RESEARCH PAPER

Recent Advances in Herbal Formulations of Indian Kino Tree for Antidiabetic Activity

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Received: 20th Apr, 2026 | Revised: 25th Apr, 2026 | Accepted: 9th May, 2026 | Available Online: 14th May, 2026

ABSTRACT

Pterocarpus marsupium (Indian Kino Tree) is a well-known medicinal plant widely used in traditional medicine for the management of diabetes mellitus. The present review highlights recent advances in herbal formulations of Pterocarpus marsupium and its antidiabetic potential. The plant contains important bioactive compounds such as pterostilbene, epicatechin, flavonoids, and tannins, which contribute to its therapeutic effects. These phytochemicals exhibit hypoglycaemic activity by enhancing insulin secretion, improving glucose uptake, and protecting pancreatic β-cells. Recent studies have focused on developing advanced herbal formulations such as extracts, nanoparticles, and polyherbal systems to improve bioavailability and efficacy. Experimental and clinical studies demonstrate significant reduction in blood glucose levels with minimal side effects. The review emphasizes the importance of integrating traditional knowledge with modern drug delivery approaches. Pterocarpus marsupium shows strong potential as a natural and effective alternative for diabetes management.

Keywords: Pterocarpus marsupium, Antidiabetic activity, Herbal formulation, Phytochemicals, Diabetes mellitus

How to cite this article: Koli N, Nhawkar S, Jadhav A, Nalawade R, Chopdar A, Patil M., Recent Advances in Herbal Formulations of Indian Kino Tree for Antidiabetic Activity. Int J Drug Deliv Technol. 2026;16(44s): 750-758; DOI: 10.25258/ijddt.16.44s.80

Introduction

1. Overview of Diabetes Mellitus

Diabetes mellitus is a chronic metabolic disorder characterized by high blood glucose levels due to defects in insulin secretion, insulin action, or both. It is one of the most common diseases worldwide and is increasing rapidly due to lifestyle changes, unhealthy diet, and lack of physical activity. Diabetes can lead to serious complications such as heart disease, kidney failure, nerve damage, and vision problems. Diabetes mellitus (DM) also complex chronic illness associated with a state of high blood glucose level, or hyperglycaemia, occurring from deficiencies in insulin secretion, action, or both. The chronic metabolic imbalance associated with this disease puts patients at high risk for long-term macro- and microvascular complications, which if not provided with high quality care, lead to frequent hospitalization and complications, including elevated risk for cardiovascular diseases (CVDs).[1] The clinical diagnosis of diabetes is reliant on either one of the four plasma glucose (PG) criteria: elevated (i) fasting plasma glucose (FPG) (>126 mg/dL), (ii) 2 h PG during a 75-g oral glucose tolerance test (OGTT) (>200 mg/dL), (iii) random PG (>200 mg/dL) with classic signs and symptoms of hyperglycaemia, or

(iv) haemoglobin A1C level >6.5%. Recent American Diabetes Association (ADA) guidelines have advocated that no one test may be preferred over another for diagnosis. The recommendation is to test all adults beginning at age 45 years, regardless of body weight, and to test asymptomatic adults of any age who are overweight or obese, present with a diagnostic symptom, and have at least an additional risk factor for development of diabetes.

Furthermore, a condition called prediabetes or impaired fasting glucose (IFG), in which the fasting blood glucose is raised more than normal but does not reach the threshold to be considered diabetes (110–126 mg/dL), predisposes patients to diabetes, insulin resistance, and higher risk of cardiovascular (CV) and neurological pathologies.[2-3] Type 2 diabetes mellitus (T2DM) can co-occur with other medical conditions, such as gestational diabetes occurring during the second or third trimester of pregnancy or pancreatic disease associated with cystic fibrosis. T2DM may also be estrogenically induced, e.g., by use of glucocorticoids in the inpatient setting or use of highly active antiretroviral agents like protease inhibitors and nucleoside reverse transcription inhibitors in HIV-positive individuals.[4] Chemical diabetes or impaired glucose tolerance (IGT) may also develop with the use of thiazide diuretics, atypical antipsychotic agents, and statins.[5-6]

Type 2 diabetes mellitus is a common and increasingly prevalent disease and is thus a major public health concern worldwide. The International Diabetes Federation estimates that there are approximately 387 million people diagnosed with diabetes across the globe.[7] According to Centre for Disease Control and Prevention, in 2012, 29.1 million adults, or 9.3% of the population, were identified with diabetes in the United States (US). Also in the same year, 86 million people had prediabetes condition and 15–30% of them developed into full-blown diabetes.[8] In general, 1.4 million newly diagnosed cases in the US are being reported every year. If this trend continues, it is projected that in 2050 one in three Americans will have diabetes. Patients with diabetes have increased risk of serious health complications including myocardial infarction, stroke, kidney failure, vision loss, and premature death. Diabetes, with its associated side effects, remains the seventh leading cause of mortality in the US. The World Health Organization estimates that by 2030, mortality related to diabetes will double in number if not given deliberate attention.[9] In addition, epidemiological studies report that diabetes causes more deaths in Americans every year compared to breast cancer and acquired immunodeficiency syndrome (AIDS) combined.[10] The increasing trend in the incidence and prevalence of diabetes is worrisome and poses a great burden on medical costs and in our current healthcare system.

The ADA has released a range of recommendations called *Standards of Medical Care in Diabetes* to improve diabetes outcomes. The recommendations include cost-effective screening, diagnostic and therapeutic strategies to prevent, delay, or effectively manage T2DM and its life-threatening complications.[11] Per recommendations of ADA and other organizations, modern approaches to diabetes care should involve a multidisciplinary team of health professionals working in tandem with the patient and the family. The primary aim of these approaches is to obtain optimal glycaemic control through dietary and lifestyle modifications and appropriate medications along with regular blood glucose level monitoring. The burden of diabetes can be potentially reduced if the standard of care is implemented as well as patients' compliance and participation is clinically implemented.

The traditional presentations of T2DM occurring only in adults and type 1 diabetes mellitus (T1DM) only in children are not entirely correctly representative, as both diseases occur in both age groups. Occasionally, patients with T2DM may develop the morbid complication of diabetic ketoacidosis (DKA).[12] Children with T1DM typically present with polyuria and polydipsia and approximately one-third of them present with DKA, which may also be the first presenting feature. The onset of T1DM may be variable in adults, and they may not present with the classic symptoms that are seen in children. The true diagnosis may become apparent with disease progression. The heterogeneity of the presentations should be kept in mind while caring for the patient with T2DM.

2. Clinical analysis of Type 1 and 2 Diabetes.

Clinical diagnosis of Type 1 and Type 2 diabetes mellitus is very important for early treatment and prevention of complications. Diabetes is a long-term metabolic disorder in which the body is not able to control blood sugar levels properly. This happens

either because the body does not produce enough insulin or because the body cannot use insulin effectively. Insulin is a hormone produced by the pancreas that helps glucose enter the cells to be used as energy.[13] When insulin does not work properly, glucose remains in the blood, leading to high blood sugar levels. The diagnosis of both Type 1 and Type 2 diabetes is mainly based on blood tests and clinical symptoms.

The most common method used for diagnosis is the measurement of blood glucose levels. There are different tests used in clinical practice. One of the most important tests is the fasting plasma glucose (FPG) test. In this test, the patient is asked to fast for at least 8 hours before blood collection. If the fasting blood glucose level is less than 100 mg/dL, it is considered normal. If it is between 100 and 125 mg/dL, it indicates prediabetes. If the value is 126 mg/dL or more, it confirms diabetes. Another important test is the oral glucose tolerance test (OGTT). In this test, the patient drinks a solution containing 75 grams of glucose, and blood sugar is measured after 2 hours. A value less than 140 mg/dL is normal, 140–199 mg/dL indicates prediabetes, and 200 mg/dL or more confirms diabetes.[14]

Another commonly used test is the glycated haemoglobin (HbA1c) test. This test shows the average blood sugar level over the past 2 to 3 months. It is very useful because it does not require fasting. A value below 5.7% is normal, between 5.7% and 6.4% indicates prediabetes, and 6.5% or higher confirms diabetes. In addition, a random blood glucose test can also be used, where blood sugar is measured at any time of the day. If the value is 200 mg/dL or more along with symptoms of diabetes, it indicates the presence of diabetes. Although the diagnostic tests are similar for both types, the clinical features of Type 1 and Type 2 diabetes are different.[15] Type 1 diabetes usually occurs in children, teenagers, or young adults. It develops suddenly and progresses rapidly. The main cause of Type 1 diabetes is an autoimmune reaction in which the body's immune system destroys the insulin-producing beta cells of the pancreas. As a result, the body produces little or no insulin. Because of this, patients with Type 1 diabetes require insulin therapy for survival. The symptoms of Type 1 diabetes are usually severe and appear quickly. These include excessive thirst (polydipsia), frequent urination (polyuria), increased hunger (polyphagia), sudden weight loss, fatigue, and blurred vision. In some cases, patients may develop diabetic ketoacidosis (DKA), which is a serious condition characterized by nausea, vomiting, abdominal pain, and fruity-smelling breath.[15]

For the diagnosis of Type 1 diabetes, in addition to blood glucose tests, some special tests may also be performed. These include autoantibody tests such as glutamic acid decarboxylase (GAD) antibodies, islet cell antibodies (ICA), and insulin autoantibodies. The presence of these antibodies confirms the autoimmune nature of the disease. Measurement of C-peptide levels can also help in diagnosis. Low or absent C-peptide levels indicate reduced insulin production, which is common in Type 1 diabetes. On the other hand, Type 2 diabetes is more common and usually occurs in adults, although it is now increasingly seen in younger individuals due to unhealthy lifestyles. It develops slowly over time and may not show clear symptoms in the early stages.[17] The main cause of Type 2 diabetes is insulin resistance, where the body's cells do not respond properly to insulin. Over time, the pancreas may also produce less insulin. Risk factors for Type 2 diabetes include obesity, lack of physical activity, unhealthy diet, family history, and increasing age.

The symptoms of Type 2 diabetes are usually mild and may go unnoticed for a long time. Common symptoms include increased thirst, frequent urination, fatigue, slow wound healing, frequent infections, and blurred vision. Because symptoms are less obvious, many people are diagnosed during routine health check-ups. In some cases, complications such as nerve damage, kidney problems, or eye disorders may be present at the time of diagnosis. The diagnosis of Type 2 diabetes mainly relies on blood glucose tests such as FPG, OGTT, HbA1c, and random blood glucose levels.[18] Unlike Type 1 diabetes, autoantibody tests are usually negative in Type 2 diabetes. C-peptide levels are usually normal or high, indicating that insulin is being produced but not used effectively by the body.

Early diagnosis of both Type 1 and Type 2 diabetes is very important to prevent complications. If diabetes is not controlled, it can lead to serious health problems such as cardiovascular diseases, kidney failure, nerve damage (neuropathy), eye damage (retinopathy), and foot ulcers. Therefore, regular screening is recommended, especially for people who are at high risk. Lifestyle modifications such as healthy diet, regular exercise, and weight management play a key role in the prevention and management of Type 2 diabetes.[19-20] The clinical diagnosis of Type 1 and Type 2 diabetes involves a

combination of blood glucose testing and evaluation of symptoms. While both types share similar diagnostic criteria, they differ in their causes, onset, and clinical features. Accurate and early diagnosis helps in proper treatment and improves the quality of life of patients.

Table: 1. Medicinal Plants Used in Antidiabetic Activity

S. No.	Plant Name	Family	Part Used	Active Constituents	Antidiabetic Action
1	*Pterocarpus marsupium*	Fabaceae	Heartwood	Pterostilbene, Epicatechin	Regenerates β-cells, lowers blood glucose
2	*Momordica charantia*	Cucurbitaceae	Fruit	Charantin, Vicine	Increases insulin secretion
3	*Gymnema sylvestre*	Apocynaceae	Leaves	Gymnemic acids	Reduces glucose absorption
4	*Azadirachta indica*	Meliaceae	Leaves	Nimbin, Azadirachtin	Improves insulin sensitivity
5	*Ocimum sanctum*	Lamiaceae	Leaves	Eugenol, Ursolic acid	Reduces blood sugar levels
6	*Trigonella foenum-graecum*	Fabaceae	Seeds	4-hydroxyisoleucine	Enhances insulin secretion
7	*Syzygium cumini*	Myrtaceae	Seeds	Jambolin e, Ellagic acid	Delays glucose absorption
8	*Aloe vera*	Asphodelaceae	Leaves	Aloin, Emodin	Improves glucose metabolism
9	*Allium sativum*	Amaryllidaceae	Bulb	Allicin	Reduces blood glucose
10	*Tinospora cordifolia*	Menispermaceae	Stem	Berberine, Tinosporin	Improves insulin function

3. Indian Kino Tree.

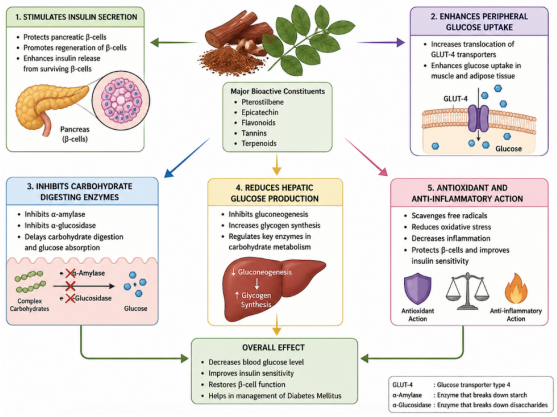

Figure: 1. Mechanism of Antidiabetic Activity of *Kino Tree* (Pterocarpus marsupium)

Pterocarpus marsupium is one such plant which has proved itself as versatile plant with a broad spectrum of pharmacological actions. It has been mentioned in various traditional systems of medicine like Ayurvedic, Unani and Homeopathic systems of medicine[23] *Pterocarpus marsupium* Roxb.- Fabaceae (PM) known as Indian Kino Tree or Malabar Tree in English; Vijayasar or Bija in Hindi and Asana in Sanskrit is indigenous to India, Nepal and Sri Lanka[24] It is found specifically in the areas of the Western Ghats, in the Karnataka-Kerala region, in the states of Gujarat, Madhya Pradesh,

Bihar and Orissa[1] *Pterocarpus marsupium* fined its place in the Rasayans group of Ayurveda Due to the exploitation of the tree for its timber and medicinal bark, its population is decreasing in the wild and thus, it has been mentioned in the red data book. As the modern way advances in technology, we should not forget the value of our plant world. *P. marsupium* is well known in India and its neighbouring countries for more than 2000 years as one of the most versatile medicinal plants having a wide spectrum of biological activity. Every part of the tree has been used as traditional medicine for household remedy against various human ailments, from antiquity. *P. marsupium* has been extensively used in ayurveda, Unani and homoeopathic medicine and has become a cynosure of modern medicine. *Pterocarpus marsupium* plant belonging to family Fabaceae has been used in India and its adjacent countries due to its various biological activities from ancient times. All parts of *P. marsupium* is used as a primitive medicine for domestic remedy against several human diseases. It has been broadly used in Homoeopathic, Ayurvedic and Unani systems of medicine.[25]

Habitat:

The plant has been traditionally used for its medicinal value The plant species is native to India, Sri Lanka and Nepal. It is particularly found in certain areas of the Western Ghats, in the Karnataka-Kerala region, in the states of Gujrat, Madhya Pradesh, Bihar and Orissa Andhra Pradesh Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal and Goa. Province of China.[26]

Morphological classification:

Family: Fabaceae
Domain: Eukaryota
Kingdom: Plantae
Subkingdom: Viridaeplantae
Phylum: Magnoliophyta
Subphylum: Euphyllophytina
Class: Magnoliopsida
Subclass: Rosidae
Order: Fabales
Super order: Fabanae
Genus: *Pterocarpus*
Species: *marsupium*[27-28]

Common names:

Assam. - Ajar
Assamese: Aajar
Bengali -Piyasala, Pitasala
English - Indian Kino, Indian Malabar Kino, Gummy Kino, Indian Kino Tree
Gujrati - Biyo Asana
Hindi - Bija, Bijasal, Vijayasara
Kannada: Bijasara, Asana
Kashmiri –LalChandeur,
Malayalam – Venga
Marathi - Biyalalakda, Bibala
Punjabi – ChandanLal, Channanlal
Sanskrit - Pitasala, Asana, Sarfaka, Pijaka, Bijaka, Pitasara, Bijasara
Tamil – Vegaimaramchakkal Nengai Vengai,
Telugu – PaiddagiChekka, Yegi, Vegisa
Odissi –Piashala,
Urdu – Bijasar

Ayurvedic Profile:

Medicinal Properties:

Guna (Qualities) - Laghu (light to digest), Ruksha (dry)
Rasa (Taste) - Kashaya (astringent), Tikta (bitter)
Vipaka (post-digestive taste) - pungent
Veerya (Sheets) - Coolant
Effect on tridosha – balances kapha and pitta dosha
Dosage – Decoction 50-100 ml; powder 3-6 gm

Plant Profile:

P. marsupium is 15-30 meters high tree. It is a medium to large sized tree reaching height up to 15-20 meter with dark brown to grey bark having swallow cracks. The bark exudes a red gummy substance called 'Gum Kino' when injured[29] *P. marsupium* is a moderate to large sized deciduous tree with spreading branches, producing a straight clean bole[30]

Leaves:

leaflets 5-7, oblong, obtuse, emarginated, glabrous with round, smooth and waved petioles; stipules absent. Large and terminal panicles. Rounded peduncles and pedicels. Small, caduceus, solitary bracts. Leaves are 3 to 5 inch long, have 5-7 leaflets, oblong, margin wavy and obtuse. The petioles are round, smooth and waved from leaflet to leaflet, 5 or 6 inches long and there are no stipules.[31]

Flower:

Numerous, white flowers with a yellowish tinge. Vexillum with a long, slender claw; sides reflexed, waved, curled and veined; keel two pettled. Flower

about 1.5 cm long, very numerous, white, with a small tinge of yellow. Flowers are yellow in terminal panicles.

Seed:
Stamens unlled, hairy ovary. Ascending style. Single and reniform seeds. Seed is convex and bony. Tree flowers and fruits in the month of March to June.

Branches:
Crooked and stout stem with widely spreading branches. The heartwood is golden yellowish-brown with darker streaks and occurs as uneven pieces of erratic sizes and thickness.

Bark:
Tree bark yields a reddish gum. Stamens are 10, united near the base, but soon dividing into two parcels of 5 each; anthers are globose and 2-lobed. Bark is about 1.25 cm thick, grey, rough, longitudinally fissured in small irregular scales, blaze pink with whitish markings and older trees exuding a blood red astringent gum resin.

Fruit:
Fruit is circular, flat, winged pod. The fruit circular, flat, winged pod. Seed is convex and bony.20 It gives flowers and fruits in the month of March to June.

Pod:
The pods are light yellowish brown, nearly orbicular, 2.5-5 cm diameter, flat, winged containing 1-2 seeds, convex and bony, seeds are dolabriform, 1-1.25 cm long, reddish brown, fairly hard, with a smooth leathery test. Under favourable conditions the tree attains a height of 33 m and a girth of 2.6 m or more.

Wood:
Wood is hard and durable. The sap wood is pale yellowish white or white, narrow, heart wood is golden yellowish brown with darker streaks, staining yellow when damp and turning darker on exposure, broadly inter locked grained, medium coarse textured, strong, tough, very hard and moderately heavy.

Table: 2. Other Pharmacological Activities of *Pterocarpus marsupium*

S. No.	Activity	Description
1	Antioxidant activity	Scavenges free radicals and reduces oxidative stress
2	Anti-inflammatory activity	Reduces inflammation and swelling in tissues
3	Antimicrobial activity	Inhibits growth of bacteria and fungi
4	Hepatoprotective activity	Protects liver from damage and toxins
5	Cardioprotective activity	Supports heart health and improves blood circulation
6	Antiulcer activity	Protects gastric mucosa and reduces ulcer formation
7	Anticancer activity	Shows inhibitory effect on cancer cell growth
8	Wound healing activity	Promotes tissue repair and faster healing
9	Antidiarrheal activity	Helps in controlling diarrhea
10	Hypolipidemic activity	Reduces cholesterol and lipid levels

Integrating traditional knowledge with modern drug delivery approaches is very important for improving the effectiveness of herbal medicines. Traditional systems like Ayurveda provide valuable information about medicinal plants, their uses, and therapeutic benefits based on long-term experience. However, many herbal drugs face challenges such as poor solubility, low bioavailability, instability, and variable dosage. Modern drug delivery systems help to overcome these limitations by improving the absorption, stability, and controlled release of active compounds. By combining traditional knowledge with advanced technologies like nanoparticles, liposomes, and controlled-release formulations, the therapeutic effect of herbal medicines can be enhanced. This integration also helps in reducing side effects, improving patient compliance, and ensuring accurate dosing. It allows scientists to scientifically validate traditional remedies and develop standardized formulations suitable for modern healthcare systems. This approach bridges the gap between ancient wisdom and modern science, leading to the development of safe, effective, and reliable herbal medicines for the

treatment of various diseases, including chronic conditions like diabetes

Table: 3 Recent Advances in Herbal Formulations of Indian Kino Tree (*Pterocarpus marsupium*) for Antidiabetic Activity.

Sr. No.	Herbal Formulation	Active constituents	Recent Advancement Delivery System	Antidiabetic Mechanism	Findings
1	Methanolic heartwood extract of *Pterocarpus marsupium*	Quercetin, epicatechin, flavonoids	Standardized herbal extract	Enhances glucose uptake, reduces oxidative stress, protects β-cells	Improved glucose uptake in HepG2 cells and reduced apoptosis[31]
2	Nanoformulated *P. marsupium* extract	Polyphenols, pterostilbene	Nanoparticle-based herbal formulation	Improved bioavailability and sustained release	Nano formulations showed better glyceric control than conventional extracts[32]
3	Liposomal formulation of *P. marsupium*	Flavonoids and tannins	Liposomal nano-delivery system	Enhanced intestinal absorption and antioxidant activity	Liposomal extract exhibited superior antidiabetic effect compared to crude extract[33]
4	Polyherbal phytosomal formulation containing antidiabetic herbs	Flavonoids	Phytosome technology	Increased oral bioavailability and sustained drug release	Significant reduction in fasting blood glucose levels in diabetic rats[34]
5	Herbal nanoformulations for Type 2 Diabetes Mellitus	Polyphenols and flavonoids	Lipid- and polymer-based nanocarriers	Enhanced permeability and prolonged circulation	Improved therapeutic efficacy and pharmacokinetic profile[35,36]
6	Standardized bark and heartwood extract	Epicatechin, marsupsin, pterosupin	Conventional herbal formulation with phytochemical standardization	Regeneration of pancreatic β-cells and antioxidant action	Scientifically validated hypoglycemic and antidyslipidemic effects[37]
7	Advanced phytosome-based herbal systems	Polyphenolic constituents	Phospholipid-complex phytosomes	Improved solubility and membrane permeability	Enhanced therapeutic efficacy and stability of herbal

					compounds[38]
8	Emerging PM nanoparticle formulations	Multiple constituents including liquiritigenin	Herbal nanoparticles	Enhanced antioxidant and glucose-lowering activity	Potential future therapeutic application in diabetes management[39]

Conclusion

Pterocarpus marsupium is an important medicinal plant with strong therapeutic potential, especially in the management of diabetes. The plant contains various bioactive compounds such as flavonoids, tannins, and phenolic compounds that contribute to its pharmacological activities. It shows significant antidiabetic action by improving insulin secretion, increasing glucose uptake, and protecting pancreatic β-cells. In addition to its antidiabetic effect, the plant also exhibits antioxidant, anti-inflammatory, antimicrobial, and hepatoprotective activities, which support overall health. Recent advances in herbal formulations, including extracts, tablets, and nanoparticle systems, have improved its effectiveness and bioavailability. These developments highlight its potential as a natural alternative to synthetic drugs. However, more clinical studies and standardization are required to ensure safety and consistency. *Pterocarpus marsupium* can be considered a promising herbal drug for future therapeutic applications in diabetes and related disorders.

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