2. REVIEW OF LITERATURE

2.1. Pharmacognostic study of the plants

Herbal drugs play an important role in health care programs especially in developing countries. Ancient Indian literature incorporates a remarkably broad definition of medicinal plants and considers ‘all’ plant parts to be potential sources of medicinal substances. However a key obstacle, which has hindered the acceptance of the alternative medicines in the developed countries, is the lack of documentation and stringent quality control. There is a need for documentation of research work carried out on traditional medicines. 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 and phytochemical studies. These studies help in 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 herbal 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 (Niranjan Sutar et al., 2011).

Botanical supplements come in various forms, including whole or chopped herbs, powders, teas, capsules, tablets, hydro-alcoholic tinctures, dry extracts, and syrups. The quality assurance and assessment of botanical drugs, traditional or modern, requires that every available tool be accessible and applied as
appropriate. Each analytical tool has its purpose and utility, and one is only superior to another in terms of the analytical goal.

For identification purposes, the highest level of confidence in identity that can be achieved is through morphological analysis. However, generally speaking, formal botanical identification is not widely employed in the trade of medicinal plants. Very seldom will manufacturers find ingredient vendors who can provide an affidavit of botanical authenticity, thus raising the question as to the authenticity of plants in trade. However, botanical identification is only specific for identification and is not appropriate for quality assessment or the evaluation of extracts.

The initial set of pharmacognostic tools used for quality assessment of medicinal plant parts is macro- and micro-anatomy and organoleptic analysis (sensory evaluation) namely size, shape, colour, form, texture, taste, and aroma. Organoleptic evaluation means conclusions drawn from studies resulted due to impressions on organs of senses. The study of form of a crude drug is Morphology, while description of the form is Morphography (Roy Upton et al., 2011).

Morphological and organoleptic analyses offer a suite of tests that can provide an assessment of the most subtle of characteristics that contribute to the identification and true quality of a plant, while the microscope allows for the assessment of plant material at a cellular level.

Pharmacognosy has vacillated between being narrowly defined as a descriptive science focused exclusively on the morphological characterization of drug plants and their adulterants. It is broadly defined as the body of knowledge needed to understand all aspects of natural products drug development, including
pharmacological activity and limited to natural products chemistry and structural and molecular elucidation. All the tools of pharmacognosy are important for the continued development and evolution of traditional plant-based medicines (Roy Upton et al., 2011).

2.2. Secondary metabolites

Studies and researches into medicinal constituents of plants, involve qualitative and quantitative analyses. There is rationale behind each experimental work involving definite steps and processes. The desired active metabolite to be isolated and studied as interested lead compound, many times is in very complex mixtures of many unwanted and undesired materials (contaminants), which have close properties to the desired bioactive molecules.

It is important to first establish proper botanical taxonomic identifications and classification of the plant of study. Scientific names must be established, common and local names must be sought. Right choice of study plant or part of plant to study may be from local or traditional surveys i.e. ethno-medicine, ethno-pharmacology or ethno-botanical uses and applications. Geographical location, environmental effects, time and period of plant collection, must be considered, which may be responsible for variations. Voucher samples of plant of study may be filed in local and national herbaria for accurate authentications. Usually plants are richer in active metabolites during their flowering and fruiting stages (Mendonca-Filho et al., 2006).

Preliminary tests and screenings on plant extracts should be done following the standard procedures and methods given in manuals and literature.
They detect the presence and amount of basic phytoconstituents like terpenoids, alkaloids, flavonoids, saponin, glycosides, steroids, tannins, phlobatannins and anthraquinones to mention few. More common and familiar separation and isolation techniques in phytochemical studies are distillation, crystallization, solvent extractions, continuous and liquid-liquid extractions, partitioning using separatory funnels, and chromatography. Bioactivities can also be tested along the above, such as antibacterial, antifungal and antioxidant.

Once preliminary separations and detections have confirmed presence of active secondary metabolites, their characterization is done. Chromatographic techniques are utilized in separations and purifications to isolate bioactive constituents based on polarity or other gradient factors. The isolated compound is characterized by spectroscopic methods. Four basic types of spectroscopy are utilized in the characterizations of purified natural product compounds. They are ultraviolet (UV), infrared (IR), mass-spectroscopy (MS) and nuclear magnetic resonance (NMR) techniques. MS is an instrumental technique, while the other three utilizes different parts of the broad electromagnetic radiation spectrum.

UV spectroscopy gives detailed information on detecting presence of conjugation in molecules and the extents of conjugation. The infrared (IR) region of EMR was utilized to detect different vibration frequencies of different chemical bonds present in the molecule. Combination of these two types of spectroscopy (UV & IR) gave information about the functional groups present in the molecule.

MS involves three important steps: Ionization and vaporization; Separation of ions by m/z; and Detections. The analytical technique provides
information which determines the molecular ion. Compounds are ionized for analysis, and also fragments are produced useful for structural characterizations. Almost all compounds can be analyzed by MS, but modes of ionization and type of instruments determine the results (Moronkola Dorcas Olufunke, 2012).

Flavonoids belong to a very vast group of plant secondary metabolites with variable phenolic structures and are found in fruits, vegetables, grains, bark, roots, stems, flowers, tea and wine. In plants, flavonoids are performing a variety of functions including pollination, seed dispersal, pollen tube growth, resorption of mineral nutrients, tolerance to abiotic stresses, protection against ultraviolet and allelopathic interactions, etc. More than 8,000 different compounds of polyphenols have been known and that can be further subdivided into ten different general classes (Ververidis et al., 2007, Harborne et al., 2000). Flavonoids are part of this family and have more than 4,000 varieties (Harborne, 1994).

Isoflavonoids (phytoestrogens or non-steroidal estrogens) such as the soy isoflavones-genistein and daidzein, have also been known for their therapeutic significance particularly in the protection of human health (Wiseman et al., 2000, Stevens et al., 2004). There are a variety of factors such as species, variety, climate, degree of ripeness and post harvest storage which influence the concentration of flavonoids in foods (Holland et al., 1995, Robards et al., 1997). Flavonoids have a remarkable reducing ability and ability to interact with proteins (Haslam, 1996, Havsteen, 2002). Flavonoids, especially flavanols, flavonols and anthocyanins are relatively abundant in human diet and possibly involved in prevention of cancers, cardiovascular diseases and neurodegeneration. The flavonoids are formed in plants
and participate in the light-dependent phase of photosynthesis during which they catalyze electron transport (Das, 1994). They are synthesized from the aromatic amino acids-phenylalanine and tyrosine, together with acetate units (Priya Batra et al., 2013).

Leguminous plants are a rich source of flavonoids (Harborne, 1994). The most striking structural feature of legume phytoalexins is the isoflavonoid skeleton. Also, 5-deoxy (iso) flavonoids compose many biologically active leguminous flavonoids (Hegnauer et al., 1993). Methylation, prenylation and other structural modifications are also noted for the structural properties of flavonoids produced by individual legume species (Dixon, 1999).

Flavonoids are postulated to play pivotal roles in the adaptation of producer legumes to their biological environments both as defensive compounds (phytoalexins) and as chemical signals in symbiotic nitrogen fixation with rhizobia. Because legumes are a significant source of food and forage, the effects of leguminous flavonoids on human and animal health are being studied intensively (Dixon et al., 1999, Toshio Aoki et al., 2000).

Natural bioactive compounds especially from plant sources, including spices have been investigated for their characteristics and health effects. Plants are potential sources of natural bioactive compounds such as secondary metabolites and antioxidants. They absorb the sun light and produce high levels of oxygen and secondary metabolites by photosynthesis. Medicinal components produced are stored in plant leaves. Most of the secondary metabolites of herbs and spices are commercially important and find use in a number of pharmaceutical compounds.
Flavonoids and phenolics acids are the most important groups of secondary metabolites and bioactive compounds in plants (Kim et al., 2003). They are also a kind of natural product and antioxidant substance capable of scavenging free superoxide radicals, anti-aging and reducing the risk of cancer. Secondary metabolites are chemicals produced by plants and their functions in growth, photosynthesis, reproduction and other primary processes are not known yet. Secondary chemicals are important in plant use by widely used especially in Asia (Bodeker, 2000). It was found that flavonoids reduce blood-lipid and glucose of humans. Most pharmaceuticals are based on plant component structures; as such, secondary metabolites enhance human immunity (Atoui et al., 2005).

Flavonoids constitute a wide range of substances that play important role in protecting biological systems against the harmful effects of oxidative processes on macromolecules, such as carbohydrates, proteins, lipids and DNA. Quercetin, rutin, caffeic acid, vanillic acid and gallic acid and myricetin could inhibit Gram-positive bacteria at a higher rate when compared to Gram-negative. Flavonoids are able to inhibit aldose reductase enzyme (that converts sugars to sugar alcohols) and is implicated with diabetic complications, such as neuropathy, heart disease and retinopathy (Ali Ghasemzadeh et al., 2011).

Most of drugs have definite chemical constituents to which their biological or pharmacological activity is attributed. Qualitative chemical test are used to identify certain drug or to test their purity. The isolation, purification, identification of active constituents is based on chemical methods of evaluation. Qualitative chemical test such as acid value, saponification value etc. (Anjoo
Kamboj, 2012). Chemical and chromatographic tests help to provide batch-to-batch comparability and the chromatogram may be used as a 'fingerprint' for the herbal ingredient by demonstrating the profile of some common plant constituents such as flavonoids, alkaloids and terpenes.

TLC, HPLC, GC, quantitative TLC (Q TLC), and high-performance TLC (HPTLC) can determine the homogeneity of a plant extract. Infrared and UV-Visible spectrometry, MS, GC, liquid chromatography (LC) used alone, or in combinations such as GC-MS and LC-MS, and nuclear magnetic resonance (NMR), electrophoretic techniques, especially by hyphenated chromatographic techniques, are powerful tools, often used for standardization and to control the quality of both the raw material and the finished product. The results from these sophisticated techniques provide a chemical fingerprint as to the nature of chemicals or impurities present in the plant or extract (WHO, 2002, Kunle et al., 2012).

2.3. Antimicrobial activity of plant substances

Plants are continuously in contact with different microorganisms, including viruses, bacteria and fungi. To arrest the spread of pathogens, plants possess an innate immunity that involves different layers of defence responses. Some of these defences are preformed and others are activated after recognition of pathogen elicitors and include reinforcement of the cell wall, biosynthesis of lytic enzymes and production of secondary metabolites and pathogenesis related proteins (Rocio Gonzalez-Lamothe et al., 2009).

Apparentl y, bacterial species present the genetic ability to acquire and transmit resistance against currently available antibacterial drugs since there are
frequent reports on the isolation of bacteria that are known to be sensitive to routinely used drugs and became multi-resistant to other medications available on the market. Most plants contain several compounds with antimicrobial properties for protection against aggressor agents, especially microorganisms. Active compounds found in some plants have antiseptic action (Silva et al., 2010).

It is believed that plants which are rich in a wide variety of secondary metabolites belonging to chemical classes such as sterols, alkaloids, glycosides, saponins, flavonoids, tannins, and carbohydrates are generally superior in their antimicrobial activities (Chinnaperumal Kamaraj et al., 2012).

Identification of new chemotypes for drug development remains an urgent need in antifungal therapeutics. Simultaneously, a number of antifungal compounds reported till date, are tested for their in vitro activities not for in vivo activities. In vivo and in vitro activities of a compound may be different and a very small number of plant extracts or components have been studied for their in vivo activity. Therefore these should be subjected to animal and human studies to determine their effectiveness in whole-organism systems. Also in vitro testing and method of extraction should be standardized so that the search could be more systematic.

The current set of clinically available antifungal agents includes three classes of natural product and four classes of synthetic chemicals. Furthermore, the inactive plant extracts may be subjected to chemical diversification of their components to increase the activity. The transformation of chemical groups in natural products into rare chemical groups is possible which are rarely produced by secondary metabolism. Therefore, biosynthesis machinery can be complemented to
produce a whole range of new semisynthetic compounds in one step which may become an alternative source of compounds. Plants are rich source of bioactive secondary metabolites of wide variety such as tannins, terpenoids, alkaloids, and flavonoids, reported to have in vitro antifungal properties. A series of molecules with antifungal activity against different strains of fungus have been found in plants, which are of great importance to humans and plants. These molecules may be used directly or considered as a model for developing better molecules (Tasleem Arif et al., 2011).

Antibacterial activity has been displayed by a number of flavonoids. Quercetin has been reported to completely inhibit the growth of *Staphylococcus aureus*. Most of the flavonones having no sugar moiety showed antimicrobial activities whereas none of the flavonols and flavonolignans tested showed inhibitory activity on microorganisms.

The methanol extracts of forty nine different plant extracts were screened for antifungal activity, out of which forty three plant extracts exhibited varying degrees of inhibition activity against the fungi (Varaprasad et al., 2009). Antibacterial activities of aqueous and methanol extracts of some medicinal plants against some human pathogenic bacteria showed the methanol extracts had wider range of activity on these organisms than the aqueous extracts, which indicates that the methanol extracts of all selected plants may contain the active components.

2.4. Antioxidant activities of plant products

The best-described property of almost every group of flavonoids is their capacity to acts as antioxidants. The flavones and catechins seem to be the most
powerful flavonoids for protecting the body against reactive oxygen species (ROS). Body cells and tissues are continuously threatened by the damage caused by free radicals and ROS which are produced during normal oxygen metabolism or are induced by exogeneous damage. Free radicals and ROS have been implicated in a large number of human diseases.

Quercetin, kaempferol, morin, myricetin and rutin, by acting as antioxidants, exhibited beneficial effects such as anti-inflammatory, antiallergic, antiviral, as well as anticancer activity. They have also been suggested to play a protective role in liver diseases, cataracts, and cardiovascular diseases. Quercetin and silybin, acting as free radical scavengers, were shown to exert a protective effect in liver reperfusion ischemic tissue damage. The scavenging activity of flavonoids has been reported to be in the order: Myrcetin > quercetin > rhamnetin > morin > diosmetin > naringenin > apigenin > catechin > 5,7-dihydroxy-3’,4’,5’-trimethoxyflavone > robinin > kaempferol > flavones (Tapas et al., 2008).

Accumulation of reactive oxygen species (ROS) coupled with an increase in oxidative stress has been implicated in the pathogenesis of several disease states such as aging, inflammation, and neurodegenerative disorders. The role of oxidative stress in vascular diseases, diabetes, renal ischemia, atherosclerosis, pulmonary pathological states, inflammatory diseases and cancer has been well established.

Free radicals and other reactive species are constantly generated in vivo after exposure to drugs, xenobiotics, or ionizing radiation and causes oxidative damage to biomolecules, a process held in check by the existence of multiple antioxidant and repair systems as well as the replacement of damaged nucleic acids,
proteins, and lipids. Measuring the effect of antioxidant therapies and ROS activity intracellularly is crucial for suppressing or treating oxidative stress inducers. The major biochemical change associated with cancer cells after treatment with anticancer drugs is the increase in ROS generation which is often considered as a cancer promoting factor. Studies have demonstrated that high levels of ROS can cause cellular damage and play an important role in mediating apoptosis. Interestingly, ROS has been demonstrated to selectively kill cancer cells (Mondal et al., 2013).

The oxidative damage to DNA may play vital role in aging and the presence of intracellular oxygen also can be responsible to initiate a chain of inadvertent reaction at the cellular level and these reaction cause damage to critical cell biomolecules. These radicals are highly toxic and thus generate oxidative stress in plants. Plants and other organism have in built wide range of mechanism to combat with these Free Radical problems.

Free radicals are an atom or molecule that bears an unpaired electron and is extremely reactive, capable of engaging in rapid change reaction that destabilize other molecules and generate many more free radicals. In plants and animals these free radicals are deactivated by antioxidants. These antioxidants act as an inhibitor of the process of oxidation, even at relatively small concentration and thus have diverse physiological role in the body. Antioxidant constituents of plant materials act as radical scavengers, and convert the radicals to less reactive species (Kris-Etherton et al., 2004).
Plants have developed an array of defense strategies (antioxidant system) to cope up with oxidative stress. The antioxidative system includes both enzymatic and non-enzymatic systems. The non enzymatic system includes ascorbic acid (vitamin C), α-tocopherol, carotenes etc. and enzymatic system include superoxide dismutase (SOD), catalase (CAT), peroxidase (POX), ascorbate peroxidase (APX), glutathione reductase (GR) and polyphenol oxidase (PPO) etc. The function of this antioxidant system is to scavenge the toxic radicals produced during oxidative stress and thus help the plants to survive through such conditions. Natural antioxidants occur in all parts of plants. These antioxidants include carotenoids, vitamins, phenols, flavonoids, dietary glutathione, and endogenous metabolites.

Plant-derived antioxidants have been shown to function as singlet and triplet oxygen quenchers, free radical scavengers, peroxide decomposers, enzyme inhibitors and synergists. Most of the current research on antioxidant action focuses on phenolic compounds such as flavonoids. Fruits and vegetables contain different antioxidant compounds, such as vitamin C, vitamin E and carotenoids, whose activities have been established in recent years (Sulekha Mandal et al., 2009).

2.5. Anti-proliferative activity of the plants

The antitumor area has the greatest impact of plant derived drugs, where drugs like vinblastine, vincristine, taxol and camptothecin have improved the chemotherapy of some cancers. Plants have an almost unlimited capacity to produce substances that attract researchers in the quest for new and novel chemotherapeutics. The continuing search for new anticancer compounds in plant medicines and traditional foods is a realistic and promising strategy for its prevention. Numerous
groups with antitumor properties are plant derived natural products including alkaloids, phenyl propanoids and terpenoids (Wamidh H Talib et al., 2010).

Cancer is a multi-step disease incorporating physical, metabolic, environmental, chemical and genetic factors, in which each plays a direct and/or indirect role in the induction and deterioration of cancers. Diet with high consumption of antioxidant rich fruits and vegetables reduces the risk of many cancers types, significantly suggesting that these antioxidants could be effective agents to inhibit cancer (Fimognari et al., 2005). Antioxidants in the diet are very promising as cancer inhibitors because of their low toxicity, safety and general acceptance (Ogasawara et al., 2007, Ramos, 2007). Isolated polyphenols from different plants have been considered in a number of cancer cell lines at different stages of cancer growth. For example, the isolated polyphenols from strawberry including kaempferol, quercetin, anthocyanins, coumaric acid and ellagic acid, were shown to inhibit the growth of human breast (MCF-7), oral (KB, CAL-27), colon (HT-29, HCT-116), and prostate (LNCaP, DU-145) tumour cell lines (Zhang et al., 2008; Damianaki et al., 2000). Similar results have also been reported in previous studies with wine extracts and isolated polyphenols (resveratrol, quercetin, catechin and epicatechin) as well as green tea polyphenols (epigallocatechin, epicatechin) (Weisburg et al., 2004). Additionally, Manthey et al., (2001) reported that citrus flavonoids inhibited the growth of HL-60 leukemia cells.

Kaempferol, which is also a type of flavonoid, was shown to inhibit the growth of ovarian cancer cell lines (91%), and A2780/CP70 (94%) by concentration of 20 and 40 μM, respectively as well as breast cancer cell lines (Luo et al., 2009).
Epigallocatechin 3-gallate is an effective antiangiogenesis agent which inhibits tumor cell invasion and proliferation (Tang et al., 2007) and, inhibits growth of the NBT-II bladder tumour cells and breast cancer cell lines (Chen, 2004). Several studies revealed that quercetin’s significant anti-inflammatory activity is due to the direct inhibition of initial processes in inflammation (Park et al., 2008). Additionally, potent anticancer activity of quercetin has been demonstrated as well. For example, some tests showed its antitumor properties including the inhibition of cancer cells proliferation and migration (Lim et al., 2006). Combined application of quercetin and ultrasound on skin and prostate cancer showed 90% mortality within 48 h with no visible mortality on normal cells (Paliwal et al., 2005). Significantly higher anticancer activities of gallic acid, caffeic acid and ferulic acid have been reported earlier (Hwang et al., 2006, Ali Ghasemzadeh et al., 2011).

Phenolic compounds constitute one of the most numerous and ubiquitous group of plant metabolites, and are an integral part of the human diet. It was found that in addition to their primary antioxidant activity, this group of compounds displays a wide variety of biological functions which are mainly related to modulation of carcinogenesis. Various in vitro and in vivo systems have been employed to determine the anticarcinogenic and anticancer potential of these natural phenolic compounds or extracts (Jin Dai et al., 2010).

2.6. Phylogenetic study

Phylogenetic analyses of meliaceae, including representatives of all four currently recognized subfamilies and all but two tribes (32 genera and 35 species, respectively), were carried out using DNA sequence data from three regions: plastid
genes rbcL, matK (partial), and nuclear 26S rDNA (partial). Individual and combined phylogenetic analyses were performed for the rbcL, matK, and 26S rDNA data sets. Although the percentage of informative characters is highest in the segment of matK sequenced, rbcL provides the greatest number of informative characters of the three regions, resulting in the best resolved trees (Alexandra et al., 2003).

To evaluate relationships at the generic level, the commonly used rbcL gene is well suited for higher-level intrafamilial problems (Bremer et al., 1995, Plunkett et al., 1996, Cameron et al., 2001). The large existing database of rbcL sequences makes this gene the locus of choice for evaluating taxa of uncertain affinity and the monophyly of families (Chase et al., 2002, Kenneth et al., 2004).

The Trichomonads have been the subject of several molecular studies that reported some discrepancies both at the lower and higher taxonomic levels. The purpose of this study was to make an extensive phylogenetic analysis of the Trichomonadidae using ITS-1/5.8S/ITS-2 sequences, to better understand its phylogeny and the usefulness of this marker. ITS-1/5.8S/ITS-2 sequences of 36 strains from 14 species belonging to Trichomonadidae and Monocercomonadidae were analysed, in which 20 were newly determined. Maximum likelihood, maximum parsimony, neighbour joining, and Bayesian phylogenetic methods were employed in order to reconstruct and compare the evolutionary history of this group. The ITS-1/5.8S/ITS-2 seems to be a reliable locus for phylogenetic studies in the Trichomonadida, mainly at lower taxonomic levels, and at least up to the family level (Peter Kleina et al., 2004).
The nuclear ribosomal RNA (rRNA) gene complex is a tandem repeat unit of one to several thousand copies. This complex has several domains that evolve at varying rates and thus have different phylogenetic utilities. The 18S and 28S rRNA genes evolve relatively slowly and are useful in addressing broad phylogenetic hypotheses involving a broad range of organisms (Kenneth et al., 1998).

2.7. *Sesbania sesban*

*Sesbania sesban* Linn. is a well known medicinal plant commonly found in India and other tropical countries. *Sesbania sesban* commonly known as ‘Egyptian sesban’ is one of the six species of genus *Sesbania* which is commonly found to be grown in tropical region of India. The origin of *Sesbania sesban* is unclear, but it is widely distributed and cultivated throughout tropical Africa and Asia. The plant is widely grown for its nitrogen fixing ability and as wind shades. The plant has got good medicinal importance (Mohammed Rageeb et al., 2013).

2.7.1. Nutritional profile

The seeds of *S. sesban* are reported to contain 30 to 40% crude protein, 5 to 6% of crude lipid and 2.7 to 3.3% of ash (Hossain et al., 2002). Debela et al., (2011) reported that the crude protein contents of *Sesbania sesban* fractions varied from 194 g/kg dry matter in twigs to 297 g/kg dry matter in leaves. In addition, Akkasaeng et al., (1989) found that the *in vitro* dry matter digestibility of *S. sesban* was 75%.
2.7.2. Phytochemical properties

The pods and leaves contain campesterol and beta-sitosterol. Flowers contain cyanidin and delphinidin glucosides. Pollen and pollen tubes contain alpha-ketoglutaric, oxaloacetic and pyruvic acids (Pandhare et al., 2011). From the root extracts of *S. sesban*, Das *et al.* (2011) isolated Oleanolic acid 3-β-D-glucuronide and found that it has potential spermicidal activity. Among the glucuronide derivatives of oleanolic acid, saponin was responsible for the molluscicidal activity of the plant (Vadivel *et al.*, 2012). Phytochemical investigations in the seeds of the plant led to the isolation of oleanolic acid, galactomannan and stigmastane-5,24(28)-dienes-3β-O-β-D-galactopyranoside (Das *et al.*, 2011). The extracts had a high content of phenols, flavonoids and anthocyanins (Zerihun Nigussie *et al.*, 2013).

Seed and bark are used as astringent, emmenagogue, in menorrhagia, spleen enlargement and diarrhoea. The pods and leaves contain campesterol and beta-sitosterol. Flowers contain cyanidin and delphinidin glucosides. Pollen and pollen tubes contain alpha-ketoglutaric, oxaloacetic and pyruvic acids (Khare, 2007). Leaves are used as anthelmintic and also useful in diabetes, colic and skin diseases. Seeds are stimulant, emmenagogue, astringent and also useful in diarrhea (Yusuf *et al.*, 1994).

2.7.3. Ecological adaptation

*Sesbania sesban* is found in areas with a semi-arid to sub-humid climate with a rainfall between 500 and 2000 mm per year (Heering, 1995, Orwa *et al.*, 2009) and temperature of 18 to 23°C (Orwa *et al.*, 2009). In the regions with low precipitation however, they occur primarily on poorly drained soils which are
subjected to periodic water-logging or flooding. Because of its good tolerance to low temperatures, it can be grown at an altitude of 100 to 2300 m. It has moderate shade tolerance as well, and it is adapted to a wide variety of soil types, ranging from loose sandy soils to heavy clays. Furthermore, it has an excellent tolerance to water logging and flooding (Heering, 1995) as well as saline, acidic, alkaline soils (Orwa et al., 2009) and soils laden with heavy metals (Gupta et al., 2011).

2.7.4. Green manure

*Sesbania sesban* is a fast growing nitrogen-fixing leguminous tree species which has the capacity of rapid decomposition when incorporated into soil serving as a green manure (Patra et al., 2006) in alley cropping (Heering, 1995) which could bring about substantial increase in crop available nitrogen and soil organic carbon.

2.7.5. Nitrogen fixation

In symbiosis with *Rhizobium*, nitrogen fixing bacteria *Sesbania sesban* can fix up to 542 kg N ha\(^{-1}\) (Shaheen et al., 2004). Degefu et al., (2011) reported nitrogen fixation of 500 to 600 kg N/ha/year and is particularly promoted for soil fertility replenishment through ‘improved fallow’ agroforestry practice.

2.7.6. Forage source

*Sesbania sesban* tree has a high level of foliage nitrogen and is an excellent supplement to protein-poor roughage. The leaves and tender branches of this tree have high levels of protein (with 20 to 25% crude protein), and easily digestible when consumed by ruminants (Mohammed Rageeb et al., 2013).
2.7.7. Bioenergy source

The stem and thick branches of *Sesbania sesban* is popular for firewood and charcoal production because it produces a relatively smokeless, quick kindling and hot burning woody biomass in a short time (Heering, 1995, Orwa *et al*., 2009, Naik *et al*., 2011, Pravin Gomase *et al*., 2012). Because of its rapid growth, the plant also has a potential for pulpwood production.

2.7.8. Ethanobotany

The cataplasm prepared from leaves of *Sesbania sesban* facilitates discharge of boils and abscesses and absorption of inflammatory rheumatic swellings (Dande *et al*., 2010, Pravin Gomase *et al*., 2012). In addition, juice of fresh leaves is credited with anthelmintic properties. The fresh root of *Sesbania sesban* is also said to be an excellent remedy for scorpion stings (Vadivel *et al*., 2012, Orwa *et al*., 2009).

The crude drug extract obtained from the bark of *S. sesban* have been examined and found to have a potential central nervous system stimulant effect that can be explored for therapeutic advantage as an alternative treatment in medical conditions associated with dizziness and sedative (Naik *et al*., 2011, Pravin Gomase *et al*., 2012). Powdered wood of *S. sesban* is reported to have potent antinociceptive activity (Nirmal *et al*., 2012).

One of the most promising uses of *S. sesban* is as mosquito repellant. Washing the bodies of animals with its water extract can serve as protection against mosquito bites (Vadivel *et al*., 2012). Orwa *et al*., (2009) reported the use of
decoctions of leaves of this plant as a drench for cattle to repel tsetse fly from cattle by the Hausa people of Ghana.

Taking fresh root decoction twice a day for 3 to 4 days following menstrual phase serve as an antifertility agent. Therefore, *S. sesban* seed powder hinders the ovarian normal function, change the uterine structure and prevent implantation, thus, control the fertility (Singh, 1990, Saravanan *et al.*, 2012). With this respect, Das *et al.* (2011) reported that the Kandha tribe of India uses the root extracts as contraceptive. Furthermore, Alagesa Boopathi (2012), reported that decoction of the leaf is mixed with hot milk and given once a day for seven days for treatment of diarrhoea, itches and skin diseases.

### 2.7.9. Other uses

Various medicinal uses for *Sesbania sesban* have been recorded in Africa and Asia. The leaves and flowers are used in medicinal poultices and teas, which are said to have the effect of astringency, or contraction of body tissues. Bark exudates from *Sesban* produce a gum of medium commercial quality. The leaf of *Sesbania sesban* has traditionally been used as purgative, demulcent, maturant, anthelmintic and for all pains and inflammation (Mohammed Rageeb *et al.*, 2013).

The antidiabetic activity of aqueous leaves extract of *Sesbania sesban* in normal, glucose-loaded hyperglycemic and streptozotocin STZ induced diabetic rats was evaluated. The results of the study have shown that the aqueous extract of leaves at dose 500 mg/kg has a marked hypoglycemic activity by improvement of the glucose tolerance test in normo-glycemic rats and by lowering the blood glucose levels in STZ-induced diabetic rats. The aqueous leaves extract of *Sesbania sesban*
has beneficial effects in reducing the elevated blood glucose level and lipid profile of STZ induced diabetic rats (Ramdas B Pandhare et al., 2011).

The leaves of Sesbania sesban were evaluated for the anti-inflammatory activity by carrageenan induced rat paw edema method by preparing the gel formulation. The effects of exogenous administration of petroleum ether, chloroform and methanol extracts of bark of Sesbania sesban in carrageenan induced inflammation model was also studied. The result of anti-inflammatory activity of extracts showed that the petroleum ether extract of bark of Sesbania sesban was having better anti-inflammatory activity as compare to other extracts in carrageenan induced paw oedema in rats (Dande et al., 2010).