A SYSTEMATIC REVIEW ON NATURAL MEDICINE USED FOR THERAPY OF DIABETES MELLITUS OF SOME INDIAN MEDICINAL PLANTS


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ABSTRACT
Diabetes mellitus is one of the world’s major diseases. It currently affects an estimated 143 million people worldwide and the number is growing rapidly. In the India, about 1-5% population suffer from diabetes or related complication. Plant-based medicinal products have been known since ancient times, and several medicinal plants and their products (active natural principles and crude extracts) have been used to control diabetes in the traditional medicinal systems of many cultures worldwide. Several medicinal plants have found potential use as hypoglycemic in the Indian system of medicines. Several oral hypoglycaemic agents are the primary forms of treatment for diabetes. However, prominent side-effects of such drugs are the main reason for an increasing number of people seeking alternative therapies that may have less severe or no side-effects. In this review, we represent the profile of plants commonly used in India in the treatment of diabetes, reported in literature. A total of 45,000 plant species have records of a popular use in the treatment of this syndrome in India. The profile presented includes information about scientific name, family, species, methodology used, the degree of hypoglycaemic activity and the active agents. Indian plants which are most effective and the most commonly studied in relation to diabetes and their complications are: Allium cepa, Allium sativum, Aloe vera, Beta vulgaris, Catharanthus roseus, Azadirachta indica, Gymnema sylvestre, Ipomoea batatas, Momordica cymbalaria, Momordica charantia, Ocimum sanctum, Pterocarpus marsupium, Swertia chirayita, Tinospora cordifolia, and Trigonella foenum graecum. All plants have shown varying degree of hypoglycemic and anti-hyperglycemic activity with different mechanism of action.

Keywords: - Diabetes mellitus, Hypoglycemic, Family, Anti-hyperglycemic

INTRODUCTION
Diabetes mellitus is a metabolic disorder in the endocrine system & metabolic disorder causing hyperglycemia. Diabetes affects about 5% of the global population[^1] and management of diabetes without any side effects is still a challenge to the medical
In India, the prevalence rate of diabetes is estimated to be 1-5%. Diabetes is becoming the third “killer” of the health of mankind along with cancer, cardiovascular and cerebrovascular diseases because of its high prevalence, morbidity and mortality. The cause of diabetes is a mystery, although both genetic and environmental factors such as obesity and lack of exercise appear to play a role. Ethnic and racial differences have been found in heterogeneous populations within the same area. As a rule, incidence is highest in Scandinavian countries, intermediate in the US, Spain, and Israel, and lowest in Asian and most Latin American countries. Most researchers believe that, in the presence of a genetic predisposition, something in the environment triggers the development of diabetes. With a long course and serious complications often resulting in high death rate, the treatment of this disorder takes three main forms: (I) Diet and exercise (II) Insulin replacement therapy and (III) the use of oral hypoglycemic agents. Currently available synthetic antidiabetic agents like sulfonyl ureas, biguanides, a glucosidase inhibitors etc besides being expensive produce serious side effects. Further their use is not safe during pregnancy. Apart from currently available therapy, herbal medicines recommended for treatment of diabetes throughout the world. Herbal drugs are prescribed widely because of their effectiveness, less side effects and relatively low cost.

Thus due to an increase in demand by patients to use natural products with antidiabetic activity, investigations on hypoglycemic agents derived from medicinal plants have gained popularity in recent years. Laboratories are conducting research on these medicinal plants in a scientific manner for the development of alternative drugs and strategies for better management of diabetes. The main aim of present review is to collate the all available data on Indian medicinal plants with hypoglycemic effect reported in literature which may be useful to researcher as well as practitioners. This list is best used only as a preliminary screening of potential antidiabetic plants, not as a definitive or complete list of hypoglycemic plants.

**Mechanism involve in treatment of diabetes**

The present treatment of diabetes is focused on controlling and lowering blood glucose to a normal level. The mechanisms of medicines and the Medicines to lower blood glucose are:

- To stimulate cell of pancreatic islet to release insulin;
To resist the hormones which rise blood glucose;
To increase the number or rise the appetency and sensitivity of insulin receptor site to insulin;
To decrease the leading-out of glycogen;
To enhance the use of glucose in the tissue and organ;
To clear away free radicals, resist lipid per oxidation and correct the metabolic disorder of lipid and protein;
To improve microcirculation in the body.

Anti-diabetic medicinal plants undoubtedly have significant effect on the lowering of blood sugar but their mechanism of action is yet to be elucidated. The first evidence that the natural products have insulin potentiating activity was reported in 1929 by Glazer and Halpern. There are several mechanisms through which these herbs act to control the glucose level. They are more or less similar actions to the synthetic drugs. The mechanism of action of herbal anti-diabetics could be grouped as:

- Stimulation of insulin secretion (Teucrium polium, Allium sativum, Allium cepa, Panax ginseng)
- Inhibition in renal glucose reabsorption (Fraxinus excelsior)
- Stimulation of glycogenesis and hepatic glycolysis (Momordica charantia)
- Protective effect on the destruction of the beta-cells (Thea sinensis)
- Improvement of digestion and reduction of blood sugar and urea (Aegle marmelos)
- Prevents pathological conversion of starch to glucose (Eugenia jambolina, Pterocarpus marsupium)
- Increasing the use of glucose by tissues and effect on adrenergic receptors (Panax ginseng, Allium sativum, Allium cepa)
- Potentiates the action of exogenously injected insulin
- Cortisol lowering activities (Boerhaavia diffusa, Ocimum sanctum)

Wide range of plant constituents could have different site of action within the body and herbs exert similar mechanism of action like synthetic oral hypoglycemic drugs. Many of these herbs may have a direct or an indirect impact on blood glucose levels, thus interfering with the clinical management of diabetic patients. The above mentioned plants have been considered for possible hypoglycemic actions and some
preliminary investigations have been carried out by the researchers. Scientific studies available on a good number of medicinal plants indicate that promising phytochemicals can be developed for diabetes too. However, there are numerous other plants which are mentioned in the indigenous systems of health care but still await scientific inquiry. There are many grey areas, which need substantial amount of work in the case of herbal antidiabetics. For a given dose of herbal medicine, its physiological effect will be governed by the effective tissue concentration of the remedy, which in turn is determined by pharmacokinetic parameters, absorption, distribution, metabolism and excretion of its various components. Only knowledge of herbal pharmacokinetics can provide valuable information to practitioners in prescribing herbs safely and effectively. Much more work should be done in this direction to make the herbs useful. [4]

Indian medicinal plants with hypoglycemic activity

India has an officially recorded list of 45,000 plant species and a various estimation of 7500 species of medicinal importance [5]. 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 reported in numerous scientific journals. This article highlight on the chemo profiles from Indian biosphere for treating diabetes with major thrust on the dosage and possible mode of action of the herbal hypoglycemic so far reported. Various Indian medicinal plants of different families having potent hypoglycemic activity are described in the following section.

Acanthaceae

Andrographis paniculata

Oral administration of Andrographis paniculata and andrographolide in normal and streptozotocin induced diabetic rat shows promising antihyperglycemic activity. The hypoglycemic action of plants may be due to the prevention of glucose absorption from gut [6,7]. Zhang and Tan shows the antioxidant activity of Andrographis paniculata extract in diabetic rats, which may be responsible for beneficial effect in the diabetic state [8].

Anacardiaceae

Mangifera indica
The antidiabetic activity of *Mangifera indica* L. (Mango) was seen when an extract of the leaves of *M. indica* was given to rats 60 min before the glucose. The hypoglycaemic effect of the aqueous extract was compared with that of an oral dose of chlorpropamide (200 mg/kg). The hypoglycaemic action of this plant may be due to a reduction in the intestinal absorption of glucose [9]. However, possibility of other mechanism can not be excluded. *Mangifera indica* has also been shown to exert powerful anti-oxidant activity in vitro [10].

**Annonaceae**

*Annona squamosa*


**Apocynaceae**

*Catharanthus roseus*

Oral administration of water-soluble fraction of ethanolic extract of *Vinca rosea* leaves (100, 250, 500 and 1000 mg/kg) showed significant dose-dependent reduction in blood sugar at 4 h by 26.22, 31.39, 35.57 and 33.37%, respectively, in normal rats. In addition, oral administration of 500 mg/kg 3.5 h before OGTT (10 gm/kg) and 72 h after STZ administration (50 mg/kg IP) in rats showed significant anti-hyperglycemic effects. No gross behavioral changes and toxic effect were observed up to 4 gm/kg IP [13].

**Areceaceae**

*Cocos nucifera*

The hypoglycaemic effect of neutral detergent fiber from *Cocos nucifera* L. (coconut) was tested in rats fed 5%, 15% and 30% glucose. Increase in fiber intake caused a significant lowering in glycaemia and serum insulin. Moreover, it increases the fecal excretion of Cu, Cr, Mn, Mg, Zn and Ca. The results suggest the beneficial effect of inclusion of coconut fiber in the diet [14].

*Areca catechu*
Subcutaneous administration of alkaloid fraction of *Areca catechu* (0.05_/0.5 mg/kg) in alloxanized rabbits (140 mg/kg) showed significant hypoglycemic effect lasting for 4_/6 h\[^{15}\].

Asclepiadaceae

Gymnema sylvestre

GS4 (400 mg/kg) extracted from leaves of *Gymnema sylvestre* R. Br., was administered to type II diabetic patients for 18-20 months as a supplement to the conventional oral drugs. During GS4 supplementation, the patients showed a significant reduction in blood glucose, glycosylated haemoglobin and glycosylated plasma proteins, and conventional drug dosage could be decreased. Five of the 22 diabetic patients were able to discontinue their conventional drugs and maintain their blood glucose homeostasis with GS4 alone. These data suggested that pancreatic beta cells may be regenerated and/or repaired in type II diabetic patients on GS4 supplementation. This is supported by the appearance of raised insulin levels in the serum of patients after GS4 supplementation.\[^{35}\] Furthermore, GS4 was administered (400 mg/day) to 27 patients with insulin-dependent diabetes mellitus (type I). GS4 therapy appears to enhance endogenous insulin release, possibly by regeneration/revitalisation of the residual beta cells\[^{16}\].

Water soluble fraction of an alcoholic extract of *G. sylvestre* leaves on glycogen content of isolated rat hemidiaphragm was studied in normal and glucose fed hyperglycaemic rats. In glucose fed rats, the leaf extract lowered the glycogen content of the tissue and this effect was amplified by insulin\[^{17}\].

Bombacaceae

Bombax ceiba

In Sprague-Dawley rats, a dose of 500 mg/kg of Shamimin (a C-flavonol glucoside from *Bombax ceiba*) produced a significant reduction in glycaemia\[^{18}\].

Brassicaceae

Brassica juncea

This study demonstrated the effect of *Brassica juncea* Coss (Leaf Mustard) on carbohydrate metabolism in rats. It showed significant hypoglycaemic action. There was increased activity of glycogen synthetase, and a decrease in glycogenolysis and
gluconeogenesis demonstrated by a decreased activity of glycogen phosphorylase and gluconeogenic enzymes \[^{[19]}\].

Celastaceae

Salacia reticulata

Oral administration of aqueous decoction (1 ml/rat/day) of Salacia reticulata root bark to over night fasted rats caused 30% reduction in glucose levels at 3 h \[^{[20]}\]. Potent natural a-glycosidase inhibitors such as kotalanol and salacinol isolated from the roots and stems of the plant exert potent inhibitory activity against sucrase \[^{[21]}\].

Salacia oblonga

Aqueous extract of the root bark of Salacia oblonga has shown hypoglycemic activity \[^{[20]}\]. Two biologically active fractions from the petroleum ether extract of the root bark has been shown to exert hypoglycemic effect of about 60 and 76% potency of an equal dose of tolbutamide (250 mg/kg) in albino rats \[^{[22]}\]. Petroleum ether extract of the bark of the root has been shown to prevent STZ (65 mg/kg) induced hyperglycemia and hypoinsulinemia in rats. The aqueous-methanolic extract of the roots inhibited increase in serum glucose level in sucrose and maltose loaded rats. The water-soluble and ethyl acetate soluble portions of the same extract showed inhibitory activities on alpha-glucosidase and aldose reductase. Further, salacinol and kotalanol with nine other sugar related component were isolated from the water soluble portion while, a new triterpene, kotalagenin 16-acetate along with known diterpene and triterpenes isolated from the ethyl acetate portion were found to be responsible component for the inhibitory activity on aldolase reductase \[^{[23]}\]. In addition, the extract has shown significant anti-oxidant activity \[^{[24]}\].

Chenopodiaceae

Beta vulgaris

Administration of extracts obtained from Beta vulgaris var. Cicla L. (Leaf beet); (Sugar beet) inhibited the increase in the nonenzymatic glycosylation of skin proteins and blood glucose. These results demonstrated the ability of this plant in preventing or at least retarding the development of some diabetic complications \[^{[25]}\]. Betavulgarosides I, II, III, IV oleanolic acid oligoglycosides were isolated together with betavulgarosides VI, VII, VIII from the roots of B. vulgaris. Betavulgarosides II, III and IV produced
hypoglycaemic effects that were demonstrated by an oral glucose tolerance test in rats [26].

**Compositae**

*Artemisia pallens*

Oral administration of an extract of the aerial parts of *Artemisia pallens* Wall. produced a dose-dependent reduction in glycaemia in alloxan-induced diabetic rats. In fasted healthy rats, the extract caused moderate hypoglycaemia at a higher dose. Only the methanol extract was active whereas the water extract was inactive. Authors hypothesized that the plant extract increased peripheral glucose utilization or inhibited glucose reabsorption in the proximal tubules [27].

**Convolvulaceae**

*Ipomea batatas*

Oral administration of *Ipomea batatas* L. (white skinned sweet potato) produced a reduction in hyperinsulinemia in Zucker fatty rats by 23%, 26%, 60% and 50%, 3, 4, 6 and 8 weeks after treatment respectively. These results were comparable to that of troglitazone, an insulin sensitizer. After 7 weeks of treatment, increase in glycaemia after glucose load was inhibited by the administration of *I. batatas*. Moreover, it normalized lipid metabolism and produced a regranulation of pancreatic islet B-cells after 8 weeks of treatment [28].

**Cucurbitaceae**

*Citrullus colocynthis*

Aqueous extract of *Citrullus colocynthis* fruit showed dose-dependent increase in insulin release from isolated islets. Oral administration of aqueous extract (300 mg/kg) in normal rabbits significantly reduced plasma glucose after 1 h and highly significant reduction after 2, 3 and 6 h. Glycosidic extract (50 mg/kg) was more effective in lowering fasting glucose as compared to alkaloidal extract. Graded doses (10, 15 and 20 mg/kg) of saponin also reduced plasma glucose concentration in alloxanized rabbits. Thus, saponins and glycosidic components levels of the rind of *Citrullus colocynthis* are responsible for its hypoglycemic effect [29].
Coccina indica

The leaves of Coccina indica Wight & Am. (Ivy Gourd) were extracted with 95 % ethanol. The residue obtained after evaporation of the solvents was suspended in distilled water. Oral administration of this extract produced a decrease in glycaemia in normal-fed (21 %) and 48 h fasted rats (24 %). This effect was due in part to the inhibition of the key gluconeogenic enzyme glucose-6-phosphatase \(^{[30]}\). Furthermore, the oral administration of the pectin isolated from the fruit of the C. indica at a dose of 200 mg/100 g BW/day produced a reduction in glycaemia and an increase in liver glycogen. Glycogen synthetase activity was significantly increased. Incorporation of labeled glucose into hepatic glycogen was also found to be higher. A significant reduction in phosphorylase activity was noted in the pectin-administered groups \(^{[31]}\).

Momordica charantia

In healthy mice, an aqueous extract obtained from Momordica charantia L. (Karela); (Balsam Pear) attenuated the glycemic response to both oral and intraperitoneal glucose, without altering the insulin response. This aqueous extract and the residue after alkaline chloroform extraction reduced hyperglycemia in diabetic mice after 1 h. It was concluded that the hypoglycaemia activity activity of orally administered Karela extracts was independent of intestinal glucose absorption and involved an extrapancreatic effect.\(^{10}\) The alcoholic extract of the pulp (500 mg/kg), administered to healthy glucose primed rats depressed plasma glucose levels at 1 h. Tolbutamide (100 mg/kg), under similar conditions, produced the same effect. This reduction in plasma glucose levels was not accompanied by increased insulin secretion. In streptozotocin-induced diabetic rats, it improved the oral glucose tolerance causing significant reduction in plasma glucose. The M. charantia extract caused a 4-5 fold increase in the rate of glycogen synthesis from U-14C glucose in the livers of normally fed rats. These data suggest that the mechanism of action of this plant could partly be attributed to increased glucose utilization by the liver rather than an insulin secretion effect \(^{[32]}\). Another study showed the effects of oral feeding of M. charantia fruit juice on the hepatic cytochrome P450 and glutathione S-transferase drug-metabolizing enzymes in streptozotocin-induced diabetic rats. The results obtained suggest that the changes in hepatic phase I and phase II drug-metabolizing enzyme activities in the diabetic animals may be associated with altered expression of
different cytochrome P450 and glutathione S-transferase isozymes. In addition, *M. charantia* did not always reverse the effects on drug metabolizing enzymes in streptozotocin-induced diabetes \[^{33}\]. The activity of the juice of *M. charantia* fruit was tested on streptozotocin(STZ)-treated RIN cells and isolated islets *in vitro*. Feeding the juice of *M. charantia* fruit produced a reduction in hyperglycaemia in STZ-induced diabetic mice. It strongly reduced the STZ-induced lipid peroxidation in the pancreas of mice, RIN and islet cells. Moreover, it reduced the STZ-induced apoptosis in RIN cells \[^{34}\].

**Momordica cymbalaria**

Treatment over 15 days with *Momordica cymbalaria* Hook fruit powder produced a significant blood glucose lowering effect in alloxan-induced diabetic rats, but not in normoglycaemic rats. Moreover, the fruit powder reduced the level of cholesterol and triglycerides in diabetic rats \[^{35}\].

**Euphorbiaceae**

**Phyllanthus amarus**

Ten human subjects were treated with a preparation of the whole plant, *Phyllanthus amarus* Shum. & Thon., for ten days (9 subjects were hypertensive and four were diabetic). Glycaemia was reduced in the treated group. In a clinical observation, oral administration of a preparation of the whole plant of *P. amarus* (syn. *Phyllanthus niruri*) (5 gm/day in divided doses) for 10 days to 9 mild hypertensives (4 with DM) reduces blood glucose (5-50 mg) in diabetic as well as non-diabetic subjects along with significant reduction in systolic blood pressure. No harmful side effects were noted in this study \[^{36}\].

**Fabaceae**

**Cajanus cajan**

Single doses of unroasted seeds of *Cajanus cajan* Millsp. (Pigeon pea) (60 % and 80 %) caused a significant reduction in serum glucose levels 1-3 h after oral administration to healthy and alloxanized mice. In contrast, roasted seeds caused a significant increase in serum glucose levels during the 3 h experimental period. The authors concluded that roasting of seeds at high temperature for 30 min resulted in the
total loss of the hypoglycaemic component but not the hyperglycaemic principle present in the seeds \[37\].

**Securigera securidacea**

A new cardenolate (-)-14-methoxyhyrcanoside was isolated from an aqueous extract of the seeds of *Securigera securidacea* L together with five new dihydrobenzofuran derivatives (securigran I to V). Kaempferol and astragalin were also isolated from the aqueous extract of the flowers of the plant. The total aqueous extract of these seeds was hypoglycaemic \[38\].

**Mucuna pruriens**

Feeding of *Mucuna pruriens* seed diet (96.5 gm seed powder per 100 gm of the total constituents) for 1 week to normal albino rat showed 39 and 61% reduction in fasting blood glucose and cholesterol level, respectively \[39\]. Administration of powdered seeds (0.5, 1 and 2 g/kg) significantly decreased the blood glucose levels of normal rabbits while 1 and 2 g/kg caused a significant fall in alloxandiabetic rabbits. Hypoglycemic principles of *M. pruriens* seeds may be both organic and mineral, which seem to act indirectly by stimulating the release of insulin and/or by a direct insulin-like action \[40\].

**Flacourtiaceae**

**Casearia esculenta**

Antihyperglycaemic activity of *Casearia esculenta* Roxb. root extract (300 mg/kg p.o.) in normal and streptozotocin-induced diabetic rats for 45 days showed blood glucose lowering activity of aqueous extracts in normal and glucose loaded rats along with reduction in the increased plasma thiobarbituric acid reactive substance and blood urea. There was decrease in the activities of glucose-6-phosphatase and fructose-1,6-bishophatase and an increase in the activity of liver hexokinase, resulting in potent hypoglycemic activity. It showed the significant antioxidant activity of aqueous extract in STZ diabetic rats at doses of 200 and 300 mg/kg for 45 days \[41\].

**Gentianaceae**

**Swertia chirayita**

The effect of swerchirin isolated from hexane fraction of *S. chirayita* on blood sugar levels of healthy and streptozotocin-treated rats was studied. Swerchirin (50 mg/kg,
p.o.) suspended in gum acacia was fed through cannula to healthy and diabetic rats. Blood glucose levels measured at 0, 1, 3 and 7 h after treatment showed a very significant glucose lowering effect of this plant in healthy and mildly diabetic rats \(^{[42]}\). Single oral administration of the crude/impure swerchirin (SWI) isolated from the hexane fraction of \textit{S. chirayita} (50 mg/kg) to fed CF rats induced an approximately 60 % fall in blood glucose by 7 h post-treatment. This was associated with marked depletion of aldehyde-fuc stained beta-granules and immunostained insulin in the pancreatic islets. \textit{In vitro}, glucose uptake and glycogen synthesis by muscle (diaphragm) was enhanced by the serum of SWI-treated rats. At 100, 10 and 1 \(\mu\)M final concentrations, SWI greatly enhanced glucose (16.7 mM)-stimulated insulin release from isolated islets. It is therefore concluded that SWI lowers glycaemia by stimulating insulin release from the islets of Langerhans \(^{[43]}\).

\textbf{Enicostemma littorale}

Whole plant aqueous extract of \textit{Enicostemma littorale} Blume in alloxan induced diabetic rats along with reduction of glycosylated hemoglobin and glucose-6-phosphatase activity in liver \(^{[44]}\). It also shows glucose lowering activity of aqueous extract (2 g/kg p.o.) daily for 6 weeks in neonatal non insulin-dependent diabetes mellitus (NIDDM) rats along with a decrease in the elevated cholesterol, triglyceride and creatinine levels \(^{[45]}\).

\textbf{Gramineae}

\textit{Hordeum vulgare}

In humans the postprandial glycaemic response of \textit{Hordeum vulgare} L. (Barley) was studied in a pool of 18 healthy volunteers and 14 patients having non-insulindependent diabetes mellitus (type II). The glycaemic response to barley was significantly lower than that to white bread in both groups of subjects. However, the insulinemic response to barley was significantly lower than that to white bread in healthy subjects only. In type II diabetic subjects, there was a tendency for the response to barley to be higher than that to white bread 0.5 h after ingestion. Barley, with a low glycaemic index (105.2), seems to mobilize insulin in NIDDM subjects. This makes it an especially suitable cereal for diabetic patients \(^{[46]}\).

\textbf{Lamiaceae}
Ocimum sanctum

Oral administration of an alcoholic extract of leaves of Ocimum sanctum Linn. (Tulasi) reduced glycaemia in normoglycaemic, glucose-fed hyperglycaemic and streptozotocin-induced diabetic rats. Furthermore, the extract potentiated the action of exogenous insulin in healthy rats. The activity of the extract was 91% and 70% that of tolbutamide in healthy and diabetic rats, respectively. Reduction in fasting blood glucose was obtained after one month of treatment of healthy and diabetic rats with Ocimum sanctum leaf powder [47]. Treatment with Ocimum sanctum and Ocimum album Roxb. (Holy basil) leaves showed a significant decrease in fasting and postprandial blood glucose levels compared to treatment with placebo leaves. Fasting blood glucose fell by 21.0 mg/dl, and postprandial blood glucose fell by 15.8 mg/dl. The lower values of glucose represented reductions of 17.6% and 7.3% in the levels of fasting and postprandial blood glucose, respectively. Urine glucose levels showed a similar trend [48].

Salvia lavandifolia

The authors confirmed the hypoglycaemic effect of Salvia lavandifolia Vahl. reported previously and suggested that this hypoglycaemic effect may arise by several mechanisms: a). potentiation of insulin release induced by glucose; b) increased peripheral uptake of glucose; c) decreased intestinal absorption of glucose; d) hyperplasia of the pancreatic islet beta cells [49]. The antidiabetic activity of the extract of S. lavandifolia was investigated in streptozotocin-induced diabetic rats. The extract (10 mg dry residue/kg) induced an increase in the size and number of cells in the islets of Langerhans. There was also an increase in pancreatic insulin content. A significant decrease (>40%) in blood glucose levels was obtained when the extract (10 mg/kg) and glibenclamide (1 mg/kg) were both administered to streptozotocin-induced diabetic rats [50].

Leguminosea

Caesalpinia bonducella

The aqueous and alcoholic extract of Caesalpinia bonducella seeds exhibited significant hypoglycemic and anti-hyperglycemic activities in normal and STZ hyperglycemic rats [51,52]. In healthy rats, both the aqueous and 50% ethanolic extracts of Caesalpinia bonducella Fleming seeds exhibited hypoglycaemic activity as early as 4 h...
after administration at a lower dose of 100 mg/kg. The hypoglycaemia produced by the aqueous extract was of prolonged duration as compared to the ethanolic extract. In diabetic rats, both extracts produced marked antihyperglycaemic effects from day 5 onwards [53].

**Astragalus species**

Oral administration of an extract from *Astragalus species* to normoglycaemic rats produced a persistent hypoglycaemic effect. Moreover, in alloxanised diabetic rats, this extract showed hypoglycaemic effects more potent than that of Daonil [54].

**Trigonella foenum graecum**

*Trigonella foenum graecum* L. (fenugreek) is among twelve herbs mostly used to treat diabetes in Saudi Arabia [55]. In insulin-dependent diabetic patients, the fenugreek diet significantly reduced fasting blood glucose and improved the glucose tolerance test. There was a 54% reduction in the 24 h urinary glucose excretion. The results showed the usefulness of fenugreek seeds in the management of diabetes [56]. Oral administration of *T. foenum graecum* to healthy and alloxan induced diabetic rats (2 and 8 g/kg) produced a significant fall in blood glucose level (BGL) both in the normal as well as in diabetic rats. The hypoglycaemic effect was dose related [57]. On the other hand, the aqueous extract of fenugreek leaf when given to both healthy and alloxan-diabetic rats, produced a significant reduction in BGL. However, an ethanolic extract of fenugreek leaf produced no reduction in BGL in healthy rats but i.p. administration of 0.8 g/kg of the ethanolic leaf extract to diabetic rats produced a significant reduction of BGC [58].

The Soluble Dietary Fibers (SDF) fraction of fenugreek seeds showed no effect on fasting blood glucose levels of non-diabetic or NIDDM (type II) rats. However, when fed simultaneously with glucose, it showed an hypoglycaemic effect in type II diabetic rats. The major constituent of the SDF is galactomannan [59]. More recently, it has been shown that the disrupted free radical metabolism in diabetic animals may be normalized by fenugreek seed supplementation in the diet [60]. Moreover, fenugreek significantly decreased the hyperglycaemic peak and the area under the glucose tolerance curve in hyperglycaemic rabbits [61].
Medicago sativa

Medicago sativa L. (Lucerne, alfalfa) when supplied in the diet (6.25 % by weight) and infusion (1g/400 ml) reduced the level of hyperglycaemia in streptozotocin-induced diabetes [62].

Pterocarpus marsupium

The hypoglycaemic effect was investigated after i. p. administration of marsupsin, pterosupin and pterostilbene (3 important phenolic constituents of heartwood of Pterocarpus marsupium). Marsupsin and pterostilbene significantly lowered the glycaemia of diabetic rats, and the effect was comparable to that of 1,1-dimethylbiguanide (metformin) [63].

Cassia auriculata

Oral administration of aqueous flower extract of Cassia auriculata L. in streptozotocin-induced diabetic rats at different doses for 30 days produced a significant antihyperglycemic activity. [64,65] in addition to pronounced alpha-glucosidase inhibitory actions resulting in a significant and potent lowering of blood glycemic response [66]. The aqueous extract also shows antioxidant activity in the brain of streptozotocin diabetic rats [66,67]. Such activity may be due to suppression of enhanced gluconeogenesis during diabetes and, enhance utilization of glucose through increased glycolysis [64,65].

Acacia arabica

Hypoglycaemic activity of 94% seed diet of Acacia arabica in normal rats orally with no blood sugar lowering activity in alloxanized rats at the same dose level. The plant may acts through release of insulin from pancreatic beta cells, which accounts for the hypoglycemic activity in normal rabbits (2, 3 and 4 mg/kg) administered orally [68,69].

Liliaceae

Allium sativum

S-allyl cysteine sulphoxide (SACS), a sulphur-containing amino acid of Allium sativum L. (Garlic) that is the precursor of allicin and garlic oil, has been found to show significant antidiabetic effects in alloxan diabetic rats. Administration of a dose of 200 mg/kg significantly decreased the concentration of serum lipids, blood glucose and activities of serum enzymes like alkaline phosphatase, acid phosphatase and lactate dehydrogenase and liver glucose-6-phosphatase. It significantly increased liver and
intestinal HMG CoA reductase activity and liver hexokinase activity\textsuperscript{[70].} Oral administration of SACS to alloxan diabetic rats for a month ameliorated the diabetic conditions of treated rats comparable with rats treated with glibenclamide and insulin\textsuperscript{[71].} Treatment of alloxan diabetic rats with SACS ameliorated the diabetic condition almost to the same extent as glibenclamide and insulin. In addition, SACS controlled lipid peroxidation better than the other two drugs. Furthermore, SACS significantly stimulated \textit{in vitro} insulin secretion from beta cells isolated from healthy rats. Hence it can be surmised that the beneficial effects of SACS could be due to both its antioxidant and its secretagogue actions. The former effect is predominant and the latter is only secondary\textsuperscript{[72].}

\textbf{Allium cepa}

Oral administration of \textit{Allium cepa} L. (Onion) S-methyl cysteine sulphone oxide (SMCS) daily at a dose of 200 mg/kg body weight for a period of 45 days to alloxan diabetic rats controlled the blood glucose and lipids in serum and tissues and altered the activities of liver hexokinase, glucose 6-phosphatase and HMG CoA reductase towards normal values. These effects of SMCS were comparable to those of glibenclamide and insulin\textsuperscript{[73].} Oral administration of onion SMCS to alloxan diabetic rats for a month, ameliorated the diabetic condition similar to rats treated with glibenclamide and insulin. The effect of feeding a 15 mg % capsaicin diet or 3 % freeze-dried onion powder containing diet produced a significant reduction in the hyperglycaemic status of diabetic animals. This study revealed that onion feeding improves the metabolic status in diabetes probably because of its hypocholesterolemic as well as its hypoglycaemic effect\textsuperscript{[74].}

\textbf{Aloe barbadensis}

Acute oral administration of an exudate of \textit{Aloe barbadensis} Mill. (Barbados) leaves (500 mg/kg) produced no reduction in blood glucose level whereas its bitter principle (5 mg/kg) administered intraperitoneally produced a significant hypoglycaemic effect that extended over a period of 24 h with maximum hypoglycaemia observed after 8h. In chronic studies, \textit{A. barbadensis} and its bitter principle produced a maximum effect after 5 days. It seems that the hypoglycaemic effect of this plant and its bitter principle may be mediated through stimulating synthesis and/or release of insulin from the beta-cells of the islets of Langerhans\textsuperscript{[75].} Moreover, this plant slightly decreased the area
under glucose tolerance curve compared to control (1.4 %) or tolbutamide (14.3 %) in healthy rabbits [76].

**M alvaceae**

**Hibiscus rosa-sinesis**

Single oral administration of 250-mg/kg ethanol extract of *Hibiscus rosa-sinesis* showed mild but significant hypoglycemia at 120 min in glucose loaded rat. Daily administration of same dose for 7 days showed significant hypoglycemic effect at 30, 90, 120 min after glucose loading in normal rats. The action was similar to tolbutamide and possibly due to insulin release by stimulation of pancreatic beta cells or an increase of the glycogen deposition in liver [77].

**M elastomaceae**

**Memecylon umbellatum**

Oral administration of alcoholic extract of the leaves of *Memecylon umbellatum* (250 mg/kg) caused a significant reduction in the serum glucose levels in normal and alloxanized rats at 30, 60 and 90 min after administration [78].

**M eliaceae**

**Azadirachta indica**

Hydroalcoholic extract of *Azadirachta indica* showed hypoglycemic and anti-hyperglycemic effect in normal, glucose fed and STZ diabetic rats [79]. The plant exerts its pharmacological activity independent of its time of administration i.e. either prior or after alloxan administration [80]. The plant blocks the action of epinephrine on glucose metabolism, thus increasing peripheral glucose utilization [81]. It also increased glucose uptake and glycogen deposition in isolated rat hemidiaphragm [82].

**M enispermaceae**

**Tinospora cordifolia**

Oral administration of 400 mg/kg of aqueous extract of TC for 15 weeks of treatment showed maximum hypoglycemia of 70.37, 48.81 and 0% in mild (plasma sugar 180 mg/dl), moderate (plasma sugar 280 mg/dl) and severe (plasma sugar 400 mg/dl) diabetic rats, respectively. Hypoglycemic effect depended upon the functional status of the pancreatic beta cells [83]. Oral administration of the water extract of *Tinospora cordifolia* root (2.5, 5 and 7.5 mg/kg) caused a significant reduction in blood glucose,
brain lipid level, hepatic glucose-6-phosphatase, serum acid phosphatase, alkaline and lactate dehydrogenase and increase in body weight, total hemoglobin and hepatic hexokinase in alloxanized diabetic rats (150 mg/kg, IP) [84]. Anti-oxidant [85] and hypolipidemic activity is described [86].

**Moraceae**

**Ficus bengalensis**

The oral administration of the extract obtained from *Ficus bengalensis* L. (Banyan) resulted in enhancement of serum insulin levels in normoglycaemic and diabetic rats. The incubation of isolated islets of Langerhans from healthy as well as from diabetic animals with this plant extracts resulted in increased insulin secretion. This extract inhibited insulinase activity from liver and kidney [87]. The antidiabetic effect of a dimethoxy derivative of perlargonidin 3-O-alpha-L rhamnoside (250 mg/kg, single dose study and 100 mg/kg/day, long term study) isolated from the bark of *F. bengalensis* has been compared with that of glibenclamide (2 mg/kg and 0.5 mg/kg/day respectively) in moderately diabetic rats. The single dose glycoside treatment decreased fasting blood glucose by 19 % and improved glucose tolerance by 29 %. After one-month treatment with the plant, the fasting blood glucose level went down to almost half of the pre-treatment levels in both the groups and their glucose tolerance improved by 41 % in the glibenclamide group and by 15 % in the glycoside treated group. Urine sugar decreased to trace amounts in both groups. *In vitro* studies showed that insulin secretion by beta-cells was greater in the presence of the pelargonidin derivative than in the presence of a leucocyanidin derivative, reported to be a good antidiabetic agent [88]. Glycoside of leucopelargonidin isolated from the bark of *F. bengalensis* demonstrated significant hypoglycaemic, hypolipidemic and serum insulin raising effects in moderately diabetic rats with close similarities to the effects of a minimal dose of glibenclamide [89]. Dimethoxy ether of Leucopelargonidin-3-O-alpha-L rhamnoside isolated from the bark of *F. bengalensis* was used at a dose of 100 mg/kg on oral administration. The compound showed significant hypoglycaemic and serum insulin raising actions in healthy and alloxan induced-diabetic dogs during a period of 2h. This compound appears to stimulate insulin secretion [90]. A leucodelphinidin derivative isolated from the bark of *F. bengalensis* L. showed hypoglycaemic action at a dosage of 250 mg/kg when given to
both healthy and alloxan diabetic rats. Its action was similar to that of an effective dose of glibenclamide (2 mg/kg) tested under the same conditions. However, after a glucose load, the plant product was only just significantly active and not as effective as the sulphonylureas. The efficacy of the plant product as an hypoglycaemic agent adds to the other therapeutic effects associated with this class of flavonoids [91].

**Morus alba**

Chronic subcutaneous administration of the extract of the leaves of *Morus alba* to rabbits led to degranulation of beta-cells of the Langerhans islets [92]. Single intra-peritoneal dose of 200 mg/kg of ethanol insoluble fraction of hot water extract of *M. alba* leaves exhibited a potent hypoglycemic activity in fasted and non-fasted STZ (150 mg/kg IV) diabetic mice and the glucose level fell by 24.69/6% and 81.49/7.9%, respectively. Increase in glucose uptake was postulated as the mechanism of hypoglycemic action [93]. Alkaloids of this plant are known to possess glycosidase inhibitory activity [94]. Antioxidant activity has been described previously [95].

**Musaceae**

*Musa sapientum*

Among the plants most used in the treatment of diabetes mellitus *Musa sapientum* Kuntze (Banana) significantly decreased the hyperglycaemic peak and the area under the glucose tolerance curve in hyperglycaemic rabbits [96]. Oral administration of 1.5, 0.2 and 0.25 g/kg body weight of the chloroform extract of the flowers of *M. sapientum* during a 30-day period caused a decrease in blood glucose I and glycosylated haemoglobin levels and an increase in total haemoglobin. The extract showed antihyperglycaemic action and an antioxidant effect. Banana flower was more effective than glibenclamide [97].

**Myrtaceae**

*Eucalyptus globulus*

*Eucalyptus globulus* Labill. (Tasmanian Bleu Gum) when given to streptozotocin-diabetic mice reduced the level of hyperglycaemia [98]. In contrast, it has been found that the decrease in hyperglycaemia caused by *E. globulus* was not significant.41 In another study, it was demonstrated that *E. globulus* possesses an antihyperglycaemic action due to pancreatic and extrapancreatic effects in diabetic mice [99].
Eugenia jambolana

The hypoglycaemic activity of the extract of jamun pulp from the fruit of *Eugenia jambolana* Lam. (Gambol) = *Syzigium cumini* Skeels (Jamum) was seen after 30 min, while the seeds of the same fruit required 24 h to produce the same effect. These results were confirmed in streptozotocin-induced diabetic animals. The oral administration of the extract resulted in the enhancement of insulinemia in normoglycaemic and diabetic rats. The incubation of isolated pancreatic islet cells of normal and diabetic animals with this plant extracts resulted in increased insulin secretion. This extract inhibited insulinase activity from liver and kidney. Oral administration of 2.5 and 5.0 g/kg body weight of the aqueous extract of the seeds of *S. cumini* for six weeks in alloxan-diabetic rats resulted in a significant reduction in blood glucose concentration and an increase in total haemoglobin, but in the case of 7.5 g/kg body weight, the effect was not significant. It also resulted in decreased free radical formation in tissues.

Nyctagenaceae

Boerhavia diffusa

The hypoglycemic activity of aqueous leaf extract of *Boerhavia diffusa* L. at a dose of 100, 200 and 400 mg/kg in alloxan induced diabetic rats. Aqueous leaf extract (200 mg/kg p.o., daily for 4 weeks) in normal and alloxan induced diabetic rats cause increases plasma insulin levels and improves glucose tolerance. The extract showed antihyperglycemic and significant antioxidant activity.

Nymphaeaceae

Nelumbo nucifera

A methanol extract of *Nelumbo nucifera* Gaerth (East Indian Lotus) obtained by soxhlet extraction from finely pulverized rhizomes was used. The extract (300 mg/kg and 600 mg/kg, orally) caused a decrease in glycaemia in streptozotocin-induced diabetic rats by 53% and 55%, respectively at the end of 12 h. Oral administration of the ethanolic extract of rhizomes of *N. nucifera* markedly reduced the glycaemia of healthy, glucose-fed hyperglycaemic and streptozotocin-induced diabetic rats compared to control. The extract improved glucose tolerance and potentiated the action of exogenously injected insulin in normal rats. The extract exhibited activity of 73% and 67% of that of tolbutamide in normal and diabetic rats, respectively.
Oleaceae
Olea europea

Maximum hypoglycaemic activity of *Olea europea* L. olive leaf was obtained from samples collected in the winter months, especially in February. One of the compounds responsible for this activity was oleuropeoside, which showed activity at a dose of 16 mg/kg. This compound also demonstrated antidiabetic activity in animals with alloxaninduced diabetes. The hypoglycaemic activity of this compound may result from two mechanisms: (a) potentiation of glucose-induced insulin release, and (b) increased peripheral uptake of glucose.

Oxalidaceae
Averrhoa bilimbi

Oral glucose tolerance test (OGTT) in both normoglycaemic and streptozotocin-induced diabetic rats showed an optimal hypoglycaemic effect at a dose of 125 mg/kg. Repeated administration (twice a day) of a dose of 125 mg/kg of ethanolic extract obtained from *Averrhoa bilimbi* L. (bilimbi) leaves reduced glycaemia in diabetic rats by 50% and blood triglyceride by 130% when compared with vehicle (water).

Biophytum sensitivum

Subdiabetic, mildly diabetic and severely diabetic male rabbits were induced by alloxan. Assessment of the activity of the extract from *Biophytum sensitivum* DC leaves was made by measuring the fall in fasting plasma glucose level and improvement in the OGTT, following single dose and prolonged administrations. Following a single dose administration, there was fall in 1 and 2.5 h glucose values by 26 % and 27 %, respectively in the subdiabetic rabbits, and by 37 % and 38 % in the mildly diabetic rabbits. Improved OGTT response was also shown in the subdiabetic as well as in the mildly diabetic rabbits. More significant improvements occurred following one week of the above treatment. It was concluded that the plant composites had an hypoglycaemic effect probably due to pancreatic β-cell stimulating action.

Punicaceae
Punica gratum

Oral administration of the aqueous-ethanolic (50%, v/v) extract of the flowers of *Punica gratum* L. (Gulnar farsi) produced a significant decrease in glycaemia in
normoglycaemic, glucose-fed hyperglycaemic and alloxan induced diabetic rats. The maximum effect was found at 400 mg/kg \[^{109}\].

**Rutaceae**

*Aegle marmelose*

Oral administration of aqueous decoction of *Aegle marmelose* root bark (1 ml/100 gm) showed hypoglycemic effect which was maximum (44%) at 3 h in normal fasted rats. In addition, the same extract completely prevented peak rise of blood sugar at 1 h in OGTT. The hypoglycemic activity was reduced upon storage of extract \[^{110}\]. The leaf extract of *Aegle marmelose* (L.) Corea ex Roxb. was found to be as effective as insulin in the restoration of blood glucose and body weight to normal levels. *A. marmelose* can be used as potential hypoglycaemic agent \[^{111}\]. Alloxan-induced diabetic animals were given insulin injections while another group received *A. marmelose* leaf extract. The blood glucose levels in the extract-treated animals was near to that of controls. Blood urea and serum cholesterol increased significantly in alloxan diabetic rats. Treatment with the leaf extract decreased the blood urea and serum cholesterol compared to controls. A similar effect was seen with insulin treatment. Consequently, the active principle of *A. marmelose* extract had similar hypoglycaemic effect to that of insulin \[^{112}\]. Aqueous leaf extract administered orally for 28 days also normalized STZ (45mg/kg body weight) induced histo-pathological alterations in the pancreatic and kidney tissues of rats \[^{113}\].

**Murraya koeingii**

Oral feeding of *Murraya koeingii* leaves diet (10% w/w) for 60 days to normal rats showed hypoglycemic effect associated with increased hepatic glycogen content due to increased glycogenesis and decreased glycogenolysis and gluconeogenesis \[^{114}\]. Dietary supplement with curry leaves has been shown to increase lecithin cholesterol acyl transferase activity activity \[^{115}\]. Curry leaves powder supplementation (12 g providing 2.5 g fiber) for a period of 1 month in 30 NIDDM patients showed reduction in fasting and post-prandial blood sugar levels at 15-day period with no significant changes in serum glycosylated protein levels, glycosylated low density lipoprotein cholesterol fraction, serum lipids, lipoprotein cholesterol levels, uronic acid and total amino acids \[^{116}\].
Sapotaceae

*Bumelia sartorum*

An unsaturated triterpene acid isolated from an ethanolic extract of *Bumelia sartorum* Mart. root bark produced an hypoglycaemic effect in alloxan-induced diabetic rats. It increased glucose uptake and glycogen synthesis in isolated rat diaphragm and plasma insulin levels. It appears that this effect was mediated by an insulin secretagougue effect in pancreatic β cells \[^{117}\].

Scrophulariaceae

*Picrorhiza kurroa*

Alcoholic extract of *Picrorhiza kurroa* (75 mg extract/kg) reduced serum glucose that was maximum 2 h after the dose. It also showed antihyperglycemic effect in alloxanized diabetic rats. Serum glucose decreased by 43 and 60% with 75 and 150 mg/kg of the extracts, respectively. Anti-oxidant activity is also described in the literature \[^{118}\].

Scoparia dulcis

Aqueous leaf extract of *Scoparia dulcis* L (0.15, 0.30 and 0.45 g/kg body weight for 45 days p.o.) in experimental diabetic rats along with a reduction in glycosylated haemoglobin and an increase in total haemoglobin \[^{119}\]. There was reduction in hemoglobin, thiobarbituric acid reactive substances, hydroperoxides and plasma insulin, glutathion peroxidase, glutathion S-transferase enhancing activities of aqueous plant extract (200mg/kg) in the liver of streptozotocin adult diabetic male albino Wistar rats. The antidiabetic activity may be due to suppresses glucose influx into the polyol pathway leading to increased activities of antioxidant enzymes and plasma insulin and decreases activity of sorbitol dehydrogenase \[^{120}\]. Also potentiates insulin release from Blood glucose, sorbitol dehydrogenase, glycosylated pancreatic islets \[^{121}\].

Solanaceae

*Withania somnifera*

Six mild NIDDM subjects and six mild hypercholesterolemic subjects were treated with a powder of *Withania somnifera* (ashvagandha, Dunal, winter cherry) roots for 30 days. The treatment produced a decrease in blood glucose levels that was
comparable of that of an oral hypoglycaemic drug. The authors concluded that *W. somnifera* could be a potential source of hypoglycaemic agents \[122\].

### Sterculiaceae

*Helicteres isora*

Ethanolic root extract of *Helicteres isora* L cause decrease in plasma glucose at (300 mg/kg, after 9 days of administration) in insulin resistant and diabetic C57BL/KsJdb/db mice associated with a reduction in plasma triglyceride level may be acts through insulin-sensitizing activity \[123\].

### Theaceae

*Camellia sinensis*

The hot water extract of *Camellia sinensis* L. (black tea) significantly reduced the blood glucose levels of streptozotocin-induced diabetic in rats. This extract was found to possess both preventive and curative effects on experimentally produced diabetes in rats. The study revealed that black tea, like green tea, also possesses antidiabetic activity \[124\].

### Verbenaceae

*Lantana camara*

Once daily administration of the juice of *Lantana camara* L. leaves given at different dose levels (60, 300, 600 and 1500 mg/kg/day) for 14 days in rats resulted in alterations in various haematological and biochemical parameters. A strong hypoglycaemic effect was seen with 1500 mg only \[125\].

### Potential future research challenges

Although many plant species have been validated for their antidiabetic properties and related complications, a need exists for research in the following areas.

- Identification of phytochemical compound(s) directly associated with hypoglycaemic and antihyperglycaemic bioactivity of selected plant species
- Extensive, large-population clinical studies for selected species
- Investigation of combination dosages of natural plant products and synthetic drugs to determine the optimal combination for cost-effective therapies.
- Determination of the long-term side-effects of natural herbal product formulations individually and in combination with synthetic drugs.
• Determination of the mechanisms behind hypoglycaemic and antihyperglycaemic activity for most of the medicinal plant species.

• Assessment of the inter- and intra-specific variation in secondary metabolite production in response to environmental (soil, climate, etc.) and production (organic and inorganic fertilisers, agricultural chemicals, etc.) inputs for most species.

• Investigation of the production potential of plant species with clinically proven antidiabetic properties in diverse environments.

• Development of potentially easy-to-consume food products fortified with extracts of plant species with clinically proven hypoglycaemic or antihyperglycaemic properties that can be incorporated into diabetic diets.

CONCLUSION

Diabetes is a disorder of carbohydrate, fat and protein metabolism attributed to diminished production of insulin or mounting resistance to its action. Herbal treatments for diabetes have been used in patients with insulin-dependent and non-insulin-dependant diabetes, diabetic retinopathy, diabetic peripheral neuropathy, etc. Scientific validation of several Indian plant species has proved the efficacy of the botanicals in reducing the sugar level. From the reports on their potential effectiveness against diabetes, it is assumed that the botanicals have a major role to play in the management of diabetes, which needs further exploration for necessary development of drugs and nutraceuticals from natural resources. However lack of scientific and experimental evidence about effective constituents, toxicity, pharmacokinetics, effectiveness and efficacy resulted in deficiency of belief in effectiveness, quality and safety of herbal medicines. The need for adequate standards of herbal preparations to ensure quality, safety and efficacy has been highlighted since the use of herbal medicines and phytotherapies. This requires biological testing of plant extracts, isolation of bioactive components, as well as toxicological, pharmacodynamical and, ultimately, clinical studies. For Indian medicinal preparations, which are made from plant extracts, and often considered to be effective due to a mixture of active ingredients rather than a single constituent, standardization is difficult, furthermore, possible to lose active principles. However, the standardization is an absolute requirement. It is a significant work to isolate active components of Indian medicinal plants with confirmed hypoglycemic activity, to explain their pharmacological
mechanism, and lastly, develop normalized Chinese medicinal preparations for anti-diabetes and its complications.

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