the flavonoid and phenolic classes and are responsible for many of the plant's reported pharmacological activities. Butein is one of the most extensively studied bioactive constituents isolated from the flowers of *Butea monosperma*. It exhibits potent antioxidant, anti-inflammatory, anticancer, antidiabetic, and antimicrobial activities and has attracted considerable attention as a promising natural therapeutic molecule. Similarly, butin and isobutrin contribute significantly to the antioxidant capacity of the plant through their free radical-scavenging and cytoprotective effects. Coreopsin and monospermoside are additional flavonoid derivatives that have demonstrated promising biological activities and are believed to contribute substantially to the medicinal efficacy of the plant. In addition to flavonoids, several other important phytochemicals have been isolated from different parts of *Butea monosperma*, including stigmasterol, β-sitosterol, palasonin, and various phenolic acids. Stigmasterol and β-sitosterol are plant sterols known for their anti-inflammatory, hypocholesterolemic, and immunomodulatory properties. Palasonin, predominantly isolated from the seeds, is recognized for its potent anthelmintic activity, thereby providing scientific support for the traditional use of *Butea monosperma* seeds in the treatment of intestinal helminthic infections. The remarkable diversity of phytochemical constituents present in *Butea monosperma* underpins its extensive pharmacological profile and therapeutic potential. Continued phytochemical characterization and pharmacological investigations are expected to facilitate the discovery of novel bioactive molecules and promote the development of plant-derived therapeutic agents for the prevention and treatment of various diseases [23].

Table 1 summarizes the major phytochemical constituents identified in *Butea monosperma*, along with their chemical classification, plant source, and reported biological activities. Phytochemical investigations have revealed that different parts of the plant, including the flowers, leaves, bark, seeds, and gum, are rich in diverse secondary metabolites such as flavonoids, chalcones, glycosides, phenolic acids, tannins, terpenoids, triterpenoids, and phytosterols. These bioactive compounds are responsible for the plant's broad pharmacological profile, exhibiting antioxidant, anti-inflammatory, antimicrobial, antidiabetic, hepatoprotective, anticancer, immunomodulatory, and anthelmintic activities, thereby supporting its traditional medicinal applications and therapeutic potential [24].

Table 1: Major phytochemical constituents of *Butea monosperma* (Lam.) Taub. and their reported biological activities.

S. No.	Phytochemical	Chemical Class	Plant Part	Major Pharmacological Activities	References
1.	Butein	Chalcone flavonoid	Flowers	Antioxidant, anticancer, anti-inflammatory, antidiabetic	[25]
2.	Butin	Flavanone	Flowers	Antioxidant, anti-inflammatory, cytoprotective	[26]
3.	Isobutrin	Flavonoid glycoside	Flowers	Antioxidant, antimicrobial	[27]
4.	Coreopsin	Flavonoid glycoside	Flowers	Free radical scavenging, anti-inflammatory	[28]
5.	Monospermoside	Flavonoid glycoside	Flowers	Antioxidant, antimicrobial	[29]
6.	Sulphurein	Chalcone	Flowers	Antioxidant, anti-inflammatory	[30]
7.	Isocoreopsin	Flavonoid	Flowers	Antioxidant, cytoprotective	[31]
8.	Palasonin	Lactone	Seeds	Anthelmintic, antiparasitic	[32]
9.	Stigmasterol	Phytosterol	Bark/Seeds	Anti-inflammatory, hypocholesterolemic	[33]
10.	β-Sitosterol	Phytosterol	Bark	Immunomodulatory, anti-inflammatory	[34]
11.	Lupeol	Triterpenoid	Bark	Anti-inflammatory, hepatoprotective	[35]

12.	Friedelin	Triterpenoid	Bark	Antioxidant, hepatoprotective	[36]
13.	Gallic acid	Phenolic acid	Bark	Antioxidant, antimicrobial	[37]
14.	Ellagic acid	Polyphenol	Bark	Antioxidant, anticancer	[38]
15.	Catechin	Flavan-3-ol	Bark	Antioxidant, cardioprotective	[39]
16.	Epicatechin	Flavan-3-ol	Bark	Free radical scavenging, anti-inflammatory	[40]
17.	Tannins	Polyphenols	Bark, Gum	Astringent, antimicrobial, wound healing	[41]
18.	Quercetin	Flavonol	Leaves	Antioxidant, anti-inflammatory	[42]
19.	Kaempferol	Flavonol	Leaves	Antioxidant, antimicrobial	[43]
20.	Rutin	Flavonoid glycoside	Leaves/Flowers	Antioxidant, vasoprotective, anti-inflammatory	[44]

5. Pharmacological Activities

Butea monosperma has attracted considerable scientific interest because of its diverse pharmacological properties. Its therapeutic potential is primarily attributed to the presence of bioactive phytochemicals, including flavonoids, phenolic compounds, glycosides, terpenoids, tannins, and sterols. Numerous experimental studies have demonstrated that different parts of the plant, such as the flowers, leaves, bark, seeds, and gum, exhibit a broad range of biological activities. These findings provide scientific evidence supporting its traditional medicinal applications and highlight its potential as a valuable source of natural therapeutic agents. Among the most extensively investigated pharmacological properties are antidiabetic, anti-inflammatory, antimicrobial, antioxidant, hepatoprotective, and anticancer activities [45].

5.1 Antidiabetic Activity

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from impaired insulin secretion, insulin resistance, or both. Several experimental studies have demonstrated the antidiabetic potential of *Butea monosperma* extracts. Extracts prepared from the flowers, bark, and seeds have been shown to significantly reduce blood glucose levels in experimental models of diabetes. The antidiabetic activity is primarily attributed to flavonoids, phenolic compounds, and other bioactive constituents that improve glucose metabolism and enhance insulin sensitivity. These phytochemicals may inhibit carbohydrate-hydrolyzing enzymes such as α-amylase and α-glucosidase, thereby reducing intestinal glucose absorption. In addition, their antioxidant properties help protect pancreatic β-cells from oxidative damage, preserve insulin secretion, and reduce diabetes-associated complications. Collectively, these mechanisms support the traditional use of *Butea monosperma* in the management of diabetes mellitus [46].

5.2 Anti-inflammatory Activity

Inflammation is a complex physiological response to tissue injury, infection, or harmful stimuli. Although acute inflammation is protective, chronic inflammation contributes to the pathogenesis of numerous disorders, including arthritis, cardiovascular diseases, metabolic syndrome, and autoimmune conditions. Several investigations have demonstrated that extracts of *Butea monosperma* possess significant anti-inflammatory activity. These effects are mainly attributed to flavonoids, chalcones, and phenolic compounds that suppress the production of inflammatory mediators, including prostaglandins, nitric oxide, and pro-inflammatory cytokines. Experimental animal studies have shown that flower and bark extracts effectively reduce edema and inflammatory responses, supporting their traditional use in the treatment of inflammation, pain, and inflammatory disorders [47].

5.3 Antimicrobial Activity

The rapid emergence of antimicrobial resistance has intensified the search for effective natural antimicrobial agents. Medicinal plants represent an important source of bioactive compounds with broad-spectrum antimicrobial properties.

Various extracts of *Butea monosperma* have demonstrated inhibitory activity against numerous pathogenic microorganisms, including Gram-positive bacteria, Gram-negative bacteria, and several fungal species. The antimicrobial effects are primarily attributed to flavonoids, tannins, phenolic compounds, and terpenoids, which interfere with microbial cell membrane integrity, inhibit essential metabolic pathways, and suppress microbial growth. These findings provide scientific support for the traditional use of *Butea monosperma* in the management of skin infections, gastrointestinal infections, and other microbial diseases [48].

5.4 Antioxidant Activity

Oxidative stress, resulting from excessive generation of reactive oxygen species (ROS) and free radicals, is implicated in the development of numerous chronic

disorders, including cancer, cardiovascular diseases, diabetes, neurodegenerative disorders, and liver diseases. Antioxidants protect biological systems by neutralizing free radicals and preventing oxidative damage to cellular macromolecules. *Butea monosperma* exhibits potent antioxidant activity owing to its high content of flavonoids, phenolic compounds, chalcones, and other polyphenolic constituents. Extracts obtained from the flowers, bark, and leaves have demonstrated remarkable free radical-scavenging activity in various in vitro antioxidant assays. These antioxidant properties may contribute significantly to the plant's protective effects against oxidative stress-induced tissue damage and support many of its reported pharmacological activities [49].

5.5 Hepatoprotective Activity

The liver performs essential physiological functions, including detoxification, metabolism, protein synthesis, and regulation of biochemical homeostasis. Exposure to toxic chemicals, drugs, alcohol, and environmental pollutants can result in hepatic injury and impaired liver function. Experimental studies have shown that *Butea monosperma* possesses significant hepatoprotective activity. Plant extracts have demonstrated the ability to protect hepatic tissues against chemically induced liver injury by reducing oxidative stress, stabilizing cellular membranes, and restoring the activities of liver marker enzymes. These protective effects are largely attributed to the antioxidant and anti-inflammatory properties of the plant's phytochemicals, which minimize hepatocellular damage and promote recovery of liver function [50].

5.6 Anticancer Potential

Cancer remains one of the leading causes of morbidity and mortality worldwide, prompting continuous efforts to identify safer and more effective therapeutic agents from natural sources. Several phytochemicals isolated from *Butea monosperma*, particularly butein and other flavonoid derivatives, have demonstrated promising anticancer activity in experimental studies. These bioactive compounds inhibit the growth and proliferation of various cancer cell lines through multiple molecular mechanisms, including induction of apoptosis, cell-cycle arrest, inhibition of angiogenesis, suppression of oxidative stress, and modulation of intracellular signaling pathways involved in tumor progression. Although most available evidence is derived from in vitro and preclinical investigations, these findings indicate that *Butea monosperma* represents a promising source of natural anticancer compounds that warrants further mechanistic studies and clinical evaluation [51].

Overall, the broad spectrum of pharmacological activities exhibited by *Butea monosperma* validates its longstanding use in traditional medicine and highlights its considerable therapeutic potential. Continued phytochemical, pharmacological, toxicological, and clinical investigations are essential to identify novel bioactive constituents, elucidate their mechanisms of action, and facilitate the development of safe and effective plant-derived pharmaceuticals for the prevention and treatment of various human diseases [52].

6. Toxicity and Safety Profile

The evaluation of safety and toxicity is an essential aspect of medicinal plant research, particularly when plant-derived products are intended for therapeutic use. Although *Butea monosperma* has been extensively utilized in traditional medicine for centuries, scientific investigations are necessary to establish its safety profile, determine appropriate dosage ranges, and identify potential adverse effects or herb–drug interactions. Toxicological studies conducted on extracts prepared from different parts of the plant, including the flowers, leaves, bark, seeds, and gum, generally indicate that *Butea monosperma* possesses a favorable safety profile when administered at recommended therapeutic doses [53].

6.1 Toxicological Studies

Toxicological investigations are designed to evaluate the potential harmful effects of plant extracts on biological systems. Both *in vitro* and *in vivo* studies have been performed to assess the toxicity of *Butea monosperma*. Acute toxicity studies in experimental animals have consistently demonstrated that extracts of the plant are generally well tolerated at moderate doses and do not produce significant toxic effects. Most investigations have reported no observable behavioral abnormalities, mortality, or major physiological disturbances following administration of therapeutic doses. Nevertheless, certain phytochemical constituents may exhibit toxic effects when consumed at excessive concentrations. For example, the seeds of *Butea monosperma* contain palasonin, a bioactive compound with potent anthelmintic activity that may cause mild gastrointestinal irritation if administered in large quantities. Excessive consumption of some plant extracts has also been associated with mild adverse effects, including nausea, gastric irritation, and digestive discomfort [54].

Overall, available toxicological evidence indicates that *Butea monosperma* exhibits relatively low toxicity, particularly when used within traditional therapeutic dosage ranges. However, additional long-term toxicity studies, reproductive toxicity

assessments, genotoxicity evaluations, and well-designed clinical investigations are required to establish a comprehensive safety profile for its therapeutic use [55].

6.2 Safe Dosage Considerations

Determination of appropriate dosage is essential for the safe and effective use of medicinal plants. In traditional systems of medicine, including Ayurveda, the dosage of *Butea monosperma* preparations varies according to the plant part used, method of preparation, and intended therapeutic application. Herbal practitioners generally recommend moderate doses of plant extracts or powdered formulations to minimize the risk of adverse reactions. The seeds, commonly used as anthelmintic agents, are administered in carefully regulated doses because excessive intake may produce gastrointestinal irritation. Similarly, decoctions prepared from the bark and flowers are usually consumed in limited quantities for the management of digestive disorders, inflammatory conditions, and other ailments. The gum exudate, commonly known as Bengal kino, is likewise administered in small amounts because of its potent astringent properties [56].

Modern pharmacological research emphasizes the importance of extract standardization and dosage optimization during the development of herbal medicines. Standardized preparations containing defined concentrations of bioactive constituents can improve therapeutic consistency while minimizing toxicity. Furthermore, clinical studies and pharmacokinetic evaluations are necessary to establish evidence-based dosage recommendations and assess the long-term safety of *Butea monosperma*-derived formulations [57].

Overall, current toxicological evidence suggests that *Butea monosperma* is generally safe when administered within recommended therapeutic limits. Nevertheless, excessive consumption or inappropriate use may result in undesirable adverse effects. Continued toxicological and clinical investigations are therefore essential to establish comprehensive safety guidelines for its clinical application [58].

7. Future Perspectives

Medicinal plants continue to play an important role in the discovery of novel therapeutic agents and the development of alternative treatment strategies. Despite its extensive history of use in traditional medicine, many pharmacological properties of *Butea monosperma* remain insufficiently explored through modern scientific research. Although numerous experimental studies have demonstrated its antioxidant, antimicrobial, anti-inflammatory, antidiabetic, hepatoprotective, and anticancer activities, additional investigations are required to elucidate its molecular mechanisms of action and fully exploit its therapeutic potential. Continued research into its phytochemistry and pharmacology may facilitate the development of innovative natural products and plant-based medicines [59].

7.1 Need for Clinical Studies

Most pharmacological investigations involving *Butea monosperma* have been limited to *in vitro* experiments and animal studies. While these investigations provide valuable preliminary evidence regarding the biological activities of the plant, they cannot fully predict efficacy and safety in humans. Consequently, well-designed randomized clinical trials are required to validate the therapeutic potential of *Butea monosperma*-based formulations.

Clinical investigations are essential for determining optimal dosage regimens, pharmacokinetic behavior, pharmacodynamic properties, possible adverse effects, herb–drug interactions, and long-term safety. Such studies would also facilitate the development of standardized therapeutic protocols and support the integration of evidence-based herbal medicines into modern healthcare systems. Furthermore, clinical validation would strengthen the scientific basis of the traditional medicinal claims associated with *Butea monosperma* [60].

7.2 Potential for New Drug Discovery

The rich phytochemical diversity of *Butea monosperma* provides substantial opportunities for the discovery of novel therapeutic molecules. Bioactive constituents such as flavonoids, chalcones, glycosides, phenolic compounds, sterols, and terpenoids have demonstrated promising biological activities in experimental studies and may serve as valuable lead compounds for drug development targeting inflammatory diseases, metabolic disorders, infectious diseases, liver disorders, and cancer [61].

Recent advances in phytochemical profiling, metabolomics, molecular biology, bioinformatics, computational drug discovery, and artificial intelligence have significantly enhanced the identification and characterization of pharmacologically active natural products. Application of these modern technologies to *Butea monosperma* may accelerate the discovery of novel bioactive compounds with improved efficacy, selectivity, and safety [62].

The growing global interest in natural products, herbal medicines, nutraceuticals, and functional foods further expands the commercial and therapeutic potential of *Butea monosperma*. Plant-

derived phytochemicals may be incorporated into innovative pharmaceutical formulations, and functional food ingredients designed to promote health and prevent disease [63].

Future research should therefore focus on comprehensive phytochemical characterization, mechanistic pharmacological studies, standardized extract development, advanced toxicological assessments, pharmacokinetic investigations, and well-designed multicenter clinical trials. Such multidisciplinary efforts will be instrumental in unlocking the full therapeutic potential of *Butea monosperma* and facilitating its translation into safe, effective, and evidence-based natural medicines [64].

Conclusion

Butea monosperma, commonly known as the Flame of the Forest, is a significant medicinal plant that has been widely utilized in traditional healthcare systems for centuries. Its extensive use in Ayurveda, Unani, and various folk medicinal practices highlights its therapeutic importance and cultural value in many regions of the Indian subcontinent and Southeast Asia. Different parts of the plant—including flowers, leaves, bark, seeds, and gum have been traditionally used to treat a wide range of ailments such as intestinal infections, inflammatory disorders, skin diseases, diabetes, and gastrointestinal problems. Scientific investigations have confirmed that *Butea monosperma* contains a diverse range of phytochemical constituents including flavonoids, glycosides, tannins, phenolic compounds, and terpenoids. These bioactive compounds are responsible for many of the pharmacological properties exhibited by the plant. Experimental studies have demonstrated that extracts of *Butea monosperma* possess significant pharmacological activities such as antidiabetic, anti-inflammatory, antimicrobial, antioxidant, hepatoprotective, and anticancer effects. These findings provide scientific support for many of the traditional medicinal uses of the plant. its pharmacological potential, *Butea monosperma* has gained increasing attention in modern pharmaceutical and nutraceutical research. The plant shows promising potential for the development of herbal formulations, natural health products, and new therapeutic agents. Furthermore, standardized herbal products, dietary supplements,

its rich phytochemical profile makes it an important candidate for further drug discovery and development studies. Although numerous experimental studies have explored the biological activities of *Butea monosperma*, further research is still required to fully understand its therapeutic potential. In particular, well-designed clinical studies are necessary to confirm the efficacy and safety of plant-based preparations in humans. Standardization of plant extracts and identification of active compounds will also be essential for developing reliable and effective medicinal products.

Acknowledgements

The authors sincerely acknowledge the School of Pharmacy, RIMT University, Mandi Gobindgarh, Punjab, India, for providing the necessary facilities, academic support, and research environment for the successful completion of this review article. The authors also express their gratitude to all researchers whose published work contributed to the preparation of this manuscript.

Author Contributions

MK: Conceptualization; **AS:** Literature review; **SK:** Supervision.

Declaration of Interest statement

The authors declare no financial or non-financial conflict of interests.

Funding

Not applicable

Ethics approval and consent to participate

Not applicable

AI Declaration

The authors declare that they did not use artificial intelligence (AI) tools to generate or draft the scientific content of this manuscript. ChatGPT and Grammarly AI were used solely to improve the language, grammar, readability, and clarity of the manuscript. All AI-assisted suggestions were carefully reviewed, verified, and edited by the authors, who take full responsibility for the accuracy, originality, and integrity of the final content.

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