2. REVIEW OF LITERATURE

The uses of traditional medicinal plants for primary health care have steadily increased worldwide in recent years. Scientists are in search of new phytochemicals that could be developed as useful antimicrobials for treatment of infectious diseases. Currently, out of 80 per cent of pharmaceuticals derived from plants, very few are now being used as antimicrobials. Plants are rich in a wide variety of secondary metabolites that have antimicrobial properties. Isolation and characterization of pharmacologically active compounds from medicinal plants continue today. Natural products discovered from medicinal plants (and derivatives thereof) have provided numerous clinically used medicines (Balunas and Kinghorn, 2005). The plants in their crude form show interesting combination of activities and there is a huge potential of medicinal plants not only as a source of new drugs but also their use in the form of botanicals both in developing countries and the industrialized world (Gilani and Rahman, 2005). Scientific evidence to prove the rationale of using the traditional formulations in health care is essential to develop and to preserve the cultural heritage.

2.1. MICROBIAL INFECTIONS

Microbial infections are the cause of a large burden of diseases and bacteria are listed in the first position among the common microorganisms responsible for opportunistic diseases. The incidence
of fungal infections and inflammatory-related diseases has increased during the last decades. The difficulties encountered in their treatment, increase in drug resistance, side effects of conventional medication and treatment costs justify the development of new effective, less toxic and cheaper drugs. Therapy of bacterial infections is a frequent problem due to the emergence of bacterial strains resistant to numerous antibiotics (Keasah et al., 1998; Marimoto and Fujimoto, 1999).

2.2. SIGNIFICANCE OF MEDICINAL PLANTS

Medicinal plants have occupied a distinct place in the human life right from the primitive period. They form the backbone of traditional medicine in the last few decades and have been the subject of very intense pharmacological studies. These also represent a valuable resource for a variety of chemicals or secondary metabolites of pharmaceutical importance. It has been estimated that out of about 2000 drugs that have been used in curing human ailments in India, only about 200 are of animal origin and a similar number are of mineral origin. The rest, i.e., about 1500 are of plant origin (Srinivasan et al., 2001).

The World Health Organization (WHO) estimated that about 80 per cent of the population of developing countries relies on traditional medicines, mostly plant drugs, for their primary health care needs (WHO, 2002). In many countries such as India and China, where thousands of tribal communities still use folklore medicinal plants today to cure sicknesses. The great interest in the use
and importance of Indian medicinal plants by the World Health Organisation in many developing countries has led to intensified efforts on the documentation of ethnomedical data of medicinal plants (Dhar et al., 1968; Waller, 1993). It is a necessity from the scientific point of view, to establish a rational relationship between chemical, biological and therapeutical activities of folklore medicine (Levin, 1976; Coley and Aide, 1991; Gentry, 1993).

Plants are considered not only as dietary supplement to living organisms but also traditionally used for treating many health problems. Medicinal values of many plants still remain unexplored for its innumerable activities of compounds responsible for curable diseases. Yet, plant materials remain important resources to combat serious diseases of the world. Pharmacognostic investigations of plants are carried out to find novel drugs or templates for the development of new therapeutic agents (Koing, 1992). Various medicinal plants have been used for years in daily life to treat diseases all over the world. Interest in medicinal plants reflects the recognition of the validity of many traditional claims regarding the value of natural products in healthcare (Nair et al., 2005).

Plant materials remain as an important resource to combat serious diseases in the world. The traditional medicinal methods, especially the use of medicinal plants still play a vital role to cover the
basic health needs in the developing countries. The medicinal value of these plants lies in some chemical active 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 (Edeoga et al., 2005).

All plant parts synthesize some chemicals within themselves, which metabolize their physiological activities. These phytochemicals were used to cure the disease in herbal and homeopathic medicines. Now-a-days most of the people like to use the traditional methods to cure general diseases (Mahajan et al., 1996).

In India, the use of different parts of several medicinal plants to cure specific ailments has been in vague from ancient times. The indigenous system of medicine namely Ayurveda, Siddha and Unani have been in existence for several centuries. These systems of medicine cater the needs of nearly 70 per cent of our population residing in the villages. In Homeopathy system, 70 per cent of the medicines are prepared from plants. As Homeopathy originated in Europe, naturally, majority of the drugs prepared from plants are of exotic origin (Khan and Chaghtai, 1982).

In recent years, many possible sources of natural antibiotics have been in use for several infectious diseases, mostly bacteria and
fungi. In view of this, the searches for new anti-microbial agents from medicinal plants are even more urgent in the countries like India where infectious diseases of bacterial origin are not only rampant, but the causative agents are also developing an increasing resistance against many of the commonly used antibiotics (Abebe et al., 2003)

Conservative estimates suggest that about 10 per cent of all flowering plants on earth have at one time, been used by local communities throughout the world but only one per cent have gained recognition by modern scientists. There are about 120 plant-based drugs prescribed worldwide and they come from just 95 plant species. Approximately, out of 2,50,000 species of flowering plants only 5000 have had their pharmaceutical potential assessed. There are many published reports on the effectiveness of traditional herbs against Gram-positive and Gram-negative bacteria and as a result, plants are still recognized as the bedrock for modern medicine to treat infectious disease (Evans et al., 2002).

Current research on natural molecules and products primarily focuses on plants since they can be sourced more easily and be selected based on their ethno-medicinal uses (Arora and Kaur, 2007). During the last two decades, the development of drug resistance as well as the appearance of undesirable side effects of certain antibiotics (Okemo et al., 2003) has lead to the search of new antimicrobial agents
mainly among plant extracts with the goal to discover new chemical structures, which overcome the above disadvantages (Bouamama et al., 2006).

Over the past twenty years, there has been a lot of interest in the investigation of natural materials as sources of new antibacterial agents (Fabry et al., 1998; Perumalsamy and Ignacimuthu, 2000). Until natural products have been approved as new antibacterial drugs, there is an urgent need to identify novel substances active towards highly resistant pathogens (Recio et al., 1989; Cragg et al., 1997). Although hundreds of plant species have been tested for antimicrobial properties, the vast majority have not yet been adequately evaluated (Tshikalange et al., 2005; Dalmarco et al., 2010). Due to indiscriminate use of antimicrobial drugs, the microorganisms have developed resistance to many antibiotics. This has created immense clinical problems in the treatment of infectious diseases (Duarte et al., 2005). In addition to this problem, antibiotics are sometimes associated with adverse effects on host, which include hypersensitivity, depletion of beneficial gut and mucosal bacteria, immune suppression and allergic reactions (Al-Jabri, 2005).

From over 3,00,000 species of higher plants to occur in nature, only about 2 per cent have been screened so far. Extracts of plants from 157 families have been reported to be active against microorganisms (Lakshmanan and Sankaranarayanan, 1990). Discovery of active principles in plants have given credence to the idea that integration of traditional
medicine into the health care delivery would be very promising and should therefore be encouraged. Several medicinal plants have been screened for their activity on different species of microorganisms (Ibrahim and Osman, 1995; Chandrasekaran and Venkatesalu, 2004a). Plants in most developing countries, as a basis for promoting and maintenance of good health has been widely recognized (UNESCO, 1996).

There is increasing development of drug resistance in human pathogens as well as the appearance of undesirable side effects of certain synthetic antimicrobial agents. It is the background that necessitated the need for the extensive and intensive screening of plants for more safe, selective and efficacious natural products. Plants have been used in developing countries as alternative treatments to cure diseases. Many plant extracts and essential oils isolated from plants have shown to possess biological activity in vitro and in vivo, which justifies research on plant based medicine focused on the characterization of antimicrobial activity of the plants (Shinde et al., 2009).

The use of medicinal plants in disease treatment and prevention can also be seen as prehistoric and their present use can be supported by the traditional optimization of their application in disease control. Medicinal uses of plants range from the administration of the roots, barks, stems, leaves and seeds to the use of extracts and decoction from the plants (Ogbulie et al., 2007).
In developing countries where medicines are quite expensive, investigation on antimicrobial activities from ethno medicinal plants may still be needed. It is on this basis that researchers keep on working on medicinal plants in order to develop the best medicines for physiological uses (Usman et al., 2007).

Consumers are also concerned about the safety of foods containing synthetic preservatives. Therefore, there has been an increasing interest in the development of new types of effective and nontoxic antimicrobial compounds. There is growing interest in using natural antibacterial compounds, such as extracts of spices and herbs for food preservation (Smid and Gorris, 1999). The antimicrobial activities of plant extracts form the basis for many applications, including raw and processed food preservatives, pharmaceuticals, alternative medicines and natural therapies (Lis-Balchin and Deans, 1997). Many studies have reported that phenolic compounds in spices and herbs significantly contributed to their antioxidant and pharmaceutical properties (Cai et al., 2004; Shan et al., 2005; Wu et al., 2006).

Being natural foodstuffs, spices and herbs appeal to many consumers who question the safety of synthetic food additives. Some spices and herbs used today are valued for their antimicrobial activities and medicinal effects in addition to their flavor and fragrance qualities. The extracts of many plant species have become
popular in recent years and attempts to characterize their bioactive principles have gained momentum for varied pharmaceutical and food processing applications. Some studies claim that the phenolic compounds present in spices and herbs might also play a major role in their antimicrobial effects (Hara-Kudo et al., 2004). There has been no large scale systematic investigation on the relationship between bacterial inhibition and total phenolic content of spices and herbs.

The development of antibiotic resistance is multi-factorial, including the specific nature of the relationship of bacteria to antibiotics, how the antibacterial is used, host characteristics and environmental factors. To overcome the problem of antibiotic resistance, medicinal plants have been extensively studied as alternative treatments for diseases. The use of medicinal plants to treat human diseases has its roots in pre-historical times.

In the recent years, research on medicinal plants has attracted a lot of attentions globally. Large number of evidences have accumulated to demonstrate the promising potential of medicinal plants used in various traditional, complementary and alternate systems of treatment of human diseases (Sher, 2009). Medicinal plants have been used for centuries as remedies for human diseases because they contain components of therapeutic value. Recently, some higher plant products have attracted the attention of microbiologists to search for some
phytochemicals for their exploitation as antimicrobials, such plant products would be biodegradable and safe to human health (Kumar et al., 2008; Wang et al., 2010). The acceptance of traditional medicine as an alternative form of health care hassled researchers to further investigate antimicrobial activity of medicinal plants.

2.3. PLANTS SELECTED FOR THE PRESENT STUDY

2.3.1. Cassia alata (New Name: Senna alata)

*Senna alata* (*Cassia alata*) Linn. (Caesalpiniaceae) is an ornamental shrub, which grows well in forest areas of West Africa. The plant has been widely employed for combating dysentery, helminthic infections and stomach disorders. In Ghana and Nigeria, the decoctions of the fresh leaves, roots and seeds have been used for the treatment of wound infections, bronchitis and asthma as well as ring worm and other infectious skin diseases (Palanichamy and Nagarajan, 1990). The leaves have been reported to be useful in the treatment of convulsions, gonorrhea, heart failure, abdominal pains, oedema and also as a purgative (Ogunti and Elujoba, 1993).

2.3.2. Cassia auriculata (New Name: Senna auriculata)

*Cassia auriculata* belonging to Caesalpiniaceae is a common plant in Asia, profoundly used in Ayurvedic medicine as a tonic,
astringent conjunctivitis and ophthalmia (Joshi, 2000) and it is used in
the treatment of diabetes to control blood sugar level (Brahmachari
and Agusti, 1961). It has many medicinal properties. Its bark is used
as an astringent, leaves and fruit are antihelminthic, seeds are used
to treat in eye troubles and root is employed in skin diseases (Siva and
Krishnamurthy, 2005). The flowers of the plant are used in the
preparation of tea, which is prescribed in diabetes. Compound syrup
is prepared with the flowers, mocharas and Indian saparilla which are
prescribed for nocturnal emissions. The seeds are used in diabetes,
ophthalmia and chylous urine (Kirthkar and Basu, 1965). The plant
has been reported to have antibacterial and microbicidal activity
(Perumalsamy and Ignacimuthu, 2000).

2.3.3. *Cassia fistula*

*Cassia fistula* L. (Caesalpiniaceae), a semi-wild Indian Labernum
(also known as the Golden Shower), is distributed in various countries
including Asia, South Africa, Mexico, China, West Indies, East Africa
and Brazil. It is an ornamental tree with beautiful bunches of yellow
flowers (Duraipandiyan and Ignacimuthu, 2007). This plant is widely
used by tribal people to treat various ailments including ringworm and
other fungal skin infections (Rajan *et al.*, 2001). *C. fistula* exhibited
significant antimicrobial activity and showed properties that support
folkloric use in the treatment of some diseases as broad-spectrum
antimicrobial agents (Kumar et al., 2006). *C. fistula* plant parts are known to be an important source of secondary metabolites, notably phenolic compounds.

**2.3.4. Cassia tora (New Name: Senna tora)**

*Cassia tora* Linn (family: Caesalpiniaceae) is a shrub, extensively used in traditional medicine in tropical and warm subtropical countries. The root is used in snakebite. The decoction of the leaves is a laxative. The leaves and the seeds are used in skin diseases, particularly ringworm and itch. The dried and fresh leaves are used in northern Nigeria in the treatment of ulcers, ringworm and other parasitic skin diseases. In cultures, the leaf extracts of the plant showed anti-bacterial activity, antiviral activity, particularly against Newcastle disease virus and Vaccinia virus (Ahmad et al., 1998).

The resistance to antimicrobial agents has become increasingly important and pressing global problem, increasing the effort for the identification of new sources of antimicrobial substances, in particular plant secondary metabolites. Therefore, actions must be taken to reduce this problem of controlling the use of antibiotics and distinct need for discovery of alternative new, safer and more effective antibacterial and antifungal agents from the selected medicinal plants.
2.4. ANTIMICROBIAL PROPERTIES OF Cassia SPECIES

Antibacterial activity of plants used in the traditional medicines of Ghana with particular reference to Methicillin-Resistant Staphylococcus aureus was studied and it was found that Cassia occidentalis possessed significant antibacterial activity (Kudav and Kulkarni 1974).

The leaf extract of Cassia occidentalis when tested against different pathogenic bacteria was found to be active against Salmonella enteritidis and Staphylococcus aureus while a negative effect was observed against E. coli and Shigella dysenteriae (Muanza et al., 1993).

Ethanolic extract of Cassia alata was investigated for its antimicrobial activities on several microorganisms including bacteria, yeast, dermatophytic fungi and non-dermatophytic fungi and the extract exhibited antimicrobial activity against various species of dermatophytic fungi, Trichophyton mentagrophytes var. interdigitale, T. mentagrophytes var. mentagorophyte, T. rubrum, Microsporum gypseum and Microsporum canis but low activity against non-dermatophytic fungi (Ibrahim and Osman, 1995).

Jain et al. (1998) examined that the ethanolic extract and metabolite rich fractions of different parts of Cassia occidentalis were examined and it was observed that anthraquinones were more effective
against *Escherichia coli* and *Staphylococcus aureus* while sennosides were more effective against *Aspergillus flavus*.

Somchit *et al.* (2003) studied the crude ethanol and water extract of leaves and barks from *Cassia alata* against fungi, *Aspergillus fumigatus* and *Microsporum canis*, yeast, *Candida albicans* and bacteria, *Staphylococcus aureus* and *Escherichia coli*.

Methanolic, ethanolic and petroleum ether extracts of *Senna alata* leaves were screened for antimicrobial activity against bacteria *viz.*, *Escherichia coli*, *Bacillus subtilis*, *Salmonella typhi*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and fungi *viz.*, *Mucor* sp., *Rhizopus* sp., *Aspergillus niger*, *Candida albicans* and *Saccharomyces* sp. The methanolic extract was most active than the other crude extracts (Owoyale *et al.*, 2005).

The aqueous extract of *Ocimum sanctum*, *Piper betle*, *Acalypha indica*, *Jatropha curcas* and *Cassia auriculata* were screened for microbicidal activity and clinical experiments were conducted in birds with infection, against poultry pathogen, *Escherichia coli*. In which, *Cassia auriculata* have more potential effects than the other (Prakash, 2006). Saganuwan and Gulumbe (2006) reported that the leaves of *Cassia occidentalis* extracts obtained in different solvents showed high antimicrobial activity on *Escherichia coli*. However, *E. coli* was found
to be most susceptible to a hexane extract but there was no antimicrobial activity against other tested microorganisms, *Pseudomonas multocida*, *Salmonella typhi*, *S. typhimurium*, *Streptococcus pyogenes* and *S. pneumoniae*.

Idu *et al.* (2007) reported that the water, methanol, chloroform and petroleum ether extracts of *Senna alata* leaves showed antibacterial activity against clinical isolates of *Staphylococcus aureus*, *Candida albicans*, *Escherichia coli*, *Proteus vulgaris*, *Pseudomonas aeruginosa* and *Bacillus subtilis*.

The aqueous flower extract of *Cassia alata* showed potent antifungal activity against *Aspergillus flavus*, *A. parasiticus*, *Fusarium oxysporum*, *Helminthosporium oryzae*, *Candida albicans* and *Microsporum audouinii* (Abubacker *et al.*, 2008). The water, methanol and chloroform extracts of leaf and root of *Cassia alata* were phytochemically screened for antibacterial activity against *Escherichia coli*, *Staphylococcus aureus*, *Proteus mirabilis*, *Pseudomonas aeruginosa* and *Streptococcus pyogenes* (El-Mahmood and Doughari, 2008). The water extract of *Cassia alata* leaves was screened for antifungal activity against *Sclerotium rolfsii* and that leaves extract reduced the growth of tested fungi (Eunice *et al.*, 2008).

*Senna alata* leaf powder extracts were screened for antifungal activity against *Trichophyton rubrum*, *T. mentagrophytes*,
Microsporum gypseum and Epidermophyton floccosum, which showed the strongest inhibition against T. mentagrophytes (Nantachit, 2009). Chitravadivu et al. (2009) proved the antibacterial activity of leaves and roots of Cassia auriculata against Escherichia coli, Proteus vulgaris, Staphylococcus aureus and Bacillus subtilis.

The crude extracts of leaves of five medicinal plants viz, Aegle marmelos, Chloris virgata, Collinsonia anisata, Feronia limonia and Cassia auriculata were screened for antimicrobial property against Escherichia coli, Salmonella typhi, Proteus mirabilis and Klebsiella pneumoniae (Senthilkumar and Reetha, 2009). The methanol extracts of Aegle marmelos and Cassia auriculata exhibited higher antibacterial activity. The alcoholic and aqueous extracts of stem bark of Cassia fistula were screened for antibacterial activity against Staphylococcus aureus, Bacillus subtilis, Escherichia coli, Pasteurella multocida and Salmonella typhi. Alcoholic extract showed greater inhibition against Staphylococcus aureus when compared to aqueous extract (Vimalraj et al., 2009).

The antibacterial properties of the Cassia auriculata were tested against two Gram-positive bacteria, Enterococcus faecalis and Staphylococcus aureus and eight Gram-negative bacteria, Escherichia coli, Klebsiella pneumoniae, Proteus vulgaris, Pseudomonas aeruginosa, Salmonella typhi, S. paratyphi, Shigella boydii and Vibrio cholerae
by using different solvents namely hexane, chloroform, ethyl acetate, acetone and methanol. The highest antibacterial activity was recorded in methanol extracts against *Vibrio cholerae* and *Staphylococcus aureus*. The lowest activity was noted in chloroform extracts against *Pseudomonas aeruginosa* and no inhibition zone was present in chloroform extract against *E. coli* (Anushia *et al.*, 2009).

The methanol extract of root of *Cassia tora* was screened for antimicrobial activity against *Escherichia coli* and *Bacillus subtilis*. The maximum activity was shown against *B. subtilis* (Dave *et al.*, 2010). Thambidurai *et al.* (2010) screened the methanol extract of leaves, flower and fruits of *Cassia auriculata* for antimicrobial activity against *Bacillus aerogenes, B. coagulans, B. subtilis, Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae, Aspergillus flavus, Candida albicans* and *Trichoderma lignorum*.

Shihabudeen et al. (2010) evaluated the methanol extracts of *Eugenia jambolana*, *Cassia auriculata*, *Murraya koenigii*, *Salvadora persica*, * Ipomoea batatas* and *Andrographis paniculata* for antimicrobial activity against *Staphylococcus aureus*, *S. epidermis*, *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Candida albicans* and *Aspergillus niger*. Among the tested species, *Eugenia jambolana* and *Cassia auriculata* showed the highest antimicrobial activity. The methanol extract of *Cassia fistula* seeds showed antimicrobial activity against *Staphylococcus aureus*, *Bacillus thuringiensis*, *Escherichia coli*, *Salmonella* sp. *Micrococcus* sp. *Bacillus subtilis*, *Candida albicans* and *Aspergillus niger* (Lachumy et al., 2010).

Flower extracts of *Cassia auriculata* were screened for antibacterial activity against *Staphylococcus aureus*, *Enterococcus faecalis*, *Bacillus subtilis*, *Salmonella typhii*, *Salmonella paratyphii*, *Escherichia coli*, *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Vibrio cholerae* and *Shigella dysenteriae* in which maximum activity was observed against all organisms except *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* (Maneemegalai and Naveen, 2010).

Crude stem bark extract of *Senna alata* exhibited the antifungal activity against *Microsporum canslaslomyces*, *Trichophyton verrucosum*, *T. mentagrophytes* and *Epidermophyton floccosum* (Sule et al., 2011). The acetone extract of leaves of *Cassia auriculata* and antimicrobial
agents like Chlorhexidine, S-Flo and amoxicillin were screened against human salivary microflora. The results proved that acetone extract of *Cassia auriculata* possessed antimicrobial activity equivalent to the antimicrobial agents against human salivary microflora (Deshpande *et al.*, 2012).

Mane *et al.* (2011) reported that the water, methanol, petroleum ether extract and their acid and non acid content of extracts of the leaves, pods and bark of *Cassia fistula* were screened for antibacterial activity against *Escherichia coli*, *Staphylococcus aureus*, *Bacillus subtilis* and *Pseudomonas aeruginosa*. All the extracts, acid and non-content of extracts exhibited antibacterial activity against all the bacterial species tested.

Bhalodia *et al.* (2011) investigated the chloroform extract of *Cassia fistula* seeds against *Staphylococcus aureus*, *Streptococcus pyogenes*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Aspergillus niger*, *A. clavatus* and *Candida albicans*, which showed remarkable inhibition of the bacterial growth against the tested organisms.

Muthukumaran *et al.* (2011) evaluated the *in vitro* antimicrobial activity of crude extracts of *Cassia auriculata* and *Morinda tinctoria* against *Escherichia coli*, *Staphylococcus aureus*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Candida albicans*, *Candida tropicalis* and *Aspergillus niger*. Both the plant extracts showed inhibitory effect on tested
organisms. The extract of *Cassia auriculata* produced wider zones of inhibition against *Candida* sp. than the crude extract of *Morinda tinctoria*.

The methanol extract of *Cassia auriculata* was screened for antimicrobial activity against *Escherichia coli*, *Salmonella typhi*, *Proteus mirabilis*, *Klebsiella pneumoniae*, *Vibrio cholerae*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Candida albicans*, *C. tropicalis*, *C. krusei*, *Aspergillus fumigatus*, *A. flavus* and *Pencillium* sps. The zone of inhibition of bacteria was maximum against *Vibrio cholerae* followed by *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Proteus mirabilis*, *Pseudomonas aeruginosa* and *Escherichia coli* (Senthilkumar and Reetha, 2011).

Ethanolic and aqueous extracts of *Cassia tora* leaves were screened for antimicrobial activity against *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Bacillus subtilis*, *Aspergillus niger* and *Candida albicans*. Both the extracts exhibited significant antibacterial activity (Chavan et al., 2011). The antibacterial activity of petroleum ether, chloroform, ethyl acetate, methanol and hydro alcoholic extracts of fruits of *Cassia fistula* were screened against *Staphylococcus aureus*, *Streptococcus epidermis*, *Escherichia coli* and *Klebsiella pneumoniae*. Only methanolic extract exhibited antibacterial activity against all the tested bacteria (Neelam et al., 2011).

Muralikrishnan and Venisetty (2012) evaluated the antimicrobial activity of methanol extract of leaves and stem of *Cassia tora* against
Staphylococcus aureus, Bacillus subtilis, Bacillus cereus, Klebsiella pneumoniae, Escherichia coli, Salmonella paratyphi, Aspergillus niger and Candida albicans. Among the bacterial strains, S. aureus and K. pneumoniae exhibited the highest susceptibility. Amerasan et al. (2012) reported the adulticidal and repellent activities of crude hexane, chloroform, benzene, acetone, and methanol extracts of the leaf of Cassia tora against three important vector mosquitoes, viz., Culex quinquefasciatus, Aedes aegypti and Anopheles stephensi. The highest adult mortality was found in methanol extract.

The dried leaves and stem bark of dichloromethane and methanol extracts of Ficus carica and Cassia fistula were screened for antibacterial and antifungal activity against bacteria viz., Escherichia coli, Pseudomonas aeruginosa, Bacillus subtilis and Staphylococcus aureus and fungi viz., Aspergillus flavus and Fusarium solani. C. fistula leaves and stem bark methanol extracts showed significant antifungal activity against A. flavus and Fusarium solani (Azam et al., 2013).

Akthar et al. (2014) reported that the aqueous, ethanol, methanol and petroleum ether extracts of leaves of Piper nigrum and Cassia didymobotrya were screened for antimicrobial activity against bacteria viz., Staphylococcus aureus, Escherichia coli, Salmonella typhimurium and Pseudomonas aeruginosa, fungi viz., Aspergillus sp. and Candida albicans.
Methanol leaf extracts of both the plants exhibited greater antimicrobial activity against the tested microorganisms.

The crude extracts of leaf and stem bark of *Cassia siamea* were studied against *Escherichia coli*, *Salmonella typhi* and *Staphylococcus aureus* (Usman et al., 2014). Hossain et al. (2014) reported that the petroleum ether and methanol extracts of *Cassia renigera* were screened for antimicrobial activity against *Bacillus megaterium*, *B. subtilis*, *B. cereus*, *Staphylococcus aureus* and four Gram-negative, *Escherichia coli*, *Salmonella typhi*, *Shigella dysenteriae* and *Proteus mirabilis*. Methanol extract showed better activities than the petroleum ether extract.

The silver nanoparticles were synthesized from five common medicinal plants *viz.*, *Cassia auriculata*, *C. alata*, *C. occidentalis*, *C. roxburghii* and *Caesalpinia pulcherrima* and their particles were screened for antibacterial activity against *Shigella boydii*, *S. dysentriae*, *Staphylococcus aureus*, *Klebsiella vulgaris* and *Salmonella typhi*. Among the five plants, *C. auriculata* extract nanoparticles showed the highest activity compared with other four plants based nano particles (De Britto et al., 2014).

**2.5. COMPOUNDS ISOLATED FROM *Cassia* SPECIES**

Luteolin (flavonoid) was isolated as a pure compound from the seeds of *Senna petrisiana* and it showed antiviral and antibacterial
activities against three Gram-positive bacteria, *Bacillus cereus*, *B. pumilus* and *Staphylococcus aureus* (Tshikalange et al., 2005).

A crystal, 4-hydroxy benzoic acid hydrate was isolated from the flowers of *Cassia fistula* and it exhibited antifungal activity against *Trichophyton mentagrophytes* and *Epidermophyton floccosum* (Duraipandiyan and Ignacimuthu, 2007).

Fernand et al. (2008) reported the pharmacologically active compounds i.e., six phenolic compounds, five anthraquinones viz., rhein, aloe-emodin, emodin, chrysophanol and physcion and a flavonoid, kaempferol from the root extracts of *Cassia alata*.

Senthilkumar and Reetha (2011) isolated Oleanolic acid from *Cassia auriculata* and it showed antibacterial potential against different human pathogenic bacteria such as *Escherichia coli*, *Salmonella typhi*, *Proteus mirabilis* and *Klebsiella pneumoniae*.

Bioactive constituent, 4-butylamine 10-methyl-6-hydroxy cannabinoid dronabinol from the seeds of *Cassia alata* successfully inhibited *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Escherichia coli*, *Staphylococcus aureus*, *Candida albicans* and *Aspergillus niger* (Okwu and Nnamdi, 2011). Hydro-methanolic extract of *Cassia alata* and its active constituents, rhein and kaempferol could be potential
alternative treatment for allergic diseases on triple antigen/sheep serum-induced mast-cell degranulation in rats (Singh et al., 2012).

Paul et al. (2013) isolated 3,4-dihydroxy cinnamic acid from the leaves of Cassia alata and that compound possessed antibacterial activity against four Gram-positive strains, Staphylococcus aureus, Bacillus subtilis, B. megaterium and Streptococcus pyogenes as well as four Gram-negative strains, Shigella flexneri, Escherichia coli, Pseudomonas aeruginosa and Salmonella typhi.

The nine compounds viz., α-hydroxyemodin, lunatin, physcion, ziganein, apigenin, 7,4′-dihydroxy-5-methoxyflavone, diosmetin, trans dihydrokaempferol and trans-resveratrol were reported for the first time from Cassia alata. Lunatin exhibited strong antibacterial activity against methicillin resistant Staphylococcus aureus and B. cereus (Promgool et al., 2014). Yadav et al. (2014) reported that the four compounds namely β-sitosterol, lanosterol, campersterol and stigmasterol were isolated from Cassia pumila. β-sitosterol was more active against Staphylococcus aureus, Salmonella typhi, Escherichia coli, Pseudomonas aeruginosa, Aspergillus flavus, A. niger, Fusarium moniliforme and Rhizoctonia bataticola.

A compound, 4-(4′-chlorobenzyl)2,3,4,5,6,7hexahydro7-(2-ethoxyphenyl)benzo [h] [1,4,7] triazecin-8(1H)-one was isolated from
Cassia auriculata leaves. The isolated compound has potent anti-cancer properties against human colon cancer (Esakkirajan et al., 2014).

2.6. BIOLOGICAL PROPERTIES OF CRUDE EXTRACTS OF OTHER MEDICINAL PLANTS

The methanol extracts from 21 plant species were assayed for antimicrobial activity against Bacillus subtilis, Staphylococcus aureus, Streptococcus faecalis, Escherichia coli, Serratia marcescens, Salmonella typhimurium, Pseudomonas aeruginosa, Mycobacterium phlei, Saccharomyces cerevisiae, Candida albicans, Trichophyton mentagrophytes, Microsporum gypseum and Aspergillus fumigatus. All the 21 extracts showed activity against at least 2 bacterial strains and 20 extracts showed activity against at least 2 fungi (Taylor et al., 1995).

Andre Nick et al. (1995) reported that the pet ether, chloroform and methanol extracts of seventeen species of medicinal plants were tested in a preliminary biological screening for their antimicrobial activity against Escherichia coli, Bacillus subtilis, Micrococcus luteus and Penicillium oxalicum and molluscidal activity against Biomphalaria glabrata. Of the 51 extracts tested, 19 showed activity against at least one of the three bacteria. Only five extracts inhibited selectively the growth of the gram-negative strain, E. coli and none of the extracts contained active constituents against the fungus, Penicillium oxalicum.
The antimicrobial activities of 23 extracts of 12 Cuban plant species were reported for antimicrobial activity against *Staphylococcus aureus*, *Bacillus subtilis*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Candida albicans*. The results showed that only nine extracts were active against Gram-positive bacteria but only two of these proved to be also active against Gram-negative bacteria. None of the extracts inhibited the growth of the yeast. The most susceptible bacterium was *Staphylococcus aureus* and the best antibacterial activity was shown by *Schinus terebinthifolius* (Martinez et al., 1996).

Rabe and van Staden (1997) tested the crude extracts from 21 South African medicinal plants against bacterial strains. All the extracts exhibited strong activity against Gram-positive bacteria, 12 of 21 plant species inhibited the growth of *Bacillus subtilis*. Only the *Warburgia salutaris* methanol extract inhibited the growth of *Escherichia coli*. None of the extracts had any activity against *Klebsiella pneumoniae*. The highest activity was found in the methanol extracts from *Bidens pilosa*, *Psidium guajava*, *Artemisia afra* and *Warburgia salutaris*. The majority of the antibacterial activity was present in the methanolic extract, rather than the aqueous extracts.

Valsaraj *et al.* (1997) reported the Indian traditional medicines of 78 plants with different concentrations of 80% ethanol extracts for antimicrobial activity against *Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Candida albicans* and
Aspergillus niger. Ninety per cent of the plant extracts were active against at least two bacteria at a concentration of 25 mg/mL. Only 13 per cent of the plant extracts were active against at least one fungus at a concentration of 50 mg/mL.

Ahmad et al. (1998) reported that the aqueous, hexane and alcoholic extracts of 82 Indian medicinal plants were screened for antimicrobial activity against Bacillus subtilis, Proteus vulgaris, Salmonella typhimurium, Pseudomonas aeruginosa, Escherichia coli and Staphylococcus aureus. Among various extracts, only alcoholic extracts of Emblica officinalis, Terminalia chebula, Terminalia bellerica, Plumbago zeylanica and Holarrhena antidysenterica were found to have potential activity against tested bacteria.

Petroleum ether, ethanol, butanol and aqueous extracts of nine plants viz., Stellaria media, Salvia syriaca, Cardaria draba, Euphorbia prostrata, Rubia tinctorium, Arbutus andrachne, Cyclamen persicum, Ononis spinosa and Bryonia syriaca exhibited variable degrees of antimicrobial activity against Escherichia coli, Salmonella typhimurium, Staphylococcus aureus, Bacillus cereus, Aspergillus flavus, Fusarium moniliforme and Candida albicans. Cyclamen persicum petroleum ether extract only exhibited pronounced antibacterial activity (Mahasneh and El-Oqlah, 1999).

Sindambiwe et al. (1999) reported that EtOH (80%) extracts of seven plants were screened for antimicrobial activity against
Escherichia coli, Klebsiella pneumoniae, Proteus vulgaris, Pseudomonas aeruginosa, Salmonella paratyphi, Bacillus cereus, Mycobacterium fortuitum, Staphylococcus aureus, Streptococcus pyogenes and Candida albicans.

Four plants were diversely active against Gram-positive bacteria, two of these showing bactericidal effect against the acid-fast Mycobacterium fortuitum. None of the selected plants was active against Gram-negative bacteria or the yeast, Candida albicans.

Extracts from 50 plant parts obtained from 39 different plants were screened against twelve microorganisms, bacteria viz., Bacillus cereus, Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae and Salmonella typhimurium, the fungi viz., Aspergillus niger, Candida albicans, and the viruses, Herpes simplex, Vesicular stomatitis, Coxsackie B2 and Semliki Forest A7. The highest activity was obtained for the n-hexane extract of Elaeodendron schlechteranum root bark against the Gram-positive bacteria, Bacillus cereus and Staphylococcus aureus. Gram-negative bacteria were less sensitive. Only Balanites aegyptiaca stem bark exhibited a high antifungal activity against Candida albicans. Extracts from four plants Lannea schweinfurthii, Combretum adenogonium, Ficus sycomorus and Terminalia mollis showed strong antiviral activity with RF values of 103 and 104 against Herpes simplex at various concentrations (Maregesi et al., 2008).
Hernandez et al. (2000) screened *Lippia turbinata, Satureja parvifolia, Sambucus peruviana, Verbena officinalis* and *Chenopodium graveolens* against *Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae, Salmonella enteritidis, Shigella sp., Bacillus subtilis, Staphylococcus aureus* and *Staphylococcus epidermidis. Lippia turbinata, Satureja parvifolia, Sambucus peruviana, Verbena officinalis* and *Chenopodium graveolens* for antimicrobial activity and all the plants possessed antimicrobial activity against the tested microorganisms.

Otshudi et al. (2000) reported that twenty-four crude extracts derived from six medicinal plants were screened for antimicrobial activity against several enteric pathogens, *Shigella dysenteriae, S. sonnei, S. boydii, S. flexneri, Salmonella typhimurium, Escherichia coli, Vibrio parahaemolyticus, V. cholerae, Campylobacter jejuni* and *C. coli*. The results indicated that the methanolic and aqueous extracts derived from *Roureopsis obliquifoliolata, Epinetrum villosum* and *Cissus rubiginosa* possessed prominent antibacterial activity.

Srinivasan et al. (2001) reported that fifty medicinal plants were screened for antimicrobial activity against *Chromobacterium violaceum, Escherichia coli, Enterobacter faecalis, Klebsiella pneumoniae, Proteus mirabilis, Pseudomonas aeruginosa, Salmonella paratyphi, S. typhi, Bacillus subtilis, Staphylococcus aureus, Aspergillus flavus, A. fumigatus, A. niger* and *Candida albicans*. Among 50 plants tested, 72% showed antimicrobial
activity. About 22 plant extracts exhibited activity against both Gram-positive and Gram-negative bacteria. Only nine plant extracts showed antifungal activity. The bulb extracts of *Allium cepa* and *A. sativum* exhibited activity against both filamentous and non-filamentous fungi.

Cos *et al.* (2002) reported that 45 Rwandan plant extracts were screened for antimicrobial and antiviral activities against *Bacillus cereus*, *Enterobacter cloaca*, *Escherichia coli*, *Klebsiella pneumoniae*, *Mycobacterium fortuitum*, *Proteus vulgaris*, *Pseudomonas aeruginosa*, *Salmonella typhimurium*, *Staphylococcus aureus* and *Streptococcus pyogenes*. *Clematis hirsuta* (leaves) showed a pronounced antifungal activity against *Candida albicans*, *Trichophyton rubrum*, *Epidermophyton floccosum* and *Microsporum canis*. Seven plant extracts showed a high antiviral activity against the DNA-virus Herpes simplex type 1, while five and three plant extracts were highly active against the RNA-viruses Coxsackie and Polio, respectively. Only *Macaranga kilimandscharica* (leaves) showed an interesting anti-measles activity, whereas *Eriosema montanum* (leaves) and *Entada abyssinica* (leaves) were highly active against Semliki forest virus. Some plant extracts showed an antibacterial activity against Gram-positive bacteria and *Mycobacterium fortuitum*, but none of them were active against the Gram-negative bacteria tested.
The methanol extract of *Syzygium jambolanum* seeds showed marked inhibitory effects against *Bacillus subtilis*, *Staphylococcus aureus*, *Salmonella typhi*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Escherichia coli*, *Candida albicans*, *Cryptococcus neoformans*, *Aspergillus flavus*, *A. fumigatus*, *A. niger*, *Rhizopus* sp., *Trichophyton rubrum*, *T. mentagrophytes*, and *Microsporum gypseum* (Chandrasekaran and Venkatesalu, 2004a).

Mothana and Lindequist (2005) reported the antimicrobial activity of chloroform, methanol and hot water extracts of twenty-five plants against *Staphylococcus aureus*, *Bacillus subtilis*, *Micrococcus flavus*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Candida maltosa* and three multi-drug resistant *Staphylococcus* strains *viz.*, *Staphylococcus epidermidis*, *Staphylococcus haemolyticus* and *Staphylococcus aureus*. The greatest activity was exhibited by the methanolic extract of *Boswellia elongata*, *Boswellia ameero*, *Buxus hildebrandtii*, *Commiphora parvifolia*, *Jatropha unicostata*, *Kalanchoe farinacea*, *Pulicaria stephanocarpa*, *Punica protopunica*, *Withania adunensis* and *Withania riebeckii*. Only the methanolic extract of *Buxus hildebrandtii* displayed significant antifungal activity.

Methanol, ethanol, acetone and hot water extracts from different plant parts *viz.*, leaves, roots, bark and stem rhizome of *Indigofera daleoides*, *Punica granatum*, *Syzygium cordatum*, *Gymnosporia senegalensis*,
Ozoroa insignis, Elephantorrhiza elephantina, Elephantorrhiza burkei, Ximenia caffra, Schotia brachypetala and Spirostachys africana were screened for antibacterial activity against Vibrio cholerae, Escherichia coli, Staphylococcus aureus, Shigella spp. and Salmonella typhi. The most active extracts were those obtained from Punica granatum and Indigofera daleoides. All extracts from two plants, namely, Punica granatum and Ozoroa insignis were active against all bacterial strains while only organic extracts of Indigofera daleoides inhibited the growth of all tested microorganisms. Water extract of Punica granatum were equally active as organic extracts against bacteria such as Staphylococcus aureus, Shigella sonnei and Shigella flexneri. All extracts of Elephantorrhiza elephantina, Elephantorrhiza burkei and Ximenia caffra and Schotia brachypetala were not active against Escherichia coli and Salmonella typhi (Mathabe et al., 2006).

Al-Fatimi et al. (2007) reported that the dichloromethane, methanol and aqueous extracts of 30 medicinal plants were screened for antimicrobial activities against three Staphylococcus aureus, Bacillus subtilis, Escherichia coli, Pseudomonas aeruginosa, Micrococcus flavus, Candida maltosa and five opportunistic human fungal pathogens (two yeasts, three hyphomycetes). Most of the plants showed antibacterial activities. Extracts from Tamarindus indica flowers and Ficus vasta fruits were active against bacteria. Of the 30 plants
tested, 13 showed antifungal activity (40%) against one or more human pathogenic fungi. The strongest inhibition was exhibited by *Azima tetracantha* (fruits), *Sansevieria ehrenbergii* (fruits) and *Solanum incanum* (fruits).

Dahham *et al.* (2010) reported the antibacterial and antifungal activities of pomegranate (*Punica granatum*) peel extract (rind), seed extract, juice and whole fruit on the selected bacteria and fungi. The peel extract showed the highest antimicrobial activity when compared to the other extracts. Among the selected bacterial and fungal cultures, the highest antibacterial activity was recorded against *Staphylococcus aureus* and among fungi, high activity was against *Aspergillus niger*.

Methanol extracts of six plant species traditionally used in Indian folklore medicine for the treatment of various bacterial and fungal infections were investigated for *in vitro* antimicrobial activity against pathogens namely *Staphylococcus aureus, Staphylococcus epidermidis, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Candida albicans* and *Aspergillus niger*. Methanol extracts of *Eugenia jambolana* and *Cassia auriculata* showed the highest toxicity against all the bacteria. *E. jambolana* revealed the highest antimicrobial activity at a minimum concentration (0.75 mg/mL) against *S. aureus* (Shihabudeen *et al.*, 2010).
Dash et al. (2011) studied the antimicrobial activity of petroleum ether, ethanol, chloroform, n-hexane and water extracts of *Centella asiatica* against *Proteus vulgaris*, *Staphylococcus aureus*, *Bacillus subtilis* and *Escherichia coli* and fungal strains, *Aspergillus niger* and *Candida albicans*. The petroleum ether, ethanol and chloroform extracts of *Centella asiatica* had higher antimicrobial activities than n-hexane and water extracts whereas n-hexane extract showed no activity against *E. coli*.

Faparusi et al. (2012) investigated methanol and ethanol extracts of leaves of *Brillantaisia patula* against *Staphylococcus aureus*, *Enterococcus faecalis*, *Proteus hauseri*, *Pseudomonas aeruginosa* and *Escherichia coli*. The ethanolic extract was active against all five pathogenic bacteria while the methanolic extract inhibited only *Staphylococcus aureus*.

The antibacterial activity of the ethanolic extracts of *Vitex negundo*, *Fragaria vesca*, *Terminalia arjuna* and *Citrus maxima* was studied against *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa*. The ethanolic extracts of *Vitex negundo*, *Fragaria vesca* and *Terminalia arjuna* showed significant activity against *Staphylococcus aureus* (Borah et al., 2012).

Prasannabalaji et al. (2012) evaluated the *in vitro* antibacterial activity of various solvent extracts of South Indian traditional medicinal plants *viz.*, *Ocimum sanctum*, *O. gratissimum*, *Aegle marmelos* and
Adhatoda vasica leaves against clinical pathogens of human origin viz., Escherichia coli, Staphylococcus aureus, Salmonella typhi, S. paratyphi and Klebsiella pneumoniae. The antibacterial results showed that the methanol extracts (0.4 g/mL) of Ocimum gratissimum and Ocimum sanctum showed maximum zone of inhibition against Salmonella typhi. The methanol extracts of Ocimum gratissimum showed higher MIC against Salmonella typhi and S. paratyphi whereas the methanolic extracts of Ocimum gratissimum showed potent activity against Staphylococcus aureus at 0.078 mg/mL. Adhatoda vasica extract showed less activity against the tested pathogens.

The different solvent extracts of leaves of Achyranthes aspera, Aegle marmelos, Cleistanthus collinus, Curcuma aromatica and Strychnos nux-vomica were screened against dermatophytes viz., Trichophyton mentagrophytes, T. rubrum, Microsporum gypseum, M. canis and Epidermophyton floccosum var. nigricans. The results revealed that the ethyl acetate extract of Achyranthes aspera showed the highest zone of inhibition (26.5 mm), the lowest MIC value (7.81 μg/mL) and the lowest MFC value (15.62 μg/mL) against Trichophyton rubrum (Kalaivanan et al., 2013).

A total of 72 plant extracts were tested for their ability to inhibit the mycelial growth of plant pathogen, Lasiodiplodia theobromae and Colletotrichum musae. The results showed that the leaf extract of
Zimmu (hybrid of *Allium cepa* and *Allium sativum*) and tuber extract of *Zehneria scabra* recorded maximum inhibition of mycelial growth (Sangeetha *et al.*, 2013).

Gopalakrishnan *et al.* (2013) reported that the eight wild plant species namely *Tragia involucrata, Cleistanthus collinus, Sphaeranthus indicus, Vicoa indica, Allmania nodiflora, Habenaria elliptica, Eriocaulon thuaitesii* and *Evolvulus alsinoides* were screened for antibacterial activity against *Escherichia coli*. Effective antibacterial activity was shown by *Tragia involucrata*.

Aqueous extracts of 14 medicinal herbs were evaluated for antimicrobial activity against five common oral bacteria *viz.*, *Enterococcus faecalis, Actinomyces viscosus, Streptococcus salivarius, S. mutans* and *S. sanguis*. The extracts of *Sappan lignum, Coptidis rhizoma* and *Psoraleae semen* effectively inhibited the growth of oral bacteria and showed distinct bactericidal activity (Yim *et al.*, 2013).

Al-Daihan *et al.* (2013) evaluated the aqueous and methanol extracts of *Zingiber officinale, Curcuma longa, Commiphora molmol* and *Pimpinella anisum* against *Streptococcus pyogenes, Staphylococcus aureus, Escherichia coli* and *Pseudomonas aeruginosa*.

Rahman *et al.* (2013) reported the phytochemical, antioxidative, antimicrobial and cytotoxic effects of *Leea indica* leaf ethanol extract.
The results showed significant zones of inhibition against Gram-positive, *Bacillus subtilis*, *B. cereus*, *B. megaterium* and *Staphylococcus aureus* and Gram-negative, *Salmonella typhi*, *S. paratyphi*, *Pseudomonas aeruginosa*, *Shigella dysenteriae*, *Vibrio cholerae* and *Escherichia coli* compared to positive controls Ampicillin and Tetracycline. In antifungal assay, the extract inhibited the growth of *Aspergillus flavus*, *Candida albicans* and *Fusarium equiseti*.

Antimicrobial potential of ten medicinal plants *i.e.* *Picrorhiza kurroa*, *Datura metel*, *Acacia catechu*, *Cissus quadrangularis*, *Cassia tora*, *Berberis aristata*, *Pongamia pinnata*, *Emblica officinalis*, *Saraca asoca* and *Tinospora cordifolia* was evaluated against three fungal strains *viz.*, *Aspergillus fumigatus*, *A. flavus* and *A. niger*. Water extract of *Saraca asoca* showed maximum activity against *A. fumigatus* (Gahlaut et al., 2013).

Aqueous and organic (dichloromethane:methanol, 1:1) extracts of nineteen plant species were screened for antimicrobial activity against the STI associated pathogens: *Candida albicans*, *Ureaplasma urealyticum* (clinical strain), *Oligella ureolytica*, *Trichomonas vaginalis* (clinical strain), *Gardnerella vaginalis* and *Neisseria gonorrhoeae*. The aqueous extract of *Ranunculus multifidus* and organic extract of *Peltophorum africanum* showed the highest activity against tested pathogens. *Ureaplasma urealyticum* was the most
sensitive of the six tested organisms. *Sclerocarya birrea* was found to have the broadest spectrum of activity against all the STI associated pathogens (Naidoo *et al.*, 2013).

Santhosh Kumar *et al.* (2013) reported that *in-vitro* antimicrobial and anti-HIV activity of *Canthium coromandelicum* leaf extract with different solvents *viz.*, petroleum ether, chloroform, methanol and water against ten bacterial strains including Gram-negative, Gram-positive bacteria and six fungal strains. The methanolic extract showed the broad spectrum of antimicrobial activity.

The leaf extracts of *Dilobeia thouarsii* showed antibacterial activity against *Bacillus cereus, Bacillus megaterium, Staphylococcus aureus, Enterococcus faecalis, Vibrio harveyi, V. fisheri, Salmonella typhimurium, S. antartica, Escherichia coli* and *Klebsiella pneumoniae* (Razafintsalamo *et al.*, 2013).

The antifungal activities of the essential oils of some medicinal plants such as *Stachys pubescens, Thymus kotschyanus, T. daenensis* and *Bupleurum falcatum* were screened against *Fusarium oxysporum, Aspergillus flavus* and *Alternaria alternata*. The essential oils of *S. pubescens, T. kotschyanus* and *B. falcatum* showed strong antifungal activities (Mohammadi *et al.*, 2014).

Nono *et al.* (2014) studied the antimicrobial, antioxidant and antiinflammatory activities of methanol, ethyl acetate, *n*-butanol
and aqueous extracts of the roots of *Dissotis thollonii* against *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Enterococcus faecalis* and *Candida albicans* as well as the isolation and identification of the chemical constituents of this plant was done. That resulted in the isolation of twelve compounds *viz.*, 3,3'-di-O-methylellagic acid 4'-O-β-D-xylopyranoside, 3-O-methylellagic acid 4'-O-β-D-arabinopyranoside, casuarinin, betulinic acid, β-sitosterol-3-O-D-glucopyranosyl-6'-mirystrate, cellobiosylsterol, β-sitosterol, β-sitosterol-3-O-β-D-glucopyranoside, arjunolic acid, 3,3-di-O-methylellagic acid, ellagic acid, and 3,3-di-O-methylellagic acid 4'-O-β-D-glucopyranoside.

The antimicrobial and antioxidant activities of spray dried extracts from the leaves of *Psidium guajava* against fungi, *Candida albicans*, *C. krusei* and *C. glabrata*, Gram-positive bacteria, *Staphylococcus aureus* and Gram-negative bacteria, *Escherichia coli* and *Pseudomonas aeruginosa* and the results showed a significant antimicrobial and antioxidant activities (Fernandes *et al.*, 2014).

Hubsch *et al.* (2014) reported that the interactive antimicrobial and toxicity profiles of six South African medicinal plants *viz.*, *Agathosma betulina*, *Aloe ferox*, *Artemisia afra*, *Lippia javanica*, *Pelargonium sidoides* and *Sutherlandia frutescens* when combined with seven conventional antimicrobials namely ciprofloxacin, erythromycin, gentamicin, penicillin-G, tetracycline, amphotericin B and nystatin.
The phytochemical screening, antioxidant and antimicrobial activities of methanol, chloroform, hexane, ethyl acetate and butanol crude extracts from dry and fresh leaves of *Datura metel* were studied. The methanol crude extract and its derived fractions from dry and fresh leaves showed small and moderate antibacterial potential with one Gram-positive bacteria, *Staphylococcus aureus* and three Gram-negative bacteria, *Escherichia coli*, *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* (Alabri *et al.*, 2014).

Savithri *et al.* (2014) evaluated the six medicinal plants used as indigenous herbal medicines for antimicrobial and antifungal effects using their crude extracts and were found to inhibit a broad range of pathogenic microorganisms. Plant extracts derived from *Fibraurea tinctoria*, *Polyalthia hookeriana*, *Pyrenaria* sp., *Baccaurea lanceolata*, *Goniothalamus tapisoides* and *G. velutinus* were demonstrated to have the highest antimicrobial activities. *Pyrenaria* sp. showed significant antifungal activity against *Candida albicans*.

### 2.7. BIOLOGICAL ACTIVITY OF ISOLATED COMPOUNDS FROM OTHER PLANTS

The isolated compound, 7-hydroxy-8(17)-labden-15-oic acid (salvic acid) from *Eupatorium salvia* was screened for antimicrobial activity against *Bacillus cereus*, *Staphylococcus aureus*, *Micrococcus luteus*, *Bacillus subtilis*, *Clavibacter michiganensis* subsp.
michiganensis, Escherichia coli, Salmonella paratyphi, Proteus vulgaris, Klebsiella pneumoniae, and Erwinia carotovora (Urzua et al., 1998).

The active compound, cabreuvin (an isoflavone derivative) isolated from Myroxylon peruiferum possessed antimicrobial activity against Bacillus subtilis, Micrococcus luteus, Bacteroides fragilis, Escherichia coli, Pseudomonas aeruginosa, Saccharomyces cerevisiae and Candida albicans (Ohsaki, 1999).

The flavonoids isolated from Bartramia pomiformis, Dicranum scoparium, Plagiomnium affine, P. cuspidatum and Hedwigia ciliata, viz., the flavones apigenin, apigenin-7-O-triglycoside, lucenin-2, luteolin-7-O-neohesperidoside, saponarine and vitexin, the biflavonoid bartramiaflavone respectively possessed antibacterial effects against Enterobacter cloaceae, E. aerogenes and Pseudomonas aeruginosa (Basile et al., 1999).

Rabe and Van Staden (2000) reported that the compound, muzigadial isolated from the bark of Warburgia salutaris exhibited antimicrobial activity against Staphylococcus aureus, Bacillus subtilis, Staphylococcus epidermis, Micrococcus luteus, Escherichia coli and Klebsiella pneumoniae.

The compound, methylgallate and protocatechuic acid obtained from Sebastiania brasiliensis possessed antimicrobial activity
against *Bacillus subtilis, Micrococcus luteus, Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, Candida albicans* and *Aspergillus niger* (Penna et al., 2001).

Anjum *et al.* (2002) reported that 1-Methyl-1*H*-pyrimidine-2,4-dione and 3-0-b-D-glucopyranosyl-(24b)-ethylcholesta-5,22,25-triene were isolated from the flowers of *Alangium salviifolium* and it showed remarkable antibacterial activities against Gram-positive bacteria *viz.*, *Bacillus subtilis, B. megaterium, Staphylococcus aureus, Sarcina lutea, Streptococcus haemolyticus* and Gram-negative bacteria *viz.*, *Escherichia coli, Pseudomonas aeruginosa, Shigella dysenteriae, S. flexneri, S. sonnei, S. shiga, S. boydii, Salmonella typhi* and *Klebsiella sp.*

Freile *et al.* (2003) reported that berberine isolated from *Berberis heterophylla* showed activity against *Staphylococcus aureus, Enterococcus faecali, Pseudomonas aeruginosa, Escherichia coli, Candida albicans, C. glabrata, C. haemulonii, C. lusitaniae, C. krusei* and *C. parapsilosis.*

Sato *et al.* (2003) studied that seven compounds namely Orientanol B, Erystagallin A, Cristacarpin, Sigmoidin K, Erycristagallin, 2-{[(1)-dimethylallyl]-6a-hydroxyphaseollidin and Eryvarin A were isolated from *Erythrina variegata.* Among 7 isoflavonoids, Erycristagallin was the most potent inhibitor of oral bacterial growth against *Streptococcus mutans,*

Dongjin et al. (2004) reported that the compound namely benzylideneacetone (trans-4-phenyl-3-buten-2-one) isolated from Xenorhabdus nematophila possessed activity against Agrobacterium vitis, Pectobacterium. atrosepticum, P. carotovorum, Pseudomonas syringae and Ralstonia solanacearum.

Insecticidal protein namely finotin was isolated from Clitoria ternatea and possessed antimicrobial activity against fungal pathogens of plants, namely Rhizoctonia solani, Fusarium solani, Colletotrichum lindemuthianum, Lasiodiplodia theobromae, Pyricularia grisea, Bipolaris oryzae and Colletotrichum gloeosporioides. It also inhibited the common bean bacterial blight pathogen, Xanthomonas axonopodis (Kelemu et al., 2004).

Becker et al. (2005) isolated two antifungal triterpenoids, oleanolic and ursolic acid from Lythrum salicaria extracts against the phytopathogenic fungus, Cladosporium cucumerinum. The hexahydroxydiphenoyl ester vescalagin was isolated from Lythrum salicaria as active principle of the antibacterial activity. Furthermore, the flavon-C-glucosides vitexin, isovitexin, orientin and isoorientin were isolated from Lythrum salicaria and showed activity against the bacteria Staphylococcus aureus, Proteus mirabilis and Micrococcus luteus.
Kim et al. (2006) isolated a total of 18 organosulfur compounds originating from Petiveria alliacea L. roots and tested for their antibacterial and antifungal activities. Phytochemical analysis of the leaves of Vernonia amygdalina yielded two known sesquiterpene lactones, vernolide and vernodalol. The two compounds were tested against 10 bacterial strains and 5 fungal species. Both compounds exhibited a significant bactericidal activity against five Gram-positive bacteria while lacking efficacy against the Gram-negative strains. In the antifungal test, while vernolides exhibited high activity with LC$_{50}$ values of 0.2, 0.3 and 0.4 mg/mL against Penicillium notatum, Aspergillus flavus, A. niger and Mucor hiemalis, respectively, vernodalol showed moderate inhibitions against Aspergillus flavus, Penicillium notatum and A. niger with LC$_{50}$ values of 0.3, 0.4 and 0.5 mg/mL, respectively (Erasto et al., 2007).

Pure compounds viz., lignans, stilbenes and flavonoids were obtained from Pinus sp. Knotwood or bark extracts prepared from 30 species of hard and soft wood trees and these compounds were assayed for their antimicrobial activity against Bacillus cereus, Staphylococcus aureus, Listeria monocytogenes, Lactobacillus plantarum, Escherichia coli, Salmonella infantis, Pseudomonas fluorescens, Candida albicans, Saccharomyces cerevisiae, Aspergillus fumigatus and Penicillium brevicompactum. Purified stilbenes showed the most consistent antimicrobial and cytotoxic
activities, while purified ligands had marginal effects only. The results suggest that stilbenes account both for the antimicrobial and cytotoxic properties of *Pinus* knotwood extracts (Valimaa *et al*., 2007).

Methanolic extracts prepared from the leaves, twigs and the roots of *Vismia laurentii*, as well as nine compounds isolated from these crude extracts, were tested for their antimicrobial activity against Gram-positive bacteria (six species), Gram-negative bacteria (12 species) and two *Candida* species. The isolated compound, fridelin was found to be the most active compound, while Bivismiaquinone was the least active. The lowest value for the purified compounds was obtained with O-demethyl-3',4'-deoxypsorospermin-3',4'-diol on *Candida glabrata* and *Bacillus subtilis* and 1,8-dihydroxy-6-methoxy-3-methylantraquinone on *Bacillus subtilis* and 6-deoxyisojacareubin on *Bacillus stearothermophilus* (Kuete *et al*., 2007a).

Kuete *et al* (2007b) studied eight compounds isolated from *Treculia obovoidea* and identified as Psoralen, Bergapten, 7-methoxycoumarin, 7-hydroxycoumarin, 4,2',4'-trihydroxychalcone, 4,2',4'-trihydroxy-3-prenylchalcone, 3-hydroxy-4-methoxybenzoic acid and O-[3-{(2,2-dimethyl-3-oxo-2H-furan-5-yl)butyl}bergaptol. These compounds together with the extract were tested for their antimicrobial activity against Gram-positive bacteria (six species), Gram-negative
bacteria (12 species) and three *Candida* species. All the isolated compounds showed selective activity.

The flavonoids *viz.*, Alpinum, isoflavone, Genistein, Laburnetin, Luteolin, Catechin and Epiafzelechin isolated from *Ficus chlamydocarpa* and *F. cordata* were screened for antimicrobial activity against eighteen species of microorganisms namely *Mycobacterium smegmatis*, *M. tuberculosis*, *Bacillus cereus*, *B. stearothermophilus*, *B. subtilis*, *Staphylococcus aureus*, *Streptococcus faecalis*, *Escherichia coli*, *Shigella dysenteriae*, *Proteus mirabilis*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Morganella morganii*, *Citrobacter freundii*, *Enterobacter cloacae*, *Candida albicans* and *C. glabrata* (Kuete et al., 2008).

Kuete *et al.* (2009) reported the 3-friedelanone, taraxeryl acetate, betulinic acid, oleanoic acid, 2-hydroxyisoprunetin, 6,7-(2-isopropenyl furo)-5,2,4-trihydroxyisoflavone, Cajanin and protocatechuic acid were isolated from *Ficus ovata* and screened for antimicrobial activity against Gram-positive bacteria *viz.*, Methicillin-resistant *Staphylococcus aureus*, *Streptococcus faecalis*, *Bacillus cereus*, five Gram-negative bacteria, *Escherichia coli*, Ampicillin-resistant *Klebsiella pneumoniae*, Carbenicillin-resistant *Pseudomonas aeruginosa*, Chloramphenicol-resistant, *Salmonella typhi*, and *Citrobacter freundii*
and two fungi *viz.*, *Candida albicans, Microsporum audouinii*. The compound, 2-hydroxyisoprunetin was active against all the microbes tested.

The compounds, 4-hydroxy-2-pyrrolidinone, β-amyrin, stigmasterol and friedelin were obtained from *Jatropha tanjorensis* and tested against human pathogenic microorganisms such as Gram-positive bacteria, *Bacillus cereus, B. subtilis, Staphylococcus aureus, S. epidermis*, Gram-negative bacteria, *Aeromonas hydrophila, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Proteus mirabilis, P. vulgaris, Salmonella paratyphi, Vibrio alcaligenes, V. cholerae* and fungi of *Aspergillus fumigatus, Candida albicans, Microsporum gypseum* and *Trichophyton rubrum*. Maximum activity was observed against the tested microbes (Viswanathan *et al.*, 2012).

Five terpenoid compounds namely α-bisabolol, α-terpinene, cineole, nerolidol and terpinen-4-ol isolated from three essential oils (EOs: Tea tree oil, Lemon myrtle oil and *Leptospermum* oil) were screened against two strains of *Campylobacter jejuni* and the poultry isolate, *Campylobacter coli* and *Enterococcus faecalis, Salmonella typhimurium, Bacillus cereus* and *Escherichia coli*. The compound terpinen-4-ol showed the highest activity against *Campylobacter* sp. and other tested strains (Kurekci *et al.*, 2013).
The compounds, 5,4'-dihydroxy-6-methoxy-7-O-β-glucopyranoside flavones (hispidulin-7-O-glucopyranoside) and stigmasterol-3-O-β-glucopyranoside were reported from *Pseudognaphalium luteoalbum* for the first time. The compounds were moderately to highly active against *Aspergillus parasiticus*, *Colletotrichum gloeosporioides*, *Fusarium oxysporum*, *Penicillium expansum*, *P. janthinellum*, *Phytophthora nicotianae*, *Pythium ultimum* and *Trichoderma harzianum* (Aderogba et al., 2014).

Mpofu *et al.* (2014) isolated two compounds namely (-)-epicatechin and palmitic acid from *Elephantorrhiza elephantina* and *Pentanisia prunelloides*. The compound exhibited antimicrobial activity against *Enterococcus faecalis*, *Escherichia coli* and *Bacillus cereus*. 
PLATE 1
PLANTS SELECTED FOR THE PRESENT STUDY

Cassia alata

Cassia fistula

Cassia auriculata

Cassia alata seeds

Cassia auriculata seeds

Cassia fistula seeds

Cassia tora seeds