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Plant Secondary Metabolites of Pharmacological Significance in Reference to Diabetes Mellitus: An Update

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A B S T R A C T

Diabetes mellitus is a metabolic disorder characterized by hyperglycemia and alterations in carbohydrate, fat and protein metabolisms. Diabetes is associated with absolute or relative deficiencies in insulin secretion by pancreatic β-cells and/or insulin action. For the treatment of diabetes large numbers of herbal preparations are in vogue. Plant cells produced secondary metabolites which are biologically active constituents with therapeutic and prophylactic applications in humans. These metabolites includes alkaloides, glycosides, flavonoids, terpenoids, tannins, resins, lignins, saponins etc. majority of the world population depends on herbal drugs for their health care needs.This review gives information on secondary metabolites with pharmacological properties, techniques used in isolation and identification and also summaries data on 112 plants, plant parts, their antidiabetic properties with anti glycemic and other chemotherapeutic functions.

Introduction

Medicinal plants are the most important source of life saving drugs and since ancient time the plant based medicinal products have been known to mankind. Primary health care needs of more than 70-80% of world's population basically come from traditional herbal products (Fransworth *et al.,* 1991). Ayurveda has described about 5000 years old rich heritage of plants and their use in the treatment of various human ailments as alternative medicine. It is estimated that about 7,500 plants are used in local health traditions in India. Whereas the classical systems of medicine such as Ayurveda, Siddha, Amchi, Unani and Tibetan describe medicinal values of about 1,200 plants (Pushpangadan *et al.,* 1995). The demand for application of plant based medicines for treatment of metabolic disorders such as cancer, rheumatoid arthritis, diabetes etc., is gradually increasing (Kalia, 2005). A number of studies have been done for validation of enriched plant preparations

for therapeutic applications in diverse experimental animals. Growing recognition for the plant products is attributed to their non-toxicity and easy availability at affordable price.

Diabetes mellitus has become the prominent "killer" disease of mankind like cancer, cardiovascular and cerebrovascular diseases (Chauhan *et al.*, 2010). It is estimated that 25% of the world population is affected by diabetes mellitus (Arumugam *et al.*, 2013). Diabetes mellitus is considered a group of metabolic disorders characterized by high blood sugar (glucose) levels, which result from defects in insulin secretion or action or both. It affects not only carbohydrate but also, protein and fat metabolism (Tripathi, 2003). Insulin is a polypeptide hormone, which is secreted by the β-cells of the islets of Langerhans of the pancreas. It helps in storing the blood glucose as glycogen in the liver and muscles cells. If the pancreas does not produce enough insulin or the produced insulin does not work properly, the glucose cannot enter to the body cells. So glucose remains in the blood and get converted into unwanted products with detrimental consequences. According to the etiology of Diabetes Mellitus, it can be classified into following major categories:

Type-1

It also known as "Insulin dependent Diabetes mellitus", which occurs in the childhood, and accounts for 5 to 10% of all diabetes cases. This is mainly due to destruction of pancreatic β-cell islets, resulting in absolute insulin deficiency and is positively associated with HLA B8- DR and DR-4. Recent research has shown that there is increased susceptibility to type-1 Diabetes mellitus when the amino acid Asp 57 is absent in DQ B with the presence of Arg 52 in DQ A (Wang and He, 1993; Ronningen *et al.*,1989).

Type-2

It also known as "Non insulin dependent Diabetes mellitus," is more associated with adulthood and elderly people. Pathophysiological basis for this is a combination of impaired β- cell function, with marked increase in peripheral insulin resistance at receptor/ post receptor levels and increased hepatic glucose output production. This type of disease accounts for 90 to 95% of all diabetic patients.

Gestational

Another type of diabetes, diagnosed during the pregnancy (Lokesh and Amit, 2006; Seshiah *et al.*, 2000). It is fully treatable, but requires careful medical supervision throughout the pregnancy. About 20-50% of affected women develop type 2 diabetes later in life.

The term pre-diabetes is used for the condition in which fasting blood glucose level is ≥ 110 and < 126 mg/dl. Factors such as Heredity, Age, Obesity, Sex, Diet, Physical Inactivity, sedentary Lifestyle and various stresses etc**.** are directly or indirectly trigger pre diabetic condition. Persistent hyperglycemia, generates reactive oxygen species (ROS) which may promote peroxidation of lipids, proteins and other biomolecules. The oxidative stress inturn aggravates inflammatory response, which ultimately end up with complications such as cataract, neuropathy and nephropathy over a period of time (Dewanjee *et al.*, 2009).

The ethnobotanical studies report about wide variety of plant species which possess antidiabetic properties (Alarcon *et al.*, 1998; Rashid *et al.*, 2014; Saminathan and Kavimani, 2015). Further an array of plant derived principles mainly belonging to alkaloids, glycosides, galactomannan gum, polysaccharides, hypoglycans, peptidoglycans, guanidine, steroids, glycopeptides, and

terpenoids have demonstrated bioactivity against hyperglycemia (Ivorra *et al.,* 1988; Maries and Farnsworth, 1995). In this review we tried to provide information on the types of secondary metabolites, their identification techniques and also summarised the description of about 112 medicianal plants with antidiabetic property, their bioactive molecuels, mode of action and also application of *in vitro* culture techniques used for secondaty metabolites production.

Plants as novel source for bioactive/secondary compounds

Plants produce a vast and diverse variety of organic compounds, the great majority of which do not appear to participate directly in growth and development, traditionally referred to as "secondary metabolites". They are usually classified according to their biosynthetic pathways (Harborne *et al.,* 1999). Based on biosynthetic origins, plant natural products are classified into three major groups: viz., terpenoids, alkaloids, and the phenylpropanoids & allied phenolic compounds. Terpenoids are derived from the five-carbon precursor isopentenyl diphosphate (IPP). Most of the alkaloids, with one or more nitrogen atoms, are biosynthesized principally from amino acids. While, vast numbers of phenolic compounds are formed either by the shikimic acid pathway or the malonate/acetate pathway (Buchanan *et al.,* 2000).

A brief description of bioactive compounds, their basic nature, their major plant or family and their main Pharmacological properties reported are given in Table 1.

Techniques; identification and characterization of bioactive molecule inherbal preparation

The extraction process of bioactive compounds depends on the polarity of the molecule and the solvent used. Different solvents such as aqueous, methanol, ethanol, benzene, chloroform, ether etc. have been used for the extraction of bioactive compounds with antidiabetic property from different medicinal plants. Crude extracts contain numerous plants secondary metabolites like alkaloids, glycosides, flavonoids, terpenoids etc. which are reported to regulate the blood glucose level through different mechanism like nourish or stimulate β-cells, increase in insulin sensitivity, stimulate glycogenesis and/or suppress gluconeogenesis.

Bioactive molecules from the crude extracts can be further separated, isolated and purified by a combination of chromatographic methods and several other techniques depending on the properties of each biomolecule of intrest. Some of the most commonly used techniques for the separation; isolation and identification are given blow.

High Performance Thin Layer Chromatography (HPTLC)

TLC is the common fingerprint method for herbal analysis.The mobile phase is drawn through the stationary phase by capillary action. Samples are separated according their component's polarity. HPTLC fingerprint is mainly used to study the compounds with low or moderate polarity.

HPTLC technique is widely employed in process development, identification and detection of adulterants in herbal product and helps in identification of pesticide content, mycotoxins and in quality control of herbs and health foods (Soni and Naved, 2010). Crude extracts along with standard molecule are applied and softwares are available to analyze the amount of compounds present in the sample. In this method we can analyze 6-10 samples at a time.

High Performance Liquid Chromatography (HPLC)

This method is more refined and accurate as compared to HPTLC. In this technique very fine particles of approximately 10 µm in diameter are used as stationary phase and high pressure is used to maintain adequate flow rate of mobile phase along with sample, hence, called High Performance or High Pressure Liquid Chromatography. Small volume of sample is used and one sample at a time is analyzed. At present time, this procedure has been used principally with ion exchange and adsorption chromatography for small molecules, peptides, small carbohydrates and tRNA etc.

Preparative and analytical HPLC are widely used in isolation and purification of herbal compounds. There are basically two types of preparative HPLC: low pressure HPLC (typically under 5 bar) and high pressure HPLC (pressure >20 bar) (Chimezie *et al.*, 2008; Saravanan *et al.*, 2010).

The combination of HPLC and LC/MS is currently the most powerful technique for the quality control of herbal drugs (Zhang and Ye, 2009).

Ultra-Performance Liquid Chromatography (UPLC)

Ultra-performance liquid chromatography (UPLC) is another improved LC technique which utilizes 2 µm size particles as stationary phase and is more advanced technique with improved resolution, sensitivity and speed, without compromise.

UPLC is used to evaluate decocting-induced chemical transformations and chemical consistency between traditional and dispensing granule decoctions (Li *et al.*, 2010a; Li *et al.*, 2010b).

Liquid Chromatography - Mass Spectroscopy (LCMS)

Liquid chromatography-mass spectrometry (LC-MS) is now a routine technique with the development of electrospray ionisation (ESI). LC-MS has become method of choice in many stages of drug development (Mike and Edward, 1999). The use of tandem MS and stable isotope internal standards allows highly sensitive and accurate assays to be developed although some optimization methods are required to minimise ion suppression effects. Fast scanning speeds allow a high degree of multiplexing and many compounds can be measured in a single analytical run. The reasons for choosing LC-MS over LC with conventional detectors are essentially the same as with GC-MS, namely high specificity and the ability to handle complex mixtures.

Liquid Chromatography - Nuclear Magnetic Resonance (LC-NMR)

LC-NMR is the most versatile analytical technique for complex mixture analysis. Specifically, interfacing liquid chromatography with parallel NMR and mass spectrometry (LC–NMR–MS) gives comprehensive structural data on metabolites of novel drugs in development and applications in natural product. Recent innovations to improve NMR detection include speed and sensitivity of detection and found useful in the areas of pharmacokinetics, toxicity studies, drug metabolism and drug discovery process (Dachtler *et al.*, 2003; Pasch *et al.*, 2008; Patil and Rajani, 2010).

Gas Chromatography (GC) and Gas Chromatography-Mass Spectroscopy (GC-MS)

GC-MS is analytical method that combines the features of gas-liquid chromatography and mass spectrometry to identify different

voletile substances within a test sample. The basic principal of this technique is to measure a sample with an unknown concentration. Applications of GC-MS include; drug detection, environmental analysis, identification and quantification of chemical constituents present in polyherbal oil formulations (Kasthuri *et al.*, 2010).

Supercritical Fluid Chromatography (SFC)

It is a form of normal phase chromatography, which is used for the analysis and purification of low to moderate molecular weight and thermally labile molecules. It can also be used for the separation of chiral compounds. Basic principles for isolating compounds with SFC are similar to the fundamental rules for large-scale preparative liquid chromatography, however SFC typically utilize carbon dioxide as the mobile phase; therefore the entire chromatographic flow path must be pressurized.

Because the supercritical phase represents a state in which liquid and gas properties converge, supercritical fluid chromatography is sometimes called "Convergence Chromatography". SFC permits the separation and determination of a group of compounds that are not conveniently handled by either gas or liquid chromatography. SFC enables the resolution of unknown components and known markers such as azadirachtin A and B, salannin, and nimbin in neem seed extracts (Agrawal *et al.*, 2009).

Capillary Electrophoresis (CE)

Capillary electrophoresis is the most efficient analytical technique that separates ions based on their electrophoretic mobility with the use of an applied voltage. This method is two times shorter than that of HPLC and solvent consumption was approx 100-fold lesser than HPLC (Sombra *et al.*, 2005). The technique is available for the analysis of both large and small molecules. The electrophoretic mobility of molecules is dependent upon charge, viscosity, and atom's radius. Rate at which the particle moves is directly proportional to the applied electric field. The importance of CE in quality control of herbal medicinal products (Ganzera, 2008) especially in compounds such as alkaloids (Wen *et al.*, 2005) and flavonoids (Pietta *et al.*, 1991).

Infrared spectroscopy

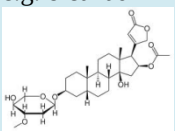
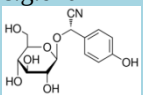
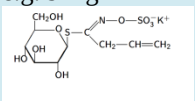
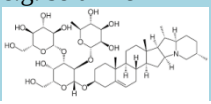
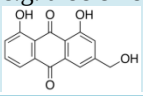
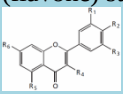
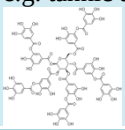
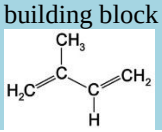
IR - spectroscopy is an accepted and wide spread analytical method to analyze a lot of chemical substances. The working principle is the excitation of vibrations and rotations of molecules by absorption of infrared radiation. The energy to excite this vibrations and rotations depends on the mass of the atoms and the binding forces between them.

A IR - spectrum of a functional group in a molecule is characteristic for this group, That's why it can be identified with the IR - spectrum like a fingerprint of this group. FTIR along with the statistical method 'principal component analysis '(PCA) has been applied to identify and discriminate herbal medicines for quality control in the fingerprint region of 400-2000 cm^{-1}.

Diabetes mellitus and its treatment

Pancreatic β-cells secretes insulin in response to sugar level of circulating blood, which reduces blood sugar level and allows glucose to more readily enter the cells, and also facilitate the storage of glucose as glycogen. On the other hand low level of insulin in blood leads to brake down of glycogen and reduced ability of cells to absorb sugar. So blood sugar level gets increased. Other than insulin many harmones like glucagon from pancreas, adrenaline and cortisteroids from the adrenal glands also regulate the blood sugar level.

Table.1 Main groups of bioactive compounds in plants

Bioactive compound	Chemical properties	Family of plant sp. Found in	Pharmacological properties
Glycoside	Mono-oligosaccharides + uronic acid		
Cardiac glycoside	Aglycan part is a steroidal moiety. e.g. oleanadrin 	Scrophulariaceae Convallariaceae	Inhibition of Na^+/K^+ATPase pumps.
Cynogenic glycoside	Derived from amino acids. e.g.dhurrin 	Rosaceae	Release of HCN, which is very toxic and being lethal at high dosages.
Glucosinolates	Derived from S-containing amino acids. e.g. sinigrin 	Brassicaceae	Antioxidant
Saponins "soap forming compound"	Consist of either pentacyclic triterpenoids or tetracyclic steroids. e.g. solanine 	Liliaceae	In vitro hemolysis of RBCs.
Anthraquinone glycosides	Derived from di, tri or tetra anthaquinone. e.g. aloe emodin 	Polygonaceae	Induced water and electrolyte secretion.
Flavonoids **and** **Proanthocyanidins**	Central three-ring (flavone) structure.  Oligomers of flavonoids.	Fabaceae	Antioxidant and also reduce inflammation and carcinogenicity.
Type I Tannins	Large polymer of flavonoids. e.g. tannic acid 	Fagaceae Polygonaceae	Astringents and used inin cases of diarrhea, skin bleedings and transudates.
Terpenoids	Derivatives of 5-C building block isoprene 	Lamiaceae	Theyare antineoplastic, antibacterial, antiviral acitivity and also stimulate gastro intestinal secreations.

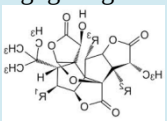
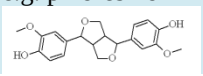
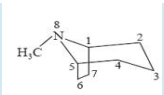
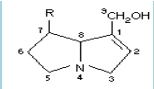
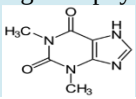
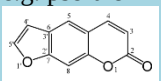
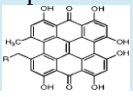
Diterpenoides	Composed of 4-isoprene unit. e.g. g inkgolide 	Coffea Arabica	Antineoplastic activity.
Resin	Complex lipid soluble mixture of Terpenoids. e.g. polymer of styrene 	Most conifers	They have Antimicrobial and wound healing activity. Resins are generally safe, but contact allergy may occur.
Lignans	Composed of two phenylpropanoid units,generally lipophilic. e.g. pinoresinol 	Oil seeds	Having phytoestrogenic and antineoplastic effects.
Alkaloids	Heterocyclic, N-containing compounds drived from amino acids.		
Tropane alkaloids		Solanaceae	Have Anticholinergic activity and also used in hypersecretion and pain.
Pyrrolizidine alkaloids		Asteraceae Boraginaceae	Hepatotoxicity.
Isoquinoline alkaloids		Papaveraceae Berberidaceae	Inhibition of various conditions as pain, cancer cells and bacteria.
Methylxanthine alkaloids		Coffea arabica Theobroma cacao	Elicit neurological effects.
Pseudoalkaloids	Have heterocyclic ring with nitrogen but not drived from amino acids. e.g. theophylline 	Apiaceae	Effect on CNS
Furocoumarins	Furan ring fused with coumarin. e.g. psoralen 	Apiaceae	Affact the metabolism of certain drugs.
Anthraqionones	Phenolic compounds based on 9, 10-antheaquinone skeleton. e.g. Hypericin, a naphthodianthrones 	Clusiaceae, Polygonaceae	Antidepressant effect.

Table.2 Potential anti-diabetic plants, their active compounds ingredients and pharmaceutical attributes

Plant Botanical name/ common name/ Family	Plant part explored	Nature of active ingredients	Solvent (s) employed in various studies for extraction	Pharmaceutical activity attributed	Reported experimental validation	Reference
Plants which shows the α-glucosidase inhibitory activity						
Acacia auriculiformis (Northern black wattle) **Leguminosae**	Bark Pods	Phenolics Flavonoids Proanthocyanidins	Acetone	Antidiabetic Antioxidant Anti bacterial Antifungal Cardioprotective Anticancer	Significant reduction of blood glucose level was evident in diabetic rats at doses of 250 and 500 mg/kg.	Ray *et al.*, 2006; Sathya and Siddhuraju, 2012
Canthium dicoccum **(Bogas) Rubiaceae**	Bark	Alkaloids Glycosides Phytosterols Saponins.	Ethanol	Antifungal Anti-inflammatory Antidiabetic Nephroprotective Antiarthritic	Ethanolic extract at doses (200, 400 mg/kg) exhibited significant anti-hyperglycaemic activity.	Santhan *et al.*, 2013.
Cassia auriculata **(Senna, sunamukhi) Caesalpiniaceae/ Leguminosae**	Leaf Seed Flower	Terpenoids Tannin Flavonoids Saponin Cardiac glycosides Steroids.	Hexane Chloroform Ethyl acetate Methanol Aqueous Absolute-alcohol	Antifungal Antibacterial Anti-inflammatory Antioxidant Hepatoprotective Antidiabetic	Oral admistration of aqueous flower extract in streptozotocin-induced diabetic rats shows anti-hyperglycemic activity.	Harborne, 1998; Faraz *et al.*, 2003; Edeog *et al.*, 2005.
Cistus laurifolius (laurel-leaved rock rose) **Cistaceae**	leaf	Favonoids	Ethanol Aqueous	Anti-inflammatory Antirheumatic Antidiabetic Antioxidant Antiulcer	Blood glucose levels of the streptozotocin-induced diabetic rats were decreased by ethanol extract at of 250 and 500mg/kg doses.	Orhan *et al.*, 2013.
Cuminum cyminum **(Jeera) Apiaceae**	Seed	Flavonoids Polyphenols	Ethanol	Antimicrobial Antidaibetic Antifertility Anticancer Antioxidant Immunomodulatory	Oral dose of 250 mg/Kg body weight shows reduction in glucose level in streptozotocin-induced diabetic rats.	Srivsatava *et al.*, 2011.
Hunteria umbellate **(Demouain) Apocynaceae**	Seed	Alkaloidal Indolealkaloids Flavonoids Tannins Glycosides	Methanol Aqueous	Antidiabetic Antioxidant Antibacterial Weightloss Anti-inflammatory Immune booster.	Oral administration of 400 mg/kg of seeds for 14 days was associated with significantly reduced blood glucose and body weight.	Igbe *et al.*, 2009.

Mukia madeaspatana (Melothria) **Cucuerbitaceae**	Root	Phenolics Carotenoids Flavonoids	Methanol	Antioxidant Hypotensive Immunomodulatory Anti-inflammatory Hepatoprotective Antimicrobial Vasodialatory Diuretic Antiasthmatic Antidiabetic	Methenolic root extract at a dose of 500 mg/kg to Alloxan induced diabetic rats showed significant reduction of blood glucose, lipid profile except HDL.	Wani *et al.*, 2011.
Rehmania glutinosa **(Chinese foxglove)** **Scrophulariaceae**	Root	Iridoids Monoterpenes Glycosides Phenols Flavonoid	Ethanol	Antidiabetic Antioxidant Hepatoprotective Anti-inflammatory Antimicrobial	Ethanolic extrat at dose 100mg/kg for 15 days) showed a significant decrease in blood glucose level.	Zhang *et al.*, 2004; Jeonga *et al.*, 2013.
Syzygium cumini **(Black Plum)** **Myrtaceae**	Leaf Stem Bark Flower Root Fruit	Glycoside Alkaloids Flavonoids	Aqueous Alcohol	Antidiabetic Diuretic Antioxidant Antidiarrhoeal Antibacterial Gastroprotective Redioprotective Anti-inflammatory	Leaf extract at dose 4g/kg of body weight found to exhibit maximum hypoglycaemic effect in rabbits	Nair *et al.*,1986; Pepato *et al.*, 2001; Ayyanar *et al.*, 2012
Vaccinium arctostaphylos **(Caucasian Whortleberry)** **Ericaceae**	Fruit	Anthocynins	Ethanol	Antidiabetic Anti-inflammatory Hepatoprotective Antioxidant Antibacterial Antifungal	Ethanolic extract of fruits showed postprandial blood glucose lowering in alloxan induced diabetic male wistar rats	Feshani *et al.*, 2011.
Plants which increases the sensitivity of liver, fat and muscle cells to insulin						
Amaranthus viridis **(Cholai)** **Amaranthaceae**	Stem	Alkaloids Steroids Glycosides Saponins Tannins	Aqueous Methanol Pet-ether	Anti-inflammatory Diuretic Antirheumatic Antidiabetic Analgesic Antirheumatic Antidiabetic	100, 200, 400 mg/ kg body weight stem aqueous extract significantly decreased the blood glucose level in streptozotocin induced diabetic rats.	Pandhare *et al.*, 2012.
Acorus calamus **(Bach)** **Acoraceae**	Rhizome	Saponins Glycosides Sequiterpenoids	Methanol Ethyl acetate	Aphrodisiac Diuretic Antisplasmodemic Antirheumetic Anti-inflammatory Antioxidant Hypoglycemic	200mg/kg of rhizome extract showed significant restoration of the blood glucose levels in streptozotocin induced diabetic rats.	David *et al.*, 2012: Prisilla *et al.*, 2012.
Bauhinia forficate **(Paw-of-cow)**	leaf	Flavonoids	Aqueous Ethanol Hexane	Antidiabetic Antimutagenic Antioxidant Hypolipidimic	Oral admistration of aqueous, ethanolic and hexane extract of leaves at dose 200 and	Lino *et al.*, 2004.

Fabacae					400 mg/kg showed significant reduction in plasma glucose level alloxan rats.	
Bryophyllum pinnatum (Air Plant) **Crassulaceae**	leaf	Bryophillin A Bersaldegenin-3-acetate Bryophillin C Alkaloids Triterpenes Glycosides Flavonoids Steroids Butadienolides Lipids Organic acids.	Aqueous Ethanol	Anthelmentic Hepatoprotectiv Anti-inflammatory Antidiabetic Diuretic Antioxidant Antimicrobial Analgesic Antipyretic	200 mg/kg aqueous extract resulted in a significant drop in blood sugar level.	Aransiola *et al.*, 2014.
Cajanus cajan **(pigeon pea/ arhar)** **Papilionaceae/ Leguminosae**	Leaf Stem Twig	Flavonoids β-Carotenoids Glycoside Resin Terpenoids Tannins	Methanol Ethanol Aqueous	Antidiabetic Hepatoprotective Anti-viral Anti-bacterial Nuroprotective Antioxident Anticancer	Single doses of unroasted seeds to normal as well as alloxanized mice shows significant reduction in the serum glucose levels	Ezike *et al.*, 2010
Camellia sininsis **(Green tea)** **Theaceae**	Leaf Flower	Epigallocatechin-gallate Epicatechin-gallate Epicatechin Catechin Epigallocatechin Gallic acid	Aqueous	Anti-aging Anticancer Cardioprotective Antidiabetic	75, 150 and 300 mg/kg body weight caused a significant decrease in blood glucose levels of alloxan-induced diabetic mice.	Han *et al.*, 2011.
Colocasia esculenta (Arbi) **Araceae**	leaf	Cynoglucosides Flavonoids β-sitosterol Steroid	Ethanol	Analgesic Anti-iinflammatory Anticancer Hypolipidemic	Ethanolic extract of leaves at dose 450 mg/kg showed significant reduction of blood glucose levels in alloxan induced diabetic rats.	Kumawat *et al.*, 2010.
Cucumis trigonus (Vishala) **Cucurbitaceae**	fruit	Emeclocycline glycodeoxycholic acid, 3α,7α,12α - Trihydroxycoprostanic acid Chlortetracycline Azafrin Methyl Ester	Ethanol Aqueous	Antibacterial Analgesic Anti-inflammatory Diuretic Antidiabetic Hepatoprotective	Oral admistration of aqueous extract to normal and streptozotocin induced diabetic rats at dose of 500mg/kg shows reduction in blood glucose level.	Salahuddin *et al.*, 2010.

		Giganteumgen in N, phorbol 12,13-Dihexanoate Astaxanthin Tetrahydro spirillo xanthin				
Cynodon datylon (Doob) **Poaceae**	Leaf	Alkaloids Tannins Saponins Carbohydrates Glycosides Steroids Terpenoids	Aqueous	Hypoglycemic Hypolipidimic Woundhealing Antibacterial Antiviral Anti-inflammatory	Aqueous extract of leaves at dose 500 mg/kg body weight significantly reduced blood glucose level.	Singh*et al.*, 2007; Vijayan *et al.*, 2014.
Emblica officinalis/ Phyllanthus Emblica **(Amla)** **Euphorbiaceae**	Fruit Leaf Seed	Tannins Alkaloids Phenolics Flavonoids	Aqueous Ethanol Butanol	Antioxidant Immunomodulatory Hepatoprotective Antimicrobial Anti-inflammatory Radioprotective Antitumor Antimutagenic	Oral administration 100 mg/kg body weight reduced the blood sugar level in normal and in alloxan induced diabetic rats.	Jain and Khurdiya, 2004; Suryanarayan *et al.*, 2007; Khan, 2009; Tirgar *et al.*, 2011.
Foenum graceum **(Methi)** **Fabaceae**	Seed Leaf	Flavonoids Saponins Alkaloids Trigonelline Choline.	Petroleum ether Chloroform Ethyl acetate Methanol Ethanol	Hypoglycemic Hypocholestrolemic Immunomodulatory Antiulcerative Antibacterial Antihypertensive Anticarcinogenic Antioxidant Diuretic.	Oral admistration of ethanol extract of seed at 2 g/kg, 1 g/kg, 0.5 g/kg and 0.1 g/kg dose, in diabetic rats.	Sarasa *et al.*, 2012.
Hypoxis hemerocallidea (yellow stars) **Hypoxidaceae**	Corm	β-Sitosterol Ergosterol Stigmasterol	Aqueous	Anti-inflammatory Antidiabetic Antioxidant	Aqueous extract 50-800 mg/kg produced dose-dependent, hypoglycaemia in normal and streptozotocin induced diabetic rats.	Ojewole, 2006.
Ipomoea reniformis **(musakani)** **Convolvulus**	Stem Leaf	Caffeic P-Coumaric Ferulic Sinapic acids Phthalate Resins Glycosides Tannins	Ethanol Aqueous	Antihyperglycemic Antihyperlipidaemic Diuretic Laxative Anti-Inflammatory Antipyretic	Ethanol extract of leaves at (400 mg/kg) dose in alloxan induced diabetic rats showed significant reduction in blood glucose level.	Bothara and Vaidya, 2016.

Juglans regia (walnut) **Juglandaceae**	Leaf	Linoleic acid Oleic acid Linolenic acid Palmitic acids	Alchohol	Antioxidant Antibacterial Antidiabetic	Alchoholic leaf extract at dose200 and 400 mg/kg body weight to streptozotocin induced male wistar rat showed significant reduction in blood glucose level.	Mohammadi *et al.*, 2011.
Lantana aculeate **(Red sage)** **Verbenaceae**	Roots	Oleanolic acid	Ethanol	Anticancer Antiulcer Anti-hyperglycemic Termiticidal	Ethanolic extract at the doses of 25, 50 and 100 mg/kg to diabetic rats, significantly reduced the level of glucose, total cholesterol and triglycerides.	*Kumar et al., 2010*
Phyllanthus neruri **(Jangli amla)** **Euphorbiaceae**	Root Stem Leaf	Flavonoids Alkaloids Terpenoids Lignin Polyphenols Tannins Coumarins Saponins	Acetone Aqueous	Anti-inflammatory Antidiabetic Antimicrobial Antihyperlipidaemic Antioxidant Anticancer Hepatoprotective Antiviral Diuretic	Oral Administration at dose 471.2mg/kg body weight caused a significant dose-related reduction in blood glucose levels in diabetic and normoglycaemic rats.	Okoli *et al.*, 2010.
Zizyphus mauritiana **(Ber)** **Rhamnaceae**	Seed	Alkaloids Flavonoids Glycosides Saponins Sterols Tannins Lignin Phenols	Petroleum ether Aqueous	Haemolytic Sedative Alkaloids Antimicrobial Hypoglycemic Antiplasmodial Antidiabetic Diuretic Analgesic Anti-inflammatory	Aqueous extracts of seeds at dose levels, 200 and 400 mg/kg, showed hypoglycaemic effect in allaxon induced diabetic mice.	Bhatia and Mishra, 2010.
Plants which stimulates the β-cells in the pancreas to release more insulin						
Acacia arabica **(Babul)** **Fabaceae**	Leaf Seed Pod Bark Gum	Flavonoids Gallic acid Isoquercitin Leucocyanadin Glucopyranoside Rutin Glucopyranoside	Methanol Ethanol Aqueous	Antidiarrhoeal Antidiabetic Antifungal Antiviral Antimutagenic Antifertility Antibacterial	About 94% seed diet showed hypoglycemic effect in rats.	Singh *et al.*, 2009; Singh., 2011
Agrimony eupatorium (Agrimony) **Rosaceae**	Leaf Stem	Catechin Palmitic-acid Quercitrin Silicic-acid Tannin	Aqueous	Anticancer Astringent Diuretic Antidiabetic Antioxidant	Agrimony incorporated into the diet (62.5 g/kg) showed the anit-hyperglycemic	Gray and Flatt, 1998.

		Thiamin Ursolic-acid			effect on streptozotocin induced diabetic mice.	
Alangium salvifolium **(Ankola)** **Alangiacea**	Leaf Seed Bark	Tannins Flavonoids Glycoside Alkaloids Gum Mucilage	Methanol	Antipyretic Laxative Astringent Antirheumatic Analgesic Antidiarrheal Antifungal Hepatoprotective Antidiabetic	Methanolic extract at dose 500 mg/kg in normal rats showed hyperglycaemic effect.	Mishra and Gary, 2011
Allium sativum **(Garlic)** **Alliaceae/ Liliaceae**	Clove Leaf Root	Alliin (diallyldisulfide oxide) Allicin APDS (allyl propyl disulfide) S-allyl cysteine S-allyl mercaptocysteine	Aqueous Methanol	Lipid-Lowering Hypotensive Anticancer Antioxidant Antimicrobial	Oral dose of 0.25 mg/kg of ethanol, petroleum ether and ethyl acetate extract in alloxanized rabbits, shows Antihyperglycemic activity.	Eidia *et al.*, 2006; Younas and Hussain, 2014.
Aloe vera **(Aloe)** **Aloaceae**	Leaf	Pentosides- Barbaloin Isobarbaloin Aloin Betabarbaloin Anthraquinones Saponins Lignin Salicylic acid	Aqueous	Cardioprotective Antitumor Antioxidant Anti-inflammatory Hepatoprotective Immunomodulatory Antifungal	*Aloe vera* extract was orally administered at 0.5 ml/100 gm body weight showed anti hyperglycemic effect.	Chauhan. *et al.*, 2010; Singh *et al.*, 2010; Saghir *et al.*,2011
Aralia cachemirica **(Aralia)** **Araliaceae**	Root	Essential oils α-Thujene α-Pinene Camphene Sabinene B-Pinene Myrcene α-Phellandrene α-Terpinene Limonene Cineole Ocimene Linalool Campholenal Camphor Borneol Terpinen-4-ol (Z)-Piperitol	Aqueous Alchhol	Anti gastritis Anti rheumatic Anti arthritic Anti-inflammatory Anti diabetic	The aqueous and alcoholic extracts at a dose of 250 mg/kg showed significant hypoglycaemic activity in normal fasted and glucose induced hyperglycaemic rats.	Bhat *et al.*, 2005: Verma *et al.*, 2010.

Asparagus racemosus **(Satavari)** **Liliaceae**	Root Flower Fruit Leaf	Alkaloid Asparagamine Spirostanosides Sparagine Flavonoids Resin Tannin	Aqueous Ethanol Alcohol Chloroform/ Methanol (1:1)	Hepatoprotective Immunomodulatory Hypoglycemic Diuretic	Daily administration to type 2 diabetic rats for 28 day, decreased serum glucose.	Shao, *et al.*, 1997.
Atriplex halimus L. (Sea orache /Shrubby orache) Chenopodiaceae	Leaf	Tannins Flavonoids Saponins Alkaloids Resins	Aqueous Methanol	Antioxidants Hypoglycemic Hypolipidemic	Aqueous extract at dosage of 20mg/kg weight to streptozotocin induced diabetic rats significantly shows the glucose lowering effect.	Chikhi *et al.*, 2014.
Bauhinia variegate **(Orchid/ Kachnar)** **Fabaceae**	Leaf Stem Bark	Lupeol β-sitosterol Tannins Kaempferol-3-glucoside Amides Rutin Apigenin Apigenin -7-O-glucoside.	Ethanol Aqueous	Antiophidian Antidiabetic Antimalarial Antimicrobial Antioxidant	200 and 400 mg/ kg aqueous extract of bark showed significant antihyperglycemic activity in Allaxon induced hyperglycaemic rats.	Kumer *et al.*, 2012; Gunalan *et al.*, 2012.
Biophytum sensitivum (Lajvanti) **Oxalidaceae**	Leaf	Amentoflavone Cupressuflavone Isoorientin Flavonoids Phenolics Steroids	Aqueous Methanol	Antibacterial Antioxidant Anti-inflammatory Antitumor Radioprotective Chemoprotective Antimetastatic Anti-angiogenesis Wound-Healing Immunomodulatory Anti-Diabetic Cardioprotective	Dose of 200 mg/kg body weight was optimum for hypoglycemia.	Puri *et al.*, 2001.
Catharanthus roseus **or** ***Vinca rosea*** **(Barah masi)** **Apocynaceae**	Root Leaf Stem Flower	Tannins Triterpenes Alkaloids Flavonoids Saponins	Aqueous Ethanol Acetone Methanol	hypotensive Antibacterial Antifungal Antiviral Anticancer	Dry leaf powder at dose 3 mg/kg shows significant antidiabetic effect in streptozotocin induced diabetic rats.	EL-Sayed and Cordell, 1981; Nayak and Lexley, 2006; Chauhan *et al.*, 2012.

Cinnamomum tamala **(Tejpatra)** **Lauraceae**	Leaf Bark	α-pinene Camphene Myrcene limonene Eugenol p-cymene Methyl eugenol acetate	Aqueous	Antihyperglycemic Antidiabetic Antioxidant Hypolipidemic Astringent Anti-inflammatory Anti-arthritic	250mg/kg body weight of aqueous leaf extract shows blood glucose lowring effects in streptozotocin induced diabetic rat.	Gupta *et al.*, 2009; Chakrabarty and Das, 2010.
Citrullus colocynthis (Bitter apple/ Bitter cucumber) **Cucurbitaceae**	Pulp	Colocynthin Colocynthein (Resin) Colocynthetin Pectin Gum	Ethanol	Analgesic Antibacterial Anti-inflammatory Analgesic Hair growth-promoting Abortifacient Antiepileptic	Oral admistration of ethanolic extract of pulp at doses 300 mg/kg shows insulinotropic action in allaxon induced diabetic rats.	Dallak *et al.*, 2009.
Clausena lansium (Wampee) **Rutaceae**	Stem Bark Fruit	β-santalol Bisabolol Methyl santalol ledol Sinensal 9-octadecenamide phellandrene limonene P-menth-1-en-4-ol.	Methanol	Anti-trichomonal Antidiabetic Anti-Inflammatory Hepatoprotective Antioxidant	100mg/kg Methanolic extract induced maximum and significant anti-hyperglycaemic activity compared to control.	Adebajo *et al.*, 2009.
Coriandrum sativum **L (Coriander/ Dhaniya)** **Umbelliferae**	Seed	Linalool Coumarins Flavonoids Phenolic Acids Polyacetylenes Phthalides Mucilage	Ethanol	Antioxidant Antilithogenic Anti-inflammatory Antidiabetics	200 and 250mg/kg ethanol extract exhibited a significant redction in serum glucose level in streptozotocin induced diabetic rats.	Chitra and Leelamma, 1999.
Coscinium fenestratum **(Jhar haldi)** **Menispermaceae.**	Whole plant	Alkaloids Berberin	Ethanol Chloroform	Anxiolytic Antidepressant Hypoglycemic Hypotensive Antidiabetic Cardioprotective	Ethanolic extract (250 -1,000 mg/kg) significantly decreased plasma glucose concentrations in a dose-dependent manner.	Sirintorn *et al.*, 2009
Ginkgo biloba **(Maiden hair tree)** **Gingoaceae**	Leaf	Polyphenol	Aqueous	Antioxidant Antihyperglycemic Antihyperlipidemia	Leaves at dose of 100 mg/kg gives a significant reduction in fasting blood sugar.	Shankar *et al.*, 2005.

Gmelina arborea **(Gamar/Gumhar)** **Verbenaceae**	Leaf Bark Root	Alkaloids Flavonoids Phenolics Saponins Steroid Glycoside	Methanol Chloroform Ethanol	Antioxidant Antimicrobial Diuretic Cardioprotective Immunomodulatory Antipyretic Analgesic	The highest depletion in blood glucose recorded in the 400 mg/kg body weight dosage in streptozotocin induced diabetic rats.	Punitha *et al.*, 2012.
Hibiscus rosa sinensis **(China Rose)** **Malvaceae**	Whole Plant Leaf Flower	Cyaniding Quercetin Hentriacontane	Aques Methanol	Anticomplimentary Antidiarrhetic Antimicrobial Antioxidant antidiabetic	Oral dose of 100 and 200 mg/kg body weight to non obese diabetic mice shows significant reduction in blood glucose level.	Moqbel *et al.*, 2011.
Momordica charantia **(Karela/ Bitter gourd)** **Cucurbitaceae**	Fruit Seed Leaf Root	Charantin Polypeptide Polypeptide-p Vicine Momordicine	Aqueous Methanol	Antidiabetic Hypoglycaemic Hepatoprotective Anti Bacterial Anti Viral Anti tumor	The treatment of streptpzotocin induced diabetic rats with M. charantia fruit extract over a 10-week period returned the levels of blood glucose and lipid profile close to normal.	Ahmed *et al.*, 2001; Kumar *et al.*, 2010.
Mucuna pruriens **(Atmagupta/ Magic bean)** **Leguminosae**	Seed Leaf Root Stem	L-DOPA Tryptamine Alkaloids Tannins	Hexane Chloroform Methanol Ethanol	Antibacterial Antifungal Hypotensive Hypoglycemic Antidiabetic Antioxidant	100, 200 and 400 mg/kg of the extract Significantly reduced the fasting blood sugar levels in alloxan-induced diabetic rats.	Eze *et al.*, 2012.
Panax ginseng (Korean ginseng) **Araliacea**	Fruits	Steroidal saponins	Ethanol	Anticancer Immunomodulatory Antioxidant Antifatigue Antimicrobial	150 mg/kg extract-significantly improved glucose tolerance in treated obese diabetic mice.	Attele *et al.*, 2002.
Quercus Infectoria **(Oliver)** **Fagaceae**	Leaf Gall Roots	Tannins Polyphenols Gallic acids Tannic acid Tannins Flavonoids	Methanol Ethanol Hexane Chloroform Aqueous	Antibacterial Antifungal Antidiabetic Antiinflammatory Anti tumor Antioxidant	Methanolic roots extract at a dose of 250 mg/kg and 500 mg/kg body weight was showed the anti-diabetic activity in Alloxan-induced hyperglycaemic rats.	Saini *et al.*, 2012.
Ricinus communis **(Castor)** **Euphorbiaceae)**	Root	Phenolic Lectins Ricin Pyridine Alkaloids Ricinoleic Acid	Ethanol	Antioxidant Antitumor Antinoceciptive Anti-Inflammatory Analgesic	500 mg/kg body weight caused the maximum lowering of the fasting blood glucose	Shokeen *et al.*, 2008.

		Tocopherols		Antipyretic Cardiactonic		
Smallanthus sonchifolius (Aricoma) **Asteraceae**	leaf	Phenolic compounds	Methanol Butanol Chloroform	Antioxidant Antilipoperoxidative Hepatoprotective Antiinflammatory Antidiabetic	Methanol, butanol and chloroform extracts showed effective hypoglycemic activity at minimum doses of 50, 10 and 20mg/kg body weight in transiently hyperglycemic and streptozotocin diabetic rats.	Susana *et al.*, 2010.
Syzygium jambolaum **or** ***Eugenia jambolana*** **(Jamboon/ sweet olive)** **Myrtaceae**	Leaf Seed Root	Anthocynins Glucoside Alkaloids Jambosin Flavonoids	Ethanol Methanol Aqueous	Anti septic Antioxidant Anti-inflammatory Antibacterial Antifungal Radioprotective	Ethanolic seed extract at 100 mg/kg of body weight significantly decreased the levels of blood glucose, blood urea, and cholesterol in streptozotocin induced diabetic rats.	Ravi *et al.*, 2004; Srivastava *et al.*, 2012.
Taraxacum officinale **(Dandelion)** **Asteraceae**	Leaf Root	Phenylpropanoids Triterpenoids Sterols Taraxasterol Taraxerol Cycloartenol β-sitosterol	Alcohol Aqueous	Hypoglycemic Immuno-modulatory Anti-inflammatory Detoxification Antiviral Antitumor	Aqueous and ethanolic extract of leaves and root at dose 300 and 500mg/kg body weight showed significant antidiabetic effect in alloxan induced diabetic rats.	Hussain *et al.*, 2004; Nnamdi *et al.*, 2012.
Plants that shows inhibitory activity on glucose absorption in the small intestine.						
Actinidia kolomikta **(kiwi)** **Actinidiaceae**	Root Leaf	Phenolics Flavonoid	Aqueous Ethanol	Hepatotoxicity Hypoglycaemia Antitumor Antiproliferative Immuno-modulatory Anti-oxidant Anti cancer	800 mg/kg Aqueous extracts of leaves prevented the increase in blood glucose level without causing a hypoglycemic state in the oral glucose tolerance test.	Hu *et al.*, 2013; Yuan *et al.*, 2014.
Psoralea corylifolia **(Babchi)**	Seed	Flavanoids Alkaloids Phenols Tannins	Chloroform Ethyal acetate Methanol	Laxative Aphrodisiac Anthelminitic Diuretic	The dose of 250mg/kg of body weight was found	Suhashini *et al.*, 2014; Dhar *et al.*, 2013.

Fabaceae		Oils		Diaphoretic Anti-inflammatory	to be the most effective in lowering blood glucose level of normal, sub, mild and severely diabetic rats.	
***Tamarindus indica* (Imli)** **Caesalpiniaceae**	Leaf Bark Fruit	N-Hexacosane Eicosanoic Acid B-Sitosterol Octacosanyl Ferulate Apigenin Catechin Procyanidin B2 Taxifolin Cardiac Glycosides Dihydroxyacetophenone	Acetone Ethanol Methanol	Anti-microbial Antioxidant Laxative Woundhealing Hepatoprotective Anti-inflammatory Analgesic	Aqueous methanolic extract of leaf at the dose 200mg/kg body weight showed blood glucose lowring activity in streptozotocin induced diabetic rats.	Maiti *et al.*, 2005; Ramchander *et al.*, 2012; Anzana *et al.*, 2013.
***Zea mays* (Maize)** **Gramineae**	Corn silk	Flavonoids Alkaloids Phenols Steroids Glycosides Terpenoids Tannins	Benzene Chloroform Ethanol Ethyl Acetate Methanol Petroleum ether	Antioxidant Diuretic Antidepresent Antifatigue Anti-hyperlipidimic Anti-inflammatory Neuroprotective	After orally administration with corn silk extract, the blood glucose and HbAIc were significantly decreased in alloxan induced hyperglycaemic mice.	Ranilla *et al.*, 2009.
Improving insulin release in response to meals						
***Aegle marmelos* (Bael)** **Rutaceae**	Flower Leaf Fruit Seed	Ascorbic acid Aegelin Coumarins Alkaloids Aegeline Skimmianine Lupeol Cineol Citral Citronella Cuminaldehyde Eugenol Marmesinine Fagarine Marmin Marmelosin Luvangetin Aurapten Psoralen Marmelide Tannin	Aqueous Alcohol	Anti-hyperglycemic Hepato-protective Analgesic Antifertility Anti Fungal Hypolipidemic Immunomodulatory Anti-Inflammatory	Oral admistration of aqueous seeds extract atdose of 250mg/kg was found to decreases blood glucose level in normal healthy rats after 6 h of administration.	Sharma *et al.*, 2011; Kesari *et al.*, 2006.

Alium cepa **(Onion)** **Alliaceae/ Liliaceae**	Root Tuber	Quercetin, Cysteine Allyl propyl disulphide Allyl propyl disulfide (APDS) S-methyl cysteine sulphoxide Essential oil	Aqueous Ethanol Ether	Hypocholesterolaemic Fibrinolytic Antioxidant Anticancer Antimutagenic Hemostatic Hypoglycaemic Hypolipidaemic	Hypoglycemic activity was showed by the ether soluble fraction of onion (0.25 mg/kg) in normal rabbits.	Ozougwu *et al.*, 2011
Costus pictus **(Spiral ginger /Insulin plant)** **Zingiberaceae**	leaf	β- L-Arabinopyranose methyl glycoside	Ethanol Acetone Aqueous Ethyl Acetate Methanol	Antidiabetic Antimicrobial Immunomodulatory	Dosage of 2gm/kg body weight exhibited a significant reduction in fasting blood glucose level and a remarkable increase in serum insulin level.	Sindhu *et al.*, 2012; Jayasri *et al.*, 2008.
Ficus religosa **(peepal)** **Moraceae**	Leaf Fruit Bark	Flavonoids Sterols	Ethanol	Antiulcer Antibacterial Antigonorrhe Antibacterial Antiprotozoal Antiviral Astringent Antidiarrhoeal	The ethanolic extract of the fruit, at a dosage of 250 mg/kg body weight, showed antidiabetic activity.	Choudhary *et al.*, 2011.
Mangifera indica **(Mango)** **Anacardiaceae**	Leaf Stem bark	Tannins Saponins Glycosides Phenols	Methanol Hexane Ethyl acetate	Antioxidant Radioprotective Immunomodulatory Anti-allergic Anti-inflammatory Anti-tumor Lipolytic Antiviral Antibacterial Antifungal Anti nociceptive	Oral administration of aqueous leaf extract 1g/kg in streptozotocin-induced diabetic rats reduced blood glucose level	Harbourne, 1973; Baker and Thormsberg, 1983; Sahm and Washington, 1990; Grover *et al.*, 2002.
Nervilia plicata **(Lotus with single leaf)** **Orchidaceae**	Stem	Tannins Gums Flavonoids Saponins Essential oils.	Alcohol	Antidiabetic Antibacterial Antifungal	Administration of 5mg/kg of plant extract showed decrease in the blood glucose levels. in type-II diabetic rats	Kumar *et al.*, 2011;
Phoenix dactylifera (Date Palm) **Arecaceae**	leaf	Tannins Alkaloids Trepenoids Flavonoids	Aqueous	Antidiabetic Antibacterial Antiinflamatory Antiasthamatic Nephroprotective Hepatoprotective	Sub-acute administration of leave's extract in alloxan-induced diabetic rats significantly reduced blood	Seyyed *et al.*, 2010.

					glucose	
Saliva lavandulifolia (Spanish Sage) **Lamiacea**	Leaf	Flavonoides Terpenoids 1,8- cineole α- pipene	Aqueous	Spasmolytic Antiseptic Analgesic Sedative Antioxidant Antidiabetic Antiinflammatory	Daily administration of 250 mg/kg of infusion resulted in a 33% decrease in blood glucose levels in alloxan-diabetic rabbits.	Jimenez *et al.*, 1986.
Stevia rebaudiana **(Meethi tulsi)** **Astraceae**	Leaf	Stevioside Rebaudioside A-F Dlucoside Steviobioside Flavonoids Anthocyanins Phenolics.	Aqueous Methanol Petroleum ether	Antihyperglycemic Hypotensive Antioxidant Anti-inflammatory Antibacterial Gastroprotective Immuno-modulatory Cardiovascular Antihistamin	Oral admistration of stevioside 0.5mg/kg body weight, lowered blood glucose level in streptozotocin induced diabetic rat.	Gregersen *et al.*, 2004.
Swertia chirata **(Chiratika/ Kutki)** **Gentianaceae**	Seed Root	Alkaloids Flavonoids Xanthones Glycosides Terpenoids	Aqueous Ethanol Methanol	Antipyretic Anthelminitic Analgesic Hypoglycemic Antifungal Antibacterial Anti-inflammatory Hepato-protective Cardio-protective	Oral admistration of the aqueous extract at dose 200 mg/kg body weight per day for 21 days in glebinclamide induced diabetic albino rats showed significant antidiabetic effect.	Sobia *et al.*, 2012; Kavitha and Dattatri, 2013.
Vitellaria paradoxa (Shea tree) **Sapotaceae**	Bark	Phenolics Palmetic acid Stearic acid Oleic acid Linoleic acid Arachidic acid	Aqueous Ethanolic Hydro-ethanol	Antiulcer Anti malarial Neuralgia treatment Antidiabetic Antioxidant	Hydro-ethanolic extracts of the bark at a dose of 250 mg/kg body weight.induce anti hyper-glycemic activity in rabbits	Coulibaly *et al.*, 2014
Zizyphus spina-Christi (Olive) **Rhamnaceae**	Leaf	Saponins Glycoside Christinin-A	Butanol	Hepatoprotective Anti-obesity Antidiabetic Antioxidant Antimicrobial Antidiarrheal	100 mg/kg butanol extract or christinin-A enhanced the glucose lowering and insulinotropic effects in type-II diabetic rats.	Abdel-Zaher *et al.*, 2005.

Zingiber officinale **(Ginger)** **Zinzibaraceae**	Rhizome Root	Phenolic compounds	Aqueous	Hypoglycemic Cardiotonic Antilipemic Antioxidant Antineoplastic Antiviral Antibacterial Antifungal	Oral admistration of the juice (4 ml/kg of body weight/ day) for 6 weeks on streptozotocin induced diabetic rats significantly reduced blood glucose level.	Khani *et al.*, 2004; Jafri *et al.*, 2011.
Preserve the function of the β-cells of the pancreas and Regenerate the damage β cells.						
Aerva lanata **(Polpala)** **Amaranthaceae**	Shoot Leaf	Alkaloids Flavonoids Tannin Steroid Saponins Phenolic compounds.	Pet-ether Methanol Alcohol Ethanol: Water (1:1)	Anti-inflammatory Diuretic Hepato-protective Nephroprotective Antidiabetic Antimicrobial Antihyperlipidaemic Antiparasitic,	The alcoholic extract at dose 500 mg/kg body weight reduces the blood sugar in alloxan induced diabetic rats.	Vetrichelvan and Jegadeesan., 2002; Shirwaikar *et al.*, 2004
Barleria prionitis (Vjradanti) **Acanthacae**	leaf Root	Sterols Saponins Tannins Flavonides	Alcohol	Diuretic Hepatoprotectve Antioxidant Antifungal Wound healing	Alcoholic extract of root and leaves at dose 200mg/kg body weight to Alloxan induced rat shows a decrease in blood glucose level.	Dheer *et al.*, 2010
Caesalpinia digyna (Teri pod/ ***Udakiryaka*****)** **Leguminosae**	Roots Bark Fruit Gall Leaf	Caesalpinine A Cellallocinnine Ellagic acid Gallic acid Bergenin Nicotinamide Tannins	Alchohol	Antioxidant Antipyretic Astringent Wound healing Antidiabetic.	Oral admistration of 750mg/kg for 14 days caused a significant decrease in blood glucose level in streptozotocin induced diabetic rats.	Kumar *et al.*, 2012
Callistemon lanceolatus (Crimson Bottlebrush) **Myrtaceae**	leaf	Phenolic Saponins Alkaloids Glycosides Sterols Tannins.	Ethanol Methanol Hexane Ethyl acetate.	**Antidiabetic** **Antifungal** **Antibacterial** **Hypolipidemic** **Antiaflatoxin** **Antioxidant** Cardioprotective Antiinflammatory Antithrombin activity	Oral admistration of dichloro-methane exract at dose 200-400 mg/kg body weight for 21 day significantly decreased the blood glucose level in streptozotocin induced diabetic rats.	Kumar *et al.*, 2011.
Ficus amplissima (kal-itchchi) **Moraceae**	Bark	Phenolic compounds	Methanol	Antidiabetic Hypololipidimic Antioxidant Antiinflammatory Antibacterial	Oral administration of methanolic extract of bark at the doses of 50, 100 and 150mg/kg showed significant antidibetic effect on	Arunachalam and Parimelazhagan, 2013.

					streptozotocinindu ced diabetic rats.	
***Nymphaea pubescens* (pink water lily)** **Nymphaeaeae**	Flower Tuber	Alkaloids Flavonoids Glycosides Terpenoids Tannins Phenols Saponins Steroids	Ethanol Aqueous	Antidiabetic Hypolipidaemic Antioxidant	The ethanol extract of tuber at a dose of 200mg/kg and 500mg/kg body weight/ day to diabetes induced rats significantly increase in plasma insulin level.	Shajeela *et al.,* 2012.
***Ocimum gratissimum* (Clove Basil)** **Lamiaceae**	Leaf	Thymol Citral Geraniol	Aqueous	Antimicrobial Antioxidant Antibacterial Antidiabetic Hepatoprotective	Oral admostration of aqueous extract at dose 100mg/g produced transient significant reduction in blood glucose in Neonatal streptozotocin induced diabetic rat model	Nelson *et al.,* 2012.
***Otostegia persica* (Goldar)** **Labiate**	Root Arial parts	Polyphenols Alkaloids Glycoside Flavones Saponins Tannins	Aqueous	Antihistamin Antispasmotic Hepatoprotective Antioxidant Antidiabetic	Oral administration of the aqueous extract of root at 200, 300 and 400mg/kg body weight, showed Plasma glucose lowering activity in allaxon induced rat.	Bagherzade *et al.,* 2014.
Prunella vulgaris (Self heal) **Labiatae**	Leaf Stem	Rosmarinic acid Ursolic acid Oleanolic acid	Aqueous Ethanol	Anti-inflammatory Antiallergic Anticancer Wound Healing Antidiabetic Hepatoprotective Antipyretic Mild Antiseptic Detoxifier Diuretic Haemostatic	Aqueous extract at dose 100 and 200 mg/kg/day suppressed hyperglycemia in high fat/ high cholesterol diet-mice.	Hwang *et al.,* 2012.
***Pterocarpus marsupium* (Vijasar)** **Leguminoceae/ Fabaceae**	Timber Bark Leaf Flower	Glycoside Flavonoids Tannins.	Ethanol Aqueous	Hypolipidemic Hepato-protective Antiulcer Anti-inflammatory Anti oxidant Cardiotonic Antibacterial Anti-diabetic	Methanol extract at dose 300 mg/kg body weight/day showed normalization of serum glucose.	Gupta *et al.,* 2009.
***Selaginella tamariscina* (Spikemoss)**	Leaf	Flavonoids	Aqueous Ethanol	Vasorelaxant Antimetastatic Antidiabetic	Oral doses (100, 200 and 400mg/kg/ day) for 8 weeks shows	Zheng *et al.,* 2011.

Selaginellacae				Antifungal Antiinflammatory Antitumor Cardioprotective Antioxidant	beneficial effects on hyperglycemia and hyperlipoidemia in streptozotocin induced diabetic rats	
Scoparia dulcis **(Bondhane / sweet broomweed)** **Scrophulariaceae**	Whole plant	Flavonoids Saponins Phenol Tannins Alkaloids Steroids Terpenes	Hexane Ethyl acetate Methanol Aqueous	Antidiabetic Antitumor Antiviral, Antiinflammatory Antioxidant Neuroprotective	200 mg/kg of the ethanolic extract showed maximum reduction in glucose levels in streptozotocin induced diabetic rats.	Latha *et al.*, 2004.
Tribulus terrestris **(Gokhru)** **Zygophyllaceae**	Seed Fruit Leaf Root Stem	Protodioscin Terrestrosins A-E Desgalactotigonin Desglucolanatigonin Fgitonin Gitonin Tigogenin Furostanol Glycosides Sterol Diosgenin Hecgenin Ruscogenin Kaempferol Quercetin Tribulusamides A and B.	Methanol	Antimicrobial Cytotoxic Antihyperlipidaemic Diuretic Antiseptic Anti-inflammatory Astringent Analgesic	Oral administration of 50mg/kg body weight methanolic extracts of aerial parts of *Tribulus terrestris* showed significant reduction inblood glucose level in streptozotocin induced diabetic rats.	Wu *et al.*, 1999; Mahato *et al.*, 1981.
Withania somnifera **(ashwagandha)** **solanaceae**	Root Fruit Leaf Seed	Sitoindosides Steroidal alkaloids Steroidal lactones	Aqueous Alcoholic	Antioxidant Antitumor Anti-inflammatory Immuno-modulatory Hematopoetic Antiageing Anxiolytic Antdepressive	Oral admistration of root powder at dose 100 mg/kg showed significant reduction in blood glucose level in streptozotocin induced diabetic rats.	Pradeep *et al.*, 2010.
Inhibits the activity of hepatic GIucose-6-phosphatase and Increased glycogenesis.						
Annona squamosa **(custard apple / Sitafal)** **Annonaceae**	Leaf Root Bark Seed	Annoreticuin Isoannoreticuin Acetogenin Flavonoids Alkaloids Glycoside Anonaine 6-Hetriacontanone Hexacontanol Higemamine Isocorydine Limonine Linalool acetate	Aqueous Methanol	Antitumor Antibacterial Wound healing Antiulcer Anthelmintic Antioxidant Antimalarial Anti HIV Hepato-protective	Oral admistration of ethanolic leaf-extract (350 mg/kg) in streptozotocin diabetic rats and alloxanized rabbits shows antihyperglycemic activity.	Mohamed., 2011
Azadirachta indica **(Neem)**	Leaf Bark Fruits	Isopreinoids Azadirone Azadirachtin	Methanol Chloroform Aqueous	Antiinflammatory Antiarthritic Antipyretic	Aqueous leaves extract at a dose of 250 mg/kg body weight for 16	Eshrat *et al.*, 2002.

Meliaceae	Seed Oils	Polyphenolic Flavonoids Glycoside Terpenoids Caumarin Tannin.		Hypoglycemic Antigastric ulcer Spermicidal Antifungal Antibacterial Diuretic Immunomodulatory Anti malarial Hepatoprotective Antioxidant	weeks resulted significant fall in blood glucose and improvement in serum total, LDL and HDL cholesterol and triacylglycerol which increased in diabetic rats.	
Bougainvillea spectabilis **(Bougainvillea)** **Nyctaginaceae**	leaf	Flavonoids Tannins Cardiac-glycosides Terpenes Steroids	Ethanol	Hypoglycemic Hypolipidimic Antibacterial Nematicidal Insecticidal Antiviral	Ethanolic extract of stem bark at dose 250mg/kg shows anti hyperglycaemic effect in alloxan induced diabetic rats.	Jawla *et al.*, 2012
Coccinia indica **(Kundru)** **Cucurbitaceae**	Leaf Fruit Stem Root	Alkaloids Steroids Tannins Phenolics Flavonoids Resins	Aqueous Ethanol Petroleum-ether Chloroform	Hepatoprotective Antioxidant Anti-inflammatory Anti-nociceptive Antidiabetic Hypolipidemic Antibacterial	Oral administration of dried extract of Coccinia indica at 500mg/kg, for 6 weeks significantly increased insulin concentration in a clinical study.	Joshi *et al.*, 2009.
Cucumis sativus **(Cucumber/ Kheera)** **Cucurbitaceae**	Fruit Seed	Steroids Carotenoids Flavonoids Tannins Resin	Ethanol	Antidiabetic Anti-hyperlipidemic Hepatoprotective Cardioprotective Diuretic Laxative	The oral Administration of ethanolic fruit's extracts at 400 mg/kg body weight dose significantly showed antidiabetic effects in Streptozotocin induced rats.	Karthiyayini *et al.*, 2009; Gopalakrishnan *et al.*, 2013. Sharmin *et al.*, 2013.
Elephantopus scaber **(Tutup bumi)** **Asteraceae**	Leaf Root	Stigmasterol Lupeol Stearic acid Deoxyelephantopin	Aqueous Acetone	Astringent Antipyretic Antidiabetic Diuretic Anticancer Antibacterial	Oral administration of aqueous extract of leaves and rootsat dose 300 mg/kg body weight significantly reduced serum glucose leavel in alloxon induced diabetic rats.	Rajathi *et al.*, 2011.
Enicostemma littorale **(Chhota-chirayta)** **Gentianaceae**	Leaf	Alkaloids Flavonoids Catechins Saponins Sterols Triterpenoids Phenolic acids Xanthones.	Aqueous Methanol Ethanol Ethyl acetate	Anti-inflammatory Antiulcer Hypoglycemic Anti-malarial Antioxidant Anticancer Anti-nociceptive Antimicrobial	1.5 g dry plant equivalent extract/100 g body weight caused significant increase in serum insulin levels of the diabetic rats.	Maroo *et al.*, 2003
Eugenia Jambolama **or** ***Syzygium cumini*** **(Jamun/ Black plum)**	Pulp Seed Bark Leaf	Jamboline-a Glucoside Mycaminose	Ethanol Methanol Aqueous	Hepato-protective Antioxidant Anti-inflammatory Anti-nociceptive Antidiabetic	100 mg/kg of body weight of ethanolic extracts of whole seeds, kernel showed hypoglycemic activity	Kumar, *et al.*, 2008; Verma *et al.*, 2010.

Myrtaceae				Hypolipidemic Antibacterial Antifungal	in streptozotocin-induced diabetic rats	
Gymnema montanum (Gymnema) Asclepiadaceae	Stem Leaf	Alkaloids Saponin Tannins Glycosides	Alchohol	Antihyperglycemic Antiperoxidative Antimicrobial	Oral administration of 200 mg /kg body weight of the alcoholic extract of the leaf resulted in a significant reduction in blood glucose and an increase in plasma insulin level.	Ananthan *et al.*, 2003; Ramkumar *et al.*, 2011.
Psidium guajava (Guava/ Amrud) Myrtaceae	Stem bark	Phenolics Glycosides Carotenoids	Ethanol	Antidihhreal Hepato-protection Antioxidant Anti-inflammatory Antispasmodic Anticancer Antimicrobial Anti-hyperglycemic Analgesic	Ethanolic extract of stem bark at dose 250mg/kg exhibited significant hypoglycaemic activity in alloxan-induced hyperglycaemic rats	Mukhtar *et al.*, 2006.
Tinospora crispa (Akar patawali) Menispermaceae	Stem Leaf	Terpenoids Borapetoside C	Aqueous	Antidiabetic Hepatoprotective Antioxidant Antimicrobial	Acute intra-venous treatment with the extract (50 mg/kg) caused an increase in plasma insulin levels	Noor *et al.*, 1989; Lokman *et al.*, 2013.
Tinospora cordifolia (Giloya / guduchi) Menispermaceae	Stem	Alkaloids Glycoside Terpenoids Lactones Steroids	Aqueous Alcohol	Hypolipidemic Hypoglycemic Cardioprotective Hepatoprotective Antioxidant Anti-inflammatory	Oral administration of the aqueous root extract led to a decrease in blood and urine glucose and lipids level in alloxanized rats.	Rajalakshmi *et al.*, 2009.
Vernonia amygdalina **(Bitter leaf)** **Asteraceae**	leaf	Polyphenols Alkaloids Saponins Tannins Glycosides	Ethanol	Antioxidant Antibacterial Anti-inflammatory Hepato-protective Anticarcinogenic Antifungal Antiplasmodial Nephroprotective	Ethanolic leaf extract at dose 400 mg/kg exhibited a significant improvement in glucose tolerance of the streptozotocin induced diabetic rats.	Ong *et al.*, 2011.
Enhance activity of enzymes involved in bile acid synthesis.						
Berberis aristata **(Daruhaldi)** **Berberidaceae**	Stem Root Seed	Alkaloids Tannins Saponins Glycosides Sterols Flavonoids Terpenoids Lignin	Methanol Aqueous Ethanol Acetic anhydride	Anti-inflammatory hepatoprotective Hypoglycemic Antibacterial Antifungal Antipyretic Anticarcer Immuno-modulatory	Oral administration of the methanolic extract at dosen250 and 500 mg/kg effectively reduced the blood glucose in diabetic rats.	Upwar *et al.*, 2011
Plants which are improves glucose tolerance.						

Boerhavia diffusa **(Santh/ punarnava)** **Nyctaginaceae**	Leaf Stem Bark Root	Alkaloids Phytosterols Lignin	Petroleum ether Chloroform Methanol Aqueous	Hepato-protective Diuretic Anti-inflammatory Antibacterial Antidiabetic Anti-urethritis Anti-asthamic	Oral administration of aqueous leaf extract (200 mg/kg daily for 4 weeks) in normal and alloxan induced diabetic rats shows hypoglycemic and antihyperglycemic activity.	Santhosha *et al.*, 2011.
Brassica juncea **(Mustard)** **Brassicaceae**	Seed	Anthocyanins Flavonoids Hydroxycinnamic acids Polyphenols	Aqueous Methanol	Antinociceptive Anti-hyperglycemic Antioxidant Antimicrobial	Dose of 250,350 and 450mg/kg body weight of seed extract has potent hypoglycemic activity in streptozotocin induced diabetic male albino rats.	Khan *et al.*, 1995.
Plants which are shows Potent insulin mimic activity						
Cornus officinalis **(Asiatic dogwood)** **Cornaceae**	Fruit	Tannins including cornusiins A, B and C Ursolic acid	Methanol	Antibacterial Antifungal Hypotensive Antitumor Astringent Diuretic Hepatoprotective Antidiabetic	100 mg/kg and 200 mg/kg body weight fruit extract had a significant hypoglycemic effect in diabetic mice.	Chen *et al.*, 2008.
Nigella sativa **(kalonji)** **Ranunculaceae**	Seed	Oil Isochinoline Alkaloids	Ethanol Aqueous	Antidiabetic Anticancer Immunomodulatory Analgesic Antimicrobial Anti-inflammatory Hepato-protective Anti-hypertensive Antioxidant	Seed extract at dose 5mg/kg of body weight significantly reduced fasting blood glucose level.	Alimohammadi *et al.*, 2013.
Rosmarinus officinalis **(Rosemary)** **Lamiaceae**	Leaf	Caffeic Acid Carnasol Ros-Maridiphenol Rosmarinic Acid	Aqueous Ethanol	Antiasthmatic Cardiotonic Hypotensive Memorybuster Antihyperglycemic Hepato-protective Antioxidant Anti-inflammatory	Water extract of leaves at dose 200mg/kg body weight for 21 days was found to be significantly reducing the blood sugar level in Streptozotocin induced diabetic rats.	Khalil *et al.*, 2012.
Solanum xanthocarpum **(Kantakari)** **Solanaceae**	leaf	Olanocarpine Carpesterol Solanocarpidine Diosgenin Sitosterol Isochlorogenic acid Neochronogenic	Methanol	Hypoglycemic Hypolipidimic Antioxidant	Methanol extracts of leaf was efficient anti hyperglycemic agents at a concentration	Poongothai *et al.*, 2011.

		acid Chronogenic acid Caffeic acid Solasodine Solasonine Solamargine Quercetin Apigenin Histamine Acetylcholine			of 200 mg/kg body weight and posses potent antioxidant activity.	
***Teucrium polium* (Kalpooreh)** **Lamiacea**	Leaves	Terpenoids Flavonoids Apigenin	Methanol Aqueous	Hypoglycemic Hepatoprotective Analgesic Antilipidemic	Single dose of 50 mg/kg body weight /day for a month significantly decrease serum glucose in streptozotocin induced diabetic rats.	Shahraki *et al.*, 2007.
Plats which are preserve β-cell function by depletion of antioxidant enzyme cascade and prevent diabetes induced ROS formation.						
***Curcuma longa* (Turmeric)** **Zinzibaraceae**	Rhizome	Curcumin Essential oils	Methanol Ethanol Chloroform-water	Antioxidant Anti-inflammatory Anti cancer Hepato-protective Anti viral Anti fungal Anti bacterial Antiseptic Analgesic	Oral administration of absolute ethanol extract of rhizome and leaves lowers blood glucose in alloxan-induced diabetic rabbits.	Sarah *et al.*, 2009; Sadak *et al.*, 2010
***Musaes paradisiaca* (Banana)** **Musaceae**	Leaf Ripe fruit's peel Root Stem.	Catecholamines Norepinephrine Serotonin Dopamine Flavonoid Sterol Alkaloids Polyphenols	Methanol Chloroform Petroleum ether Ethanol	Antioxidant Antidiarrheial Antidysentery Antidiabetic Hypotensive Cardiotonic	Leaves and fruit peels are responsible for antidiabetic potential on streptozotocin induced diabetic rats.	Reddy *et al.*,2014; Lakshmi *et al.*, 2014.
***Pongamia pinnata* (Karanj)** **Fabaceae/ Leguminoceae**	Root Fruit Leaf	Alkaloids Glycosides Flavonoids Flavone derivative 'pongol'	Ethanol Methanol	Antitumor Antiseptic Anti-inflammatory Antinociceptive Antihyperglycemic Anti-lipidoxidative Antidiarrhoeal Antiulcer Antioxidant.	Ethanolic extract of leaves at doses 500mg/kg and 1g/kg shows significant antidiabetic effect on streptozotocin induced male albino rats.	Kavipriya *et al.*, 2013.

Diospyros peregrine (Gaub persimon) **Ebenaceae**	Fruit	Alkaloids Terpinoids Polyphenolics Flavonoids	Aqueous	Antihyperglycemic Antioxidant Antihyperlipidimic	Oral administration of aqueous fruit extract at the doses of 50 and 100mg/kg body weight to streptozotocin-nicotinamide induced diabetic ratsshows significant hypoglycemic and hypolipidemic effect.	Dewanjee *et al.*, 2009.
***Piper betle* (Betel leaf)** **Piperaceae**	Leaf	Chavibetol Chavicol Eugenol Lactone Catechol Terpinene Sitosterol Stigmasterol Ursolic Acid	Aqueous Ethanol	Antioxidant Antifungal Immuno-modulatory Antileshmanial Antiamoebic Anti-Inflammatory Antimicrobial Radioprotective	200mg/kg body weight of hot water extract of leaves showed anti diabetic activity in rats.	Arambewela *et al.*, 2005.
Plants show Sodium-Glucose Transporter-2 Inhibitory activity.						
***Phyllanthus amarus* (Bhui amla, Jaramla)** **Euphorbiaceae**	Whole plant	Tannins Flvonoids	Methanol	Antioxidant Anti-inflammetory Antitumor Antiviral Antihyperglycemic Hepato-protective Immuno-modulatory	The methanolic extract was found to reduce the blood sugar in alloxanized diabetic rats.	Shetti *et al.*, 2012.

If a person's pancreas does not work properly or body cells does not response to insulin, blood glucose level gets higher and ultimately increases the risk of many secondary complications like cardiovascular disease, neuropathy, nephropathy, retinopathy, hair loss, foot and skin damage etc.

In present seneario for treatment of such type of complex metabolic disorders, differet kinds of medicinal system are available. Allopathy medicines are mostly used for treatment of diabete mellitus which bind the target site of body system and suppress the illness rather then removing it. Allopathy work by different mechanisms like improving insulin release in response to meals (sulfonylureas and meglitinides), reducing the resistance of the body cells to the effect of insulin (metformin and glitazones), preserve the function of the β-cells of the pancreas (Pioglitazone), stimulate the β-cells in the pancreas to release more insulin (sulfonylureas and meglitinides), α-glucosidase inhibitory activity (Acarbose), inhibiting the SGLT2 transporter (Gliflozins), slowing the absorption of sugar from the gut (acarbose), DPP-4 inhibitiory activity (gliptins), Sodium-Glucose Transporter-2 Inhibitory activity (forxiga-dapagliflozin and canagliflozin).

There are certain side effects associated with the allopathic medicines, which make these medicines harmful to human body if taken for

a prolonged period of time. So herbal drugs can be the best for the treatment of diabetes because these are of natural sources and have less or no side effect on human body.

Herbal remedies for management of diabetes mellitus

Many plants have been investigated for their beneficial use in different types of diseases. There are about 600 plants, which are stated to have anti-diabetic property (Murray, 1995). Herbal drugs with antidiabetic activity can be classified into four categories according to their mode of action (Wadkar *et al.*, 2008)-

The first group of plant drugs act like insulin, the classical example of this group is *Momordica charatia*.

The second group of herbal drugs is those acting on the β-cells of pancreas to increase the production of insulin, this group includes *Allium cepa* and *Pterocarpus marsupium*.

The third group of herbal drugs act by enhancing glucose utilization in diabetic patients, this group includes *Gingiber officinale*.

The last group of herbal plants with hypoglycemic potency act by miscellaneous mechanism. This group includes leguminous plants.

Wide arrays of plant derived active principles representing numerous phytochemicals have demonstrated consistent anti-diabetic activity and their possible use in the treatment of diabetes mellitus (Saminathan and Kavimani, 2015; Mamun Rashid *et al.*, 2014).

The summary of 112 plants reported to have significant anti-diabetic activity of the active compounds, used in herbal formulations in India is shown in Table 2.

In vitro production of plant secondary metabolites

Tropical zones of the globe are abundant in medicinal flora. Increase in demand for these plants in industries is leading to frequent and rapid harvesting from natural habitations resulting in erosion of natural habitat and compromization with quality of the product. Hence, there is an urgent need for take up sustainable harvesting measures by balancing the commercial demand with the conservation of the valuable plants and their contribution to biodiversity.

There is great interest in developing alternatives to the intact plant for the production of plant secondary metabolites. Plant cell cultures are capable of producing pharmaceutically important bioactive molecules, equally or in enhanced levels as compared to mother plants. The application of these techniques for bioactive molecules production is increasing rapidly (Mulabagal *et al.*, 2004; Kuruppusamy, 2009). Attempts have successfully been made in generating a range of compounds such as alkaloids, flavonoids, terpenes, steroids, glycosides, etc through tissue culture.

A total of about 28,000 patents are reported to be registed in plant cell culture related products production, especially associated with cosmetic, food and pharmaceutical industries (Marisol *et al.*, 2016). Plants producing secondary metabolites with antidiabetic property like *Allium sativum, Azadirach indica, Camellia sinensis, Coscinium fenustratum, Ginko biloba, Momordica charantia, Mucura pruriens, Psoralea cordifolia, Scoparia dulcis, Tinospora cordifolia* and *Withania somnifera* were also cultured *in vitro* for the active compounds production (Kuruppasamy, 2009). Similarly large scale cultivation of cell suspension cultures, organ cultures in bioreactors was reported in *Catharanthus*

roseus, Panax ginseng, and *stevia rebaudiana* (Ozlem *et al.*, 2010).

Plant cells can also transform natural or artificial compounds, introduced into the cultures, through a variety of reactions such as hydrogenation, dehydrogenation, isomerization, glycosylation, hydroxylation, and opening of a ring and addition of carbon atoms. Many attempts have been made to use plant cell cultures for production of plant secondary metabolites, but most of these attempts have not been cost effective, and only few commercially viable systems have been created (Alferman *et al.*, 2003).

This review summaries main group of secondary metabolites produced by plants and the techniques commonly applied for their isolation, identification and characterization. It also summaries potential 112 anti- diabetic plants, their explored plant parts producing secondary metabolites containing various pharmaceutiacal activities along with specific therapeutic and prophylactic function against diabetis.The crude extracts, however, contain a wide range of bioactive molecules whose composition of components varies from preparation to preparation. In case of herbal medicine pharmacopoeia on herbal products is not available. Hence, standardization and quality control parameters for the raw material as well as finished products are highly essential. Isolation of individual compounds and analysis of pharmaceutical properties and role of each biomolecule present in the extract hold grate importance in human trails. Although, at present increase in awareness on herbal medicine, validation of their pharmacological properties of crude extracts in appropriate experimental animal model has tricked up momentum tremendously, it is highly necessary to collect sound experimental data on toxicity studies, animal and human clinical studies for their worldwide acceptability.

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