Potential anti-diabetic plants of eastern India- A review article

Soumya Mitra* and Anima Pandey

Department of Pharmaceutical Sciences and Technology, Birla Institute of Technology, Mesra, Ranchi- 835215, Jharkhand, India.

Correspondence should be addressed to G. Renuga; mitra.soumya1990@gmail.com

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Abstract

Diabetes mellitus is one the most common diseases in the world. It is assumed that in near future the number of people affected by this disease will reach over 1 billion. There is no permanent treatment to this disease apart from some dietary controlling, exercising and few oral hypoglycemic agents. Use of various plants helps in preventing the increase of blood-glucose level. This review article aims to cover few very important plants which help in reducing the glucose levels in blood from the states of Bihar, Jharkhand, West Bengal and Orissa. The plants reviewed here are very common to the region and poses no threat to the human body.

Keywords: Diabetes mellitus, Management, Endogenous plants.

Introduction

Diabetes mellitus is one of the most commonly encountered diseases across the world. WHO recently compiled the data to show that the total number of people diagnosed with Diabetes is around 150 million. It is assumed that this number will be double by the year 2025 and most the affected patients’ age will be 65 years or more.

Diabetes mellitus is a chronic disease caused by inherited and/or acquired deficiency in production insulin and/or by the ineffectiveness of the insulin produced. Such a condition results in increased glucose levels in blood which in turn damages the body systems. The most commonly damaged body systems include blood vessels and nervous systems. The major symptoms include weight loss, polyuria (frequent urination), polydipsia (increased thirst), polyphagia (increased hunger), tiredness, blurred vision, abdominal pain, fluid retention (especially in legs and feet), poor healing of skin wound, skin infections like abscess and pimples, increased heart rate, burning pain in feet etc.

Diabetes is one of the earliest described diseases in the ancient era. In Egyptian civilization it was described as “too great loss of urine”. Indian physicians first observed it around the same time as the Egyptian physicians and termed it as “Madhumeha” around 1500
BCE. The term “Diabetes” was first used by the Greek physician Appolonius Memphis in 250 BCE. Later in late 1600s Thomas Willis added the term “Mellitus”. The first complete description of the disease was given by Greek physician Aretaeus of Cappadocia who also noted the excessive loss of urine through kidneys. At that time it was believed that the disease is incurable and this may also explain the absence of the name of the disease from the descriptions by Hippocrates.

However, it was not until 1920s when Moses Barron linked the Pancreas with Diabetes mellitus. Later on Frederick Banting conducted experiments linking the role of Pancreas with Diabetes. He also discovered the hormone Insulin and named the cells producing it as Islets of Langerhans. Banting and his colleagues were recognized for their important contribution in this field by being awarded the Noble prize.

**Types of Diabetes Mellitus**

Depending upon the pathophysiology of the Diabetes this disease can be classified mainly into three classes, Type 1 or Insulin dependent diabetes mellitus (IDDM), Type 2 or Non-insulin dependent diabetes mellitus (NIDDM) and Gestational diabetes mellitus.

Generally there are four types of cells in the Islets of Langerhans (α, β, γ, δ) of pancreas in the human body. Now α and β cells play important roles in controlling the blood glucose level by secreting Glucagon and Insulin. Glucagon helps in maintaining the blood glucose level high whereas Insulin has the opposite action. Any imbalance in the levels of these hormones in the human body results in irregular blood-glucose levels.

**Type 1 Diabetes Mellitus**

In Type 1 diabetes mellitus (IDDM) it is observed that the β cells of the islets of Langerhans get destroyed and as a result of which the human body finds itself incapable of producing the hormone insulin. Type 1 diabetes was first diagnosed in children, teenagers and young adults, thus was also known as Juvenile diabetes mellitus. The destruction of the β cells take place due to various auto-immune disorders in which the immune system of the body itself destroys the β cells. Hence the body is unable to produce insulin and consequently resulting in increased blood glucose level or hyperglycemia.

Type 1 diabetes is rarely caused by the mutational defects in a single gene. Instead they are followed by multiple other auto-immune conditions due to disruption of other regulatory pathways. One such example is the IPEX syndrome (immune dysregulation, polyendocrinopathy, enteropathy, X-linked), where mutation in Foxp3 transcription factor leads to the dysfunction of T-cells and consequently leading to multiple organ failure.

Early studies showed that the human leukocyte antigen (HLA) region of 6p21 chromosome (commonly termed as IDDM1) is a critical susceptibility locus for various human auto-immune diseases including Type 1 diabetes. Since then various other susceptibility loci have been identified but none of them could match the strong association with mutation like the HLA region. A lesser genetic predisposition to Type 1 diabetes is conferred by the IDDM2 locus on chromosome 11 containing the insulin gene region. A polymorphic region located at the 5’ end of the insulin gene was first reported in 1984 to be associated with Type 1 diabetes. Now being recognized as a primary autoantigen in Type 1 diabetes, it is not at all surprising that mutations in the insulin region could contribute to the susceptibility of the disease. Another member of the Type 1 diabetes susceptibility gene set is the protein tyrosine phosphatase non-receptor type-22 (PTPN22), which encodes the lymphoid protein tyrosine phosphatase (LYP). Interleukin (IL) -2 receptor-α-gene (IL2RA) region accounts for another genetic risk factor implicated in Type 1 diabetes.

However, it can be concluded that Type 1 diabetes is caused by a combination of genetic susceptibility and being exposed to environmental triggers. The main reason is clearly autoimmune disorders which were almost proven during the clinical diagnosis. Unfortunately there have not been any permanent treatments for this type of diabetes, but regular administration of sub-cutaneous insulin is the only known preventive measure along with proper diets.

**Type 2 Diabetes Mellitus**

Type 2 diabetes mellitus is the most common form of diabetes, accounting for more than 90% of the people
affected by the disease. Type 2 diabetes mellitus is commonly caused by relative impairment of the body’s capacity to secrete insulin and peripheral insulin resistance and thus previously was known as Non Insulin Dependent Diabetes Mellitus (NIDDM). It is typically managed by proper diets, exercise and some oral hypoglycemic agents. However, a proper solution to this disease is still being searched for.

It is to be noted that increased blood pressure, disturbance in blood-lipid level and thrombosis are also related to eventual development of the disease. Other major complications include to those similar to the Type 1 diabetes. The cardiovascular risks include coronary artery disease (leading to angina pectoris), peripheral arterial diseases (like arterial blockage in the peripheral limbs), retinal damages (eventually leading to blindness), renal complication (kidney damage) and other diseases causing major problems to the nervous system of the body.

The management of Type 2 diabetes includes self-consciousness, proper diets, exercise and some oral hypoglycemic agents. There are few Oral hypoglycemic agents which are very commonly given in the management of Type 2 diabetes mellitus. They include Sulfonylureas (Tolbutamide, chlorpropamide), Biguanides (Metformin), peroxisome proliferator-activated receptor gamma subtype (PPARγ) inhibitors (Thiazolidinediones).

Apart from these synthetic hypoglycemic agents the use of natural medicines has been quite famous. In many countries where people prefer natural drugs instead of synthetic drugs due to their less toxicity and side-effects use of natural anti-hyperglycemic agents is very popular. In India, use of plants as medicines has been known from ancient times. In recent times use of natural drugs for the treatment of Diabetes mellitus has seen a huge upsurge.

**Role of Medicinal Plants in the Treatment of Diabetes Mellitus in Eastern India**

In current scenario concerning Diabetes mellitus all over the world, the management of the disease is led primarily by plants with some antidiabetic properties. In India, it is also the same. The use of various plants for their medicinal properties is not at all new in India. From the times of Charak and Sushruta, medicines from natural sources have been well known to Indians. In recent times the Pharmaceutical industries have shown great interest in natural sources. Here are some plants which have shown great promise in the management of Diabetes mellitus.

**Aegle marmelos (family rutaceae, common name Bael tree)**

*Aegle marmelos* is one the most commonly found plants in the Eastern India and has been used in the treatment of diabetes mellitus for a long time. The methanolic extract of the leaves and the callus have shown significant antihyperglycemic activity on Streptozocin induced diabetes mellitus. Streptozocin shows immediate action on the insulin secreting β cells of the pancreas by alkylation of the DNA, resulting in the death of the β cells. It is assumed that *A. marmelos* somehow stimulates the β cells to increase insulin secretion. It may also increase the receptor responsiveness of the insulin receptors. [1] The proper mechanism of action for its antidiabetic activity is still unknown but it is assumed that the leaves of this plant may contain several elements. It is known that several inorganic elements like V, Zn, Cr, Cu, Fe, Na, K and Ni play an important role in the maintenance of glucose level by activating β cells of pancreas. Narendhirakannan et al in 2005 reported the presence of various elements like Cu, Ni, Zn, K, Na, Fe, Cr and V in trace amounts in the leaves. This may account for the β cell stimulatory activity of the leaves. [2]

*Aegle marmelos* has also shown the potential to decrease oxidative stress which indirectly simulates glycation of proteins and inactivation of enzymes. This results in increase of blood glucose level and consequently hyperglycemia occurs. The methanolic extract of *A. marmelos* has shown significant action on glucose transport protein (GLUT) and said to have properties to improve the responsiveness of the insulin receptors. This is a major influence regarding its antihyperglycemic activity. [3]

**Aloe barbadensis (family liliaceae)**

One of the most frequently used plants for its great range of pharmacological activity is *Aloe barbadensis*. The plant is known to show a wide range of pharmacological activity starting from antioxidant,
anti-inflammatory to antidiabetic actions. The ethanolic extract of the leaves and the skin of the plant have shown good hypoglycemic action in normoglycemic rats while its action on the Streptozocin (STZ) induced diabetic rats is significant. The antidiabetic action of the plant can be said to be a result of its ability to increase glucose metabolism and antioxidant activity. [4]

Other studies have reported its antidiabetic action as a result of the bitter principles of the plant. [5] The proper mechanism of action for its antidiabetic property is still not known, however studies assume that it might be a result of its ability to stimulate the synthesis and/or release of insulin from the β cells of pancreas. The phenolic and flavonoid content of the ethanolic extract of the plant may also account for its good antioxidant property which in turn would also result in its antidiabetic property. [6]

**Alstonia scholaris (family apocynaceae)**

The aqueous extract of the dried bark of *Alstonia scholaris* has been one of the more common plants to be used as antidiabetic agent. It acts as antihyperglycemic agent rather than a hypoglycemic one considering the fact that it does not lower blood glucose level in normoglycemic rats. Studies suggested that the antihyperglycemic action of the extract may be associated with its ability to improve glycogenesis and also to suppress glycogenolysis. [7]

Other studies suggest that the antidiabetic action of the plant could be due to the fact that it can increase the utilization of glucose in peripheral tissue and also improve its sensitivity towards the insulin receptors. Apart from its antidiabetic activity the plant has also shown antihyperlipidemic action by reducing serum triglyceride level in STZ induced diabetic rats. [8]

**Andrographis paniculata (family anacanthaceae, common name Kalmegh)**

*Andrographis paniculata* is one of the most widely used plants for its wide range of actions. Ethanolic extract of the whole plant and chloroform extract of the roots [9] of the plant have shown great antihyperglycemic action in Alloxan-Streptozocin induced diabetic rats. Ethanolic extract of the whole plant has shown significant antidiabetic action and also increases body weight in a dose dependent manner. However, the aqueous extract of the plant has shown significant hypoglycemic activity in normoglycemic rats.

It is believed that the major constituent of *A. paniculata*, Andrographolide, significantly lowers thiobarbituric acid-reactive substances in liver and kidney while it also increases the activity of superoxide dismutase and catalase enzymes in diabetic rats. [10]

In various studies it has been reported that Andrographolide increases the uptake of radioactive glucose by isolated Soleus muscle of STZ induced diabetic rats and thus it can be considered as an indication of the fact that Andrographolide acts by increasing the uptake of glucose by skeletal muscles. It is assumed that *A. paniculata* acts by more than mechanism and thus has a greater action than most of other drugs of this kind. Wibudi et al [11] suggested that Andrographolide acts by increasing the release of insulin from the β cells of pancreas whereas Subramanian et al [12] suggested its action due to inhibition of α-glucosidase and α-amylase for its antidiabetic actions.

Another suggested mechanism of action stated β cell protective action of Andrographolide towards Alloxan induced diabetic rats. Andrographolide-lipoic acid conjugate (AL-1) has also shown great antidiabetic activity by lowering blood glucose level at equal dose for Glibenclamide. Protective action towards the β cells can be a big boost in the management of Type 1 diabetes where β cells are destroyed. Protective action of Andrographolide can be considered as one step forward in the management of Type 1 diabetes. [13]

**Bambusa vulgaris (family Poaceae)**

*Bambusa vulgaris* is not as well known as some other antidiabetic plants. However in various regions of eastern India it has been used in the management of diabetes mellitus. The petroleum ether extract of the leaves of the plant has shown significant antihyperglycemic effect. Primary phytochemical screening of the extract has revealed the presence of various steroids, alkaloids, glycosides, tannins and flavonoids. [14]

It has shown significant antidiabetic action in rats with diabetes, induced by Streptozocin. However the exact
mechanism of action of its antidiabetic activity is still unknown. It is assumed that the action of this plant is carried out by pancreatic or extra hepatic mechanism or both. The constituents responsible for this antidiabetic action are assumed to be the phytosterols present in the leaves of the plant. [15]

*Bougainvillea spectabilis (family Nyctaginaceae)*

*Bougainvillea spectabilis* has been proved to be one of the most potent antidiabetic plants available in the regions of eastern India. The ethanolic extract of the leaves is considered to be the most effective in the management of diabetes mellitus. The most important phytoconstituent found having hypoglycemic effect is D-pinitol. The structural similarity between D-pinitol and D-chiroinositol has been a major possible factor for its hypoglycemic action. D-chiroinositol is involved in signaling of insulin via Phosphoinositide 3-kinase (PI3K) and protein kinase B pathway. PI3K may be involved in a pathway that is somehow linked with the signaling pathway of the insulin in case of glucose transportation. [16] D-pinitol being structurally similar to D-chiroinositol may act in similar pathway.

Bates et al in 2000 reported that D-pinitol activates pyruvate dehydrogenase, phosphatase and glycogen synthetase at insulin sensitive peripheral tissues which results in increased insulin sensitivity. Tietz et al in 1994 reported its similarity in action with insulin where he observed fall in plasma potassium levels.

Other studies on the same plant have shown decrease in serum Ca ion concentration due to impaired intestinal Ca absorption in the intestine. The ethanolic extract may contain certain biomolecules that cause chelation of Ca ions in the intestine. This leads to the decrease in plasma Ca concentration. The side effects of this phenomenon are impairment of the blood clotting and release of Acetylcholine, absorption of Vit B12 in small intestine. This may lead to inhibition of various enzymes that require Ca as activator. [17]

The hypoglycemic action of the ethanolic extract of the stem bark has shown significant lowering of the blood glucose level after 6 hours of administration in Alloxan induced diabetic rats. Treatment by oral doses of the ethanolic extract for one week showed reversal of permanent hyperglycemia. [18]

*Coriandrum sativum (family Apiaceae)*

One of the most widely cultivated plants in eastern India is *Coriandrum sativum*. Its use in the management of diabetes mellitus is widely known. The aqueous extract of the fruits of the plant has been experimented in the treatment of Streptozocin induced diabetes. The study has shown significant reduction in blood glucose levels. [19] The hypoglycemic activity of the fruits is assumed to be associated with its ability to stimulate insulin secretion. However enhancement of glucose uptake and better metabolism of glucose by peripheral muscles is also considered to be one of its mechanisms. [20] Other studies on the seeds of *Coriandrum sativum* have been related to its ability to increase the activity of β cells in the pancreas and consequently reduction in serum glucose levels. [21]

*Cynodon dactylon (family Poaceae Graminae, common name Doob grass)*

*Cynodon dactylon* is perhaps the most abundantly found plant in the list. The plant is well recognized in India for its use in various religious rituals. The various important phytoconstituents found in the plants are cynodin, hydrocyanic acid, triticin, β-carotene. Traces of various minerals like Ca, P, Fe and K can also be found.

*Cynodon dactylon* has shown potent hypoglycemic action in Alloxan induced rats and also been reported to possess antihypertriglyceridemia which is caused by the administration of Alloxan. The non polysaccharide fraction of the aqueous extract of the plant is responsible for its hypoglycemic effect. The proper mechanism of its antidiabetic action is still unknown but it is assumed to be due to its insulin like action. [22]

Other studies conducted on the same purpose have assumed the role of flavonoids and sterols in the management of diabetes. The mechanism of action for flavonoids as antidiabetic agent may be due to its β-cell regenerative property. Sterols also showed significant antidiabetic activity. [23]
**Gymnema sylvestre** (family Asclepiadaceae, common name Gurmar)

**Gymnema sylvestre** is possibly one of the most potent plants in traditional medicine. The plant possesses various remedial actions. The major phytoconstituent is gymnemic acid, a glycoside. Gymnemic acid has shown potent antidiabetic action in Streptozocin induced diabetes mellitus. The ethanolic extract of the plant containing gymnemic acid is one of the most potent antidiabetic agents. [24]

The mechanism of action of gymnemic acid is still unknown but it is assumed that it may stimulate β cell functions and increase the number of β cells in the islets of Langerhans in the pancreas. This phenomenon leads to the increased secretion of insulin in the body.

The extract has shown dose dependent antidiabetic action. It has shown drastic reduction in the blood glucose level when a dose of 400mg/kg is administered in male albino wistar rats. The reduction in fasting blood glucose level may be result of increase in the activity of enzymes which are responsible for utilization of glucose by insulin dependent pathway. There is another alternative mechanism which is considered to be associated with the regeneration of the β cells. It has also shown antihyperlipidemic action. [25]

Gymnemic acid is a triterpenoid glycoside which is responsible for its antihyperglycemic activity. Gymnemic acid II and IV are potent inhibitors of glucose uptake while Gymnemoside B and Gymnemic acid III, V and VII have little inhibitory action glucose uptake. [5]

### Table: Name of the plants and their parts used in the management of Diabetes

<table>
<thead>
<tr>
<th>Name of the plant</th>
<th>Family</th>
<th>Part/s used</th>
<th>Extract/s used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aegle marmelos</td>
<td>Rutaceae</td>
<td>Leaves and callus</td>
<td>Methanolic</td>
</tr>
<tr>
<td>Aloe barbadensis</td>
<td>Liliaceae</td>
<td>Leaves and skin</td>
<td>Ethanolic</td>
</tr>
<tr>
<td>Alstonia scholaris</td>
<td>Apocynaceae</td>
<td>Dried bark</td>
<td>Aqueous</td>
</tr>
<tr>
<td>Andrographis</td>
<td>Acanthaceae</td>
<td>Whole plant</td>
<td>Ethanolic and</td>
</tr>
<tr>
<td>Bambusa vulgaris</td>
<td>Poaceae</td>
<td>Leaves</td>
<td>Petroleum ether</td>
</tr>
<tr>
<td>Bougainvillea</td>
<td>Nyctaginaceae</td>
<td>Leaves</td>
<td>Ethanolic</td>
</tr>
<tr>
<td>Coriandrum sativum</td>
<td>Apiaceae</td>
<td>Fruits</td>
<td>Aqueous</td>
</tr>
<tr>
<td>Cynodon dactylon</td>
<td>Poaceae/gramineae</td>
<td>Leaves</td>
<td>Aqueous</td>
</tr>
<tr>
<td>Gymnema sylvestre</td>
<td>Asclepiadaceae</td>
<td>Whole plant</td>
<td>Ethanolic</td>
</tr>
<tr>
<td>Hibiscus rosa-sinensis</td>
<td>Malvaceae</td>
<td>Flowers</td>
<td>Ethanolic</td>
</tr>
<tr>
<td>Madhuca indica</td>
<td>Sapotaceae</td>
<td>Bark</td>
<td>Methanolic</td>
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<tr>
<td>Momordica charantia</td>
<td>Cucurbitaceae</td>
<td>fruits</td>
<td>Aqueous</td>
</tr>
<tr>
<td>Musa paradisica</td>
<td>musaceae</td>
<td>Fruits/ fresh flowers</td>
<td>Ethanolic and</td>
</tr>
<tr>
<td>Ocimum sanctum</td>
<td>Labiatae</td>
<td>Leaves</td>
<td>Aqueous and alcoholic</td>
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<tr>
<td>Psidium guajava</td>
<td>Myrtaceae</td>
<td>Leaves</td>
<td>Aqueous and</td>
</tr>
<tr>
<td>Terminalia chebula</td>
<td>Combretaceae</td>
<td>Fruits</td>
<td>Extract</td>
</tr>
<tr>
<td>Tinospora cordifolia</td>
<td>Menispermae</td>
<td>Stem</td>
<td>Aqueous and ethanolic</td>
</tr>
</tbody>
</table>

**Hibiscus rosa-sinensis** (family Malvaceae, common name China rose)

This plant is one of the most commonly found plants in the tropics. The plant can be recognized by its characteristic shape of leaves. It is widely considered as a plant with immense potential in traditional medicines. The antidiabetic property of this plant is related to the ethanolic extract of its flowers. The antidiabetic action of the extract may be due to increased insulin secretion from the existing β cells.

It is reported to have the ability to increase the plasma insulin concentration. This may be done by influencing the enzyme activity in liver which plays an important role in glycolysis and gluconeogenesis. The enzyme glucose-6-phosphatase catalyzes the hydrolysis of glucose-6-phosphate to glucose. In diabetic rats
Glucokinase activity is reduced due to lack of insulin which leads to the depletion of liver glycogen.

Another enzyme fructose-1,6-bisphosphatase catalyzes gluconeogenesis which leads to transportation of glucose out of the liver. Insulin inhibits this hepatic glucose production by reducing the secretion of glucose-6-phosphate and fructose-1, 6-bisphosphatase. Ethanolic extract of the flowers of the plant has also shown similar inhibitory action towards these enzymes to decrease gluconeogenesis. [26]

**Madhuca indica (family Sapotaceae)**

*Madhuca indica* is a well known plant in the regions of Bihar, Jharkhand and Odissa. Various studies have been conducted to explore the antidiabetic potential of the plant. The methanolic extract of the bark of the plant contains various sapogenins, triterpenoids, steroids, flavonoids and glycosides. The antidiabetic activity of the plant was tested on Streptozocin induced male wistar diabetic rats.

The proper mechanism is still unknown but it is assumed that the action may be due to its stimulatory action of the β cells of the pancreas. It may also resist hormones which rise blood glucose levels. Decrease in the leading out of glycogen from liver, increase in insulin sensitivity and increase in the utilization of glucose in tissues and organs may also contribute to its antidiabetic action. [27]

The extract has also shown potent α-amylase inhibitory action. The enzyme α-amylase is responsible for the hydrolysis of α-1,4-glycosidic linkages of starch, glycogen and various other oligosaccharides. α-glucosidase further reduces the disaccharides into simple glucose entities which leads to absorption of glucose by intestine. The inhibitory action of the extract is thus responsible for antidiabetic action. [28]

**Momordica charantia (family Cucurbitaceae, common name Bitter gourd)**

*Momordica charantia* or Bitter gourd is a very well known plant in the eastern regions of India. The fruit is a popular component of the daily diets of many local people. The fruit contains various glycosides, saponins, alkaloids, reducing sugars, resins, fixed oils and free acids. It is also used in the management of diabetes.

The bitter juice is often used for its antidiabetic activity. The major compound responsible for this action is Charatin. [29]

The proper mechanism of action of its antidiabetic action is still unknown but studies conducted on the plant have somewhat assumed a series of antidiabetic actions. It may be attributed to the inhibition of glucose uptake by the intestine, inhibition of adipocyte differentiation or suppression of key gluconeogenic enzymes. The action may be also due to stimulation of key HMP pathway enzymes. One important addition to the mechanism may be preservation of β cells by down regulation of proteins like mitogen activated protein kinase (MAPK), necrosis factor (NF-κB) in MIN6N8 cells. [30]

Other studies have assumed the antidiabetic action of the fruits by improvement in the serum glucose level by PPARγ gene expression. It has also shown inhibitory action on the enzymes glucose-6-phosphatase and fructose-1,6-bisphosphatase which leads to better glucose uptake from the body. [31] This is one possible mechanism for its antidiabetic activity.

**Musa paradisica (family Musaceae, common name Banana)**

*Musa paradisica* or Banana is one of the most well known fruits all over the world. The fruit contains very high level of electrolytes which makes it very popular among the sportspersons. However its unripe green fruit is also a popular component in diets.

The ethanolic and hydroethanolic (ethanol:water 1:1) extract of the fresh flowers of the plant is considered as a potent antidiabetic agent. The fresh flower contains carbohydrates, proteins, steroids, glycosides, saponins, alkaloids, tannins, phenolic components and flavonoids. This rich combination of nutrients makes Banana a very potent component in diet.

*Musa paradisica* exhibits dose dependent antidiabetic activity on Alloxan induced diabetic rats. Highest anti-hyperglycemic activity was seen when the extract was administered at a concentration of 100mg/kg. [32] Methanolic extract of the green fruits has also shown anti-hyperglycemic action but its mechanism of action is still unknown. [33]
Other studies based on the same plant have reported the presence of potent antidiabetic action of the stem juice of the plant. The tannins and alkaloids present in the stem juice are possibly responsible for the action by increasing insulin secretion from the $\beta$ cells of pancreas. [34]

**Ocimum sanctum** (family Labiateae, common name Holy Basil)

*Ocimum sanctum* or Holy Basil is a household name in India. The plant is used in various religious rituals. Apart from this the plant has been used in traditional medicine system since a very long time. It has been used in the treatment of common cold, influenza, swine flu, asthma, hepatitis, bronchitis etc.

However the leaves of the plant are also known for their antidiabetic action. The action may be due to hypoglycemic saponins, triterpenoids and flavonoids. They may sensitize the insulin receptors towards insulin or stimulate pancreatic $\beta$ cells. Administration of the leaves has resulted in significant rise in hepatic glycogen level which may be a result of the increase in the levels of those enzymes which are responsible in controlling overall glucose content in the body. [35]

The effect of the plant on diabetes mellitus was studied on human subjects with type 2 diabetes for a period of 90 days. And it has shown satisfactory result in the management of diabetes. Previously the use of the plant was limited as an adjuvant to marketed drugs but recent developments on its ability to increase the secretion of insulin from $\beta$ cells has proved its worth as an antidiabetic agent. [36]

**Psidium guajava** (family Myrtaceae, common name Guava)

The plant *Psidium guajava* is one of the most widely used plants in the treatment of diabetes. Various parts of the plant can be used in the management of diabetes. The leaves of the plant contain $\beta$-sitosterol, quercetin, leucocyanidin, gallic acid, ellagitannin and guavin A, B, C and D. It can be used as an astringent, anodyne, febrifuge, antispasmodic and tonic. The leaves have also proved useful in the treatment of wounds, ulcers, cholera, diarrhea, vomiting etc. [37]

Aqueous extract of the leaves has shown significant inhibitory action of the low density lipid-glycation (LDL). Methanolic and aqueous extracts were found to be potent inhibitors of glucose diffusion. [38] Other studies on the plant have reported the dose dependent inhibition of $\alpha$-amylase enzyme as well as for $\alpha$-glucosidase enzyme. Decrease in the concentration of those enzymes delay the degradation of carbohydrates which in turn decreases glucose absorption. [39]

**Terminalia chebula** (family Combretaceae)

In modern day also use of *Terminalia chebula* as a component of various traditional medicine is very well known. The antidiabetic activity of the dried pulp of the fruits in an ethanolic extract is well proven. The activity was tested on Alloxan induced diabetic rats. Earlier study on the plant showed that methanolic extract of the plant also inhibits lipid peroxide formation and scavenges hydroxyl and superoxide radicals in diabetic rats.

Its administration is also related to increased level of glycogen in the liver and this may be a result of its insulin like action. It activates glycogen synthase while inhibiting glycogen phosphorylase responsible for glycogenolysis in liver and muscles. [40]

Another mechanism for its antidiabetic action may be due to its ability to increase glycogen synthesis by stimulating glycogen synthase and hexokinase. The ethanolic extract shows its activity due to insulin like action by increasing phosphatidylinositol-3-kinase (PI-3K) action. This leads to stimulation of muscle glycogen synthase. Increased concentration of glycogen in skeletal and cardiac muscles may be attributed to the increase in expression and translocation of GLUT-4 glucose transporters as a result of increased PI-3K activation. This results in increased peripheral uptake of glucose. [41]

**Tinospora cordifolia** (family Menispermaceae)

The antidiabetic activity of *Tinospora cordifolia* is exhibited by both aqueous and alcoholic extracts of the stem of the plant. It was tested on Streptozocin induced diabetic rats and the result showed remarkable antidiabetic activity. The action was not carried out by increasing serum insulin level or $\beta$ cell regenerative property but it has shown increased hepatic glycogen
synthase and decreases glycogen phosphorylase activity. The action may be a result of increased entry of glucose into the peripheral tissues and organs like liver. [42]

Apart from the stem of the plant methanolic extract of the roots of the plant has also shown antidiabetic activity. The studies have reported pancreatoprotective, pancreatogenerative properties which lead to the antidiabetic action of the plant. [43]

**Conclusion**

Management of Diabetes mellitus has been one of the main thrust areas in the medical field and a permanent solution to this metabolic disorder is still unknown. However, various plants which are abundantly found in the eastern region of India, specifically in the states of Bihar, Jharkhand, West Bengal and Orissa, have proven to be useful in the treatment and management of Diabetes. More awareness to preserve and proper usage of these medicinal plants can prove to be helpful in future.

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