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An Analysis upon Various Herbal and Medicinal Plants Used for Treatment of Diabetes Mellitus: A Review

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Abstract – Diabetes mellitus is a group of metabolic diseases characterized by high blood sugar (glucose) levels, which result from defects in insulin secretion, or action, or both. Herbal medicines have been highly esteemed source of medicine throughout the human history. Aim of the present study is evaluated various medicinal plants used for anti diabetic activity. Diabetes mellitus is one of the most common non-communicable diseases globally. Some of the herbal plants and active chemical constituents which have a role in the management of Diabetes mellitus are compiled here are discussed in this review. Out of an estimated 250 000 higher plants, less than 1% have been screened pharmacologically and very few in regard to diabetes mellitus. Systematic studies on the folklore medicinal plants that combat diabetes mellitus are scanty.

In the last few years, there has been an exponential growth in the field of herbal medicine and gaining popularity both in developing and developed countries because of their natural origin and less side effects. A comprehensive review was conducted to pile up information about medicinal plants used for the treatment of diabetes mellitus. It is a metabolic disorder of the endocrine system and affecting nearly 10% of the population all over the world also the number of those affected is increasing day by day. The profiles presented include information about the scientific and family name, plant parts and test model used, the degree of hypoglycemic activity, and the active chemical agents.

Aim of the present study is evaluated various medicinal plants used for antidiabetic activity. Diabetes mellitus is one of the most common non-communicable diseases globally. It is the fourth leading causes of death in the most developed countries and there in substantial evendiced that it in epidemic in many developing and newly industrialized nations. This posing a serious threat to be met within 21st century. Since ancient time plants have been exemplary source of medicine. Ayurveda and other Indian literature mentioned the used of plants in treatment of various ailments. Out of an estimated 250 000 higher plants, less than 1% have been screened pharmacologically and very few in regard to diabetes mellitus. Systematic studies on the folklore medicinal plants that combat diabetes mellitus are scanty.

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INTRODUCTION

Diabetes Mellitus is a metabolic disorder characterized by hyperglycemia due to defect in insulin secretion, insulin action or both. Over the last century human life style and food habits have drastically changed which lead to various chronic diseases. Diabetes milletus is one such disease which is causing serious problems to human health. Around 200 million people around the world are being diagnosed with diabetes.according to WHO statistics diabetes is the sixth leading cause of disease-related death in the world. On long standing it leads to many micro and macro vascular complications. The microvascular complication of diabetes includes nephropathy, retinopathy, and neuropathy. In type-1 diabetes the first signs of these complications may develop during adolescence, particularly if insulin is insufficient in the body. Similar complications may occur in the later life of patients with type-2 diabetes. They frequently occur during the time of diagnosis.

Plants have been the major source of drugs in Indian system of medicine and other ancient systems in the world. Earliest description of curative properties of medicinal plants is found in Rigveda (2500 - 1800 BC). Charaka Samhita and Sushruta Samhita give extensive description on various medicinal herbs.

Information on medicinal plants in India has been systematically organized.

The World Health Organization expert committee on diabetes has listed as one of its recommendations that traditional methods of treatment of diabetes should be further investigated.

Out of the two types of diabetes, the incidence of non insulin dependent diabetes mellitus (NIDDM) is much higher than the insulin dependent diabetes mellitus (IDDM). Sulphonyl ureas and few biaguanides are valuable treatment for hyperglycemia in NIDDM, but they are unable to lower glucose concentration to within normal range and reinstate a normal pattern of glucose homeostasis permanently. Use of these therapies is restricted by their pharmacokinetic properties, secondary failure rates and accompanying side effects.

Even insulin therapy does not reinstate a permanent normal pattern of glucose homeostasis, and carries an increased risk of atherogenesis and hypoglycemia. Medicinal 151ants have the advantage of having no or only few side effects. Some of them are being used in ~raditional systems of medicine from hundreds of years in many countries of the world. Till today metformin is the only ethical drug approved for the treatment of NIDDM patients which is derived from a medicinal plant *Galega officinalis* historically used for treatment of diabetes in medieval Europe. There are many antidiabetic plants which might provide useful sources for the development of drugs which can be used in the treatment of diabetes mellitus. The literature on medicinal plants with hypoglycaemic activity is vast. Since it is difficult to include all such plants in this small review, a few commonly used plants have been covered here.

Diabetes mellitus is a common and very prevalent disease affecting the citizens of both developed and developing countries. It is estimated that 25% of the world population is affected by this disease. Diabetes mellitus is caused by the abnormality of carbohydrate metabolism which is linked to low blood insulin level or insensitivity of target organs to insulin. Despite considerable progress in the treatment of diabetes by oral hypoglycemic agents, search for newer drugs continues because the existing synthetic drugs have several limitations. The herbal drugs with antidiabetic activity are yet to be commercially formulated as modem medicines, even though they have been acclaimed for their therapeutic properties in the traditional systems of medicine. Type 2 diabetes usually occurs in obese individuals and is associated with hypertension and dyslipidemia. Thus the treatment aims to reduce insulin resistance and to stimulate insulin secretion. Diabetes is a metabolic disorder where in human body does not produce or properly us insulin, a hormone that is required to convert sugar, starches, and other food into energy. Diabetes mellitus is characterized by constant high levels of blood glucose (sugar). Human body has to maintain the blood glucose levels at a very narrow range which is done with insulin and glucagon. The function of glucagon is causing the liver to release glucose from its cells into the blood for the production of energy. Type 1 Diabetes leads to inability to release insulin results in low rates of glucose uptake into muscles and adipose tissue. Traditional medicine (herbal) is used
for treatment of diabetes in developing countries where the cost of conventional medicines is a burden to the population. Despite the introduction of hypoglycemic agents from natural and synthetic sources, diabetes and its secondary complications continue to be a major medical problem. Many indigenous Indian medicinal plants have been found to be useful to successfully manage diabetes. One of the great advantages of medicinal plants is that these are readily available and have very low side effects. Plants have always been an
exemplary source of drugs and many of the currently available drugs have been derived directly or indirectly from them.

The ethnobotanical information reports about 800 plants that may possess antidiabetic potential. Several herbs have shown antidiabetic activity when assessed using presently available experimental techniques.
This review article enumerates some medicinal plants possessing antidiabetic activity and elucidating their mechanisms of action such as Brassica juncea (B. juncea), Combretum micranthum (C. micranthum), Elephantopus scaber (E. scaber), Gymnema sylvestre (G. sylvestre), liriope spicata (L. spicata), Parinari excelsa (P. excels a), Ricinus communis (R. communis), Sarcopoterium spinosum (S. spinosum), Smallanthus sonchifolius (S. sonchifolius), Swertia punicea (5. punicea), Vernonia anthelmintica (V. anthelmintic a) etc. and method of experiment on animals and therapeutic efficiency of plant extracts were exploited. Some of the important anti—diabetic potential herbal plants sources are given in the Table 1.

S.No	Plant name	Family	Parts used	Type of extract	Activity	References
1	*Alangium lamarckii*	Alangiaceae	Leaves	Alcoholic	Antidiabetic	[15]
2	*Albizia odoratissima*	Mimosaceae	Bark	Methanol	Antidiabetic	[19]
3	*Axonopus compressus*	Poaceae	Leaves	Methanol	Antidiabetic	[13]
4	*Berberis vulgaris*	Berberidaceae	Root	Aqueous	Hypoglycaemic	[14]
5	*Brasssica juncea*	Cruciferae	Seed	Aqueous	Hypoglycemic	[7]
6	*Caesalpinia digyna*	Fabaceae	Root	Methanol	Antidiabetic	[10]
7	*Catharanthus roseus*	Apocynaceae	Leaf	Methanol	Hypoglycemic	[16]
8	*Centaurium erythrea*	Gentianaceae	Leaf	Aqueous	Antidiabetic	[17]
9	*Chaenomeles sinensis*	Rosaceae	Friuts	ethyl acetate	Antidiabetic	[18]
10	*Cocos nucifera*	Arecaceae	Leaf	hydro–methanol	Antihyperglycemic	[20]
11	*Costus speciosus*	Costaceae	rhizome	hexane	Antidiabetic	[21]
12	*Cyclocarya paliurus*	Cyclocaryaceae	Bark	Aqueous, PE, chloroform, ethyl acetate & *n*–butanol	Hypoglycemic	[22]
13	*Dillenia indica*	Dilleniaceae	Leaves	Methanolic	Antidiabetic	[23]
14	*Embelia ribes*	Myrsinaceae	Berries	Hexane	Antidiabetic	[24]
15	*Hybanthus enneaspermus*	Violaceae	Whole plant	Alcholic	Antidiabetic	[25]
16	*Lippa nodiflora*	Verbenaceae	Whole plant	Methanol	Antidiabetic and Hypolipidemic	[26]
17	*Lithocarpus polystachyus*	Fagaceae	Leaves	Ethanol & Aqueous	Hypoglycemic	[27]
18	*Marrubium vulgare*	Lamiaceae	Aerial part	Methanol	Hyperglycemia anddyslipidemia	[28]
19	*Ocimum sanctum*	Lamiaceae	Aerial part	Hydroalcholic	Antidiabetic	[29]
20	*Opuntia streptacantha*	Cactaceae	Leaves	Ethanol	Antihyperglycemia	[30]
21	*Psidium guajava*	Myrtaceae	Fruits	Ethanol	Antihyperglycemic	[31]
22	*Semecarpus anacardium*	Anacardiaceae	nut	Milk	Antidiabetic	[32]
23	*Prosopis glandulosa*	Fabaceae	Whole plant	Gelatine/Jelly	Antidiabetic	[33]
24	*Ophiopogon japonicus*	Asparagaceae	Root	Ethanol	Hypoglycemic	[34]
26	*Setaria italica*	Poaceae	Seed	Aqueous	Antihyperglycemic	[35]
25	*Solanum torvum*	Solanaceae	Friut	Methanol	Antihyperglycemic	[36]
26	*Cassia auriculata*	Caesalpiniacae	Leaves	Aqueous	Antihyperglycemic	[37]
27	*Zygophyllum album*	Zygophyllaceae	Whole plant	Ethanol	Antidiabetic	[38]
28	*Vitex negundo*	Lamiaceae	Leaves	Methanol	Antihyperglycemic	[39]
29	*Viscum schimperi*	Viscaceae	aerial parts	Methanolic	Antihyperglycemic & Hypolipidaemic	[40]
30	*Symplocos cochinchinensis*	Symplocaceae	Leaves	Hexane	Antidiabetic	[41]
31	*Enicostemma littorale*	Gentianaceae	Whole plant	aqueous	Antidiabetic	[42]
32	*Vaccinium arctostaphylos*	Ericaceae	Fruit	Ethanolic	antidiabetic	[43]
33	*Solanum xanthocarpum*	Solanaceae	Leaves	Aqueous and Methanol	Antihyperglycemic	[44]

Table 1: Medicinal plants having antidiabetic activity.

Diabetes mellitus is a common and very prevalent disease affecting the citizens of both developed and developing countries. It is estimated that 25% of the world population is affected by this disease. Diabetes mellitus is caused by the abnormality of carbohydrate metabolism which is linked to low blood insulin level or insensitivity of target organs to insulin. Despite considerable progress in the treatment of diabetes by oral hypoglycemic agents, search for newer drugs continues because the existing synthetic drugs have several limitations. The herbal drugs with antidiabetic activity are yet to be commercially formulated as modern medicines, even though they have been acclaimed for their therapeutic properties in the traditional systems of medicine. Type 2 diabetes usuallynoccurs in obese individuals and is associated with hypertension and dyslipidemia. Thus the treatment aims to reduce insulin resistance and to stimulate insulin secretion. Diabetes is a metabolic disorder where in human body does not produce or properly us insulin, a hormone that is required to convert sugar, starches, and other food into energy. Diabetes mellitus is characterized by constant high levels of blood glucose (sugar). Human body has to maintain the blood glucose levels at a very narrow range which is done with insulin and glucagon. The function of glucagon is causing the liver to release glucose from its cells into the blood for the production of energy.

Medicinal plants continue to be an important therapeutic aid for alleviating ailments of humankind. Over the last 2500 years, there have been very strong traditional systems of medicine such as Chinese, Ayurvedic, and the Unani, born and practiced, more in the eastern continent. These traditions are still flourishing, since; approximately 80% of the people in the developing countries rely on these systems of medicine for their primary health care needs .

These plants contain substances that can be used for therapeutic purposes, of which are precursors for the synthesis of drugs . A lot of research work has been carried out on some medicinal herbs and they have been found to have definite action on the nervous, circulatory, respiratory, digestive and urinary systems; as well as the sexual organs, the skin, vision, hearing and taste .

Diabetes mellitus is a group of metabolic alterations characterized by hyperglycemia resulting from defects in insulin secretion, action or both. It is made up of two types: Type I and Type II. Type I diabetes often referred to as juvenile diabetes, is insulin dependent and known to affect only 5% of the diabetic population. The Type II, which is non-insulin dependent, usually develops in adults over the age of 40. It has already been established that chronic hyperglycemia of diabetes is associated with long term damage, dysfunction and eventually the failure of organs, especially the eyes, kidneys, nerves, heart and blood vessels. It has an adverse effect on carbohydrate, lipid and protein metabolism resulting in chronic hyperglycemia and abnormality of lipid profile. These lead to series of secondary complications including polyurea, polyphasia, ketosis, retinopathy as well as cardiovascular disorder. In spite of the introduction and extensive utilization of hypoglycemic agents, diabetes and the related complications continue to be a major health problem worldwide, which is affecting nearly 10% of the population all over the world and considered as a major cause of high economic loss which can in turn impede the development of nations. It is projected to become one of the world's main disablers and killers within the next 25 years.

Many factors contribute to the on-set of diabetes and these are termed as predisposing or risk factors. Environmental factors such as diet, obesity and sedentary life style increase the risk of diabetes. Other important risk factors include high family aggregation, insulin resistance, nutritional status, age and lifestyle change due to urbanization. The management of diabetes is a global problem until now and successful treatment is not yet discovered.

Currently available therapy for diabetes includes insulin and various oral hypoglycemic agents such as sulfonylureas, metformin, glucosidase inhibitors,

troglitazone, etc. But these are reported to produce serious adverse side effects such as liver problems, lactic acidosis and diarrhea. It is currently affecting around 143 million people and the number of those affected is increasing day by day, by 2030 it is predicted to reach 366 million population worldwide. About 800 plant species have been reported to possess antidiabetic properties. Several plant species have been used for prevention or management of diabetes by the Native Americans, Chinese, South Americans and Asian Indians.

HISTORY OF DIABETES

Diabetes disease is prevalent since approximately 1550BC. An Egyptian doctor defined a unknown rare disease as a disease that causes the patient to lose weight rapidly and urinate frequently. This is considered to be the first definition to the diabetes milletus. The name diabetes was coined by the Greek Physician Aretaeus (30-90AC). He recorded the disease with symptoms such as constant thirst (polydipsia), loss of weight and excessive urination (polyuria). He named the condition 'diabetes', which means 'a flowing through'. After this period, diabetes name is rarely mentioned. Indeed, it seems to have a mystery or incredibly during the middle Ages. The first reference to the disease came from Avicenna, the famous Arabian Physician. He described the complications of the disease in detail, and how it got progressed. Around this period, 'uroscopy' came into existence as a way of identifying disease. The colour and odour of the urine were examined to establish the disease of the patient. Some physicians even tasted the urine of patients, and this apparently lead how to the second name, mellitus, meaning 'honey' in Latin.

During the early 19th Century, chemical tests have been devised through which it was possible to detect excess sugar in the urine. Despite many therapies had been proposed, in the absence of a cause, they proved unsuccessful. In 1920 an American called Moses Barron linked the Langerhans cells with the basis of diabetes mellitus. Based up on the research of Barron, a doctor called Frederick Banting conducted critical experiments linking the pancreas and diabetes. Banting discovered an essential hormone named insulin, named after the 'islands' of cells described by Langerhans. Banting and one of his colleagues were recognised for their achievement and were awarded Nobel Prize. Throughout the 20th century, treatment of the disease has advanced drastically.

Although prevention and management remains difficult for diabetes milletus, the life of an average diabetic is becoming both longer and easier due to advanced treatments which are being used now a days.

DIABETES MILLETUS OCCURANCE IN THE WORLD

Diabetes milletus is estimated to increase from 4.0 percent in the year 1995 to 5.4 percent by the year 2025. The numbers of people with diabetes milletus in the world will increase from 135 million in 1995 to 300 million in the year 2025. According to statistics, there will be a 42 percent increase, from 51 million to 72 million, in the developed countries and 70% increase, from 84 to 228 million, in the developing countries.3

There are three major types of diabetes.

1) Type-I (Insulin dependent diabetes mellitus).

2) Type-II (Non-insulin dependent diabetes mellitus).

3) Gestational diabetes mellitus.

Type -I or Insulin Dependent Diabetes Mellitus:

In insulin dependent diabetes mellitus, insulin is completely absent because the pancreas lacks cells or contains defective cells. This condition occurs in genetically susceptible individuals from an autoimmune response that selectively destroys pancreatic cells. Their life spans are drastically reduced up to one third as a result of degenerative complications like kidney dysfunction, nerve impairment, and cardiovascular complications as well as blindness. This arises from the metabolic control provided by periodic insulin injection. The usual rapid onset of the indications of insulin dependent diabetes milletus suggested that the autoimmune attack on the pancreatic cells is responsible for the shorter duration of this disease. However the disease persists for several years as the immune system slowly destroys the pancreatic cells. When >80% of these pancreatic cells have been destroyed it leads to classic symptoms of diabetic disease. It usually occurs after 30 years of age, but Peak incidence occurs during puberty, around 12-14 years in boys and 10-12 years of age in girls. The main signs and symptoms include hyperglycemia, increased thirst and hunger, frequent urination, weight loss, ketoacidosis.

Type-II or Non-insulin Dependent Diabetes Mellitus :

Non insulin dependent diabetes milletus is characterized by reduced insulin secretion in response to glucose levels and Insulin resistance which leads to the inefficient absorption of glucose into the cell for energy. It is present in 90% of the diagnosed cases of diabetes and affects 18% of the population above 65 years of age, usually occurs in obese individuals. These individuals have normal or even greatly elevated insulin levels. Perhaps, the

elevated insulin production results from overeating (obesity is almost always the result of overeating). It eventually suppresses the synthesis of insulin receptor (a plasma membrane bound glycoprotein). This hypothesis concludes that diet alone is usually sufficient to control this type of diabetes.

Gestational diabetes mellitus

Gestational diabetes mainly develops during the time of pregnancy. It results due to the hormonal changes in pregnancy which can change the body ability to use insulin leading to carbohydrate intolerance. It results in hyperglycemia of variable severity. It usually disappears after the birth of child, and does not clarify that the child will be born with diabetes.

PLANTS WITH WELL OR PARTIALLY CHARACTERIZED ANTIDIABETIC PROPERTIES

Raw onion bulb and cloves of garlic have long been used as dietary supplement for traditional treatment of diabetes. Former is used as stimulant, diuretic and expectorant. Concentrated extract of onion bulbs exerted a week hypoglycemic action in healthy and altoxan diabetic animals. Recently S-methyl cysteine sulphoxide (SMCS), a sulphur containing amino acid isolated from onion was shown to have antidiabetic and antihyperlipidemic effect when given at a dose of 200 mg/kg body weight (bw)/day for a period of 45 days to alloxan diabetic rats. Effects were comparable to those of glibenclamide and insulin. Garlic contains many sulphur containing compounds mainly in the form of cysteine derivatives viz. S-alkyl cysteine sulphoxides which decompose into a variety of thiosulfinates and polysulfides by the action of enzyme allinase on extraction.

Decomposed products are volatile and are present in the oil of garlic. They possess antidiabetic, hypocholesterolemic, fibrinolytic and various other biological actions. An ether soluble substance 'allicin' was isolated from garlic. An increase in the serum insulin release, an improvement in GTT and increased liver glycogen were shown to be allied actions of allicin. Recently hypoglycemic effects of garlic and onion were compared with that of tolbutamide in rabbits. Both have shown significant fall in hyperglycemic peak in mild diabetic rabbits.

From *Anemarrhena asfoetida* four compounds were isolated Anemarans A, B, C and D glycans. Anemarans C reduced blood glucose level, in alloxan induced hyperglycemic mice.

Azadirachta indica (Neem) is a large evergreen tree found all over India, used in leprosy, piles and urinary disease. Oil from nuts and leaves acts as local stimulant, insecticide and antiseptic. A bitter principle nimbidin isolated from seeds of the tree was effective at a dose of 200 mg/kg in reducing blood glucose in alloxan diabetic rabbits and was 50% as potent as tolbutamide. Aqueous extract of tender leaves was reported to be effective in reducing blood glucose and this effect was due to blocking the action of epinephrine on glycogenolysis and peripheral utilization of glucose.

Leaves of *Bouganvillea spectabilis* have been reported to possess hypoglycemic effect. Pinitol isolated from leaves (0.01 gm/kg, bw) produced significant hypoglycemic effect in normal and diabetic mice. *Coccinia indica* (Hindi Kanduri) grows in wild state abundantly in Bengal and in other parts of India. The plant has the reputation in Bengal of having a remarkable effect in reducing the amount of sugar in urine of patients suffering from diabetes mellitus. Ethanolic extract of the leaves showed hypoglycemic effect in rats and in human subjects. It has insulin secretagogue effect and inhibited enzymes of gluconeogenesis. The hypoglycemic activity was stated to be due to the presence of water soluble and dialyzable alkaloidal principle. *Eugenia jambo/ana or Syzygium jambo/ana* (Eng. Jambul, Hindi Jamun, Telugu Neredu) is a tree grown throughout the plains. Bark, leaves, seeds and fruits of this plant are astringent. Juice of the fruit is stomachic, astringent, diuretic and antidiabetic. Oral administration of powdered seeds to normal rats and to NIDDM patients for 15 days caused marked lowering of blood glucose level. Both the fruit pulp and seeds were found to be effective in diabetic rats. They also increased cathepsin B activity and had insulin secretogogue effect. In our laboratory Sharma et. al. isolated few highly active hypoglycemic compounds from pulp and seed (Patent applied).

Pods of *Cyamopsis tetragono/obus* (Indian cluster bean, Hindi Guar phali; Telugu - Goruchikkudu) contain an antidiabetic principle. Seeds of this plant are the source of galactomanan gum (guar) that is used as bulking agent for food and cosmetics. The viscosity effect of guar is exploited as a dietary adjunct to delay the rate of glucose absorption and thereby reduce postprandial hyperglycemia.

Ficus benga/ensis (English: Banyan tree; Hindi: Bargar, Telugu: Marrichettu) is a large tree with aerial roots. It grows wild in lower Himalayas and is found all over country. Leaves are good for ulcers. Milky juice is externally applied for pains and bruises and in rheumatism. The aerial roots are aphrodisiac, useful in gonorrhea, syphilis, dysentery and inflammation of liver. Seeds and fruits are cooling and tonic. Bark of this plant has antidiabetic properties. The hypoglycemic effect of extract of bark was

demonstrated in alloxan diabetic rabbits, rats and in humans.

METHODOLOGY

Information on the plants used for diabetes mellitus of folklore origin was obtained during the etknobotamcal survey of randomly selected districts of Madhya Pradesh. The surveys were conducted using etknobotamcal and Participator)' Rural Appraisal (PRA) methods. Twenty six villages were selected on the basis of availability of herbal healers. A total of 30 herbal healers (26 men and 04 women) of age group between 45 and 86 yrs belonging to different communities such as Swamiji, Pandit, Kuruba and tribes like Valmiki, Korava and Lambani were interviewed and recorded the information in a prescribed questionnaire[4] The questionnaire revealed the name, age and address of herbal healer, date of interview, local and botanical names of drug plants, parts used, collected fresh or dried stored material, locality, dose quantity, dose per day, method of drug preparation, care to be taken or the side effects if any and mode of administration.

Ethnic as well as the cultural importance of drug plants were also recorded. Prior informed consent (PIC) was taken from all the ethnic/tribal communities. Botanical specimens of all the medicinal plants were photographed, collected and identified by referring to the Flora of Gulbarga district and three volumes of the Flora of Presidency of Madras. Voucher specimens were made by using standard plant press, authenticated and deposited at the Herbarium centre, department of Botany, Gulbarga University, Gulbarga.

CONCLUSION

Diabetes is a serious metabolic disorder. Differences in social structure, psychic stress, obesity, hormonal imbalance and heredity are optimizing the growth of pandemic. At present, the treatment of diabetes mainly involves a sustained reduction in hyperglycemia by the use of biguanides, thiazolidinedione's, sulphonylureas, D-phenylalanine derivatives, meglitinides and α-glucosidase inhibitors in addition to insulin. However, due to unwanted side effects the efficacies of these compounds are debatable and there is a demand for new compounds for the treatment of diabetes (173,174). Hence, plants have been suggested as a rich, as yet unexplored source of potentially useful antidiabetic drugs. However, only a few have been subjected to detailed scientific investigation due to a lack of mechanism-based available in vitro assays (175-177). These efforts may provide treatment for all and justify the role of novel traditional medicinal plants having anti-diabetic potentials.

The present review has presented comprehensive details of antidiabetic plants used in the treatment of diabetes mellitus. Some of these plant derived medicines, however, offer potential for cost effective management of diabetes through dietary interventions, nutrient supplementation, and combination therapies with synthetic drugs in the short term, and as the sole medication from natural sources over the long term. The presences of bioactive chemicals are mainly responsible for this antidiabetic action. However, many other active agents obtained from plants have not been well characterized. More investigations must be carried out to evaluate the mechanism of action of medicinal plants with antidiabetic effect.

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