CHAPTER 2

COLEUS PLANT AND ITS MEDICINAL PROPERTIES

ABSTRACT

Medicinal plants are regarded as rich resources of traditional medicines and from these plants, many of the modern medicines are produced. For thousands of years, medicinal plants have been used to treat health disorders, to add flavor and conserve food and to prevent disease epidemics. The herb Coleus is a large succulent aromatic perennial herb belongs to the family of “Lamiaceae”. Coleus aromaticus, Coleus amboinicus, Coleus barbatus, Coleus forskohlii and Coleus zeylanicus are the five different Coleus species considered for the present study. The multiple potential role of this herb Coleus includes antimicrobial activity, insecticidal property and free radical scavenging activity. Carvacrol and thymol are the two major components present in the species of Coleus aromaticus responsible for the flavour; while chlorogenic acid, rosmarinic acid etc. as the phenolic compounds. Coleus forskohlii plant has high medicinal value used to treat ailments like psoriasis, eczema and cardiac diseases. The roots of C. forskohlii contain a labdane diterpenoid called forskolin with high medicinal value. Forskolin activates an enzyme adenylate cyclase, which increases cyclic adenosine monophosphate (cAMP) levels in cells, which is the most important cell-regulating compound. Coleus barbatus is used to treat skin, genitourinary, respiratory infections, fever, pain and inflammation. The other Coleus species, namely C. amboinicus and C. zeylanicus are mainly used to treat dysentery and digestive disorders. The secondary metabolites produced by the plants are usually responsible for the biological characteristics. The microbial growth in diverse situations is controlled by plant derived products. The general overview of five different Coleus species considered for the study is discussed in this chapter.
2.1 INTRODUCTION

Traditional medicine existence depends on the knowledge and the diversity of plant medicinal properties. About one-fifth of the plants are reported with medicinal properties in India. About 25,000 plants were reported to be used effectively in the preparation of traditional medicine and plant formulations most commonly in rural communities of India (Haritha et al., 2015). Tribal and rural people residing in forest areas depend mainly on medicinal plants for their health care needs as a part of their culture. Knowing the importance of medicinal plants, it was estimated that 70 - 80% of the world population depends largely on herbal medicine and on the traditional health care system (Shengji 2002). A large number of drugs have been isolated from medicinal plants as the main source and are widely used in the treatment of various infectious diseases. Medicinal plants are rich in several bioactive compounds like glycosides, flavonoids, tannins, terpenoids, steroids, alkaloids, essential oils and phenols responsible for therapeutic properties. There is an increasing demand for the use of medicinal plants in health care systems because of their importance as natural remedies. They are more reliable and effective compared to synthetic drugs. Plant based drugs are most commonly used to treat joint pains, kidney disorders and liver diseases. Seven thousand medicinal compounds are obtained from the plants and more than two third of the world population was estimated to be dependent on the drugs derived from plants (Arusa et al., 2017). Diseases such as Parkinson’s, Alzheimer, atherosclerosis, trauma, cancer and gastrointestinal disturbances are due to the increased concentrations of free radicals (Bagchi et al., 2000). Free radicals produced as a part of normal cellular function during the metabolic pathways are highly reactive. Free radicals derived from nitrogen or oxygen reacts with DNA, carbohydrates, lipids and proteins. Due to the improper balance between the antioxidants and reactive oxygen species, it leads to cellular damage causing several diseases (Fattahi et al., 2014). Phytochemicals derived from plants are capable of destroying the free radicals. They are produced in response to stress, activate proteins of cell signalling pathways (Adams et al., 2010, Finley et al., 2011). The antioxidants present in leaf, stem, root, flowers and fruits of plants play an important role of destroying the free radicals provide protection against degenerative diseases and reduces the risk of chronic diseases (Ali et al., 2014). The majority of the population chooses exogenous antioxidants to get rid of life threatening diseases as natural
antioxidants play a major role in preventing the undesirable effects caused by the oxidative stress (Kasote et al., 2013). Mitochondria, chloroplast and peroxisomes are the three major sites where the production of reactive oxygen species takes place. Toxic effects of ROS are avoided by the enzymatic and non-enzymatic antioxidants of plants. Plants produce low molecular weight antioxidants like ascorbate, glutathione, and a range of low to high molecular weight secondary metabolites act as ROS scavengers (Deepak et al., 2015). Many researchers have reported the antioxidant activity of phytochemicals, both \textit{in vitro} and \textit{in vivo}. Thus, the consumption of plant foods rich in antioxidants is highly recommended. Considering the present scenario of increased drug resistance in microbes, there is an urgent need for generating novel antimicrobial drugs for combating the growth of drug resistant microbes. Researchers and scientific professionals are in search of novel antimicrobial drugs from medicinal plants which cause no side effects to carry broad spectrum activity against gram positive bacteria, gram negative bacterial and fungal pathogens. Now-a-days a large number of medicinal plants are being screened for the active metabolites possessing the antimicrobial and antioxidant potential for the preparation of traditional and alternative medicine to replace the use of conventional drugs.

\textbf{2.2 GENUS “Coleus”}

\textit{Coleus} is a perennial, branched aromatic herb belongs to the family of “\textit{Lamiaceae}” consists of more than 500 species cultivated worldwide. The Genus \textit{Coleus} derived from the Greek word \textit{Koleos}, meaning sheath around style described by De Loureiro in 1970. \textit{Coleus} plants can adapt to semi-dry conditions and are capable of tolerating low levels of light, warm and dry environmental conditions provides an additional advantage of growing the plant with ease (Rice et al., 2011). They can grow up to the height of 30 cm to 60 cm with thick, tuberous roots which are aromatic in nature. The colour of the flowers varies from blue to pale lavender (Himesh Soni and Akhlesh 2012). \textit{Coleus} plant can be propagated using seeds and by means of vegetative method (Prajapati et al., 2003). The whole plant of \textit{Coleus} used since ancient times possess medicinal value includes anticancer, antispasmodic, antidepressant, antiaggregant, antidiuretic, antimetastatic and antiglaucomic properties (Duke et al., 2002). Species of \textit{Coleus} can be grown indoor as well as outdoors possess medicinal properties against various dreadful diseases are due to the presence of various bio-active compounds. \textit{Coleus} species are used in the preparations
of Ayurvedic medicines and are used against worms, skin problems, heart diseases, abdominal colic, respiratory disorders, painful micturition, insomnia and convulsions. A large number of Coleus species are used in Southern Africa for the preparation of traditional medicine as they possess the potential of curing several diseases (Gaspar-Marques et al., 2006). The leaves of Coleus are used against a number of health related conditions like malarial fever, epilepsy, cough, dyspepsia, otalgia, cephalagia, flatulence, diarrhoea, cholera, convulsions, hepatopathy, bronchitis, hiccough, halitosis and strangury. The antibacterial, antifungal, antiplasmodial, antitumoral and insecticidal properties of Coleus are due to the presence of diterpenoids particularly of abietane diterpenes (Stavri et al., 2009, Grayer et al., 2010, Simoes et al., 2010, Van Zyl et al., 2008). The major phytoconstituents of Coleus reported so far are flavonoids, glycosides, phenolic and volatile compounds. The presence of these bioactive compounds with potential pharmacological properties makes genus Coleus an important medicinal plant for the development of novel drugs.

### 2.3 ETHNOBOTANICAL PROPERTIES OF THE GENUS COLEUS

The medicinal properties of different Coleus species were shown in the Table 2.1. Coleus species plant tissues like leaf, root, stem and tubers have a potential role of treating several ailments mentioned in the Economic Botany Data Collection Standard (Cook 1995). Since they possess several medicinal and therapeutic properties, several varieties of Coleus species are used widely in traditional medicine. Apart from the medicinal use, they are also used as insect repellents (Pooley 1998) and culinary herbs (Lukhoba et al., 2006). The screening of plants gives valuable information and the ethno medicinal knowledge provides the scope of developing new drugs to combat dreadful diseases.
Table 2.1: Medicinal uses of different *Coleus* species.

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Medicinal use</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Coleus ambiguous</em></td>
<td>Used to treat respiratory disorders (Hulme 1954, Neuwinger 2000)</td>
</tr>
<tr>
<td><em>Coleus barbatus</em></td>
<td>Used to cure digestive, liver complaints (Albuquerque 2001) and to treat skin, genito-urinary, respiratory infections, fever, pain, inflammation, poison treatment (Lukhoba et al., 2006)</td>
</tr>
<tr>
<td><em>Coleus amboinicus</em></td>
<td>Used to treat respiratory infections (Albuquerque 2001)</td>
</tr>
<tr>
<td><em>Coleus hadiensis</em></td>
<td>Used to treat respiratory disorders (Pooley 1998, Hutchings et al., 1996)</td>
</tr>
<tr>
<td><em>Coleus esculentus</em></td>
<td>Used to treat pain and digestive system disorders (Neuwinger 2000)</td>
</tr>
<tr>
<td><em>Coleus ecklonii</em></td>
<td>Used for headache, hayfever (Pooley 1998) and skin infections (Nyanyiwa and Gundidza 1999)</td>
</tr>
<tr>
<td><em>Coleus laxiflorus</em></td>
<td>Used against skin infections, inflammation, pain, gastro-urinary disorders (Neuwinger 2000), digestive, respiratory disorders (Hutchings et al., 1996), fever (Rabe and Van Staden 1998), and also used as mouth wash (Pooley 1998).</td>
</tr>
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2.4 *COLEUS* SPECIES CONSIDERED FOR THE PRESENT STUDY

The five *Coleus* species considered for the present study are *Coleus aromaticus* (Herbarium Specimen No. 21901), *Coleus amboinicus* (Herbarium Specimen No. 21903), *Coleus zeylanicus* (Herbarium Specimen No. 21904), *Coleus forskohlii* (Herbarium Specimen No. 21905) and *Coleus barbatus* (Herbarium Specimen No. 21906) respectively (Figure 2.1) identified by Dr. S.B. Padal, Associate Professor, Department of Botany, ANDHRA UNIVERSITY, VISAKHAPATNAM. The brief description about the species considered for this study is depicted below.
2.4.1 **COLEUS AROMATICUS**

*Coleus aromaticus* is a succulent perennial herb grows up to the height of 50 cm with leathery heart shaped, thick and juicy leaves, aromatic in nature used to enhance the flavor of meat dishes. It has fleshy, tomentose stems of about 30 to 90 cm and the flowers are pale purplish in colour. It is commonly known as “Karpurvalli in South India and as “Parnayavani” in Sanskrit popularly known as “Indian Oregano”. It possesses anti-microbial (Rao et al., 1991, Deena et al., 2002), antilithotic (Baskar et al., 1992, Jose et al., 2005), anti-tumour, antiepileptic (Buznego and Perez-Saad 1999), radioprotective (Rao et al., 2006), antimutagenic and strong anti-oxidant properties (Kumaran and Karunakaran 2006). The leaves of *Coleus aromaticus* are used to treat malaria, convulsions, dyspepsia, flatulence, epilepsy, cough, cephalagia, otalgia, colic, diarrhea, anorexia and halitosis (Warrier et al., 1995). *C. aromaticus* leaves contain volatile oils, carvacrol, thymol, quercitin, luteoline, apigenin and triterpenoids (Chatterjee and Pakrashi 2001). It exhibits anti-tumour and cytotoxic activities used against cancer. The leaves are more commonly used to control diarrhea in developing countries like India. *Coleus aromaticus* is found effective against
mycobacteria, the causative agent of tuberculosis. This herb is popularly known as “Karpuravalli” as it has an ability to remove stones formed in kidneys. The other disease cholera can also be cured with the use of this medicinal plant. The root extracts were used to cure fever in infants, diphtheria, tetanus and for the treatment of menorrhagia. This herb is diaphoretic, antimicrobial, antiepileptic, hepatoprotective, radio protective and a stimulant effective in curing ailments containing active compounds like epigenin, luteolin, quercetin, eugenol, p-cymene, patchoulane, salvigenin, carvacrol, thymol etc.. The major compound responsible for the radical scavenging activity of *C. aromaticus* was found to be rosmarinic acid. The fresh leaves of *C. aromaticus* can be applied directly on sprains, burns, insect bites and skin infections by crushing the leaves, while the decoction of leaves also used to support lactation in breastfeeding mothers after childbirth. *C. aromaticus* leaves can be used externally to cure headache, conjunctivitis and the extracts or juices are used to treat gastrointestinal and other convulsive disorders. *C. aromaticus* ethanol extract showed anticlastogenic potency against certain anti-cancer drugs (Prasad et al., 2002).

### 2.4.2 COLEUS ZEYLANICUS

*Coleus zeylanicus* is an aromatic herbaceous plant popularly known as “Iruveli”, grown in tropical countries. It grows up to the height of 1 m with thin, slender, aromatic fibrous roots of 30 to 90 cm long. Leaves are simple, sub-succulent and petiolate. It is used as a hair tonic and to treat fever, hyperpiesia, skin diseases, leprosy, ulcers, leucoderma and burning sensation (Sharma et al., 1997). More than 75 Ayurvedic drugs currently available in the local and global markets are prepared by extracting the essential oil from the root of *Coleus zeylanicus*. Urinal disorders and the problem of indigestion can be cured using this plant preparation marketed in the name of Snana Choornam, Devashtagandha and Kashayam. The National Medicinal Plants Board (NMPB), Government of India recognised the importance of this plant and promoted its cultivation, Research and Development (Nisheeda et al., 2016). *C. zeylanicus* possesses anti-microbial, anticancer (Jaslin and Padmaja 2015) antidiabetic (Gopalakrishnan and Dhanapal 2014, Manoharan et al., 2015), antioxidant (Gopalakrishnan and Dhanapal 2014) and hepatoprotective properties (Sundara Ganapathy et al., 2015). This plant is used against several health related conditions like vomiting, nausea, strangury, genitourinary diseases, insanity, giddiness and thirst. The essential oil obtained from the root of *Coleus zeylanicus* can be used as hand
sanitizer (Das et al., 2005, Kolhapure 2004). Several house hold products like agarbathi and bathing soaps are prepared using the root of *C. zeylanicus* (Safeer et al., 2013) whereas; the mosquitoes can be controlled using the alcoholic extract of this plant having adulticidal property (Beenarani et al., 2008).

### 2.4.3 **COLEUS AMBOINICUS**

*Coleus amboinicus* is a succulent herb grows up to the height of 30 to 90 cm with simple, broad leaves and hairy roots. It is used to treat indigestion, fever, epilepsy, headache, dyspepsia, diarrhea, toothache, insect bites, nervous tension, earache, rheumatism, bronchitis and whooping cough. It is well known as an effective expectorant used commonly in India and Southeast Asia to treat sore throat and cough. The herbal tea made from the leaves of *Coleus amboinicus* is used to treat pain, insomnia, asthma and flatulence.

### 2.4.4 **COLEUS BARBATUS**

*Coleus barbatus* is a perennial, succulent branched fleshy herb grows up to the height of 15-40 cm between 1000-2600 m altitudes above sea level (Ryding 2006) used as a stimulant in the treatment of cough. The aerial parts of the plant have cytotoxic, anti-tumor and diuretic activities, also used in the treatment of gums and teeth disorders. The major active compounds present in this plant were diterpenes, triterpenes, tormentic acid, α-amyrin and the flavones 3,7 dimethyl quercetin, sitosterol and kumatakinin.

### 2.4.5 **COLEUS FORSKOHLLII**

*Coleus forskohlii* commonly called as “pashanbhedi” or “Makandi” in Sanskrit is cultivated throughout the country grows up to the height of 1-2 feet approximately. It contains teardrop shaped leaves and thick brown coloured tuberous roots. The areas of Maharashtra, Rajasthan, Tamil Nadu and Karnataka were popular with growing this plant commercially. The thick, golden brown, fibrous and tuberous roots were seen only in the species of *C. forskohlii* whereas not seen in the other species of *Coleus*. The tuberous roots of *C. forskohlii* are rich in a compound called forskolin which is considered as a drug with potential anti-algal, anti-bacterial, anti-protozoan, anti-fungal and anti-inflammatory properties. Forskolin; a labdane diterpene possess therapeutic value used to treat cancer, psoriasis, asthma, cardiovascular diseases and
hypertension (Kavitha et al., 2010). It is also used to treat eczema, insomnia, painful urination, congestive heart failure, convulsions and respiratory disorders. It possesses anti-inflammatory properties used to treat tumor metastases and thromboembolic platelet disorders of certain cancers. It prevents cancer and relaxes smooth muscles by activating the enzyme adenylate cyclase and by increasing the intracellular cAMP levels prevents the release of histamine, platelet aggregation, degranulation of mast cells and basophils, lowers intraocular pressure and blood pressure, stimulates the breakdown of lipids in fat cells and promotes the secretion of thyroid hormone, bronchodilation and vasodilation. Forskolin stimulates cAMP, regulates hormones, enzymes, biological activities and also acts as a secondary messenger for intracellular signal transduction. The decrease in the level of cyclic AMP leads to the development of disease (Reddy et al., 2005) as it plays a major role of maintaining the body’s basal metabolic rate, regulates the body’s thermogenic response to food and also increases the body’s fat utilization. Body fat can be controlled when forskolin is used in combination with hydroxycitric acid (Gupta 2004).

The compound forskolin has an ability to activate all the nine different types of adenylate cyclase enzymes present in humans except type 9 enzyme present in spermatozoa (Iwatsubo et al., 2003). The compound forskolin present in the roots of Coleus forskohlii was first discovered in the year of 1974 initially termed as “coleonol”. After further studies, the name coleonol changed to forskolin due to the identification of diterpenoids along with the other coleonols (Saksena et al., 1985). The absence of forskolin in the roots of other species of Coleus like C. blumei, C. canisus, C. spicatus, C. parviflorus, C. amboinicus, C. malabaricus etc... was reported (Shah et al., 1980). Forskolin inhibits the transport of glucose in various cells, platelets, adipocytes and in erythrocytes (Mills et al., 1984), produce independent cyclic AMP effects by modulating the receptor channel of nicotinic acetylcholine, voltage dependent potassium channels and the reversal of resistance against multiple drugs (Morris et al., 1991). The root extracts of Coleus forskohlii is used to treat skin infections, also used to kill worms in the stomach. C. forskohlii used widely for curing several disorders like intestinal disorders, respiratory disorders, heart diseases, asthma, bronchitis, convulsions, insomnia, burning sensation, epilepsy and constipation (Ammon and Muller 1985). C. forskohlii is found to be effective in treating obesity, congestive heart failure, hypertension, psoriasis, glaucoma, asthma,
depression and cancer metastasis. Apart from the medicinal value of this plant, *forskohlii* also contains essential oils used in the food industries as flavoring agents, and as an anti-microbial compound (Chowdhary and Sharma 1998). Oil extracted from *Coleus forskohlii* possesses antimicrobial property used to treat acne effective against the causative organism *propionibacterium acne* (Barkat et al., 2012). Many researchers reported the effective antimicrobial activity against several microbes, effective in inhibiting the growth of pathogens responsible for skin infections and eruptions. *C. forskohlii* is found to be effective against yeast (Majeed and Prakash 2007). The high antioxidant activity and high amounts of flavones, flavanols and polyphenols were reported in the leaf extracts of *Coleus forskohlii* compared to other species (Rasineni et al., 2008). The major constituents reported in the essential oil of *C. forskohlii* root are sesquiterpene hydrocarbon (7.5%), β-sesquiphellandrene (13.15%), γ-eudesmol (12.5%), 3-decanone (7%) and bornyl acetate (15%) (Misra et al., 1994). α-pinene, α-copaene, β-phellandrene, caryophyllene oxide, limonene, α-humulene and β-caryophyllene are the major compounds identified in the stem of *C. forskohlii* (Kerntopf et al., 2002).

### 2.5 PHYTOCHEMISTRY OF COLEUS SPECIES

Plants contain several bioactive compounds or secondary metabolites occur either single or in combination with different polarity. The identification, separation and characterization of these compounds remain to be a big challenge. Thin layer chromatography, high performance liquid chromatography, sephadex chromatography, flash chromatography and column chromatography are some of the techniques used to analyse the compounds present in the plant extracts (Krishnananda et al., 2017). The structural and the biological activity of compounds can be further determined using the techniques of GC-MS and NMR.

*C. aromaticus* contains a large number of bioactive compounds with potential antimicrobial and antioxidant potential. The presence of compounds like carvacrol (13.25%), γ-terpinolene (3.75%), pinene (2.50%), β-caryophyllene (4.20%), methyl eugenol (2.10%), 1,8-cineole (5.45%), eugenol (4.40%), phellandrene (1.90%) and thymol (41.3%) were reported in the essential oil of *C. aromaticus* (Baslas et al., 1981). The important compounds like 3-hexadiene (0.1%); (Z)-3-hexenol (0.6%); (E,Z) farnesene (0.2%); (E,E) farnesene (0.2%) and murolene (0.2%)and (Z)-1 were
identified in this plant (Prudent et al., 1995). 26 different compounds were identified by GC-MS analysis from the leaf extracts of C. aromaticus extracted using hexane, steam distillation and supercritical fluid extraction (Pino et al., 1996). C. aromaticus contains a major compound called Rosmarinic acid responsible for the radical scavenging activity (Kumaran and Karunakaran 2007). The compound eucalyptol was isolated by the method of solid phase micro extraction and steam distillation from the leaves of C. aromaticus (Knab et al., 2009). The antioxidant activity of C. aromaticus is due to the presence of rosmarinic acid, caffeic acid, chlorogenic acid, flavonoids and carvacrol (Palani et al., 2010, Rasineni et al., 2008). The presence of compounds namely Eudesma-4 (14), 11-diene, Squalene, phytol and 1,2-Benzene diol 4-(1,1 dimethyl ethyl) was reported from the acetone extracts of C. aromaticus responsible for the antimicrobial activity (Jasmine and Selvi 2013).

The diterpenoids forskolin, deactylforskolin, 9–deoxyforskolin, 1,9-deoxyforskolin and 1,9-dideoxy-7-deacetylforskol were identified in the root extracts of Coleus forskohlii (Saleem et al., 2006). 14-deoxycoleon U, demethylcryptojaponol, α -amyrin, betulic acid, α -cedrol and β –sitosterol compounds were identified from the root extracts of C. forskohlii (Xu et al., 2005). Shen and Xu, 2005 identified two new compounds namely forskolin I and J which are diterpenoids. The major components responsible for the biological properties were identified to be β-cadinene, citronellal, two labdane derivatives, β-citronellol and α-cedrene (Murugesan et al., 2012).

By using the techniques of GC-MS and GLC, 13 terpene hydrocarbons and 7 oxygenated compounds were identified in the essential oil of C. amboinicus (Pino et al., 1989). The major compounds like thymol, carvacrol, 1,8-cineole, spathulenol, terpine-4-ol and p-cymene were identified in the essential oil of C. amboinicus (Singh et al., 2002). The three flavones namely crisimaritin, salvigenin and chrysoeriol were isolated from the leaves of C. amboinicus using silica gel chromatography (Ragasa et al., 1999).

The presence of phytochemicals used for the traditional medicine preparation was also reported in the other Coleus species; Coleus barbatus and Coleus zeylanicus. The main constituents reported in the essential oil of Coleus zeylanicus were δ-cadinene, α-Terpineol, geraniol, hexane, octane and nerol derivatives (Thoppil 1993,
Jirovetz et al., 1998). Flavonoids and diterpenes were some of the compounds identified in the species *Coleus barbatus* (Jaslin and Padmaja 2011, Arihara et al., 1977, Cameron et al., 1943).

### 2.6 BIOLOGICAL ACTIVITIES OF COLEUS SPECIES

The free radical scavenging activity was reported in three *Coleus* species; *Coleus zeylanicus*, *Coleus forskohlii* and in *Coleus aromaticus* (Rasineni et al., 2008). He stated that the content of polyphenols and the antioxidant activity was high in the species of *C. forskohlii* compared to *C. zeylanicus* and *C. aromaticus*. The antioxidant activity of leaf, stem, tubers and roots of *C. forskohlii* was reported (Khatun et al., 2011). The enzymatic antioxidants like catalase, polyphenol oxidase, peroxidase and superoxide dismutase was found to be high in the tubers of *C. forskohlii* compared to the other parts of the plant. Apart from the antioxidant potential, *Coleus* species extracts and volatile oils also exhibit antimicrobial potential against several pathogenic microbes. The essential oils of *C. zeylanicus* and *C. aromaticus* was tested against the strains of *Fusarium solani*, *Candida albicans*, *Alternaria brassicicola*, *Aspergillus niger*, *A. parasiticus*, *Rhizoctonia oryzae*, *Colletotrichum musae*, *Pseudomonas aeruginosa*, *Xanthomonas campestris*, *Bacillus megaterium*, *B. subtilis*, *Escherichia coli* and *Proteus vulgaris* in which *C. zeylanicus* showed higher antimicrobial activity compared to *C. aromaticus* (Deena et al., 2002). The presence of compounds carvacrol and βcaryophyllene-4, 5-oxide in *Coleus amboinicus* was found to be responsible for the antimicrobial activity against the strains of *Cladosporium cucumerinum*, *Pseudomonas fluorescens* and *Bacillus subtilis* (Vasquez et al., 2004). The antifungal activity of *Coleus barbatus* and *Coleus forskohlii* extracts against the strains of *Candida albicans*, *Proteus vulgaris*, *Aspergillus fumigatus* and *Aspergillus niger* was reported (Nilani et al., 2006). The anti-inflammatory activity of aqueous leaf extracts of *Coleus aromaticus* and the methanol, chloroform and hexane extracts of *Coleus forskohlii* were reported (Begum et al., 2009, Menon and Latha 2011). The leaves of *Coleus aromaticus* possess antiurolithiatic activity effective in reducing the deposition of calcium oxalate stones in the kidney and urinary tract (Venkatesh et al., 2010). The anthelmintic activity and the antioxidant activity of stem, leaf and root alcoholic extracts of *Coleus amboinicus* was reported (Prasenjit et al., 2011). The anti-convulsant and antiepileptic activity of leaf, stem and root extracts of *Coleus amboinicus* was reported (Kumari et al., 2012).
The present study provides the importance of *Coleus* in health care and the benefits of *Coleus* cultivation. Screening of different *Coleus* species and their extracts is necessary for the isolation, identification and the characterization of bioactive compounds responsible for various biological activities. The isolated novel metabolite from *Coleus* species is characterized using the techniques of NMR and GC-MS for the structural elucidation. The study of their mechanism of action gives valuable information for the development of drugs to enhance the treatment against dreadful diseases.

### 2.7 OBJECTIVES OF THE STUDY

The major objective of the present study is to determine the physiological and biochemical responses of five different *Coleus* species subjected to salinity stress with special emphasis on the isolation and characterization of the bioactive compounds up regulated under salinity stress. The broad objectives of the investigation are:-

- To study the effect of salt stress on physiology of five different *Coleus* species in response to salinity stress.
- *In-vitro* antimicrobial study of root, stem and leaf extracts of five different *Coleus* species subjected to salinity stress.
- Screening and quantification of secondary metabolites in five different *Coleus* species under salinity stress.
- Extraction, isolation and characterization of novel compound from *Coleus zeylanicus* subjected to salinity stress.
- Extraction of essential oil from *Coleus zeylanicus* plant under normal and salinity stress conditions. Determination of antimicrobial and antioxidant properties of essential oils isolated from *Coleus zeylanicus* plant under normal and salinity stress conditions.
- Extraction & identification of bioactive compounds from *Coleus forskohlii* root using conventional and supercritical fluid extraction methods.
REFERENCES


