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 alkaloids, 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.
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 medicinal plants with antidiabetic property, their bioactive molecules, mode of action and also application of in vitro culture techniques used for secondary 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 in herbal 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 interest. Some of the most commonly used techniques for the separation; isolation and identification are given below.

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 minimize 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
voiletile 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        | Scrophulariaceae, Convallariaceae | Inhibition of Na\(^+\)/K\(^+\) ATPase pumps.                   |
| Cardiac glycoside      | Aglycan part is a steroidal moiety. e.g. oleanadrin | Scrophulariaceae, Convallariaceae |                                                                 |
| 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. | 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                   | They are antineoplastic, antibacterial, antiviral acitivity and also stimulate gastro intestinal secretions. |

3414
| **Diterpenoids** | 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 derived 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 derived from amino acids. e.g. theophylline | Apioceae | Effect on CNS |
| **Furocoumarins** | Furan ring fused with coumarin. e.g. psoralen | Apioceae | Affect the metabolism of certain drugs. |
| **Anthraqionones** | Phenolic compounds based on 9, 10-antheaquinone skeleton. e.g. Hypericin, a naphthodianthrones | Clusiaceae, Polygonaceae | Antidepressant effect. |
| 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 |
|-----------------------------------------|---------------------|------------------------------|-----------------------------------------------------|----------------------------------|--------------------------------|-----------|
| **Acacia auriculiformis** (Northern black wattle) | Bark | 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 Sidduraju, 2012 |
| **Canthium dicoccum** (Bogas) | 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) | Leaf Flower | Terpenoids Tannin Flavonoids Saponin Cardiac glycosides Steroids. | Hexane Chloroform Ethyl acetate Methanol Aqueous Absolute-alcohol | Antifungal Anti-bacterial Antioxidant Antioxidant Hepatoprotective Antidiabetic | Oral administration 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) | leaf | Favonoids | Ethanol Aqueous | Anti-inflammatory Anti-rheumatic 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 cymimum** (Jeera) | Seed | Flavonoids Polyphenols | Ethanol | Antimicrobial Antidiabetic Antifertility Anticancer Antioxidant Immunomodulatory | Oral dose of 250 mg/Kg body weight shows reduction in glucose level in streptozotocin-induced diabetic rats. | Srivstatava et al., 2011. |
| **Hunteria umbellate** (Demouain) | 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. |
| Plant Name                                      | Part             | Constituents                                                                 | Solvent    | Activity                                                                 | Reference                                    |
|------------------------------------------------|------------------|------------------------------------------------------------------------------|------------|-------------------------------------------------------------------------|-----------------------------------------------|
| *Mukia madeaspatana* (Melothria)               | Root             | Phenolics, Carotenoids, Flavonoids                                            | Methanol   | Antioxidant, Hypotensive, Immunomodulatory, Anti-inflammatory, Hepatoprotective, Antimicrobial, Vasodialatory, Diuretic, Antiasthmatic, Antidiabetic | Wani et al., 2011.                           |
|                                                |                  | Methanol root extract at a dose of 500 mg/kg to Alloxan induced diabetic rats showed significant reduction of blood glucose, lipid profile except HDL. |
| *Rehmania glutinosa* (Chinese foxglove)        | Root             | Iridoids, Monoterpenes, Glycosides, Phenols, Flavonoid                        | Ethanol    | Antidiabetic, Hypotensive, Hepatoprotective, Anti-inflammatory, Antimicrobial | Zhang et al., 2004; Jeonga et al., 2013.      |
|                                                |                  | Ethanolic extract at dose 100mg/kg for 15 days) showed a significant decrease in blood glucose level. |
| *Syzygium cumini* (Black Plum)                 | Leaf, Stem, Bark, Flower, Root, Fruit | Glycoside, Alkaloids, Flavonoids                                              | Aqueous Alcohol | Antidiabetic, Diuretic, Antioxidant, Antiarrheoal, Antibacterial, Gastrophective, Rudioprotective, Anti-inflammatory | Nair et al., 1986; Pepato et al., 2001; Ayyanar et al., 2012 |
|                                                |                  | Leaf extract at dose 4g/kg of body weight found to exhibit maximum hypoglycaemic effect in rabbits |
| *Vaccinium arctostaphylos* (Caucasian Whortleberry) | Fruit            | Anthocynins                                                                  | Ethanol    | Antidiabetic, Anti-inflammatory, Hepatoprotective, Antioxidant, Antibacterial, Antifungal | Feshani et al., 2011.                        |
|                                                |                  | Ethanolic extract of fruits showed postprandial blood glucose lowering in alloxan induced diabetic male wistar rats |
| Plants which increases the sensitivity of liver, fat and muscle cells to insulin | | | | | |
| *Amaranthus viridis* (Cholai)                  | Stem             | Alkaloids, Steroids, Glycosides, Saponins, Tannins                           | Aqueous Methanol Pet-ether | Anti-inflammatory, Diuretic, Anti-hemorrhagic, Antidiabetic, Analgesic, Anti-inflammatory, Anti-diabetic | Pandhare et al., 2012.                       |
|                                                |                  | Aqueous extract significantly decreased the blood glucose level in streptozotocin induced diabetic rats. |
| *Acorus calamus* (Bach)                        | Rhizome          | Saponins, Glycosides, Sequiterpenoids                                         | Methanol Ethyl acetate | Aphrodisiac, Diuretic, Antispasmodenic, Anti-hemorrhagic, Anti-inflammatory, Antioxidant, Hypoglycemic | David et al., 2012; Prisilla et al., 2012.   |
|                                                |                  | 200mg/kg of rhizome extract showed significant restoration of the blood glucose levels in streptozotocin induced diabetic rats. |
| *Bauhinia forficate* (Paw-of-cow)              | Leaf             | Flavonoids                                                                    | Aqueous Ethanol Hexane | Antidiabetic, Antimutagenic, Antioxidant, Hypolipidimic | Lino et al., 2004.                           |
|                                                |                  | Oral administration of aqueous, ethanolic and hexane extract of leaves at dose 200 and |
| Plant Family | Part | Chemicals | Solvent | Pharmacological Activity | Reference |
|-------------|------|-----------|---------|--------------------------|-----------|
| Fabaceae    |      |           |         |                          |           |
| Bryophyllum pinnatum (Air Plant) | leaf | Bryophillin A, Bersaldegenin-3-acetate, Bryophillin C, Alkaloids, Triterpenes, Glycosides, Flavonoids, Steroids, Butadienolides, Lipids, Organic acids. | Aqueous Ethanol | Anthelmintic, Hepatoprotective, Anti-inflammatory, Antidiabetic, Diuretic, Antioxidant, Antimicrobial, Analgesic, Antipyretic | Aransiola et al., 2014. |
| Bryophyllum pinnatum (Air Plant) |     |           |         |                          |           |
| Papilionaceae/ Leguminosae |     |           |         |                          |           |
| Cajanus cajan (pigeon pea/ arhar) | Leaf, Stem, Twig | Flavonoids, β-Carotenoids, Glycoside, Resin, Terpenoids, Tannins | Methanol, Ethanol, Aqueous | Antidiabetic, Hepatoprotective, Anti-viral, Anti-bacterial, Neuroprotective, Antioxidant, Anticancer | Ezike et al., 2010 |
| Camellia sinensis (Green tea) | Leaf, Flower | Epigallocatechin-gallate, Epicatechin-gallate, Epicatechin, Catechin, Epigallocatechin, Gallic acid | Aqueous | Anti-aging, Anticancer, Cardioprotective, Antidiabetic | Han et al., 2011 |
| Colocasia esculenta (Arbi) | leaf | Cynoglucosides, Flavonoids, β-sitosterol, Steroid | Ethanol | Analgesic, Anti-inflammatory, Anticancer, Hypolipidemic | Kumawat et al., 2010 |
| Cucurbitaceae | fruit | Emeclocyline glycodeloxycholic acid, 3α,7α,12α - Trihydroxycoprostanic acid, Chlortetracycline, Azafrin, Methyl Ester | Ethanol, Aqueous | Antibacterial, Analgesic, Anti-inflammatory, Diuretic, Antidiabetic, Hepatoprotective | Salahuddin et al., 2010. |

400 mg/kg showed significant reduction in plasma glucose level alloxan rats.

200 mg/kg aqueous extract resulted in a significant drop in blood sugar level.

Single doses of unroasted seeds to normal as well as alloxanized mice shows significant reduction in the serum glucose levels.

75, 150 and 300 mg/kg body weight caused a significant decrease in blood glucose levels of alloxan-induced diabetic mice.

Ethanol extract of leaves at dose 450 mg/kg showed significant reduction of blood glucose levels in alloxan induced diabetic rats.
| Plant Family | Genus, Species | Part(s) | Secondary Metabolites | Extraction Method | Effect | Reference(s) |
|--------------|---------------|---------|----------------------|------------------|--------|--------------|
| Poaceae      | Cynodon dactylon (Doob) | Leaf | Alkaloids, Tannins, Carbohydrates, Glycosides, Steroids, Terpenoids | Aqueous | Hypoglycemic, Hypolipidimic, Woundhealing, Antibacterial, Anti-viral, Anti-inflammatory | Singh et al., 2007; Vijayan et al., 2014. |
|              | Emblica officinalis/Phyllanthus Emblica (Amla) | Fruit, Leaf, Seed | Tannins, Alkaloids, Phenolics, Flavonoids | Aqueous | Antioxidant, Immunomodulatory, Hepatoprotective, Anti-microbial, 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. |
| Euphorbiaceae | Foenum graecum (Methi) | Seed, Leaf | Flavonoids, Saponins, Alkaloids, Trigonelline, Choline | Ethanol, Aqueous | Hypoglycemic, Hypocholesterolemic, Immunomodulatory, Antiinflammatory, Antiulcerative, Anticancerous, Antihypertensive, Anticarcinogenic, Antioxidant, Diuretic | Oral administration 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. |
| Hypoxidaceae | Hypoxis hemerocallidea (yellow stars) | 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. |
| Convolvulus  | Ipomoea reniformis (musakani) | Stem, Leaf | Caffeic, P-Coumaric, Ferulic, Sinapic acids, Phthalate, Resins, Glycosides, Tannins | Ethanol, Aqueous | Anthyperglycemic, 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 | Alcholoh | 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  
Termitecidal | 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  
Petroleu m ether | Alkaloids  
Flavonoids  
Glycosides  
Saponins  
Sterols  
Lignin  
Phenols | Aqueous | Haemolytic  
Sedative  
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  
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 anti-hyperglycemic | *Gray and Flatt*, 1998. |
| Plant Name                  | Part       | Constituents                                      | Extraction Method | Phytochemical Activity                                                                 | Reference                                                                 |
|----------------------------|------------|--------------------------------------------------|-------------------|---------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| *Alangium salvifolium* (Ankola) | Leaf, Seed, Bark | Tannins, Flavonoids, Glycoside, Alkaloids, Gum, Mucilage | Methanol          | Antipyretic, Laxative, Astringent, Anti-rheumatic, Analgesic, Anti-diarrheal, Hepatoprotective, Antidiabetic | Mishra and Gary, 2011                                                   |
| *Allium sativum* (Garlic)   | Clove, Leaf, Root | Allin, (diallyl disulfide oxide), Allicin, APDS (allyl propyl disulfide), S-allyl cysteine, S-allyl mercaptocysteine | Aqueous Methanol  | Lipid-Lowering, Hypotensive, Anticancer, Antioxidant, Antimicrobial                    | Eidia *et al*., 2006; Younas and Hussain, 2014.                            |
| *Aloe vera* (Aloe)          | Leaf       | Pentosides, Barbaloin, Isobarbaloin, Aloin, Betabarbaloin, Anthraquinones, Saponins, Lignin, Salicylic acid | Aqueous           | Cardioprotective, Antitumor, Antioxidant, Anti-inflammatory, Hepatoprotective, Immunomodulatory, Antifungal | Chauhan. *et al*., 2010; Singh *et al*., 2010; Saghir *et al*., 2011 |
| *Aralia cachemirica* (Aralia) | 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 Alcohol   | Anti gastritis, Anti rheumatic, Anti arthritic, Anti-inflammatory, Anti diabetec          | Bhat *et al*., 2005; Verma *et al*., 2010.                                |
| Plant Name | Family | Part | Secondary Metabolites | Extraction Method | Activity | Reference |
|------------|--------|------|-----------------------|-------------------|----------|-----------|
| 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, 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, Antimetastastic, 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) | Leaf | α-pinene | Aqueous | Antihyperglycemic | Gupta *et al.*, 2009; Chakrabarty and Das, 2010. |
| **Lauraceae** | Bark | Camphene | | Antidiabetic | |
| | Myrcene | | | Antioxidant | |
| | limonene | | | Hypolipidemic | |
| | Eugenol | | | Astringent | |
| | p-cymene | | | Anti-inflammatory | |
| | Methyl eugenol acetate | | | Anti-arthritic | |

| **Citrullus colocynthis** (Bitter apple/ Bitter cucumber) | Pulp | Colocynthin | Ethanol | Analgesic | Dallak *et al.*, 2009. |
| **Cucurbitaceae** | | Colocynthein (Resin) | | Antibacterial | |
| | | Colocynthetin Pectin Gum | | Anti-inflammatory | |

| **Clausena lansium** (Wampee) | Stem | β-santalol | Methanol | Anti-trichomonal | Adebajo *et al.*, 2009. |
| **Rutaceae** | Bark | Bisabolol | | Antidiabetic | |
| | Fruit | Methyl santalol ledol Sinensal | | Anti-Inflammatory | |
| | | 9-octadecenamid e phellandrene limonene | | Hepatoprotective | |
| | | P-menth-1-en-4-ol. | | Antioxidant | |

| **Coriandrum sativum** L (Coriander/ Dhaniya) | Seed | Linalool | Ethanol | Antioxidant | Chitra and Leelamma, 1999. |
| **Umbelliferae** | | Coumarins Flavonoids Phenolic Acids Polyacetylenes Phthalides Mucilage | | Antilithogenic | |
| | | | | Anti-inflammatory | |
| | | | | Antidiabetics | |

| **Coscinium fenestratum** (Jhar haldi) | Whole plant | Alkaloids | Ethanol | Anxiolytic | Sirintorn *et al.*, 2009 |
| **Menispermaceae** | Berberin | Chloroform | | Antidepressant | |
| | | | | Hypoglycemic | |
| | | | | Hypotensive | |
| | | | | Antidiabetic | |
| | | | | Cardioprotective | |

| **Ginkgo biloba** (Maiden hair tree) | Leaf | Polyphenol | Aqueous | Antioxidant | Shankar *et al.*, 2005. |
| **Gingkoaceae** | | | | Antihyperglycemic | |
| | | | | Antihyperlipidemia | |
| Species                          | Family     | Parts               | Constituents                  | Solvents    | Uses                          | Ref.                          |
|---------------------------------|------------|---------------------|-------------------------------|-------------|------------------------------|-------------------------------|
| *Gmelina arborea* (Gamar/Gumhar)| Verbenaceae| Leaf, Bark, Root    | Alkaloids, Flavonoids, Phenolics, Saponins, Steroid, Glycoside | Methanol, Chloroform, Ethanol | Antioxidant, Diuretic, Antimicrobial, Cardioprotective, Immunomodulatory, Antipyretic, Analgesic | Punitha *et al.*, 2012. |
|                                 |            |                     |                               |             | The highest depletion in blood glucose recorded in the 400 mg/kg body weight dosage in streptozotocin induced diabetic rats. |
| *Hibiscus rosa sinensis* (China Rose) | Malvaceae  | Whole Plant, Leaf, Flower | Cyaniding, Quercetin, Hentriacontane | Aqueous, Methanol | Anticomplimentary, Antidiarrhetic, Antimicrobial, Antioxidant, Antidiabetic | Moqbel *et al.*, 2011. |
|                                 |            |                     |                               |             | Oral dose of 100 and 200 mg/kg body weight to non obese diabetic mice shows significant reduction in blood glucose level. |
| *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 | Ahmed *et al.*, 2001; Kumar *et al.*, 2010. |
|                                 |            |                     |                               |             | The treatment of streptozotocin 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. |
| *Mucuna pruriens* (Atmagupta/ Magic bean) | Leguminosae | Seed, Leaf, Root, Stem | L-DOPA, Tryptamine, Alkaloids, Tannins | Hexane, Chloroform, Methanol, Ethanol | Antibacterial, Anti fungal, Hypotensive, Hypoglycemic, Antidiabetic, Antioxidant | Eze *et al.*, 2012. |
|                                 |            |                     |                               |             | 100, 200 and 400 mg/kg of the extract Significantly reduced the fasting blood sugar levels in alloxan-induced diabetic rats. |
| *Panax ginseng* (Korean ginseng) | Araliacea  | Fruits              | Steroidal saponins            | Ethanol     | Anticancer, Immunomodulatory, Antioxidant, Antifatigue, Antimicrobial | Attele *et al.*, 2002. |
|                                 |            |                     |                               |             | 150 mg/kg extract-significantly improved glucose tolerance in treated obese diabetic mice. |
| *Quercus Infectoria* (Oliver)   | Fagaceae   | Leaf, Gall, Roots   | Tannins, Polyphenols, Gallic acids, Tannins acid, Tannins, Flavonoids | Methanol, Ethanol, Hexane, Chloroform, Aqueous | Antibacterial, Anti fungal, Antidiabetic, Antiinflammatory, Anti tumor, Antioxidant | Saini *et al.*, 2012. |
|                                 |            |                     |                               |             | 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. |
| *Ricinus communis* (Castor)     | Euphorbiaceae | Root                | Phenolic Lectins, Ricin, Pyridine, Alkaloids, Ricinoleic Acid | Ethanol     | Antioxidant, Antitumor, Antinocepicitive, Anti-Inflammatory, Analgesic | Shokeen *et al.*, 2008. |
|                                 |            |                     |                               |             | 500 mg/kg body weight caused the maximum lowering of the fasting blood glucose |
| **Smallanthus sonchifolius** (Aricoma) | Leaf | Phenolic compounds | 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. |
| **Asteraceae** | | | | |
| **Syzygium jambolanum** or **Eugenia jambolana** (Jamboon/ sweet olive) | Leaf | Anthocyanins Glucoside Alkaloids Jambosin Flavonoids | Methanol, Ethanol Aqueous | Ethanol 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. |
| **Myrtaceae** | Seed | | | |
| **Taraxacum officinale** (Dandelion) | Leaf | Phenylpropanoids Triterpenoids Sterols Taraxasterol Taraxerol Cycloartenol β-sitosterol | Alcohol Aqueous | 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. |
| **Asteraceae** | Root | | | |
| **Plants that shows inhibitory activity on glucose absorption in the small intestine.** | | | | |
| **Actinidia kolomikta** (kiwi) | Root Leaf | Phenolics Flavonoid | Aqueous Ethanol | 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. |
| **Actinidiaceae** | | | | |
| **Psoralea corylifolia** (Babchi) | Seed | Flavanoids Alkaloids Phenols Tannins | Chloroform Ethyl acetate Methanol | The dose of 250mg/kg of body weight was found | Sahashini *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) | Leaf Bark Fruit N-Hexacosane | Acetone Ethanol Methanol | Anti-microbial Antioxidant Laxative Woundhealing Hepatoprotective Anti-inflammatory Analgesic |
| Caesalpiniaeae | Eicosanoic Acid Octacosanyl Ferulate Apigenin | Aqueous methanolic extract of leaf at the dose 200mg/kg body weight showed blood glucose lowering activity in streptozotocin induced diabetic rats. |
| Zea mays (Maize) | Corn silk | Benzene Chloroform Ethanol Ethyl Acetate | Antioxidant Diuretic Antidepresent Antifatigue Anti-hyperlipidimic Anti-inflammatory Neuroprotective |
| Gramineae | Flavonoids Alkaloids Phenols Steroids Glycosides Terpenoids Tannins | Aqueous Methanol Petroleum ether | After orally administration with corn silk extract, the blood glucose and HbA1c were significantly decreased in alloxan induced hyperglycaemic mice. |
| Improving insulin release in response to meals | Ascorbic acid Aegeline Coumarins Alkaloids Aegeline Skimmianine Lupeol Cineol Citral Citronella Cuminaldehyde Eugenol Marmesinine Fagarine Marmin Marmelosin Luvangetin Aurapten Psoralen Marmelide Tannin | Aqueous Alcohol | Oral admistration of aqueous seeds extract at dose of 250mg/kg was found to decreases blood glucose level in normal healthy rats after 6 h of administration. |
| Aegle marmelos (Bael) | Flower Leaf Fruit Seed | Aqueous Alcohol | Int.J.Curr.Microbiol.App.Sci (2018) 7(5): 3409-3448 |
| Rutaceae | Anti-hyperglycemic Hepato-protective Analgesic Antifertility Anti Fungal Hypolipidemic Immunomodulatory Anti-Inflammatory | 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 | Hypocholesterolemic 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 Antidiarrhoecal | 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)**  
**Arecaaceae**  
- **leaf**  

| Tannins Alkaloids Trepenoids Flavonoids | Aqueous | Antidiabetic Antibacterial Antiinflammatory Antiasthamatic Nephroprotective Hepatoprotective | Sub-acute administration of leave’s extract in alloxan-induced diabetic rats significantly reduced blood | Seyyed et al., 2010. |
| Plant                          | Part(s) | Active compounds                                | Extraction | Action(s)                                                                 | Reference(s)                              |
|-------------------------------|---------|-------------------------------------------------|------------|---------------------------------------------------------------------------|-------------------------------------------|
| *Salvia lavandulifolia* (Spanish Sage) | Leaf   | Flavonoids Terpenoids 1,8- cineole α- pipene     | Aqueous    | Spasmolytic Antiseptic Analgesic Sedative Antioxidant Antidiabetic Antiinflammator y | 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) | Leaf   | Stevioside Rebaudioside A-F Dlucoside Steviobioside Flavonoids Anthocyanins Phenolics. | Aqueous Methanol Petroleum ether | Antihyperglycemic Hypotensive Anti-inflammatory Antibacterial Gastroprotective Immuno-modulatory Cardiovascular Antiinflammator y | Oral administration of stevioside 0.5mg/kg body weight, lowered blood glucose level in streptozotocin induced diabetic rat. Gregersen *et al.*, 2004. |
| *Swertia chirata* (Chiratika/ Kutki) | Seed Root | Alkaloids Flavonoids Xanthones Glycosides Terpenoids | Aqueous Ethanol Methanol | Antipyretic Anthelmintic 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) | Bark   | Phenolics Palmetic acid Stearic acid Oleic acid Linoleic acid Arachidic acid | Aqueous Ethanol 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) | 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 insulintropic effects in type-II diabetic rats. Abdel-Zahe *et al.*, 2005. |
| **Zingiber officinale** (Ginger) | Rhizome Root | Phenolic compounds | Aqueous | Hypoglycemic Cardiotoxic Antilipemic Antioxidant Antineoplastic Antiviral Antibacterial Antifungal | Oral administration 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. |
| **Zinzibaraceae** | | | | | | |

Preserve the function of the β-cells of the pancreas and Regenerate the damage β cells.

| **Aerva lanata** (Polpala) | 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 |
| **Amaranthaceae** | | | | | | |

| **Barleria prionitis** (Vjradanti) | leaf Root | Sterols Saponins Tannins Flavonoids | Alcohol | Diuretic Hepatoprotective 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 |
| **Acanthaceae** | | | | | | |

| **Caesalpinia digyna** (Teri pod/ Udakiryaka) | 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 |
| **Leguminosae** | | | | | | |

| **Callistemon lanceolatus** (Crimson Bottlebrush) | leaf | Phenolic Saponins Alkaloids Glycosides Sterols Tannins. | Ethanol Methanol Hexane Ethyl acetate. | | | |
| **Myrtaceae** | | | | | | |

| **Ficus amplissima** (kal-itchchi) | Bark | Phenolic compounds | Methanol | Antidiabetic Hypolipidimic Antioxidant Antiinflammatory Antibacterial | Oral administration of methanolic extract of bark at the doses of 50, 100 and 150mg/kg showed significant antidiabetic effect on | Arunachalam and Parimelazhagan, 2013. |
| **Moraceae** | | | | | | |
| Plant Name                  | Part(s)   | Constituents                       | Extract Form  | Activity                                      | Reference                          |
|-----------------------------|-----------|------------------------------------|---------------|-----------------------------------------------|-----------------------------------|
| *Nymphea pubescens* (pink water lily) | Flower Tuber | Alkaloids, Flavonoids, Glycosides, Terpenoids, Tannins, Phenols, Saponins, Steroids | Ethanol Aqueous | Antidiabetic, Hypolipidemic, Antioxidant       | Shajeela *et al.*, 2012. |
| *Nymphea sp.* (Nymphaeaeae) | Flower Tuber | Alkaloids, Flavonoids, Glycosides, Terpenoids, Tannins, Phenols, Saponins, Steroids | Ethanol Aqueous | Antidiabetic, Hypolipidemic, Antioxidant       | Shajeela *et al.*, 2012. |
| *Ocimum gratissimum* (Clove Basil) | Leaf       | Thymol, Citral, Geraniol           | Aqueous       | Antimicrobial, Antibacterial, Antidiabetic, Hepatoprotective | Nelson *et al.*, 2012. |
| *Otoestegia persica* (Goldar) | Root, Aerial parts | Polyphenols, Alkaloids, Glycoside, Flavones, Saponins, Tannins | Aqueous       | Antihistamin, Antispasmodic, Antioxidant, Antidiabetic | Bagherzade *et al.*, 2014. |
| *Prunella vulgaris* (Self heal) | Leaf, Stem | Rosmarinic acid, Ursolic acid, Oleanolic acid | Aqueous Ethanol | Anti-inflammatory, Anti-allergic, Anticancer, Wound Healing, Antidiabetic, Hepatoprotective, Antipyretic, Mild Antiseptic, Detoxifier, Diuretic, Haemostatic | Hwang *et al.*, 2012. |
| *Pterocarpus marsupium* (Vijasar) | Timber Bark, Leaf, Flower | Glycoside, Flavonoids, Tannins. | Ethanol Aqueous | Hypolipidemic, Hepato-protective, Anti-ulcer, Anti-inflammatory, Anti-oxidant, Cardiotonic, Antibacterial, Anti-diabetic | Gupta *et al.*, 2009. |
| *Selaginella tamariscina* (Spikemoss) | Leaf       | Flavonoids                         | Aqueous Ethanol | Vasorelaxant, Antimetastatic, Antidiabetic | Zheng *et al.*, 2011. |
| Selaginellaceae | | | | |
|---|---|---|---|---|
| | | | | |
| *Scoparia dulcis* (Bondhane / sweet broomweed) | Whole plant | Flavonoids | Hexane | Antidiabetic |
| Scrophulariaceae | Saponins | Ethyl acetate | Methanol | Antitumor |
| | Phenol | Aqueous | | Antioxidant |
| | Tannins | | | Neuroprotective |
| | Alkaloids | | | |
| | Steroids | | | |
| | Terpenes | | | |
| *Tribulus terrestris* (Gokhru) | Seed | Protodioscin | Methanol | Antimicrobial |
| Zygoophyllaceae | Fruit | Terrestrosins A-E | | Cytotoxic |
| | Leaf | Desgalactotigonin | | Antihyperlipidaemic |
| | | Desglucolanatigonin | | Diuretic |
| | Stem | Fgitonin | | Anti-inflammatory |
| | | Gitonin | | Astringent |
| | | Tigogenin | | Analgesic |
| | | Furostanol | | |
| | | Glycosides | | |
| | | Sterol | | |
| | | Diosgenin | | |
| | | Hecgenin | | |
| | | Ruscogenin | | |
| | | Kaempferol | | |
| | | Quercetin | | |
| | | Tribulosamides A and B. | | |
| *Withania somnifera* (ashwagandha) | Root | Sitoindosides | Aqueous | Antioxidant |
| Solanaceae | Fruit | Steroidal alkaloids | | Antitumor |
| | Leaf | Steroidal lactones | Alcoholic | Anti-inflammatory |
| | Seed | | | Immuno-modulatory |
| | | | | Hematopoetic |
| | | | | Anti-ageing |
| | | | | Anxiolytic |
| | | | | Anti-depressive |
| | | | | |
| *Annona squamosa* (custard apple / Sitafal) | Leaf | Annoreticuin | Aqueous | Antitumor |
| Annonaceae | Root | Isannoreticuin | Methanol | Antibacterial |
| | Bark Seed | Acetogenin | | Wound healing |
| | | Flavonoids | | Anti-ulcer |
| | | Alkaloids | | Anthelmintic |
| | | Glycoside | | Antioxidant |
| | | Anonaine | | Anti-malarial |
| | | 6-Hetriacontanone | | Anti-HIV Hepato-protective |
| | | Hexacontanol | | |
| | | Higemamine | | |
| | | Isocorydine | | |
| | | Limonine | | |
| | | Linalool acetate | | |
| *Azadirachta indica* (Neem) | Leaf | Isoprenoids | Methanol | Anti-inflammatory |
| | Bark | Azadirone | Chloroform | Antiarthritic |
| | Fruits | Azadirachtin | Aqueous | Antipyretic |

Inhibits the activity of hepatic Glucose-6-phosphatase and Increased glycogenesis.

- **Antifungal**
- **Antiinflammatory**
- **Antitumor**
- **Cardioprotective**
- **Antioxidant**

beneficial effects on hyperglycemia and hyperlipidemia in streptozotocin induced diabetic rats

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200 mg/kg of the ethanolic extract showed maximum reduction in glucose levels in streptozotocin induced diabetic rats.

Latha *et al.*, 2004.

Oral administration of 50 mg/kg body weight methanolic extracts of aerial parts of *Tribulus terrestris* showed significant reduction in blood glucose level in streptozotocin induced diabetic rats.

Wu *et al.*, 1999; Mahato *et al.*, 1981.

Oral administration of root powder at dose 100 mg/kg showed significant reduction in blood glucose level in streptozotocin induced diabetic rats.

Pradeep *et al.*, 2010.

Oral admsistration of ethanolic leaf-extract (350 mg/kg) in streptozotocin diabetic rats and alloxanized rabbits shows antihyperglycemic activity.

Mohamed., 2011

Aqueous leaves extract at a dose of 250 mg/kg body weight for 16 days.

Eshrat *et al.*, 2002.
| Family          | Plant                  | Part            | Constituents                                      | Pharmacological Activities                                                                 | References                                                                 |
|-----------------|------------------------|-----------------|--------------------------------------------------|------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Meliaceae       | Bougainvillea spectabilis (Bougainvillea) | Leaf            | Flavonoids Tannins Cardiac-glycosides Terpenes Steroids | Hypoglycemic Hypolipidimic Antibacterial Nematicidal Insecticidal Antiviral Ethanol extract of stem bark at dose 250mg/kg shows anti hyperglycaemic effect in alloxan induced diabetic rats. | Jawla et al., 2012 |
| Nyctaginaceae   | Coccinia indica (Kundru) | Leaf Fruit Stem Root | Alkaloids Steroids Tannins Phenolics Flavonoids Resins | 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. |
| Cucurbitaceae   | Cucumis sativus (Cucumber/ Kheera) | Fruit Seed | Steroids Carotenoids Flavonoids Tannins Resin | 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. | Karthiayini et al., 2009; Gopalakrishnan et al., 2013. Sharmin et al., 2013. |
| Asteraceae      | Elephantopus scaber (Tutup bumi) | Leaf Root | Stigmasterol Lupeol Stearic acid Deoxyelephantopin Aqueous Acetone | Astringent Antipyretic Anti-diabetic Anti-inflammatory Anticancer Antibacterial Oral administration of aqueous extract of leaves and rootsat dose 300 mg/kg body weight significantly reduced serum glucose level in alloxon induced diabetic rats. | Rajathi et al., 2011. |
| Gentianaceae    | Enicostemma littorale (Chhota-chirayta) | Leaf | Alkaloids Flavonoids Catechins Saponins Sterols Terpenoids 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 | in streptozotocin-induced diabetic rats |
| --- | --- | --- |
| Gymnema montanum (Gymnema) | Alkaloids Saponin Tannins Glycosides Alcohols | 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. |
| Asclepiadaceae | Stem Leaf | Gymnema |
| Psidium guajava (Guava/ Amrud) | Phenolics Glycosides Carotenoids Ethanol | Antidiabetic Hepatoprotective Antioxidant Antioxidant Antimicrobial Oral administration of the alcoholic extract of the leaf at dose 250mg/kg exhibited significant hypoglycaemic activity in alloxan-induced hyperglycaemic rats Mukhtar et al., 2006. |
| Myrtaceae | Stem bark | Gymnema |
| Tinospora crispa (Akar patawali) Menispermaceae | Terpenoids Borapetoside C Aqueous | Antidiabetic Hepatoprotective Antioxidant 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 Anticarcin Antiglomerular Immuno-modulatory Oral administration of the methanolic extract at dosens250 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**

| Compound | Petroleum Ether | Chloroform | Methanol | Aqueous |
|----------|-----------------|------------|----------|---------|
| Alkaloids | Phytosterols    | Lignin     |          |         |

**Hepato-protective**

**Diuretic**

**Anti-inflammatory**

**Antibacterial**

**Antidiabetic**

**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**

| Compound | Methanol | Aqueous |
|----------|----------|---------|
| Anthocyanins | Flavonoids | Hydroxycinnamic acids Polyphenols |

**Antinociceptive**

**Anti-hyperglycemic**

**Antioxidant**

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 cornusins A, B and C Ursolic acid |

**Methanol**

**Antibacterial**

**Antifungal**

**Hypotensive**

**Antitumor**

**Astringent**

**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**

| Compound | Methanol | Aqueous |
|----------|----------|---------|
| Oil Isochinoline | Alkaloids |    |

**Antidiabetic**

**Anticancer**

**Immunomodulatory**

**Analgesic**

**Antimicrobial**

**Anti-inflammatory**

**Hepato-protective**

**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**

| Compound | Aqueous |
|----------|---------|
| Caffeic Acid | Carnosol Ros-Maridiphenol Rosmarinic Acid |

**Ethanol**

**Antiasthmatic**

**Cardiotonic**

**Hypotensive**

**Memorybuster**

**Antihyperglycemic**

**Hepato-protective**

**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**

| Compound | Methanol |
|----------|----------|
| Olanocarpine Carpenersterol Solanocarpidine Diosgenin Sitosterol Isochlorogenic acid Neochronogenic |

**Hypoglycemic**

**Hypolipidimic**

**Antioxidant**

Methanol extracts of leaf was efficient anti hyperglycemic agents at a concentration.

Poongothai *et al.*, 2011.
| Genus                  | Plant Part       | Constituent                        | Solvent                  | Effect                                      | Preparation                                                                 | Reference                                                                 |
|-----------------------|------------------|------------------------------------|--------------------------|---------------------------------------------|-----------------------------------------------------------------------------|---------------------------------------------------------------------------|
| **Teucrium polium**   | Leaves           | Terpenoids                         | Methanol                 | Hypoglycemic                                | 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.                                                     |
| (Kalpooreh)           |                  | Flavonoids                         | Aqueous                  | Hepatoprotective                            |                                                                            |                                                                           |
| Lamiaceae             |                  | Apigenin                           |                          | Analgesic                                   |                                                                            |                                                                           |
|                       |                  |                                    |                          | Antilipidemic                                |                                                                            |                                                                           |
|                       |                  |                                    |                          |                                            |                                                                            |                                                                           |
| **Curcuma longa**     | Rhizome          | Curcumin                           | Methanol                 | Antioxidant                                 | 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                                     |
| (Turmeric)            |                  | Essential oils                     | Chloroform-water         | Anti-inflammatory                           |                                                                            |                                                                           |
| Zinzibaraceae         |                  |                                    |                          | Anti cancer                                 |                                                                            |                                                                           |
|                       |                  |                                    |                          | Anti viral                                  |                                                                            |                                                                           |
|                       |                  |                                    |                          | Anti fungal                                 |                                                                            |                                                                           |
|                       |                  |                                    |                          | Anti bacterial                              |                                                                            |                                                                           |
|                       |                  |                                    |                          | Antiseptic                                  |                                                                            |                                                                           |
| **Musaes paradisiaca**| Leaf             | Catecholamines                     | Methanol                 | Antioxidant                                 | Leaves and fruit peels are responsible for antidiabetic potential on streptozotocin induced diabetic rats. | Reddy et al., 2014; Lakshmi et al., 2014.                                   |
| (Banana)              | Ripe fruit’s peel| Norepinephrine                     | Chloroform               | Antidiarrheal                                |                                                                            |                                                                           |
| Musaceae              | Root             | Serotonin                          | Petroleum ether          | Antidyssenterent                             |                                                                            |                                                                           |
|                       | Stem             | Dopamine                           | Ethanol                  | Antidiabetic                                 |                                                                            |                                                                           |
|                       |                  | Flavonoid                          |                          | Hypotensive                                 |                                                                            |                                                                           |
|                       |                  | Sterol                             |                          | Cardiotonic                                 |                                                                            |                                                                           |
| **Pongamia pinnata**  | Root             | Alkaloids                           | Ethanol                  | Antitumor                                   | Ethanololic extract of leaves at doses 500mg/kg and 1g/kg shows significant antidiabetic effect on streptozotocin induced male albino rats. | Kavipriya et al., 2013.                                                   |
| (Karanj)              | Fruit            | Glycosides                         | Methanol                 | Antiseptic                                  |                                                                            |                                                                           |
| Fabaceae/             | Leaf             | Flavonoids                         |                          | Anti-inflammatory                           |                                                                            |                                                                           |
| Leguminocae           |                  | Flavone derivative ‘pongol’         |                          | Antiinflammatory                            |                                                                            |                                                                           |
|                       |                  |                                    |                          | Antinociceptive                              |                                                                            |                                                                           |
|                       |                  |                                    |                          | Antihyperglycemic                           |                                                                            |                                                                           |
|                       |                  |                                    |                          | Anti-lipidoxidative                          |                                                                            |                                                                           |
|                       |                  |                                    |                          | Antidiarrhoeal                               |                                                                            |                                                                           |
|                       |                  |                                    |                          | Antiucler                                   |                                                                            |                                                                           |
|                       |                  |                                    |                          | Antioxidant                                 |                                                                            |                                                                           |

Plants which are preserve β-cell function by depletion of antioxidant enzyme cascade and prevent diabetes induced ROS formation.
If a person’s pancreas does not work properly or body cells does not respond 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 senario for treatment of such type of complex metabolic disorders, differet kinds of medicinal system are available. Allopathy medicines are mostly used for treatment of diabetes 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 inhibitory 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 charatta*.

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 registred 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 fenestratum*, *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 pharmaceutical 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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