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MEDICINAL PLANTS AS NATURAL ANTI-DIABETIC AGENTS

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ABSTRACT: Diabetes is a growing health concern worldwide and now emerging as an epidemic world over. The management of diabetes is still a major challenge. Plants have always been a source of drugs for humans since time immemorial. The Indian traditional system of medicine is replete with the use of plants for the management of diabetic conditions. According to the World Health Organization (WHO), up to 90% of population in developing countries use plants and its products as traditional medicine for primary health care. There are about 800 plants which have been reported to show anti-diabetic potential. Thus there is great demand for research on natural products with anti-diabetic properties. Numerous studies have confirmed the benefits of medicinal plants with anti-hyper-glycaemic effects in the management of diabetes mellitus. The present paper is an attempt to list of the plants with anti-diabetic and related beneficial effects originating from different parts of world. History showed that medicinal plants have been used in traditional healing around the world for a long time to treat diabetes; this is because such herbal plants have hypoglycemic properties and other beneficial properties, as reported in scientific literature. The review provides a starting point for future studies aimed at isolation, purification, and characterization of bioactive anti-diabetic compounds present in these plants.

INTRODUCTION: Diabetes mellitus is a growing problem worldwide entailing enormous financial burden and medical care policy issues [1]. According to International Diabetes Federation (IDF), the number of individuals with diabetes in 2011 crossed 366 million, with an estimated 4.6 million deaths each year [2]. The Indian subcontinent has emerged as the capital of this diabetes epidemic.

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The reported prevalence of diabetes in adults between the ages of 20 and 79 is as follows: India 8.31%, Bangladesh 9.85%, Nepal 3.03%, Sri Lanka 7.77%, and Pakistan 6.72% [3].

Indians show a significantly higher age-related prevalence of diabetes when compared with several other populations [4]. For a given BMI, Asian Indians display a higher insulin level which is an indicator of peripheral insulin resistance. The insulin resistance in Indians is thought to be due to their higher body fat percentage [5, 6]. Excess body fat, typical abdominal deposition pattern, low muscle mass, and racial predisposition may explain the prevalence of hyperinsulinemia and increased development of type 2 diabetes in Asian Indians.

Diabetes is characterized by metabolic dysregulation primarily of carbohydrate metabolism, manifested by hyper-glycaemia resulting from defects in insulin secretion, impaired insulin action, or both [7]. Uncontrolled diabetes leads to a plethora of complications affecting the vascular system, eyes, nerves, and kidneys leading to peripheral vascular disease, nephropathy, neuropathy, retinopathy, morbidity, and/or mortality.

Diabetes is a chronic metabolic disorder that poses a major challenge worldwide. Currently in India the number of people with diabetes is around 40.9 million and it is expected to rise to 69.9 million by 2025 [8]. India has emerged as the diabetic capital of the world [9]. Unless urgent preventive steps are taken, it will become a major health problem. The Indian Diabetes Federation (IDF) estimated 3.9 million deaths for the year 2010, which represented 6.8% of the total global mortality [10].

Traditional anti-diabetic plants might provide new oral anti-diabetic compounds, which can counter the high cost and poor availability of the current medicines for many rural populations in developing countries [11]. Plant drugs are frequently considered to be less toxic and free from side effects than synthetic ones [12]. In India, indigenous remedies have been used in the treatment of diabetes mellitus since the time of Charaka and Sushruta (6th century BC) [13]. The World Health Organization (WHO) has listed 21,000 plants which are used for medicinal purposes around the world. Among these, 2500 species are in India. There are about 800 plants which have been reported to show antidiabetic potential [14]. India is the largest producer of medicinal herbs endowed with a wide diversity of agro-climatic conditions and is called as botanical garden of the world [15]. Pharmacological and clinical trials of medicinal plants have shown anti-diabetic effects and repair of *β*-cells of islets of Langerhans [16].

Indian Medicinal Plants to Treat Diabetes: India has a rich history of using various potent herbs and herbal components for treating diabetes. Many Indian plants have been investigated for their beneficial use in different types of diabetes and ported in numerous scientific journals. This review article enumerates some medicinal plants belonging to different families possessing antidiabetic activity and elucidating their mechanisms of action such as *Adhatoda zeylanica, Brassica juncea* etc. **Table 1** shows the information about scientific name, family, parts of the plant used to treat diabetes and their mode of action/Observation

TABLE 1: ANTI-DIABETIC MEDICINAL PLANTS AND THEIR MODE OF ACTION/OBSERVATION

Botanical Name	Family	Parts used	Observation/ Mode of action
Adhatoda zeylanica [17]	Acanthaceae	Leaf	Significant reduction in blood glucose level in alloxan induced Diabetic rats.
Adenia lobata [18]	Passifloraceae	Stem	Significantly reduce the blood glucose level in STZ induced Diabetic rats.
Acacia tortilis [19]	Mimosoideae	seed	Lowers serum glucose levels in normal and diabetic rats and significantly increases glucose tolerance in Alloxan- induced diabetic rats
Aloe vera [20]	Liliaceae	Leaf	Shows Ant diabetic activity in streptozotocin induced diabetic rats
Astragalus membranaceus [21]	Fabaceae	PLSH. fraction	Shows hypoglycemic effect of polysaccharides enriched extract in diet induced insulin resistant mice
Andrographis stenophylla [22]	Acanthaceae	Leaf	Shows Hypoglycaemic Activity
Abutilon indicum [23]	Malvaceae	Whole plant	Aqueous extract inhibits glucose absorption and stimulates insulin secretion in rodents.
Acosmium panamense [24]	Fabaceae	Bark	Glucose lowering activity in streptozotocin diabetic rats
Acourtia thurberi [25]	Asteraceae	Root	Reduces blood glucose in normal mice & Lowered hyperglycemia in rabbits

		Fruit	Improve functional state of the pancreatic ss-cells and partially reversed the damage caused by STZ to the pancreatic Islets
Aegle marmelos [26-28]	Rutaceae	Leaf	Modulates the activity of enzymic and nonenzymic antioxidants and enhances the defense against reactive oxygen species-generated damage in diabetic rats, Effectively reduced the oxidative stress induced by alloxan and produced a reduction in blood sugar.
Agarista Mexicana [29]	Ericaceae	Stem	Hypoglycemic activity in alloxan induced diabetic mice
Aloe barbedensis [30]	Liliaceae	Leaf	Significant decrease in serum glucose, total cholesterol and triacylglycerols
Panax quinquefolius [31]	Araliaceae	Root	Significant effects on fasting blood glucose levels and glucose tolerance test
Anacardium occidentale [32]	Anacardiaceae	Leaf	Significantly reduced the blood glucose levels in a dose dependent manner in streptozotocin-induced diabetic rats
Anemarrhena asphodeloides [33]	Asphodelaceae	Rhizome	Stimulates insulin secretion in islets of normal Wistar and diabetic GK rats.
Arachis hypogaea [34]	Fabaceae	Nut	Hypoglycemic activity in normal and in streptozotocin induced diabetic rats
Artemisia pallens [35]	Asteraceae	Aerial part	Blood glucose lowering effects in hyperglycaemic and alloxan induced diabetic rats
Artemisia judaica [36]	Asteraceae	Whole plant	Significantly reduce the blood glucose level in diabetic rats.
Artemisia Afra [37]	Asteraceae	Leaves	Hypoglycemic activity in alloxan-induced diabetic rabbits
Annona squamosa [38, 39]	Annonaceae	Root	Antidiabetic activity in Streptozotocin induced-hyperglycemic Rats
Azadirachta indica [40-42]	Meliaceae	leaf	Hypoglycemic and antidiabetic effect in streptozotocin (STZ)- induced diabetic rats and alloxan-induced diabetic rabbits
		Fruit	Beneficial effects on blood glucose levels in Normoglycemic rabbits
		leaf	Blood sugar lowering activity in streptozotocin induced diabetic rats
		Seed	The whole oil and the acidic portion of oil shows very significant hypoglycaemic effect
Artocarpus heterophyllus 43	Moraceae	Leaf	Significant reduction in the F.B.S. conc. and a significant improvement in glucose tolerance in normoglycemic rats,
Beta vulgaris [44]	Amaranthaceae	Rhizome	Reversed the effects of diabetes on blood glucose and tissue lipid peroxidation and glutathione levels.
Biophytum sensitivum [45]	Oxalidaceae	Leaf	Significantly reduce the blood glucose and glycosylated haemoglobin level
Barleria lupulina [46]	Acanthaceae	Aerial part	Reduction of blood glucose in streptozotocin hyperglycemic Rats
Bauhinia candicans [47]	Fabaceae	Leaf	Hypoglycemic activity in alloxan-induced diabetic rabbits

Bauhinia forficata[48-49]	Fabaceae	leaf	Shows hypoglycemic effect Reducing hyperglycemia as well as hyperlipidemia in alloxan- induced diabetic rats
Boerhavia diffusa [50]	Nyctaginaceae	Leaf	Significant reduction in serum and tissue cholesterol, free fatty acids, phospholipids, and triglycerides in alloxan induced diabetic rats.
Berberis aristata [51]	Berberidaceae	Root	Strong potential to regulate glucose homeostasis through decreased gluconeogenesis and oxidative stress.
Begonia malabarica [52]	Begoniaceae	Stem	Reduction in fasting and postprandial plasma glucose levels, increase inSerum insulin levels and liver glycogen levels
Benincasa hispida [53]	Cucurbitaceae	Fruit	Improve the glucose level and metabolic derangements in lipid caused by alloxan induced diabetes in rats
Bougainvillea spectabilis [54]	Nyctaginaceae	Bark	Sugar-lowering capacity streptozotocin induced diabetic albino rats
Brassica juncea [55]	Brassicaceae	Seed	Significant dosage dependent augmenting effect of the seed extract on the serum insulin was recorded on streptozotocin induced diabetic male albino rats.
Brassica oleracea [56]	Brassicaceae	Stem	Hypoglycaemic activity in alloxan induced hyperglycaemic rats
Bryophyllum pinnatum [57]	Crassulaceae	Leaf	Antidiabetic properties in streptozotocin (STZ)-induced diabetes mellitus
Butea monosperma [58]	Fabaceae	Leaf	Significant hypoglycemic and anti-oxidant activity in alloxan induced diabetic male adult mice
Caesalpinia bonducella [59]	Caesalpiniaceae	Seed	Significant recovery in the activities of metabolic enzymes along with correction in FBG and glycogen carbohydrate levels
Calamintha officinalis [60]	Lamiaceae	Aerial part	Hypoglycemic effect independently of insulin secretion in streptozotocin induced diabetic rats
Camellia sinensis [61]	Theaceae	Leaf	Effective to reduce most of the diabetes associated abnormalities in a steptozotocin-induced diabetes model of rats
Carica papaya [62]	Caricaceae	Leaf	Exerted a hypoglycemic and antioxidant effect and also improved the lipid profile in diabetic rats
Catharanthus roseus [63]	Apocynaceae	Leaf	Lowering of plasma glucose and an increase in plasma insulin were observed
Caralluma attenuata [64]	Asclepidaceae	Whole plant	Glucose lowering activity in both diabetic and normal rats
Cyanodon dactylon [65]	Poaceae	Whole plant	Aqueous extract and non-polysaccharide fraction of Cyanodon dactylon shows Antidiabetic activity
Cichorium intybus [66]	Asteraceae	Whole plant	Shows Antidiabetic Effect in STZ-Diabetic Rats
Cassia fistula [67]	Fabaceae	Stem	Reduced serum blood glucose conc., induced favorable changes in body weight, improved transaminase activity.

Citrullus colocynthis [68, 69]	Cucurbitaceae	Root	Significant reduction in blood sugar level, serum creatinine, serum urea and serum protein
		Fruit	Significant reduction in F.B.S.,P.P.B.S. and glycosylated haemoglobin in clinical trial
Carthamus tinctorius [70]	Asteraceae	Flower	Meaningful decrease in FBS, triglyceride, cholesterol, LDL-C and VLDL-C in diabetic rats
Carum carvi [71]	Apiaceae	Seed	Caraway has both antihyperglycemic and hypolipidemic activity
Cinnamomum tamala [72]	Lauraceae	Oil	Significant reduction in blood glucose level liver glycogen content, plasma insulin level and glycosylated hemoglob in streptozotocin induced diabetic rats
Coccinia indica [73]	Cucurbitaceae	Fruit	Reduction of fasting blood sugar alloxan induced diabetic rats.
Costus speciosus [74]	Costaceae	Root	Significantly decreased Plasma glucose level, glycosylated hemoglobin (HbA(1c)), increased plasma insulin & tissue glycogen.
Costus igneus [75]	Costaceae	Leaf	Reduced the fasting and postprandial blood sugar levels, bringing them towards normal, in dexamethasone- induced hyperglycemia in rats.
Cogniauxia podolaena [76]	Cucurbitaceae	Leaf	Hypoglycemic activity in alloxan induced diabetic rats
Cecropia pachystachya [77]	Urticaceae	Leaf	Significant hypoglycemic effect with a blood glucose reduction & antioxidant activity
Coriandrum sativum [78]	Apiaceae	Fruit	Reduced plasma glucose, insulin and IR, TC, LD L-cholesterol in obese-hyperglycemic-hyperlipidemic (OHH) Meriones shawi rats
Clerodendron Infortunatum [79]	Verbenaceae	Leaf	Significantly reduced blood glucose levels SGOT, SGPT, alkaline phosphatase in STZ diabetic rats.
Cucumis trigonus [80]	Cucurbitaceae	Fruit	Significant increase in the body weight, liver glycogen and serum insulin level and decrease in the blood glucose, glycosylated hemoglobin levels.
Curcuma longa [81]	Zingiberaceae	Rhizome	Significantly suppressed an increase in blood glucose level in type 2 diabetic KK-A(y) mice
Cucurbita ficifolia [82]	Cucurbitaceae	Fruit	Hypoglycemic action, improve GSH redox state, increasing glutathione pool
Cyamopsis tetragonoloba [83]	Fabaceae	Bean	Antihyperglycaemic activity in alloxan induced diabetic rats
Datura metel [84]	Solanaceae	Seed	Blood glucose lowering effect in normoglycemic and in alloxan-induced hyperglycemic rats
Dillenia indica [85]	Dilleniaceae	Leaf	Beneficial effect on blood glucose level and enhance serum insulin level
Dalbergia sissoo [86]	Fabaceae	Bark	Significant reduction in blood glucose levels increase in glycogen content in liver of Alloxan-induced diabetic rats

Desmodium gangeticum [87]	Fabaceae	aerial parts	Significant reduction in blood glucose & increase in insulin secretion from MIN6 cells grown as monolayers and as pseudo islets, indicating the antidiabetic activity
Diospyros peregrina [88]	Ebenaceae	Fruit	Possess significant dose dependent hypoglycemic and hypolipidemic activity
Dioscorea alata [89]	Dioscoriaceae	Tuber	Blood glucose level was reduced significantly and Serum lipid levels, total protein, albumin, and creatinine were reversed toward near normal
Dioscorea bulbifera [90]	Dioscoriaceae	Bulb	Showed α-amylase inhibitory activity
Emblica officinalis [91]	Euphorbiaceae	Leaf	Showed a significant decrease in fasting blood glucose and increase insulin level as compared with the diabetic rats
Enicostemma littorale [92]	Gentianaceae	Whole plant	Significant decrease in serum glucose and triglycerides
Equisetum myriochaetum [93]	Equisetaceae	Aerial part	Showed Hypoglycemic activity
Eugenia jambolana [94]	Myrtaceae	Seed	Showed dose-dependent decrease in blood glucose level in diabetic rats
Eugenia uniflora [95]	Myrtaceae	Leaf	Inhibitory activities on increase plasma glucose level in sucrose tolerance test
Eucalyptus globulus [96]	Myrtaceae	Leaf	Reduces the oxidative stress in alloxan-induced rat
Ficus glomerata [97]	Moraceae	Leaf	Shows hypoglycaemic Activity in alloxan Induced Diabetic Rats
Ficus bengalensis [98]	Moraceae	Aerial root	Hypoglycemic effect in normoglycemic and antidiabetic effect in sub- and mild-diabetic models
Ficus religiosa [99]	Moraceae	Bark	Significant reduction in blood glucose levels glucose- loaded hyperglycemic and streptozotocin (STZ)-induced diabetic rats.
Ficus racemosa [100]	Moraceae	Bark	Glucose lowering efficacy in alloxan induced diabetic rats
Ficus hispida[101]	Moraceae	Bark	Hypoglycemic activity in normal and diabetic rats
Ganoderma lucidum [102]	Ganodermataceae	Fruiting bodies.	Body weights and serum insulin levels of the Gl-PS treated groups are significantly higher whereas FBG levels significantly are lower.
Ginkgo biloba [103]	Ginkoaceae	Root	Antihyperglycaemic, antioxidant & antihyperlipidemia activities in STZ-induced chronic diabetic rats

Garuga pinnata [104]	Burseraceae	Bark	Significant increase in the liver glycogen and serum insulin level and a significant decrease in fasting blood glucose and glycated hemoglobin levels
Gymnema sylvestre [105]	Asclepiadaceae	Leaf	Significant reduction in fasting blood glucose, cholesterol and serum triglyceride content
Helicteres isora [106, 107]	Sterculiaceae	Fruit	Exhibit significant antioxidant activity and moderate antidiabetic activity
		Root	Hypoglycemic activity
Hemidesmus indicus [108]	Asclepiadaceae	Root	Decrease blood glucose level significantly and restored serum electrolytes, glycolytic enzymes and hepatic cytochrome P-450-dependent enzyme systems
Indigofera tinctoria [109]	Fabaceae	Leaf	Significant decrease in blood glucose level of rabbits as estimated by Folin-Wu Method.
Ipomoea aquatic [110]	Convolvaceae	Leaf	Reduces the fasting blood sugar level of streptozotocin induced diabetic rats
Inula racemosa [111]	Asteraceae	Root	Significant decrease in blood glucose levels,super oxide dismutase and glutathione
Juglans regia [112]	Juglandaceae	Leaf	Significant reduction of glucose, HbA1c, total cholesterol and serum triglycerides
Jatropha curcas [113]	Euphorbiaceae	Leaf	Significant reduction in blood glucose level in alloxan induced diabetic rats.
Kigelia pinnata [114]	Bignoniaceae	Flower	Significantly reduced blood glucose, serum cholesterol and triglycerides levels
Leucas lavandulaefolia [115]	Lamiaceae	Whole plant	Significant and consistent hypoglycemic effects in Alloxan induced hyperglycemic rats
Loranthus micranthus [116]	Loranthaceae	Leaf	Hypoglycemic and antihyperglycaemic activity
Luffa acutangula [117]	Cucurbitaceae	Seed	Significantly reduced fasting blood sugar of diabetic rats in a dose-related manner, with Streptozotocin maximum hypoglycemic effect at/after 21 days
Luffa cylindrical [118]	Cucurbitaceae	Fruit	Shows promising antidiabetic activity in alloxan-induced diabetic Wistar rats.
Malmea depressa [119]	Annonaceae	Root	Hypoglycemic effect in streptozotocin diabetic rats
Mangifera indica [120]	Anacardiaceae	Leaf Kernel	Significantly increased insulin level at the dose level of 100, 200 mg/kg in alloxan induced diabetic rats.
Momordica charantia [121]	Cucurbitaceae	Fruit	Isolated compounds, bitter gourd extract, juices and powders have demonstrated potential in lowering blood sugar
Merremia emarginata [122]	Convulvulaceae	Whole plant	Carbohydrate metabolizing enzymes such as hexokinase were significantly increased whereas G-6-P, fructose-1, 6-bisphosphatase were significantly decreased in diabetic rats.

Morinda citrifolia [123]	Rubiaceae	Fruit	Gluconeogenic genes, phosphoenolpyruvate C kinase (PEPCK) and glucose-6-phosphatase (G6P), were significantly inhibited
Morus alba [124]	Moraceae	Root bark	Hypoglycemic effect in streptozotocin-induced diabetic rats
Moringa oleifera [125]	Moringaceae	Leaf	FBG and PPG levels were reduced whereas, total protein, body weight and haemoglobin were increased
Murraya koenigii [126]	Rutaceae	Leaf	Increases plasma insulin level in alloxan-induced diabetic rats
Merremia tridentate [127]	Convulvulaceae	Root	Significant increase in serum insulin, body weight and glycogen content in liver and skeletal muscle of STZ-induced diabetic rats
Musa sapientum [128]	Musaceae	Flower	Antihyperglycaemic activity in alloxan diabetic rats
Mucuna pruriens [129]	Fabaceae	Seed	Hypoglycemic activity in STZ induced diabetic rats.
Ocimum sanctum [130,131]	Labiatae	Leaf	Restored the depressed hepatic glycogen levels possibly by increasing the level of insulin
		Aerial part	Found potent ant diabetic by ameliorating glucose and lipid parameters
Origanum vulgare [132]	Lamiaceae	Leaf	Antihyperglycemic activity in STZ diabetic rats without affecting insulin secretion
Otostegia persica [133]	Labiateae	Whole plant	Shows ant diabetic effects on STZ diabetic rats.
Paspalum scrobiculatum [134]	Poaceae	Grain	Significant increase in serum insulin level, liver glycogen and a significant decrease in glycated haemoglobin levels
Phoenix dactylifera [135]	Arecaceae	Leaf	Significantly reduced blood glucose &Plasma insulin level increased in alloxan-induced diabetic rats
Plectranthus amboinicus [136]	Lamiaceae	Leaf	Significant reduction in blood glucose, possesses hypoglycemic and antihyperlipidemic effects mediated through the restoration of the functions of pancreatic and insulinotropic effect.tissues
Pterocarpus santalinus [137]	Fabaceae	Bark	Significant antidiabetic activity by reducing the elevated blood glucose levels and glycosylated hemoglobin, improving hyperlipidemia and restoring the insulin levels in treated experimental induced diabetic rats
Punica granatum [138, 139]	Punicaceae	Rind	Showed significant and dose dependent antidiabetic activity by maintaining the blood glucose levels within the normal limits.
Phyllanthus niruri [140]	Euphorbiaceae	Leaf	Significant increase in glycogen content in the liver, cardiac, and skeletal muscle and reduced intestinal glucose absorption.
Pandanus fascicularis [141]	Pandanaceae	Leaf	Reduces the levels of plasma glucose
		Arieal root	Significant dose-dependent reduction in serum glucose in both normoglycemic and hyperglycemic rats and also improved glucose tolerance test

Psidium guajava [142]	Myrtaceae	Leaf	Increase the plasma insulin level and glucose utilization in diabetic rats
Pterocarpus marsupium [143]	Fabaceae	Bark	Exhibits significant antidiabetic activity and corrects the metabolic alterations in diabetic rats and this activity may resemble insulin-like properties.
Potentilla fulgens [144]	Rosaceae	Root	Hypoglycemic activity in alloxan-induced diabetic mice
Pongamia pinnata [145]	Fabaceae	Leaf	Decreased the blood glucose level in alloxan-induced diabetic albino rats
Panax ginseng [146]	Araliaceae	Root, Berry	Antidiabetic and antihyperglycemic activity
Retama raetam [147]	Fabaceae	Flower	Hypoglycaemic activity in normal and diabetic rats
Rehmannia glutinosa [148]	Scrophulariaceae	Root	Hypoglycemic activity in glucose-induced hyperglycemic and alloxan-induced diabetc rats
Rubus fructicosis [149]	Rosaceae	Leaf	Hypoglycemic activity in streptozotocin diabetic rats
Salacia Oblonga [150]	Celastaceae	Root	Serum insulin was significantly increased & Plasma HbA1c was significantly decreased
Salmalia malabarica [151]	Bombacaceae	Sepal	A significant reduction of FBG level in STZ-induced Diabetic rat.
Salvia officinalis [152]	Lamiaceae	Leaf	Hypoglycaemic effect on streptozotocin-induced hyperglycaemic rats
Sclerocarya birea [153]	Anacardiaceae	Stem, bark	Hypoglycemic activity in normal and in alloxan induced diabetic rats
Santalum album [154]	Santalaceae	Heart wood	Santalum album pet ether fraction has potential antihyperlipidemic activity that can help in overcoming insulin resistance
Scoparia dulcis [155]	Scrophulariaceae	Whole plant	Significant increase in plasma insulin levels, evoked two-fold stimulation of insulin secretion from isolated islets, indicating its insulin secretagogue activity
Sida tiagii [156]	Malvaceae	Fruit	Significant improvement in blood glucose level, glycated hemoglobin and liver glycogen contents
Silybum marianum [157]	Asteraceae	Aerial part	Hypoglycemic and antihyperglycemic activity in normal and STZ diabetic rats without affecting insulin secretion
Sizygium cumini [158]	Myrtaceae	Bark	Significantly decreased the blood glucose, effect exerted by the extract was greater than that of glibenclamide.
Syzygium cordatum [159]	Myrtaceae	Leaf	Short-term hypoglycaemic effect in streptozotocin-induced diabetic rats
Stereospermum suaveolens [160]	Bignoniaceae	Bark	Significantly reduced the fasting blood glucose and pancreatic TBARS level and significantly increased the liver glycogen
Stevia rebaudiana [161]	Asteraceae	Leaf	Significant decrease in the blood glucose level, without producing condition of hypoglycemia

Swietenia macrophylla [162]	Meliaceae	Seed	Significantly reduced blood glucose levels after 45 days of treatment in STZ-diabetic rats.
Symplocos cochinchinensis [163]	Symplocaceae	Leaf	Significant reduction in plasma insulin, plasma and hepatic total cholesterol and a significant increase in liver glycogen were observed in treated diabetic rats.
Tamarindus indica [164]	Fabaceae	Seed	Antidiabetic activity in streptozotocin induced diabetic rats
Terminalia arjuna [165]	Combretaceae	Leaf	Demonstrated remarkable antihyperglycemic activity in STZ- induced diabetic rats
Terminalia belerica [166]	Combretaceae	Fruit	Lower the serum glucose level in alloxan diabetic rats
Terminalia chebula [167]	Combretaceae	Fruit	Significantly reduced the elevated blood glucose and elevated glycosylated hemoglobin
Toddalia asiatica [168]	Rutaceae	Leaf	Significant decrease in blood glucose, plasma enzymes(SGOT, SGPT and ALP) and significant increase in body weight, total protein, serum insulin and liver glycogen levels in treated diabetic rats
Terminalia paniculata [169]	Combretaceae	Bark	Significantly reduced elevated blood glucose, HbA1c, creatinine, urea, SGPT and SGOT levels
Tetrapleura tetraptera [170]	Fabaceae	Fruit	Hypoglycemic activity
Tectona grandis [171]	Lamiaceae	Flower	Shows antidiabetic activity in STZ induced diabetic rats
Tinospora cardifolia [172]	Meninspermaceae	Stem	prevented the rise in glucose levels by 21.3%, insulin by51.5%, triglycerides by 54.12% and glucose-insulin index by 59.8% of the fructose fed rats
Trigonella Foenumgraecum [173]	Meninspermaceae	Seed powder	Reversed the hyperglycemia induced changes to normal levels in diabetic rat brain.
Tridax procumbens [174]	Asteraceae	Leaf	Shows antidiabetic activity
Vernonia colorata [175]	Composeae	Leaf	Antidiabetic activity in normoglycaemic and alloxan-induced diabetic rats
Vinca rosea [176]	Apocyanaceae	Whole plant	Shows antidiabetic activity in Alloxan diabetic rats.
Viscum album [177]	Viscaceae	Leaf, stem	Shows anti-diabetic and anti-hyperlipidemic effects in STZ- diabetic rats
Withania coagulans [178]	Solanaceae	Fruit	Activities of glucokinase and phosphofructokinase were significantly increased ,whereas glucose-6- phosphatase activity was significantly decreased
Withania somnifera [179]	Solanaceae	Root, Leaf	Possess hypoglycaemic and hypolipidaemic activities in alloxan-induced diabetes mellitus (DM) rats.
Woodfordia fruticosa [180]	Lythracea	Flower	Possess hypoglycaemic activity in alloxan-induced diabetes mellitus (DM) mice

Zingiber officinale [181]	Zingiberaceae	Rhizome	Reduced fasting blood glucose, increased serum insulin level and also enhanced insulin sensitivity in alloxan- induced diabetic and insulin resistant diabetic rats
Zizyphus spina-christi [182]	Rhamnaceae	Leaf	Antidiabetic activity
Zizyphus jujube [183]	Rhamnaceae	Leaf	Significantly reduced fasting serum glucose level and increase serum insulin level

CONCLUSION: This review discussed medicinal plant species from India and showed that they have anti-diabetic activity. In addition, many of these species have a phenolic content, phytosterols, saponins and flavonoids. However, an overall ranking of the anti-diabetic strength of these species cannot be determined because of the different experimental methods used in various studies. We have focused on plants belonging to several different families to understand their therapeutic use and their potential anti-diabetic activities. It requires biological testing of plant extracts, isolation of bioactive components, as well as toxicological, pharmacodynamical and, ultimately, clinical studies.

Indian medicinal preparations are often considered being effective due to a mixture of active ingredients rather than a single constituent. To make herbal therapies more effective, it is pertinent to isolate anti-diabetic molecules, define their targets for understanding their modes of action, and establish structure and function relationship for better efficacy and pharmacokinetic profile. Prevention of diabetes is our most powerful intervention and successful implementation of these proven strategies should be the focus of our efforts. In future, these efforts will lead to new chemo-types which will be safer and more cost-effective for the rural Indian population suffering from diabetes, whose numbers are increasing linearly.

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