2. REVIEW OF LITERATURE

2.1. Pharmacognostical Investigations

Medicinal plants are as expensive gift from nature to human. Since prehistoric times, the medicinal plants are nature’s hidden and to a large extent unexplored treasure. The art of medicine consists of a musing the patient while nature cures the diseases. Nature’s pharmacy has been widely utilized virtually in almost all human cultures around the world. Medicinal plants have provided the modern medicine with numerous plant-derived therapeutic agents. Many plants contain a variety of phytopharmaceuticals, which have found very important applications in the fields of agriculture, human and veterinary medicine. Natural products play a dominant role in the development of novel drugs which lead for the treatment and prevention of diseases (Evans, 2000 and Cragg and Snadder, 2003). The medicinal value of these plants lies in some chemical substances that produce a definite physiological action on the human body. The most important of these bioactive constituents of plants are alkaloids, tannins, flavonoids, and phenolic compounds (Hill, 1952). Knowledge of these chemical constituents of plant is helpful in the discovery of therapeutic agents. The evaluation of all these drugs is based on phytochemical and pharmacological approaches (Foye et al., 2008).

Phytochemical studies have attracted the attention of plant scientists due to the development of new and sophisticated techniques. These techniques play a significant role in giving solution to systematic problems on the one hand and in the search for additional resources of raw materials for pharmaceutical industry on the other hand (Mojab et al., 2003). With this backdrop, it becomes extremely important to make an effort towards standardization of the plant material to be used as medicine. The process of standardization can be achieved by stepwise pharmacognostic studies (Ozarkar, 2005). The American Society of Pharmacognosy refers to pharmacognosy as “the study of the physical, chemical, biochemical and biological properties of drugs, drug substances, or potential drugs or drug substances of natural origin as well as the search for new drugs from natural sources”. As practiced today, pharmacognosy involves the broad study of natural products from various sources including plants, bacteria, fungi,
and marine organisms. Pharmacognosy includes both the study of botanical dietary supplements, as well as the search for single compound drug leads that may proceed through further development into Food and Drug Administration (FDA)-approved medicines (Tagboto and Townson, 2001). These studies help in the identification and authentication of the plant material. Correct identification and quality assurance of the starting materials is an essential prerequisite to ensure reproducible quality of plant medicine which will contribute to its safety and efficacy. Simple pharmacognostic techniques used in standardization of plant material include its morphological, anatomical and biochemical characteristics (Anonymous 1998).

2.1.1. Anatomical studies

Anatomical characterization of plants used in traditional medicines has been carried out to evolve standards for genuine source plant from the spurious ones. Bharti (2010) investigated the anatomical feature of leaf and seed of *Elaeocarpus ganitrus*. The results revealed the presence of anomocytic stomata and calcium oxalate crystals in the leaf powder and starch grains in the seed powder. Microscopic evaluation of seed powder of *Elaeocarpus ganitrus* revealed the presence of a hard endocarp with lignified isodiametric sclereids, seeds with membranous seed coat which enclosed a dense cellular endosperm comprising of calcium oxalate druses (Singh et al., 2010).

Vijayan et al. (2010) investigated the anatomical features of the fresh leaves of *Elaeocarpus blascoi*. Internally, the leaf showed the presence of anomocytic stomata, multicellular covering trichomes with an acute apex, prism and clustered crystals of calcium oxalate and fibre elements. The chemo-microscopy revealed the presence of lignin, starch grains and calcium oxalate crystals. The anatomical section of leaf of *Elaeocarpus ganitrus* revealed the absence of trichomes, presence of calcium oxalate crystal in the mesophyll, midrib regions, a patch of pericyclic fibres above and below of each vascular bundle (Priya Shaival et al., 2012).

2.1.2. Physiochemical studies

Singh et al. (2010) studied the physiochemical parameters of dried seed of *Elaeocarpus ganitrus*. The result showed the total ash of 1.5%, acid insoluble ash 1.1%, water soluble ash 0.96%, petroleum ether soluble extractive 1.3%, chloroform
soluble extractive 0.5%, ethanol soluble extractive 2.4%, water soluble extractive 1.8% and loss on drying 9.7%. Physiochemical parameters showed that the total ash was 1.36 times and 1.56 times more than the acid insoluble ash and water soluble ash, respectively. Further, ethanol had a maximum extractable value of 2.4% and moisture content was found to be 9.7%.

Vijayan et al. (2010) analysed the physico-chemical parameters of leaf powder of *Elaeocarpus blascoi*. The results showed total ash of 7.23%, acid-insoluble ash 4.20%, water-soluble ash 5.44%, sulphated ash 0.70%, ethanol soluble ash 8.30%, methanol soluble ash 7.40%, water soluble extractive 6.45% and moisture content 3.10%.

### 2.1.3. Phytochemical studies

Rastogi and Mehrotra (1984) isolated palmitic, isopalmitic and linolenic acids from the seeds of *Elaeocarpus sphaericus*. Phytochemical analysis of methanolic extract of leaf of *Muntingia calabura* (Elaeocarpaceae) revealed the presence of flavonoids, steroidal, triterpenoidal compounds and their glycosides (Perez et al., 1998). Morice (2001) phytochemically analysed the fruit and the seed fats of *Elaeocarpus dentatus* and found that it contained fatty acids palmitic 11-35%, oleic 13-68%, linoleic 16-31% and the fruit coat fat 13% linolenic acid and the seed fat 10% hexadecenoic acid. Chemically the petroleum ether, chloroform, ethanol and water extracts of seed of *Elaeocarpus ganitrus* showed the presence of phytosterols, fats, alkaloids, flavonoids, carbohydrates, proteins and tannins (Singh et al., 2010).

Fresh aqueous extract of seed of *Elaeocarpus ganitrus* showed the presence of alkaloids, steroid, triterpenoids, glycosides, tannins, flavonoids, glycosides, carbohydrates and cardiac glycosides (Juvekar et al., 2011). Phytochemical screening of the powdered leaves of *Elaeocarpus serratus* was performed using the solvents chloroform, acetone, petroleum ether and benzene. Anthraquinone glycosides were found in the chloroform, acetone and benzene extracts whereas alkaloids were found in chloroform extract and flavonoids were detected in acetone and petroleum ether extracts (Sriti et al., 2011).
Kothal and Rothe (2012) screened the leaf and stem of *Elaeocarpus tuberculatus* for the presence of phytochemicals by using various solvents namely, petroleum ether, benzene, chloroform, acetone, ethanol, methanol, rectified spirit and water. The result revealed the presence of carbohydrates, proteins, alkaloids, tannins, flavonoids, saponin, anthraquinone glycosides, cardiac glycosides, phenolic compounds, quinone and steroids. The majority of phytoconstituents were found in acetone, ethanol, methanol, rectified spirit and water extracts. Steroids and saponin were present in leaf. Fixed oil and fats were totally absent in all extracts of stem and leaf.

### 2.1.4. GC-MS Analysis

Gas-liquid chromatography and Mass Spectrometry techniques are used to identify different substances within a test sample. Applications of GC-MS include drug detection, fire investigation, environmental analysis, explosives investigation, and identification of unknown samples. GC-MS can also be used in airport security to detect substances in luggage or on human beings. Additionally, it can identify trace elements in materials that were previously thought to have disintegrated beyond identification. GC-MS has been widely heralded as a "gold standard" for forensic substance identification because it is used to perform a specific test. A specific test positively identifies the actual presence of a particular substance in a given sample (Sahil, 2011).

Meshkatalsadat and Mahbobeh (2010) performed the GC-MS analysis of the oil of aerial parts of methanolic extract of *Salvia brachycalx* (at flowering). 21 compounds were identified representing 94.9% of total oil. The major components were 1,8-cineole (76.58%), geraniol (15.08%) and α-pinene (0.78%) mainly of oxygenated monoterpenes (92.52%), hydro-carbonated monoterpenes (92.52%) and sesquiterpenes (0.83%). Garima and Amla (2011) investigated the essential chemicals of methanol extract of whole plant of *Nerium oleander* and *Thevetia peruviana*. In *N. oleander* 16 compounds were identified, highest peak area 17.05% was obtained by 2-nonanol, (Retention-time 18.87) and the lowest peak area of 0.59% was obtained by 2-(2,2,3-trimethylcyclopent-3-en-1-yl) (Retention-time 17.92), whereas, in another plant *T. peruviana* 46 compounds were identified, the highest peak area 48.83% was
obtained by di isoprophy ether (Retention-time 12.62) and the lowest peak area of 0.10% was obtained by chloroform (Retention-time 18.10).

Ezhilan and Neelamegam (2011) evaluated the bioactive compounds of ethanol extract of the whole plant of *Polygonum glabrum* using GC-MS. The study revealed the existence of the ether compound-propane 1,1-diethoxy (64.86%), alkane compound-2-heptane,5-ethyl-2,4-dimethyl-(13.51%), sulphur compound-tiophene-2-carboxamide, N-(2-furfuryl)-(8.11%), alcoholic compound-1,14-tetradecanediol (5.41%), and plasticizer compounds-1,2-benzenedicarboxylic acid, isodecyloctyl ester (5.41%) and 1,2,3-benzenetriol (2.79%). The ethanol extract of wood and bark of *Pterocarpus marsupium* was subjected to GC-MS analysis (Maruthupandian and Mohan, 2011). Eight phytochemical constituents were identified in wood and bark respectively. The major chemical constituents were 3-0-methyl-d-glucose, n-hexadecanoic acid, 1, 2-benzene-dicarboxylic acid, diisoctyl ester, tetradecanoic acid and 9, 12-octadecadienoic acid (Z, Z) in wood. D-friedoolean-14-en-3-one and lupeol were the major constituents in bark.

Mohan et al. (2011) determined the bioactive components of the ethanolic extract of leaves and bark of *Naringi crenulata* using GC-MS study. 17 compounds were identified in leaf, the prevailing compounds were caryophyllene (12.22%), propane, 1,1,3-triethoxy-(13.12%), butane, 1,1- diethoxy-2-methyl-11.76%, octane, 3,5-dimethyl-(10.86%), cyclohexane, 1,3,5-trimethyl-2-octadecyl-(4.98%), choles-8, 24-dien-3-ol,4-methyl-(3a,4a) (4.98%), sumatriptan (3.17%) and 4-rifluoroacetoxy tridecane (3.17%). 23 compounds were identified in the ethanolic extract from bark. The results revealed that octane, 3,5-dimethyl-(24.96%) was formed as major component followed by 2-dimethysilyloxy tridecane (11.54%), n-octanol,3,7-dimethyl-(10.14%), isoquinolin-6-ol, 7-methoxy-1- methyl-(5.15%), n-hexadecanol, 2-methyl-(3.28%) and dibutyl phthalate (2.34%).

The ethanolic extract of leaves of *Mallotus tetracoccus* has been subjected to GC-MS analysis (Ramalakshmi and Muthuchelian, 2011). The major chemical constituents were bis (2-ethyl hexyl) phthalate (46.78%), 3-methyl-2-(2-oxypropyl)furan (13.31%), E-8-methyl-9-tetradecene-1-olacetate (6.63%), octadecanoic acid, 2-
oxo (4.46%) and longiborneol (2.39%). The extract of M. tetracoccus was characterized by substantial levels of diesters (50%), alcohols (15%), alkanes (3%), sesquiterpenes (5%), terpenoids (13%), fatty acid (5%) and sugars (2.6%). The ethanolic leaf extract of Abutilon indicum revealed the presence of six bio-active chemical compounds (Shanthi et al., 2011). They were 5-oxatricyclo (didicane12-trimethylene, 9-methylene) 4.35% cubenol 4.45%, hinesol 12.04%, acetic acid 4.70%, palmitic acid 43.18% and phytol 31.27%. The hexane extract of leaves showed eighteen compounds in which palmitic acid 5.47%, phytol 17.12%, all-trans-squalene 13.66%, n-tetracosane 5.68% (terta contane). 7.35%, dl-alpha-tocopherol 15.79% gamma-sistosterol 6.62%, lupeol 5.23% were in high proportion.

GC-MS analysis of methanolic extract of whole plant of Vernonia cinerea revealed the existence of the GC-MS chromatogram of the seven peaks presented. The major compounds were n-hexadecanoic acid (42-88%) (Retention-time16.26) and 1,2 benzenedicarboxylic acid disoocty ester (23.00%) (Retention-time 24.81)(Abirami and Rajendran, 2012). GC-MS study of hexane extract of Juglans regia revealed the 11 major constituents like n-octedecane, n-hexadecanoic acid (palmitic acid), 9-E-hexadecenoic acid, tetra-tetracotane, 4,8,12,16 tetramethylheptadecane-4-olide, n-heptadecanoic acid, n-iodohexadecane, stearic acid, oleic acid, erucic acid and di-n-octyl phthalate (Asha et al., 2012). Chemical constituents of hexane, ethyl ester and chloroform extracts from the aerial parts of Fagonia Longispina were identified by CG-MS and their relative concentrations were determined (Hamidi et al., 2012). All the plant extracts contained 13 compounds: ethyl palmitate (26.71%), 9,12 octadecadienoic acid, ethyl ester (16.03%), 9,12,15 octadecatrienoic acid, ethylester (z,z,z) (57.25%), phenol 2,6-bis (1,1-dimethylethyl)-4-methyl- (27.21%),decanoic acid (12.24%), N-hexadecanoicacid (12.24%), tridecanoicacid (9.25%), 9-elcosene, (E) (15.62%), n-nonadecene (06.25%), 9,12-octadecadienoicacid (z,z), methylester (8.16%), 11,14,17-elcosatrienoicacid, methyl ester (34.69%), cyclotetracosane (03.75%), n-heptadecene (23.12%).

The chemical compositions of the ethanol extract of seed of Entada pursaetha were investigated using GC-MS (Kalpana Devi et al., 2012). Fourteen compounds were identified; 1,2,benzene dicarboxylic acid, diisooctyl ester (69.52%) was found to
be major component followed by benzeneacetic acid, 2,5-dihydroxy- (8.12%), n-hexadecanoic acid (4.48%) oleic acid (4.39%) azulene, undecanoic acid (2.46%) and 1,4-dimethyl 1-7-(1-methylethyl)-(3.86%). Mamza et al. (2012) investigated the bioactive components of ethanolic leaf extract of *Phyllanthus amarus* using GC-MS analysis. Nine components were identified; the prevailing components were 3,5-di-t-butylphenol (1.2%), methyl 14-methyl pentadecanoate (1.4%), palmitic acid (hexadecanoic acid) (11.8%), 10-octadecanoate (5.5%), 9-hexadecenal (9.0%), glycerol 1, 3-dipalmitate (5.7%), 2, 13-octadecadiene-1-ol (8.2%), dioctyl ester (10.1%) and heptanoic acid (9-dece-1-yl ester), (4.6%).

Peter et al. (2012) revealed the bioactive components in the ethanol extract of leaves of *Stylosanthes fruticosa* using GC-MS analysis. The result showed that among the 33 compounds, 1-(p-methylphenyl)-1-(phenylthio)-2, 2-diphenylethene and ethyl 2-methyl-4-(2-thienyl)-6-trifluoro methylpyridine-3-carboxylate were present in minimum percentage. The phenolic type compounds were recorded predominantly. nonanoic acid (6.58%), methyl ester (6.58%), trans-5-hexyl-1,4-dioxane-2-carboxylicacid (9.26%), (2R, 3R)-4-methyl-2,3-epoxypentan-1-ol (9.26%), (2R,3R)-4-methyl-2,3-epoxypentan-1-ol (9.26%), dodecanoic acid, methyl ester (6.58%), 5-methyl-10-(3,5-dinitrobenzyl)-5,10-dihydrophenazine (6.58%). 35 components were identified in the methanol extract of fresh stem parts of *Naringi crenulata* using the GC-MS analysis. The result showed the existence of palmitic acid (23.90%), cyclopentadecanone (16.60%), lupeol (9.97%), stearic acid (9.74%), linoleic acid (6.96%), lupenone (4.94%), n-dodecanoic acid (3.86%), 4H-pyran-4-On, 2,3-dihydro-3,5-dihyroxy-6-methyl (2.86%), myristic acid (2.55%), heptane dicarboxylic acid (2.07%), stigmask-4-en-3-one (1.99%) etc., other major and minor components were also present (Sampath Kumar and Ramakrishnan, 2012).

Senthil Kumar et al. (2012) identified some compounds from the leaves of methanolic extract of *Trichilia connaroides* through GC-MS. The identified compounds were methyl 11', 13'-dioxo-12'-aza-[4,4,3]-pro,(methaniminomethano) naphthalene-9,11, naphthalene, tetradecene, bicyclo, heptan-3-one,2,6,6-trimet, isotridecanol, octane, 1-bromo-2-chloro-1,1-difluoro-2-tridecan (hexacosane), tetrahydroxy myrcenol, dodecyl acrylate (oleic acid), benzene,1-(1,5-dimethyl-4-
hexyl-4-methyl), pentatriacontane, phenol, 2,4-bis (1,1-dimethylethyl), silane-trichlorodocosyl, undecanethiol, pentadecane, undecane, hydroxylamine, o-decyl, dodecanoic acid hexyl-1-octanol, hexadecanoic acid methyl ester (palmitic acid), ethyl oleate, phthalic acid etc. An investigation was carried out to determine the ethanolic extract of whole plant of *Tylophora indica* by GC-MS analysis. The ten chemical components identified were n-hexadecanoic acid, nonadecanoic acid, ethyl tridecanote, phytol, oleic acid, 9,12-octadecadien-1-ol, 2, 9-dimethyldecane, 6,11-dimethyl-2,6,10-dodecatrien-1-ol, ethyl tridecanote and pentacosane (Suhas et al., 2012). Mahadkar et al. (2013) elucidated the bioactive compounds from the five plants like *Bauhinia recemosa* (fruit), *Caryota urens* (fruit), *Commelina benghalensis* (leaf), *Garcinia indica* (leaf) and *Gmelina arborea* (fruit) through GC-MS study. Majority of the common compounds are hexadecanoic acid.

2.2. Antioxidant Activity of Plant Extracts

A free radical may defined as a molecule or molecular fragments containing one or more unpaired electrons in its outermost atomic or molecular orbital and are capable of independent existence (Halliwell and Gutteridge, 1999). Overproduction of the free radicals can be responsible for tissue injury. The role of free radicals and active oxygen in the pathogenesis of human diseases including cancer, aging and atherosclerosis has been recognized (Halliwell and Gutteridge, 1992; Saikat et al., 2010). Antioxidants are reducing agents, and limit oxidative damage to biological structures by passivating free radicals. Currently available synthetic antioxidants like butylated hydroxy anisole (BHA), butylated hydroxy toluene (BHT), tertiary butylated hydroquinone and gallic acid esters show low solubility and have been suspected to cause or prompt negative health effects. Hence, strong restrictions have been placed on their application and there is a trend to substitute them with naturally occurring antioxidants (Branen, 1975 and Barlow, 1990). Recently there has been an upsurge of interest in the therapeutic potentials of medicinal plants as antioxidants in reducing such free radical induced tissue injury.

Currently, many researchers have focused their attention on the natural antioxidants derived from plants. The antioxidant activities of twelve medicinal plants (*Acacia kempeana, Acacia, tetragonophylla, Acacia ligulata, Beyeria lechenaultii, ...
Euphorbia drummondii, Santalum lanceolatum, Santalum spicatum, Boerhaavia diffusa, Curculigo orchioides, Eugenia jambolana, Mucuna pruriens and Pterocarpus marsupium) extracts were assessed (Gulati et al., 2012).

Dubey and Batra (2009) evaluated the antioxidant activities of ethanol fraction of aerial parts of Thuja occidentalis in various systems such as DPPH radical, superoxide anion radical, hydroxyl radical scavenging and lipid peroxidation. The antioxidant activity of ethanol extract was increased in a concentration-dependent manner. The ethanol fraction of T. occidentalis inhibited lipid peroxidation (IC$_{50}$ value 195.60μg/ml) and scavenged DPPH radical (IC$_{50}$=202.45μg/ml), hydroxyl radical (IC$_{50}$=158.59μg/ml), superoxide radical (IC$_{50}$=124.11μg/ml).

Afolayan et al. (2010) reported the in vitro antioxidant activity of aqueous extract of bark of Strychnos henningsii using DPPH$^-$, superoxide anion, H$_2$O$_2$, NO$^-$, ABTS$^{**}$and the ferric reducing agent. Free radical scavenging activity of the plant extract against H$_2$O$_2$, ABTS$^{**}$ and NO$^-$ was concentration-dependent with IC$_{50}$ value of 0.023, 0.089 and 0.49mg/ml, respectively. The plant extract exhibited lower inhibitory activity against DPPH$^-$ with IC$_{50}$ value of 0.739mg/ml. The reducing power of the extract was found to be concentration-dependent. Al-Fartosy (2010) assessed the possible antioxidant activities of 80% methanolic extract of Inula graveolens. The methanolic extract possessed strong antioxidant activity (64.28%) as well as strong reducing power and ferrous ion chelating (96%) abilities. Moreover, the methanolic extract showed the highest free radical scavenging activities of superoxide anion and hydroxyl radical, reaching 93.43% and 91.38%, respectively.

Alisi et al. (2011) assessed the ethanol extract of the leaf of Chromolaena odorata for free radical-scavenging and antioxidant potentials using different in vitro antioxidant assays like superoxide ion, hydrogen peroxide, nitric oxide, hydroxyl radical and DPPH$^-$ radical with IC$_{50}$ values of 222.38 ± 14.66, 17.66 ± 1.23, 9.860 ± 0.68, 151.48 ± 9.61 and 124.08 ± 8.50μg/ml, respectively. Results obtained showed the ability of the extract to scavenge free radicals and reactive intermediates in a dose-dependent manner. Panda et al. (2011) evaluated the antioxidant potency of the ethanol extract of aerial parts of Cocculus hirsutus. The extract was investigated for
its free radical scavenging action towards DPPH´ (94.45%), nitric oxide (92.4%), superoxide (53.7%) and hydroxyl radicals (58.31%) and found that the ethanol extract shows promising free radical scavenging activity in a dose-dependent manner.

Julie and Ernest (2012) investigated the in vitro antioxidant activities of methanolic extract of the rhizome of Alpinia smithiae and Alpinia vittata. Both the plant extracts exhibited their scavenging effects in a dose-dependent manner. The assays were carried out against superoxide anion radical, hydroxyl radical, nitric oxide radical and inhibition of lipid peroxidation. Superoxide, hydroxyl radical scavenging activities and inhibition of lipid peroxidation was found to be higher in A. smithiae extract (81.53, 57.05 and 60.87% at 100 µg/ml) whereas, NO scavenging activity was found to be more effective in A. vittata extract (63.45% at 100 µg/ml).

Kurian et al. (2012) studied the free radical scavenging potential of chloroform extract of root of Desmodium gangeticum in vitro by using different antioxidant models such as DPPH´, super oxide radical, hydroxide radical and nitric oxide radical and inhibition of lipid peroxidation. The plant extract showed potent activity in all the assays with IC_{50} values of (36.0 ± 1.47, 55.3 ± 1.29, 43.7 ± 2.43, 39.4 ± 2.33 and 297 ± 1.47µg/ml, respectively).

Mohan et al. (2012) evaluated the in vitro antioxidant activity of methanol extract of plant parts (root, stem, leaf and flower) of Sauropus bacciformis. The in vitro antioxidant activity was assessed by DPPH´ radical scavenging activity, OH´, O_{2}^{•−} and ABTS^{+•} radical cation scavenging activities with reference standard ascorbic acid and trolox. The methanolic leaf extract of S. bacciformis exhibited a maximum DPPH´ scavenging activity of 98.27% at 500µg/ml whereas, for ascorbic acid it was found to be 54.26 % at the same concentration. The IC_{50} values of methanol extract of root reached 98.11% in the hydroxyl assay. The scavenging activity of leaf extract and ascorbic acid at 500µg/ml was found to be 96.31% and 99.74%, respectively. In the ABTS^{+•} assay the percentage activity of the leaf extract and trolox (standard) were found to be 96.31 and 54.26 µg/ml, respectively.

Pushplata et al. (2012) investigated the in vitro antioxidant activity of ethanolic extract of roots of Centaurea behens by using various in vitro assays. The
extracts efficiently scavenged the DPPH• radical (IC$_{50}$ value = 80.12 ± 0.101 µg/ml), NO• radical (IC$_{50}$ value = 68.90 ± 0.148 µg/ml), H$_2$O$_2$ radical (IC$_{50}$ value = 85.94 ± 0.150 µg/ml) and OH• radical (IC$_{50}$ value = 71.59 ± 0.146 µg/ml). Results suggested that the extract possessed significant antioxidant activity as compared to the standard ascorbic acid. Senthil Kumar et al. (2012) elucidated the antioxidant potential of methanolic leaf extract of Indigofera cassioides using various in vitro assays like ABTS$^{+}$, DPPH•, nitric oxide, superoxide, hydrogen peroxide and hydroxyl radical scavenging assays. The I. cassioides extract exhibited potent DPPH• radical scavenging activity with IC$_{50}$ value of 13.97 ± 0.80 µg/ml. Results were compared to standard ascorbic acid and rutin with (IC$_{50}$ value of 9.03 ± 0.09, 9.65 ± 0.19 µg/ml, respectively.

The methanolic leaf extract of Cassia tora was evaluated in vitro by experimental parameters such as DPPH•, total antioxidant assay, NO• radical and H$_2$O$_2$ radical scavenging capacities was in a concentration-dependent manner (Sirappuselvi and Chitra, 2012). The scavenging of DPPH radicals (IC$_{50}$ value of 35.59µg/ml), total antioxidant assay (IC$_{50}$ value of 38.19µg/ml), NO• radical (IC$_{50}$ value of 49.36µg/ml) and H$_2$O$_2$ radical scavenging (IC$_{50}$ value of 40.49µg/ml). Sreedevi (2012) studied the free radical scavenging property of ethanolic extract of the leaves of Blumea mollis using different in vitro antioxidant tests like DPPH•, OH•, NO•, O$_2$$^{-}$ radical scavenging activity and reducing power. The extract showed free radical scavenging property in a dose-dependent manner. The ethanolic extract of B. mollis showed good reducing power that was comparable with ascorbic acid.

Sridhar et al. (2012) evaluated the antioxidative potential of petroleum ether, chloroform, ethyl acetate, methanol and water extracts of bark of Crataeva magna using DPPH•, ABTS$^{+}$, super oxide radical, OH•, NO• radical scavenging activities and lipid peroxidation inhibition assay. Among the solvent extracts, methanolic extract of C. magna was active in the DPPH• test with an IC$_{50}$ value of 18.12 ± 0.24µg/ml and petroleum ether extract was active in scavenging the OH• radicals (IC$_{50}$ value of 68.27 ± 2.0 at 100µg/ml). In the lipid peroxidation assay the methanolic extract showed the good effectiveness and inhibition values of 25.27 ± 1.1% at 100µg/ml.
Parimala and Shoba (2013) assessed the in vitro antioxidant activity of hydroalcoholic extract of seed of *Nymphaea nouchali* Burm. F. using DPPH*, NO* radical scavenging activities and lipid peroxidation inhibition assay. The plant extract exhibited free radical scavenging property in a dose-dependent manner (1000µg/ml) with IC$_{50}$ value of (42.84, 23.58 and 54.65µg/ml, respectively).

2.3. Evaluation of Pharmacological Activity

2.3.1. Anti-arthritic Activity of Plant Extracts

Natural products have played an important role throughout the world in treating and preventing human diseases (Soumya et al., 2009). Rheumatoid arthritis (RA) is an autoimmune disorder characterized by synovial proliferation, inflammation, subsequent destruction like deformity of joints or destruction of cartilage and bone (Firestein, 2003). Rheumatoid arthritis is one of the oldest known diseases of mankind and also causes inflammation of the tissue around the joints, as well as in other organs in the body (Hard, 1979). Various phytochemical constituents from herbal plant showed beneficial effect in rheumatoid arthritis.

Anti-arthritic activity of different plant parts were assessed by different authors. Some plants like roots of *Ficus bengalensis*, *Trewia polycarpa*, *Strobilanthus callosus*, *Strobilanthus ixiocephala* (Nadkarni, 1955; Tao, 1989; Agarwal and Rangari, 2003); fruit juice of *Morinda citrifolia* (Latha et al., 1998); bark of *Delonix elata* (Kirtikar and Basu, 1999); leaf of *Urtica pilulifera* and bark of *Machilus macrantha* (Riehemann et al., 1999); root of *Asparagus racemosus* (Goyal et al., 2003); tuber of *Berberis vulgaris*, rhizome of *Curcuma longa*, fruit of *Syzygium aromaticum*, gum resin of *Commiphora mukul*, seed of *Glycine max*, bulb of *Allium cepa*, fruit of *Vitis vinifera*, leaf of *Camellia sinensis* (Khanna et al., 2007); root of *Cissampelos pareira* (Amresh et al., 2007); root and aerial parts of *Merremia tridentate* (Kamalutheen et al., 2009); leaf of *Salacia reticulata* (Sekiguchi et al., 2010); bark of *Sesbania grandiflora* and *Sesbania sesban* (Patil et al., 2010); seed of *Vernonia anthelmintica* (Otari shete et al., 2010). Harish Singh et al. (2010) reported that the 23 plants such as root of *Andrographis paniculata*, *Sida rhombofolia*, fresh root of *Leuca macrophylla*, leaves of *Elephantopus scaber*, *Calotropis procera*, *Crotalaria prostrata*, *Hygrophilla auriculata*, *Paederia foetida*, *Turnera ulmifolia*,
Vitex negundo, rhizome of Curcuma amada, Curcuma caesia and Gloriosa superba, seed of Celastrus paniculatus, Schleichera oleosa, tuber of Kaempferia galangal, stem bark of Dalbergia sissoo, Morinda tinctoria, Polyalthia longifolia and Pterospermum heyneanum, fruit of Terminalia bellerica, whole plant of Viscum articulatum, Ocimum basilicum. Stem, bark, leaves of Euphorbia tirucalli (Priya and Bhaskara Rao et al., 2011); rhizome of Glyceriza glabra (Mishra et al., 2011); whole plant of Urginea indica (Rehaman et al., 2011); leaf of Cassia uniflora (Sheetal Chaudhari et al., 2012); root and rhizome of Nymphoids macrospermum (Vedha Hair et al., 2012) are known for their anti-arthritis activity.

**In vitro Studies**

Lavanya et al. (2010) analysed the in vitro anti-arthritis activity of methanolic extract of leaf of Coldenia procumbens by the inhibition of protein denaturation method. The methanolic extract exhibited significant inhibition of protein denaturation 52.84% at 250μg/ml and its effect was compared with the standard drug diclofenac sodium. The methanolic extract was capable of controlling the production of auto antigen and inhibited denaturation of protein in rheumatic disease. Sangeetha et al. (2011) estimated the in vitro anti-arthritis activity of petroleum ether, chloroform, ethyl acetate, ethanol and water fractions of the leaves of Cleodendron inerme by protein denaturation method. All the extracts showed positive response as compared to standard diclofenac sodium. The ethyl acetate and ethanol extracts showed maximum activity. The order of effect of different extracts was represented as follows: ethyl acetate> ethanol >water> chloroform> petroleum ether.

Meena and Seema, (2011) examined the in vitro anti-arthritis activity of methanolic extract of leaves of Centella asiatica compared to standard diclofenac sodium. The maximum percentage inhibiton of protein denaturation and proteinase inhibitory action for C. asiatica extracts was found to be 89.76, 94.97 and 91.63%, respectively at a dose of 2000μg/ml. Shravan Kumar et al. (2011) studied to the in vitro anti-arthritis activity of aqueous and methanolic extract of leaves of Physalis angulata using protein denaturation method 10, 62.5, 125, 250, 500, 1000, 2000μg/ml. The extracts showed positive response as compared to standard diclofenac sodium. The
ethanolic extract showed maximum activity. The order of effect of different extracts were represented as follows ethanol > water > methanol.

Shivhare et al. (2011) evaluated the ethanolic leaf extract of *Manilkara zapota* using the *in vitro* inhibition of protein denaturation model. Acetyl salicylic acid was used as a standard drug. The ethanolic extract of *M. zapota* at two different concentrations (100 and 250mcg/ml) possessed significant anti-arthritic activity as compared to standard. According to Hamed et al. (2013) observed that the *in vitro* anti-arthritic activity of the ethanolic extract of *Terminalia pallida* using bovine serum albumin. The ethanolic extract of the *T. pallida* possess excellent anti-arthritic activity.

**In vivo Studies**

Jubie et al. (2008) investigated the anti-arthritic activity of stem bark of petroleum ether, ethyl acetate, chloroform, methanol extracts of *Alangium salviifolium* by using Fruend’s adjuvant arthritis model. Indomethacin was used as a standard drug. All the extracts exhibited significant anti-arthritic activity in the following order standard > chloroform > ethyl acetate > aqueous > petroleum ether > methanol. Chitme and Patel (2009) studied the anti-arthritic activity of petroleum ether extract, chloroform and methanolic extracts of whole plant of *Aristolochia bracteata* using Freund’s complete adjuvant (FCA) in rats. The methanolic extract of *A. bracteata* at low dose (100mg/kg) and moderate dose (200mg/kg), but results were varying at higher (400mg/kg) dose of extract showed significant activity than other extracts.

The ethanolic extracts of *Merremia tridentata* was investigated for anti-arthritic activity using FCA-induced arthritis model (Kamalutheen et al., 2009). Indomethacin (10mg/kg b.w.) was used as a standard drug. The doses of 100 and 200mg/kg b.w. of the ethanol extract of *M. tridentata* produced maximum inhibition of 49.0 and 51.7%, respectively when compared with that of the standard drug (55.5%). Woode et al. (2009) examined the anti-arthritic effects of *Palissota hirsuta* ethanolic leaf extract using FCA-induced arthritic rats. The plant extract showed significant dose-dependent anti-arthritic properties. The plant extract (30-300mg/kg) significantly reduced the arthritic edema in the ipsilateral paw (injected paw) with the highest dose used giving a maximum inhibition of 13.02 ± 8.77%. The plant extract
(300mg/kg) also significantly prevented the spread of the edema from the ipsilateral to the contralateral paw (non-injected paw) indicating inhibition of systemic spread.

Chakraborty and Roy (2010) reported the anti-arthritic activity of ethanolic extract, petroleum ether, diethyl ether and ethyl acetate extracts of whole plant of Cleome rutidosperma using FCA-induced arthritis model. Prednisolone (5mg/kg b.w.) was used as a standard drug. Oral administration of 200 mg/kg of ethanolic extract inhibited FCA-induced rat paw edema by 44% whereas prednisolone (5mg/kg) inhibited rat paw edema by 59%. The anti-arthritic effect of hydroalcoholic extract of aerial parts of Leucas aspera was evaluated using FCA-induced arthritic rats (Kripa et al., 2010). Antioxidant marker enzymes such as superoxide dimutase (SOD), glutathione peroxidase (GPx) and catalase (CAT) were estimated in plasma and tissue of control and arthritic animals. Diclofenac sodium was used as standard drug. The administration of the plant extract increased the enzymatic activities of SOD, GPx, CAT significantly in plasma and tissue and the increase was comparable to that of the standard drug treated group.

Malik et al. (2010) estimated the anti-arthritic activity of petroleum ether and aqueous extracts of leaf of Gymnema sylvestre using FCA-induced arthritis in rats. The study revealed that the petroleum ether (40-60\(^{0}\)) extract and aqueous extract of G. sylvestre possessed significant anti-arthritic activity in all parameters of the study compared to control group. Otari et al. (2010) investigated the anti-arthritic activity of Ethanolic extract of seeds of Vernonia anthelmintica in FCA-induced arthritis in rats. The treatment with plant sample 250 and 500mg/kg showed significant prevention of the paw edema.

Anti-arthritic activity of ethanol extract of wood of Premna serratifolia was investigated by FCA-induced arthritis in albino rats (Rekha and Krishnakumar, 2010). Biochemical parameters such as hemoglobin content, total WBC, RBC, erythrocyte and sedimentation rate were also estimated. The ethanol extract at the dose of 300mg/kg b.w. inhibited the rat paw edema by 68.32% which was comparable with standard drug indomethacin which showed 74.87% inhibition of rat paw edema after 21 days. Sandeep Biradar et al. (2010) explored the anti-arthritic activity of ethyl acetate extract of essential oil of Cyperus rotundus using formaldehyde-induced
arthritis model in wistar albino rats. Diclofenac sodium was used as standard drug. C. rotundus (500 mg/kg) significantly reduced the swelling in the injected (left) hind paw (75.54%), as compared to diclofenac sodium-treated animals which showed maximum % of inhibition of paw edema (81.37%).

Shankaranarayanan et al. (2010) observed the anti-arthritic activity of alcoholic extract of Glycine max seeds using FCA-induced arthritis in rats. The biochemical parameters such as total protein, alanine aminotransferase, aspartate aminotransferase and alkaline phosphatase levels were increased significantly in the arthritic control group than normal group, while the level of serum albumin was reduced significantly. The oral administration of the plant extract at the dose of 60mg/kg showed a significant decrease in all the parameter studied when compared to the arthritic control group. Uma et al. (2010) evaluated the anti-arthritic activity of petroleum ether, chloroform and alcoholic extracts of rhizome of the Alpinia galanga by using FCA-induced rat model. Application of petroleum ether, chloroform and alcoholic extracts of A. galanga showed 48.69, 44.63 and 54.68% inhibition of this edema, respectively. The studies revealed that the petroleum ether was better than that of chloroform and alcoholic extracts of A. galanga rhizomes in respect to their anti-arthritic activity.

Yende et al. (2010) investigated the anti-arthritic activity of aqueous extract of the fruit of Piper longum using FCA-induced arthritis rats. The aqueous extract of P. longum in doses of 400mg/kg as well as 200mg/kg showed significant reduction in paw swelling and diclofenac sodium (13.5mg/kg) showed 55% inhibition of paw swelling. Abudoleh et al. (2011) studied the anti-arthritic effect of methanolic leaf extract of Urtica pilulifera using FCA-induced arthritis model. The extract inhibited paw swelling compared with the untreated control dose-dependently in both the right and left paws. Asadulla (2011) revealed that the petroleum ether, chloroform, acetone, alcoholic and aqueous extracts of the fruits of Tribulus terrestris exhibited significant anti-arthritic activity in albino rats. The extract doses were compared with phenyl butazone as standards. The alcoholic extract of T. terrestris (0.06618gms/kg) showed significant decrease in paw volume induced by carrageenan in rats.
Bothara et al. (2011) assessed the anti-arthritic effect of oral administration of methanolic and aqueous extracts of root (100 and 200mg/kg) of *Cocculus hirsutus* using FCA-induced arthritis rats. Anti-arthritic activity of methanolic extract was dose-dependent and the dose of 200 mg/kg was more effective than 100 mg/kg b.w. Gangu et al. (2011) showed that the alcoholic extract of *Sida rhombifolia* roots exhibited significant anti-arthritic activity in adjuvant-induced rats. The biological defense system constituting the superoxide dismutase, glutathione peroxidase, ascorbic acid showed a significant increase while the lipid peroxide content was found to decrease to large extent in plant sample and diclofenac-treated groups.

Harpalani et al. (2011) elucidated the anti-arthritic potential of aqueous and alcoholic extracts of *Euphorbia antiquorum* against chronic inflammation using cotton pellet-induced granuloma in rats and complete FCA-induced arthritis in rats. Ibuprofen 50mg/kg used as standard drug. The aqueous extract of 400mg/kg, p.o. effectively prevented the primary lesions and alcoholic extracts of 400mg/kg, p.o. effectively prevented both primary and secondary lesions of FCA-induced arthritis in rats.

The anti-rheumatic activities of the methanolic extract of the stem bark of *Ficus bengalensis* at doses of 100, 200 and 300mg/kg (i.p.) was estimated using Freund’s adjuvant arthritis model (Manocha et al., 2011). The extract produced marked inhibitory effect on edema especially on secondary immunological arthritis and caused graded inhibition of both phases of formalin-induced pain. Murugananthan and Mohan (2011) studied the anti-arthritic effect of petroleum ether, chloroform and 40% hydroalcoholic bark extracts of *Delonix elata* using FCA-induced model. The extracts of *D.elata* showed potent activity and oral administration of 250mg/kg of hydroalcoholic extract significantly inhibited the rat paw edema when compared with the standard drug diclofenac (10mg/kg).

Sutharsingh et al. (2011) studied the chloroform and ethanolic extracts of aerial parts of *Naravelia zeylenica* by carrageenan-induced edema in rats and anti-arthritic activity. The percentage increase in paw edema reduced in both chloroform (20.70± 3.64%) and ethanol extract (29.38 ± 2.19%) treated animals when compared with standard indomethacin (22.01 ± 4.08%) and control (38.20 ± 1.63%)
animals. The results were statistically significant. The anti-arthritic activity was evaluated in FCA-induced arthritis model in albino rats. The percentage increase in paw volume 7 days and 21 days after the drug administration was noted. It was noted that a moderate reduction in paw volume in the right and left paw of rats treated with chloroform extract (69.86 ± 3.39 and 50.88 ± 2.51%), ethanolic extract (66.99 ± 3.85 and 49.040±2.87%) and prednisolone 10 mg/kg p.o. (63.82 ± 1.86 and 34.90 ± 3.00%) treated animals when compared with control (147.94 ± 5.84 and 111.97± 8.45%) group animals. Both the extracts (200 mg/kg) were statistically significant.

Tatiya and Saluja (2011) evaluated the anti-arthritis activity of petroleum ether, alkaloidal fraction, acetone extract and mucilage extracts of bark of Machilus macrantha using FCA-induced arthritic model. Administration of the plant extracts at dose of 250 and 500mg/kg p.o. showed chronic anti-rheumatic effect by suppressing the swelling volume in FCA-induced arthritis. Uma et al. (2011) validated the anti-arthritic activity of petroleum ether, chloroform and alcoholic extracts of the heart wood of Ceder deodar using the Freund’s adjuvant rat. All the three extracts exhibited significant inhibition of FCA-induced rat paw edema when compared with the arthritic control.

Desai Nilesh et al. (2012) assessed the anti-arthritic nature of aqueous extract of Aegle marmelos leaves against formaldehyde-induced arthritis in rats. The degree of inflammation was evaluated by hind paw swelling and increase in paw diameter. The plant extract showed significant changes in paw swelling, paw diameter and percent inhibition of paw volume. The results of the study concluded that the plant extract possessed a significant anti-arthritic activity. The protective effect of ethanolic extract of leaves of Michelia champaca against FCA-induced arthritis in rats was evaluated (Dhanalakshmi et al., 2012). The ethanolic extract was administered orally at dose of 250 and 500 mg/kg b.w. Indomethacin at dose of 10 mg/kg used as standard drug. The results indicated that the ethanolic extract at the dose of 500mg/kg protected rats against the primary and secondary arthritic lesions, induced by FCA.

The anti-arthritic activity of 70% ethanolic extracts of whole plant of Ajuga bracteosa was assessed using chronic models of arthritis (Gaurav et al., 2012).
The plant extract exhibited better anti-arthritic activity than the standard aspirin. Treatment with plant extract (5, 10 and 20mg/kg) exhibited 64.55%, 73.42%, and 81.01% of protection against joint edema in comparison to standard aspirin. The secondary inflammation was also inhibited much more effectively by the plant sample at a dose of 20mg/kg (68.31%) when compared with aspirin (60.49%). Jagan et al. (2012) evaluated the anti-arthritic activity of petroleum-ether extract of leaves of Portulaca oleracea using evaluated by FCA-induced arthritis model. Petroleum-ether extract exhibited significant anti-arthritic activity. Jaijesh et al. (2012) studied the anti-arthritic effect of ethanolic extract of root of Rubia cordifolia. The plant extract showed significant anti-arthritic activity which was statistically similar to aspirin.

Paval et al. (2012) compared the anti-arthritic activities of the ethanolic leaf and root extracts of Justicia gendarussa and Withania somnifera. Arthritis was induced in male albino rats using FCA-induced and bovine type II collagen. The effect of these plant extracts on arthritic rats were assessed by various blood parameters and also by taking the change in paw volume. The plants suppressed the arthritic changes induced in rats and the results were statistically significant. Ramesh and Vijaya (2012) studied the anti-arthritic activity of ethanolic extract of stem bark of Glycosmis pentaphylla was using the FCA-induced arthritis rats. The administration of extract of G. pentaphylla significantly protected against joint swelling in arthritis induced paw when compared with arthritis control group indomethacin. There was a reduction in paw volume after treating with 400mg/kg. However the effect of 800mg/kg treatment was found to be more significant.

Saraswathi et al. (2012) investigated the anti-arthritic activity of Morinda citrifolia fruit juice using FCA-induced arthritis in rats. Administration of the fruit juice showed a dose-dependent significant reduction in paw thickness, arthritic index, secondary lesions, increase in body weight and decreased levels of alkaline phosphatase (ALP), aspartate aminotransferase (AST) and alanine transaminase (ALT). Pradeep et al. (2012) evaluated the anti-arthritic potential of the methanolic extract of the aerial parts of Costus speciosus by FCA-induced rats. The methanolic plant extract in doses of 400 and 800mg/kg showed 75.50% and 68.33% protection against increase in paw edema, respectively. Plant showed a dose-dependent action in
all the experimental models. Vinyas *et al.* (2012) assessed the anti-arthritic effects of alcohol and water extracts of *Brassica nigra* seed using the FCA-induced arthritic model. The effect of these plant extracts on arthritic rats was assessed by the various blood parameters and also taking the changes in paw volume. The plant suppressed the anti-arthritic changes induced in rats and results were statically significant.

Vikas Kumar *et al.* (2012) studied the anti-arthritic activity of methanolic leaves extract of *Melastoma malabathricum* at dose level of 25-100mg/kg against turpentine oil-induced paw edema, formaldehyde-induced paw edema and FCA-induced arthritis. The percentage protection against the turpentine oil on the 6th hr. was 29.26, 84.62 and 94.31% and 100mg/kg respectively. The percentage protection against the formaldehyde on the 10th day was 24.63, 52.57 and 70.03% at 25, 50 and 100mg/kg, respectively. The percentage protection against the FCA on the 28th day was 47.16, 73.99 and 89.66% at 25, 50 and 100mg/kg, respectively. Vaishali and Piyush (2013) evaluated the anti-arthritic activity of methanolic extract of whole plant of *Rivea ornata* was studied by hind paw swelling, body weight estimation of AST and ALT. The plant extract was administered orally at the dose of 200 and 400 mg/kg/b.w. significantly reduced hind paw swelling, body weight AST and ALT.

### 2.3.2. Cardio productive Activity of Plant Extracts

Heart is an incredible organ, which determines survival of an individual. The basic physiological function of heart is to make blood circulation, myocardium (cardiac tissue) contracts and relaxes rhythmically. The natural rhythm is generated within the muscles itself, not by impulses from the nervous system; hence human heart is called myogenic. Cardiovascular diseases (CVDs) have a high prevalence in developing and developed countries and Myocardial infarction (MI) is one of the leading causes of mortality (WHO, 2006). MI could trigger complex impact on the biochemical functioning heart (Petrich *et al.*, 1996) and is expected to occupy the first position as a killer disease by 2020 (Levy *et al.*, 1984). Myocardial infarction is caused due to an interruption in blood supply to any part of heart, resulting in death of cardiac tissue (myocardium). MI is called a heart attack or a coronary thrombosis (Thygesen *et al.*, 2007). The most common cause of MI is the formation of blood clot
(thrombosis) inside a coronary artery, or its branches. So the blood flow to a part of the heart gets blocked. MI needs immediate medical emergency. During the last few decades, research data has prompted a passionate debate as to whether oxidative stress mediated by free radicals or reactive oxygen species or reactive nitrogen species (RNS), is a primary or secondary cause of many chronic diseases. As a result, scientific resources have focused to a larger extent on the role that antioxidants could play to delay or prevent oxidative stress and consequently the incidence of chronic disorders. Oxidative stress induced by reactive oxygen species (ROS) is implicated in the pathogenesis of a variety of vascular diseases, including atherosclerosis, hypertension and coronary artery disease (Agarwal et al., 2006).

Although existing modern drugs can help in the management of heart diseases they are bound to cause side effects (Rajadurai and Prince, 2005) and plant sources are emerging as alternate therapy for reducing the risks of cardiac problems. Several medicinal plants have been found to possess antioxidant properties and have beneficial effects in pathological conditions like cancer, liver diseases, cataract and myocardial ischemia (Shalini and Srinivas, 1987; Hertog et al., 1993). The use of herbal medicines has been steadily increasing over the past decade. A considerable number of these plants or plant based products have been widely used (Das et al., 1993). Several medicinal plants have been described to be beneficial for cardiac ailments. A few of them, *Cicer arietinum, Curcuma longa, Ocimum sanctum, Terminalia arjuna* are identified and researched to have lipid lowering and cardio protective activities (Dwivedi, 1996). Other antioxidant rich and angiogenic herbs such as green tea, black tea and red wine have the potential to reduce the progression of atherosclerosis (Heber, 2001). Therefore, interest in the examination of plants as potential sources of new drugs is increasing. In India, medicinal plants are traditionally used in the treatment of cardiovascular disease, as they are inexpensive, efficacious and safe (Fugh Berman, 2000).

In the traditional Indian medicinal system, a major role has been played by the medicinal plants especially, in the aspect of cardio protection. The root of *Desmodium gangeticum* is also used in the treatment of ischemic heart disease in the Indian system of medicine (Kiritikar and Basu, 1987; Kurian et al., 2005). Fresh stem bark and stem wood of *Premna serratifolia* (Yoganarasimhan, 2000); Some plants like
Allium sativum, Allium cepa, Curcuma longa, Emblica officinalis, Momordica cymbalaria, Mangifera indica, Daucus carota, Punica granatum, Piper longum, Ocimum sanctum, Withania somnifera, Zingiber officinalis (Tilak Jain and Devasagayam, 2006); fruit of Capparis spinosa (Eddouks et al., 2007); bark, leaf and fruits of Terminalia arjuna (Warrier et al., 2010); Arya and Vivek Kumar (2011) reviewed the 31 plants used ayurvedic origin for cardio protectivity. Root, flower and seed of (Achyranthus aspera); root, fruit of (Bombax mori); leaf and flower of (Eugenia uniflora and Psidium guajava); leaf and seed of (Anethum graveolens and Cannabis sativa); seed latex of (Antiaris toxicaria); seed of (Linum usitatissimum and Euryale ferox); roots of (Asparagus racemosus, Delphinium demudatum and Pueraria lobata); flowers of (Cheiranthus cheiri, Hibiscus sabdariffa and Nelumbo nucifera); leaves of (Cinnamomum tamala, Digitalis purpurea, Onosma bracteatum, Cymbopogon citrates); fruits of (Garcinia indica, Mimusops elengi, Morus alba, Punica granatum, Emblica officinalis, Coriandrum sativum, Prunus cerasus); barks of (Cordia rothii, Crataeva nurala); bulb of (Allium sativum); whole plant of (Tinospora cordifolia); leaf of Gomphrena globosa (Arcanjo et al., 2011); fresh juice of aerial parts Portulaca oleracea (Bidkar et al., 2011); leaves of Ziziphus mauritiana (Gupta et al., 2012); leaf of Gynura procumbens (Kaur et al., 2012) for alleviating the cardiovascular diseases.

Okokon and Anita (2007) elaborated the cardio protective activity of ethanolic stem bark extract of Mammea africana on total cholesterol, triglyceride and lipoproteins levels was studied on normal rats. The plant extract produced a significant dose-dependent decrease in the levels of total cholesterol, triglyceride, LDL cholesterol and VLDL cholesterol, with a significant increase in the level of HDL cholesterol.

Rajaprabhu et al. (2007) examined the protective effects of ethanolic extract of root and rhizome of Picrorhiza kurroa on myocardial antioxidant defense system in adriamycin-induced cardiomyopathy in rats. Intraperitoneal administration of adriamycin (1.5 mg/kg b.w./day, i.p. for 15days) caused significant rise in the levels of diagnostic marker enzymes [alanine amino transferase (ALT), aspartate aminotransferase (AST), lactate dehydrogenase (LDH) and creatine phosphokinase
(CK-MB)] in plasma and lipid peroxidation in the heart tissue of experimental rats. Concomitant decline in the level of reduced glutathione (GSH) and the activities of glutathione dependent antioxidant enzymes (GPx and GST) and anti-peroxidative enzymes (SOD and CAT) in the myocardial tissue were also observed. Oral administration of *P. kurroa* extract (50 mg/kg b.w./day, for a period of 15 days) significantly prevented all these adriamycin-induced adverse effects and maintained the rats at normal status.

Mastan *et al.* (2009) scientifically evaluated the cardio protective effect of methanolic extract of *Syzygium cumini* seeds on isoproterenol (ISO)-induced myocardial infarction in rats. Isoproterenol significantly increased the activities of CK-MB, LDH and the transaminases in serum with a concomitant decrease in these enzymes in tissue. Pretreatment with the plant extract at a dose of 500 mg/kg b.w. had a more significant effect on the activities of marker enzymes AST, ALT, LDH and CK-MB compared to 250 mg/kg b.w. treated group. Serum uric acid level, which increased on isoproterenol administration, registered near normal values on treatment with the plant extract under study.

The aqueous extract of *Elaeocarpus ganitrus* seed powder was evaluated for its anti-hypertensive activity in renal artery occluded hypertensive rats (*Juvekar et al.*, 2009). Elevated blood pressure of the animals was significantly decreased by the aqueous extract of *E. ganitrus* at the dose levels of 25, 50 and 100 mg/kg, captopril, angiotensin converting enzyme inhibitor (ACE-I) at the dose of 1 mg/kg showed significantly reduced the elevated blood pressure. Velavan *et al.* (2009) showed the cardio protective effect of ethanolic extract of leaf of *Trichopus zeylanicus* against isoproterenol-induced myocardial ischemia. In ISO-treated group, shrinkage of cardiac markers such as AST, ALT, LDH and CK-MB. Troponin T was estimated in serum, and the levels of TBARS and reduced glutathione (GSH) in plasma and elevated lipid peroxidation were accompanied by decreased content of reduced glutathione in heart and plasma. The prior administration of plant extract significantly prevented the ISO-induced alterations and restored the cardiac markers.
Thippeswamy et al. (2009) identified the cardio protective effect of ethanolic extract of fruit of *Cucumis trigonus* on isoproterenol-induced myocardial infarction in rats. The activities of serum marker enzymes (ALT, AST, LDH and CK-MB) were increased significantly in ISO-induced rats. The plant sample at concentration of 150 mg/kg b.w., when administered orally showed a decrease in serum enzyme levels and the ECG changes brought to the near normal values. Hassanpour et al. (2010) investigated the cardio protective effect of *Lagenaria siceraria* fruit juice on doxorubicin-induced cardio toxicity in rats. Administration of dox (10 mg/kg) increased serum CK-MB, LDH and AST levels compared to that of control, whereas the administration of plant sample at the dose of 5 and 10 ml/kg b.w. decreased the levels of CK-MB and AST significantly compared to that of dox alone. The level of LDH decreased non-significantly.

El-Sayed et al. (2011) elucidated the cardio protective effects of ethanol and aqueous extracts of rhizome of *Curcuma longa* against doxorubicin-induced rats. Administration of doxorubicin (15 mg/kg i.p.) induced cardiomyopathy manifested by significant elevation in serum CK-MB and LDH activities. Oral administration of *C. longa* ethanolic and water extract (200mg/kg) prior to doxorubicin produced a significant protection which was evidenced by significant reduction in mortality, CK-MB and LDH activities. In addition, both extracts significantly reduced serum antioxidant enzyme activities.

Thippeswamy et al. (2011) revealed that the effect of the aqueous extract of whole plant of *Phyllanthus niruri* against doxorubicin-induced myocardial toxicity in rats. Pretreatment with the aqueous extract *P. niruri* significantly protected the myocardium from the toxic effects of dox by reducing the elevated level of biomarker and diagnostic enzymes like LDH, CK-MB, AST and ALT to normal levels. Aqueous plant extract also increased the GSH, SOD and CAT levels in cardiac tissue. Viswanatha Swamy et al. (2012) reported the cardio protective effect of curcumin against doxorubicin-induced myocardial toxicity in albino rats. The repeated administration of dox-induced cardiomyopathy associated with an antioxidant deficit and increased level biomarkers. Pretreatment with the curcumin significantly restored the biomarker enzymes like LDH and CK-MB and biochemical parameters such as
AST, ALT and ALP back to normal. Curcumin increased the reduced level of GSH, SOD and CAT in cardiac tissue.

Asha and Taju (2012) investigated the effects of ethanolic bark extract of *Terminalia arjuna* on caffeine-induced coronary heart disease. The results indicate that oral administration of caffeine-induced animals produced an increase in total serum cholesterol, triglyceride, LDL cholesterol and VLDL cholesterol with a decrease in HDL cholesterol level relative to the control animals. It was also found that the rats receiving *T. arjuna* had a marked reduction in total cholesterol, triglycerides, LDL cholesterol and VLDL cholesterol. However, it also showed a significant increase in HDL cholesterol when compared to the induced animals.

Momin et al. (2012) evaluated the effect of methanolic extract of *Ixora coccinea* leaves on doxorubicin-induced cardiac toxicity in rats. Pretreatment with methanolic plant extract significantly maintained the blood pressure close to normal. The plant extract significantly reduced the elevated level of biomarkers like CK-MB, LDH, SGOT, SGPT near to normal and also increased the tissue antioxidant markers CAT, SOD in cardiac tissue in a dose-dependent manner. Ashok Kumar et al. (2012) explored the cardio protective activity of ethanol extract of *Bixa orellana* on isoproterenol-induced myocardial infarction in rats. A significant increase in serum cardiac marker enzymes and lipid levels and a decrease in enzymatic and non-enzymatic antioxidants were observed in ISO-treated group. All these levels were significantly reversed upon treatment with extract and were comparable to α-tocopherol. A dose-dependent increase in protective effect was observed.

Madhumitha and Indhuleka (2012) evaluated the cardio protective effect of methanolic extract of *Morus alba* leaves against isoprenaline- induced myocardial infarction in vivo method in rats. Pretreatment with *M. alba* (500mg/kg b.w.) significantly decrease the levels of TBARS when compared with the ISO-induced rats. On treatment with *M. alba* (500 mg/kg b.w.) significant increase in the activities of antioxidant enzymes (SOD, CAT, GPx and GSH) was observed in the ISO-treated rats when compared with the ISO-induced rats. ISO-induced rats showed decreased biomarkers (CK-MB and LDH) level in heart tissue. Pretreatment with *M. alba* almost restored all the ISO-induced alterations in creatine kinase and lactate dehydrogenase...
activity to normal levels. Manimegalai and Venkatalakshmi (2012) assessed the cardio protective effect of Cassia auriculata floral aqueous extract on isoproterenol-induced myocardial infarction in albino rats. The oral administration of aqueous extract of C. auriculata, afforded protection against ISO-induced alterations in cholesterol, LDL, HDL, TG, protein, AST, ALT, LDH, catalase and GPx.

2.3.3. Anti-diabetic Activity of Plant Extracts

Diabetes mellitus is a chronic disease caused by inherited or acquired deficiency in insulin secretion and by decreased responsiveness of the organs to secreted insulin. Such a deficiency results in increased blood glucose level, which in turn can damage many of the body’s systems, including blood vessels and nerves (Matsui et al., 2007). For its therapy, along with the synthetic drugs, many agents of the plant origin are also in use particularly for the treatment of non-insulin dependent diabetes mellitus.

Medicinal plants are reservoirs of natural products with anti-diabetic potentials. According to world ethno botanical information reports, almost 800 plants may possess anti-diabetic potential (Alarcon-Aguilara et al., 1998). The medicinal plants and natural products decrease the absorption of glucose by inhibiting the carbohydrate hydrolyzing enzymes, such as pancreatic amylase (Tripathi, 2003). In the past decade, research has been focused on scientific evaluation of traditional drugs of plant origin and screening of more effective and safe hypoglycemic agents has continued to be an important area.

Several reports on anti-diabetic and hypoglycaemic activity of medicinal plants like leaves of Azadirachta indica (Chattopadhyay et al., 1987; Ocimum sanctum (Chattopadhyay et al., 1993), leaf of Aloe vera (Bunyapraphatsara et al. 1996); roots of Momordica cymbalaria (Rao et al. 1999); Leaf, stem and root of Andrographis paniculata (Zhang and Tan, 2000); rhizome of Curcuma longa (Hussain and Eshrat, 2002); seed of Trigonella foenum graecum, bulb of Allium sativum, leaf of Gymnema slyvestre and seed of Syzigium cumini (Grover et al., 2002); fruit of Coccinia indica (Kar et al., 2003); fruit and bark of Terminalia glaucescens, Terminalia arjuna, Terminalia bellerica, Terminalia chebula, Terminalia catappa and Terminalia pallida (Kameswara Rao et al., 2003); stem bark of Pterocarpus
**In vitro Studies**

Dinesh Kumar *et al.* (2010) tested the α-amylase inhibitory activities of ten common plants namely, *Acalypha indica*, *Allium cepa*, *Allium sativum*, *Azadirachta indica*, *Musa sapientum*, *Mangifera indica*, *Murraya koenigii*, *Ocimum sanctum*, *Phyllanthus amarus* and *Tinospora cordifolia* to establish their anti-diabetic potentials. The plant extracts were prepared sequentially with petroleum ether, hexane, chloroform, ethanol and aqueous. The extracts obtained were subjected to *in vitro* α-amylase inhibitory assay using starch azure as a substrate and porcine pancreatic amylase enzyme. Ethanol extracts of *Mangifera indica*, *Azadirachta indica* and petroleum ether extract of *Murraya koenigii* (at a concentration 10-100µg/ml) showed maximum percentage inhibition on alpha amylase activity with an IC$_{50}$ value of 37.86 ± 0.32, 62.99 ± 1.20 and 59.0 ± 0.51µg/ml, respectively when compared with acarbose (IC$_{50}$ value of 83.33 ± 0.75 µg/ml).

Raju *et al.* (2010) assessed the effects of ethanolic extract of whole plant of *Piper trioicum* on the *in vitro* α-amylase and α-glucosidase activity. The plant extract
at the doses (1000 and 2000 mcg/ml) showed maximum inhibition of α-amylase and α-glucosidase activity. Ahmad et al. (2011) studied the anti-diabetic potential of methanol extract of leaf and stem of Uncaria acida, U.cordata, U.callophylla and U. longiflora var. pteropoda by α-glucosidase inhibitory assays. The α-glucosidase inhibitory assay, the stem extracts of the two plants showed strong α-glucosidase inhibition.

Narkhede et al. (2011) screened the methanol extract of root of Caesalpinia digyna for its in vitro anti-diabetic activity. The result suggested that methanol extract of C. digyna exhibited a dose-dependent increase in percentage inhibitory activity on α-glucosidase enzymes (IC<sub>50</sub> = 402.23 ± 10.14μg/ml) and α-amylase (IC<sub>50</sub> = 686.94 ± 3.98μg/ml). Acarbose was used as a standard drug. Chandrashekar et al. (2012) analysed the anti-diabetic activity of petroleum ether and aqueous extract of stem bark of Bauhinia purpurea. The samples showed inhibition of α-amylase in a dose-dependent manner.

The medicinal plant extracts were investigated for their therapeutic potential to inhibit key enzymes in carbohydrate metabolism, which has relevance to the management of hyperglycemia and type 2 diabetes (Gulati et al., 2012). Of the twelve plant extracts (Acacia kempeana, Acacia tetragonophylla, Acacia ligulata, Beyeria lechenaultii, Euphorbia drummondii, Santalum lanceolatum, Santalum spicatum, Boerhaavia diffusa, Curculigo orchioides, Eugenia jambolana, Mucuna pruriens and Pterocarpus marsupium) evaluated the highest inhibitory activity against both α-amylase and α-glucosidase enzymes was exerted by Santalum spicatum and Pterocarpus marsupium with IC<sub>50</sub> values of 5.43 and 0.9μg/ml, respectively, and 5.16 and 1.06μg/ml, respectively. However, the extracts of Acacia ligulata (IC<sub>50</sub> = 1.01μg/ml), Beyeria leshnaultii (0.39μg/ml), Mucuna pruriens (0.8μg/ml) and Boerhaavia diffusa (1.72μg/ml) exhibited considerable activity against α-glucosidase enzyme only.

Kavitha Sama et al., (2012) screened the in vitro α-amylase and α-glucosidase inhibition activity using various concentrations of anthocyanin flower extract. The extract showed significant inhibitory activity, at the concentration of 400mg/ ml the
plant showed appreciable $\alpha$-amylase and $\alpha$-glucosidase inhibitory activity (71.46 and 76.85%, respectively) with IC$_{50}$ value of 260 and 244μg/ml, respectively. The inhibitory activities of isolated sinensetin and 50% ethanolic extract of Orthosiphon stamineus were evaluated in vitro using $\alpha$-glucosidase and $\alpha$-amylase inhibitory assays (Mohamed et al., 2012). The results showed inhibitory activity on $\alpha$-glucosidase (IC$_{50}$= 4.63 and 0.66mg/ml, respectively) and $\alpha$-amylase (IC$_{50}$= 36.70 and 1.13mg/ml, respectively). Inhibition of these enzymes provides a strong biochemical basis for the management of type 2 diabetes through the control of glucose absorption.

In vivo Studies

Okokon et al. (2007) identified the anti-diabetic activity of ethanolic root extract of Homalium letestui using streptozotocin (STZ)-induced diabetes in rats. The extract caused a significant reduction in fasting blood glucose levels of the diabetic rats in acute toxicity study and on prolonged treatment (2weeks) the activity of the extract was comparable to that of the reference drug, glibencalmide. Bhagwat et al. (2008) worked out the anti-diabetic activity of aqueous, alcoholic and petroleum ether extracts of leaf of Tridax procumbens using STZ-induced diabetes in wistar rats. The oral administration of leaf extracts at doses of 200mg/kg led to a significant blood glucose reduction.

Nirmala et al. (2009) examined the hypoglycemic effect of leaf pulp of Basella rubra in streptozotocin-induced diabetic rats. Oral administration of the leaf pulp (400mg/100gm b.w. p.o.), remarkably reduced the fasting blood glucose levels to normal. Azadbakhta et al. (2010) scrutinized the hypoglycemic effect of aqueous fruits extract of Diospyros lotus on streptozotocin-induced diabetic rats. Administration of different doses of D. lotus extracts (500, 750, 1000 and 1500 mg/kg p.o.) to diabetic animals caused significant decrease in glucose level and the maximum reduction was observed in the animals group with 1000 mg/kg p.o. after 16 days post-treatment.

The hypoglycemic effects of aqueous extract of Cynara scolymus in streptozotocin-induced diabetic rats were screened. The oral administration of the extract (200 and 400mg/kg b. w.) for 21days significantly reduced hyperglycemia in
treated diabetic rats as compared to diabetic control group (Heidarian and Soofiniya, 2011). Meera et al. (2011) elucidated the anti-diabetic effect of aqueous extract of Hypsizygus ulmarius on streptozotocin-nicotinamide-induced diabetic rats. Biochemical constituents and marker enzymes (AST, ALT, ALP and LDH) in serum and tissues and carbohydrate metabolizing enzymes were evaluated in tissue (kidney and liver) homogenate. The activity of two gluconeogenic enzymes (glucose-6-phosphatase and fructose-1, 6-bisphosphatase) in tissues and serum glucose level were also increased in STZ-NAD-induced diabetic rats. The H. ulmarius aqueous extract resisted the damage caused by the STZ by bringing the serum and tissue marker enzymes and glucose to normal level and also decreased the activity of gluconeogenic enzymes to normal level.

The anti-diabetic properties of aqueous leaves extract of Leonotis leonurus in streptozotocin-induced diabetic rats was studied (Oyedemi et al., 2011). The continuous oral administration of the extract at the dose of 125, 250 and 500 mg/kg p.o. for 15 days was able to lower the blood glucose level. Also, the weight loss of diabetic rats (31g) after extract treatment was near that of glibencalmide treated groups. Patil et al. (2011) tested the anti-diabetic activities of aqueous, ethanol and chloroform bark and root extracts of Caesalpinia bonduroid by glucose tolerance test in normal rats and alloxan-induced diabetic rats. In alloxan-induced diabetic rats the maximum reduction in blood glucose was observed after 3 hours at a dose level of 250mg/kg of b.w. The percentage protection by aqueous, chloroform and ethanol extracts were 22, 28 and 23%, respectively. Both the extracts showed a significant anti-diabetic activity comparable with that of glibencalmide, standard anti-diabetic drug.

Rahman and Venkatraman (2011) examined the anti-diabetic activity of ethanol and chloroform rhizome extracts of Picrorhiza scrophulariiflora (250 and 500mg/kg) on fasting blood glucose levels in streptozotocin-induced diabetic rats. After 21 days of repeated oral administration of 500mg of ethanolic extract of P. scrophulariiflora, a significant decrease on fasting blood glucose was noticed. Ramakrishna et al. (2011) evaluated the anti-diabetic activity of ethanolic whole plant extract of Triumfetta pilosa in streptozotocin-induced diabetic rats. The extract shown
significant protection and lowered the blood glucose levels when compared to normal in glucose tolerance test.

Saha et al. (2011) noted the anti-diabetic activity of methanol extract of aerial parts of Cucurbita maxima in wistar albino rats against streptozotocin. Glibencalmide was used as reference drug. Fasting blood glucose levels were reduced in a treatment-duration dependent manner and 60.88, 67.79 and 64.30% reduction with respect to the initial levels were observed on 15th day with low and high dose of methanol extract of aerial parts of C. maxima and glibencalmide, respectively. The changes in biochemical parameters observed with diabetic control group were reversed towards normal levels with extract and standard treated groups.

Sankaran and Vadivel (2011) evaluated the anti-diabetic effect of alcoholic extract of flower of Hibiscus rosasinensis against streptozotocin-induced diabetic rats. The hypoglycemic activity of H. rosasinensis extract was investigated in a dose-dependent manner such as (125, 250 and 500mg/kg b.w.) by evaluating various biochemical parameters. The levels of blood glucose, carbohydrate metabolizing enzymes were found to be significantly increased in diabetic rats when compared to control groups. Administration of extract in the treated groups showed altered changes in the above mentioned parameters and among the three doses, 250mg/kg showed best result when compared to other two doses.

Balamurugan et al. (2012) investigated the anti-hyperglycemic activity of methanol extract of Acorus calamus rhizome in streptozotocin-induced diabetic rats. Oral administration of plant methanol extract (40mg/kg, 200mg/kg p.o.) showed significant restoration of blood glucose level. After 21days of treatment, blood glucose, glucose 6-phosphatase and fructose 1,6-bis phosphatase levels were decreased when compared with diabetic control. Cao et al. (2012) reported the anti-diabetic effect of Arctium lappa root ethanolic extract on streptozotocin-induced diabetic rats. The oral administration of the plant extract (400mg/kg b.w.) significantly decreased the blood glucose and increased the insulin level in diabetic rats compared to the control diabetic group.
Christudas *et al.* (2012) investigated the effect of aqueous solution of *Biophytum sensitivum* leaf on normal and streptozotocin-nicotinamide-induced diabetic rats. The plant extract (200mg/kg b.w.) significantly reduced the blood glucose and glycosylated haemoglobin levels and significantly increased the total haemoglobin, plasma insulin and liver glycogen levels in diabetic rats. It also increased the hexokinase activity and decreased glucose-6-phosphatase, fructose-1-6-biphosphatase activities in diabetic rats. El-Desoky *et al.* (2012) examined the anti-diabetic effects of aqueous bark extract of *Cinnamon verum* in alloxan-induced diabetic rats. Extract was administered to rats at different dosages (200, 400, 600 and 1200mg/kg b.w.) for thirty days followed by a fifteen day wash out period. After thirty days, the administration of diabetic rats with the lowest dose (200mg/kg b.w.) of *C. verum* extracts was the most efficient in affecting significant reduction in the levels of fasting blood glucose, but no hypoglycemic activity was observed in the untreated diabetic control rats.

Hamdy, (2012) investigated the effect of aqueous extract of leaves of *Morus alba* on lipid hepatic glucose-regulating enzymes in STZ-induced diabetic rats. The activities of hexokinase, glucose-6-phosphate dehydrogenase and lactate dehydrogenase significantly raised in *M. alba* treated diabetic rats, whereas glutathione-s-transferase and glucose-6-phosphatase activity reduced. Naquvi *et al.* (2012) revealed the anti-diabetic activity of aqueous fruit extract of *Coriandrum sativum* in STZ-induced diabetic rats. In doses of 250 and 500mg/kg b.w. the aqueous extract showed significant decrease in blood glucose level. Pahwa *et al.* (2012) studied the anti-diabetic effect of the methanolic bark extract of *Bauhinia purpurea* in streptozotocin-induced diabetic rat. Decreased blood glucose level of the test animals showed that the extract exhibited significant dose-dependent anti-diabetic activity when compared to diabetic control group.

The anti-diabetic activities of the aqueous and methanolic extracts of aerial parts (leaves, stem and seeds) of *Cassia occidentalis* were evaluated for anti-diabetic activity against alloxan-induced animal model (Arya *et al.*, 2013). Amongst all the extracts, potent anti-diabetic activity was observed in aqueous extracts of leaf of *C. occidentalis* followed by aqueous extracts of seed and aqueous extracts of stem.
In normal animals, significant reduction in the blood glucose level was observed by the aqueous extracts as compared to the control and methanolic extracts. Bhavsar and Talele (2013) evaluated the petroleum ether, ethyl acetate and ethanol extracts of *Bombax ceiba* bark was evaluated for its hypoglycemic potential through normal and STZ-induced diabetic rats administered with graded oral doses (200, 400, 600mg/kg/day) for 21 days. The results showed that a dose of 600mg/kg p.o. of *B.ceba* extract is the most effective to cause significant hypoglycemic effects on streptozotocin-induced diabetic rats.

Fathiazad *et al.* (2013) focused the hypoglycaemic effects of methanolic extract of aerial parts of *Fumaria parviflora* using normal and streptozotocin-induced diabetic rats. Administration of *F. parviflora* extract showed a potent glucose lowering effect on diabetic rats. Gnananath *et al.* (2013) evaluated of anti-diabetic activity of the ethanol extract of rhizome of *Corallocarpus epigaeus* using alloxan-induced diabetic rats. The plant extract at a high dose of 400 mg/kg p.o. was capable of inhibiting the elevation of blood glucose level. Mitali and Palash, (2013) intended to evaluate the hypoglycemic activity of *Calamus erectus* fruit in streptozotocin-induced diabetic wistar rat. The fruit extracts of 100, 200, 300 and 400mg/kg b.w. were administrated orally to normal and STZ-induced (55mg/kg b.w.) diabetic rats. Glibencalmide (10mg/kg) was used as a reference drug. The study demonstrated that *C. erectus* fruit extract possessed good anti-diabetic potential.

### 2.4. Chemical Profile of Elaeocarpaceae


Cambie *et al.* (1992) reported triterpenes from the fruits of *Elaeocarpus chelonimorphus*. Tannin, geraniin and 3, 4, 5-trimethoxy geraniin have been isolated.
from the leaf of *Elaeocarpus grandiflorus* (Rahman *et al*., 1998). Ito *et al.* (2002) isolated two cucurbitacins, cucurbitacin D and cucurbitacin F as cytotoxic principles, together with two ellagic acid derivatives, 4′-O-methylellagic acid 3-(2″,3″-di-O-acetyl)-α-L-rhamnoside (1) and 4,4′-O-dimethylellagic acid 3-(2″,3″-di-O-acetyl)-α-L-rhamnoside (2) from the bark of *Elaeocarpus mastersii*. Elkhateeb *et al.* (2005) isolated three new ellagic acid derivatives 4-O-methylellagic acid 3′-α-rhamnoside, 4-O-methylellagic acid 3′-(3″-O-acetyl)-α-rhamnoside, and 4-O-methylellagic acid 3′-(4″-O-acetyl)-α-rhamnoside in addition to the known ellagic acid derivative, 4-O-methylellagic acid 3′-(2″,3″-di-O-acetyl)-α-rhamnoside from the bark of *Elaeocarpus parvifolius*.

Katavic *et al.* (2006) isolated the five new indolizilidine alkaloids grandisines C, D, E, F, and G and one known indolizidine alkaloid isoelaeocarpiline from the leaf of *Elaeocarpus grandis*. Grandisine is isomeric compound rudrakine. The absolute configuration of grandisine D was deduced by its conversion isoelaeocarpiline. Grandisine E contains a novel tetracyclic ring system. Grandisine F is the 14-amino analogue of grandisine C. Grandisine G contains the novel combination of piperidine attached to an indizolidine. Miller *et al.* (2006) isolated a cyanogenic glycoside 6′-O-galloylsambunigrin from the methanolic extract of leaf of *Elaeocarpus sericopetalus*.

### 2.5. Pharmacological Investigation of Elaeocarpaceae

Plants of the family Elaeocarpaceae exhibited diverse pharmacological activities. *Elaeocarpus grandiflorus* possessed anti-diuretic activity (Van Der Woerd, 1950). Water extract of leaves, fruit and twigs of *Elaeocarpus grandiflorus* possessed hypoglycemic effect (Bualee *et al*., 2007). Ethanolic extract of fruit of *Elaeocarpus ganitrus* exhibited sedative, hypnotic, tranquillizing, anti-convulsive, anti-epileptic and anti-hypertensive and analgesic activity (Bhattacharya *et al*., 1975). The bark *Elaeocarpus parvifolius* was effective in malarial infections (Sosef *et al*., 1998). *Elaeocarpus polydactylus, Elaeocarpus dolichostylis, Elaeocarpus densiflorus* have anti-tumour, analgesic and cardiovascular effect (Collins *et al*., 1990). Chloroform soluble extract of the bark of *Elaeocarpus mastersii* was cytotoxic and possessed anticancer activity (Kinghorn *et al*., 1999). Singh *et al*. (2000) investigated the anti-asthmatic activity and anti-inflammatory activity of petroleum ether, benzene,
chloroform, acetone and ethanol extracts of dried fruit of *Elaeocarpus sphaericus*. Petroleum ether, ethanol extracts indicated anti-depressant activity.

*Elaeocarpus floribundus* bark stem and leaf is used as mouth wash and fruits used as antiseptic, *Elaeocarpus oblongus* fruit is used as antiseptic, rheumatism, pneumonia, ulcers, piles and leprosy, *Elaeocarpus tuberculatus* leaf and stem bark used in rheumatism, typhoid and epilepsy. An infusion of bark stem and leaf of *Elaeocarpus floribundus* has been used as mouth wash and fruits have been used as anti-septic (Pullaiah, 2006). The petroleum ether, benzene, chloroform, acetone, and ethanol, extracts of dried fruits of *Elaeocarpus sphaericus* showed anti-ulcerogenic activities. Ethanolic extract of fruit exhibited sedative, hypnotic, tranquillizing, anticonvulsive, antiepileptic and anti-hypertensive properties (Bhattacharya *et al.*, 1975; Pandey and Bhattacharya, 1985).