Review of Literature
Plants have been used since time-immemorial to heal and cure diseases and disorders and to improve health condition of human beings. Much of the medicinal use of plants seem to have been developed through the observation of wild animals or by trial and error methods. In those days, knowledge of the use of plants for medicinal purpose was carried over from generation to generation, orally.

The Indian record on medicinal plants date back to the Vedic periods (3000-1000 BC). The Vedas are among the world's oldest literature. Rigveda (2000 BC) is the oldest document recording the use of plants for medicine in India, and the tradition continued in another ancient text, Atharvaveda (1500-1000 BC), which described more plants and introduced the basic concepts of phytotherapy (Anon., 2010b). Ayurveda or “life knowledge” practiced unbroken for thousands of years, has been handed down from teacher to student. The brilliant scholars of the school of medicine headed by Punarvasu Atreya (1000 BC) faithfully documented the precepts of their masters in their compendia, popularly known as the Samhitas namely, Charaka Samhita and Sushruta Samhita. The Charaka Samhita, as it is available to us, is in a redacted form written by Drithhabala during 400 AD (Menon and Haberman, 1969; Satyavati, 2003; Loon, 2003). In Charaka Samhita, Charaka mentions about 526 medicinal plants (Anon., 2011c). Sushruta, the closest successor to the Charaka, is believed to have been written Sushrutha Samhitha about 100-200 years later.

In medieval India, with the supplanting of Brahmancial religion by Buddhism, there was a decline in surgery, which practically came to be abandoned; while
considerable progress took place, on the other hand, on the treatment using medicinal plants and herbs. With the advent of the European conquerors and their doctors, the flame of Indian medicine had almost faded out. By the middle of the eighteenth century, the Western medicine or allopathy in India really began; this system contributed to the decay and degeneration of the pre-existing indigenous systems of medicine (Banerji, 1979; Rao, 1996). The allopathy mainly uses pharmacologically active chemical agents and physical equipments rather than plant derivatives to treat diseases and disorders. In addition, the side-effects of these medicines were also reported (Etkin, 1992; Wong et al., 1993; Ma, 1999). Nowadays, the herbal drugs or plant-based drugs are gaining demand all over the world in primary health care because of better cultural acceptability, better compatibility with the human body and less side-effects (Kamboj, 2000). According to the WHO report, in some Asian and African countries, 80% of the population still depend on traditional system of medicine for primary health care and in many developed countries, 70% to 80% of the population has used some form of alternative or complementary system of medicine (Anon., 2008a). An alternative and complementary systems of medicine include Ayurvedic, Unani, traditional Chinese medicine, Homeopathy, Chiropractic (practiced by the early Egyptians), naturopathic medicine and many others. In allopathy, there is usually one cure for one disease, regardless of the person, but in alternative systems, the treatment is person-specific rather than disease-specific (Larsen, 1999; Selin and Shapira, 2003). Moreover, in alternative systems, plant-derived drugs are preferred over the chemical drugs and are believed to have few side-effects. Recent scientific researches have proved that the drugs derived from plants cure ailments better
than the chemically synthesized drugs (Hussian and Manyam, 1997; Santos-Neto et al., 2006).

Besides the treatment of human diseases and disorders, medicinal plants also play a major role in veterinary medicine. In rural India, veterinary medicine practitioners are the real life-savers of cattle and other livestocks, since plants are readily available for the treatment, rather than waiting for modern day drugs. A number of reports are available on the use of medicinal plants to treat of veterinary ailments in India (Rajkumar and Shivanna, 2009; Singh et al., 2011; Tiwari and Pande, 2010). According to S.K. Jain, 836 plants are used for ethno-veterinary medicine in India (Tiwari and Pande, 2010). Such ethno veterinary medicinal knowledge is also reported all over the world - Saudi Arabia (Abbas et al., 2002), Pakistan (Sindhu et al., 2010), Afghanistan (Davis et al., 1995), Africa (Mccorkle and Mundy, 1992; Moyo, 2008; Toyang, 2007), Nigeria (Ibironke and Olutayo, 2007), Peru (Jernigan, 2009), Canada (Lans et al., 2007), and Zimbabwe (Matekaire, 2004).

The Indian systems of medicines, viz., Ayurveda, Siddha, Unani and Homeopathic systems and ethnomedicine (folk/vaidyas/medicine/house-hold remedies), predominantly use plant-based raw materials for most of their preparations and formulations. According to the All India coordinated Ethnobiological Project (AICP), all these systems use about 7500 medicinal plants as formulations (Rawat and Ginwal, 2009). The Indian Systems of Medicine and Homoeopathy (Ayurvedic, Yoga and Naturopathy, Unani, Siddha and Homeopathy, AYUSH) which cover both systems which originated from within and outside India, but which got adopted in India in the course of time (Anon., 2007a). The demand for AYUSH products has been increasing all over the
world. In 1995-96, the total AYUSH products exported from India is worth of Rs. 627.48 crore and in 2009-10 it increased to Rs. 2887.01 crore; it showed the growth rate of 13.08% per annum. This indicated that AYUSH products are contributing significantly to the foreign exchange of the country.

There is a lot of demand for herbals and herbal products all over the world. To meet this demand, there were 8,644 manufacturing units existing in the country as on April 2010, engaged in manufacturing of herbal products (Anon., 2011e). The domestic trade of the herbal drug industry is about Rs. 80 to 90 billion (Anon., 2011f). Besides these, there is a tremendous demand for medicinal plants throughout the world. Trade in medicinal plants is difficult to estimate accurately, as much of the local trade is either unrecorded or poorly classified, and also medicinal plants are used for non-medicinal end-uses which is not reported separately (Anon., 2007a). According to National Medicinal Plant Board (NMPB, India), world herbal trade is about US$ 120 billion and is expected to reach US$ 7 trillion by 2050 (Anon., 2011f). According to International Trade Center, Geneva, Switzerland, Indian export of medicinal plants to overseas is estimated at US$ 1,06,291 thousands (Anon., 2011b). The countries importing medicinal plant products are shown in Figure 2.1.
Fig. 2.1. List of importing markets for a products exported by India in 2009
Product: 1211 medicinal plants
India is a major exporter of psyllium husk and seeds, menthol, senna leaves and pods, sandalwood chips, ojuba seeds, aloe, pyrethrum, basil, neem, chirayata, gymnema, vinca, sarsaparilla, garcinia, liquorice and other products to USA, Germany, France, Switzerland, UK, Japan, Australia and New Zealand (Singh and Vadera, 2010). In India, major herbal drug manufacturing companies include Himalaya health care, Zandu, Dabur, Surya herbals, and Arya Vaidya Sala and their products have world-wide demand. Some of the important active principles extracted from climbers for the therapeutic use are detailed in ANNEXURE II.

In the modern health care system, instead of using the whole medicinal plant, their secondary metabolites like alkaloids, flavonoids, glycosides, terpenoids, steroids, lignins, or phenols are extracted as the active principles and used in drug manufacture based on their phytochemical, pharmacological and clinical studies. Many recent studies have proved that the secondary metabolites or active principles of plants are more promising than the synthetic drugs.

Animals eliminate unwanted metabolic products through kidney, liver and other excretory organs and microorganisms easily release such compounds into the surrounding medium, but plants store their secondary metabolic products. This facilitates the further transformation and multiplicity of secondary metabolites in plants (Luckner, 1984). Secondary metabolites may possess physiological significances; for example, as co-enzymes or co-substrates. They may increase membrane rigidity, be involved in light perception and ATP regeneration. They may be used as chemical signals during the coordination of cell metabolism, and during the attack of pathogens. Along with these, certain secondary metabolites serve an important role in host defense mechanism. Plant
synthesises certain chemicals as protectants against pathogens called ‘phytoalexins’ during infection. Synthesis of phytoalexins is triggered by the production of certain peptides and glycoproteins from pathogens. In addition to the above, the infecting pathogens also produce certain chemical substances called pathotoxins, which degrade the plant cell wall and decay the protoplast. Plant synthesise these secondary metabolites of diverse chemical structure through a network of metabolic pathways by utilizing the specific enzymes. Plant, microbes and animals have their own unique pathways. However, the pathways like pentose phosphate pathway, glycolysis and tricarboxylic acid cycle are common to all. Some pathways are unique to plants, such as carbon reduction cycle (photosynthesis) and shikimic acid pathway (Cseke et al., 2006). A general scheme of secondary metabolite pathways in plants is detailed in the ANNEXURE III. During the plant-pathogen interaction, the pathotoxins might dysregulate the metabolism in plant cell. Both the host plant and invading microorganism try to detoxify toxin(s) produced by rivals by the process of hydroxylation and conjugation (Luckner, 1984). During this process, certain secondary metabolites of plants might be transformed into some other chemical compounds. However, this complicated metabolism is poorly understood, and more research is needed in this regard.

**Plant diseases**

Plant diseases are of paramount importance because they damage plants and plant products on which human beings depend upon for food, clothing, furniture, and the environment and in many cases, housing. Millions of people all over the world still depend on their own plant produces for survival. Plant diseases can make the difference between a comfortable life, and a life haunted by hunger or even death from starvation.
Death from starvation of one and a quarter million Irish people in 1845 and much of the hunger of the underfed million living in the under-developed countries today are examples of the consequences of plant disease (Agrios, 2005). Hence, the study of plant diseases and their control is necessary, in view of the above. It is not surprising, therefore, that plant diseases are mentioned in some of the oldest books available. Robert Petri, developed artificial nutrient media for culturing the microorganisms (Petri dishes), and Robert Koch (1887) formulated the rules of disease called ‘Koch’s postulates’. These postulates became the standard procedures for proving incitant of a disease, be it bacterium or any other kind of pathogen.

As the knowledge about the causal agent(s) of plant diseases increased, the study of their control also began, and it dates back to 1600 in England, where farmers accidentally used sodium chloride solution for seed treatment to control bunt disease in wheat. Later, in 1700, copper sulfate was substituted with sodium chloride. In 1885, Millardet formulated Bordeaux mixture, which is being used for more than 100 years, than any other fungicide against a wide variety of plant diseases all over the world. In 1913, organic mercury compounds were introduced as seed treatments, but due to their toxic effects, they were banned in 1960s. First dithiocarbamate fungicide - Thiram was discovered in 1934, which led to the development of series of effective and widely used fungicides, including Ferbam, Zineb and Maneb. First systemic fungicide, carboxin was discovered in 1965 and was followed by Benomyl and many other fungicides. The discovery of penicillin opened up a new area of control of bacterial diseases. Between 1950-1960’s antibiotics like streptomycin, cycloheximide, and tetracycline were developed against bacterial diseases. However, now-a-day the awareness of the toxic
effects of chemical pesticides has turned farmers towards the use of biological control with antagonistic microorganisms (Vasanthakumari, 2010).

Agricultural crops like cereals, pulses, grains, vegetables, and horticulture crops are the most studied plants for their diseases and management. The management of diseases includes the eradication of parasites from the field, control of pathogens using chemicals, and biological control agents, and resistant varieties. Similarly, medicinal plants have been studied for their diseases, to some extent. However, when compared to the total number of medicinal plants used for medicinal purposes, the number of wild medicinal plants studied for their diseases are negligible. Now-a-day, due to the high demand for herbal drugs in the domestic and international markets, the demand for medicinal plants is increasing. To fulfill the demand and to reduce the pressure on forest, due to the collection of wild medicinal plants, their cultivation offers a very good alternative method to conserve the valuable plants in their natural habitat.

Most of the medicinal plants, even today, are collected destructively from wild (Ved and Goraya, 2007). The continued commercial exploitation of these plants has resulted in the decline of the population of many species in their natural habitats. It is necessary to initiate the systematic cultivation of medicinal plants in order to protect endangered species and to conserve biodiversity. Good Agricultural Practices (GAP) include proper cultivation technique, proper disease management and harvesting method (Anon., 2012c). Today, only a few medicinal plants are cultured with GAP. Disease management is one among the important practices required for better cultivation practices.
Diseases of medicinal plants

A large number of reports are available on diseases of agricultural and horticultural crops (Mehta et al., 1950; Singh, 2005). Many of the culinary and spice plants have been cultivated since time-immemorial and their diseases have been well studied and documented (Ananadaraj and Sarma, 1995; Koche et al., 2009). As for as the diseases in medicinal plants are concerned, only a few prioritized medicinal plants under cultivation are studied for their diseases and their control (Farooqi and Sreeramu, 2001). However, in these plant species only a few diseases are reported with no emphasise on control measures. This could be due to the fact that pesticide treatment of herbs and their products is discouraged. In contrast to the cultivated medicinal plants, uncultivated ones have always attracted less attention.

The disease reports in medicinal plants are broadly categorized into cultivated and wild medicinal plants for the sake of convenience. In each of the category, information of the plant species are arranged according to their family.

Diseases of cultivated medicinal plants

The sole intention of cultivation of medicinal plants is to produce herbal drugs in large quantity without sacrificing the quality. They are cultivated for the medicine besides for spice/condiment, culinary, aroma/flavour or vegetables.

Amaranthaceae

Aerva lanata is a herbaceous medicinal plant reported for its diuretic, and dimulcent properties (Trivedi, 2009). This plant affected by the fungal pathogen - Cercospora aervae-lanatae Raghu Ram & Mallaiah (Ram and Mallaiah, 1996). Another
plant is *Amaranthus spinosus* L. used in the treatment of migraine (Kamble *et al*., 2010), toothache (Parinitha *et al*., 2004), dysentery (Achar *et al*., 2010), and has galactogenetic, laxative, emollient, spasmolytic, and diuretic properties (Khare, 2007); it is also used as leafy vegetable and is affected by *Alternaria compacta* (Cooke) McClellan. (Kar and Das, 1988).

*Alternanthera sessilis* is a common crawling leafy vegetable used in the treatment of night blindness, leprosy and fever (Shiddamallayya *et al*., 2010), and stomach-ache (Rajakumar and Shivanna, 2009). Wilt is the common disease reported in the species which is caused by fungal pathogen *Fusarium oxysporum* Schltdl. (Mahmood, 1990).

**Apiaceae**

*Ammi majus* is one of the richest known sources of linear furocoumarins used in the treatment of asthma and vitiligo (Duke, 1983). In this plant, the bacterial pathogen *Erwinia carotovora* subsp. *carotovora* cause soft root (Kanehashi *et al*., 2006).

*Centella asiatica* also known as 'brahmi', is used in the treatment of wounds, burns, and ulcerous skin ailments, and prevention of keloid and hypertrophic scars (Anon., 1999a). This plant is affected by leafspot causing fungi - *Cercospora centellae* Manohar, Kunwar & Sharath (Manoharachary *et al*., 2003) and *Pseudocercospora centelli* sp. nov. (Dubey and Pandey, 2008). The disease is characterized by several minute, circular, dirty brown spots surrounded by yellow halo zone; at advanced stage, the spots coalesced to form large spots.

*Trachyspermum ammi* is an important ayurvedic medicinal herb with good germicidal and antiseptic properties (Shiddamallayya *et al*., 2010). Singh and Singh
(2001) reported the stem rot disease caused by the soilborne fungal pathogen, *Sclerotinia sclerotiorum* (Lib.) de Bary.

**Apoecynaceae**

*Catharanthus roseus* is a valuable medicinal plant employed in the treatment of blood pressure, and diabetes (Rajakumar and Shivanna, 2009) and is a potential source of vincristine and vinblastine (Samy and Gopalakrishnakone, 2007). This plant is infected by fungal pathogens like *Botrytis cinerea* Pers. (Garibaldi et al., 2009), *Phytophthora tropicalis* Aragaki & J.Y. Uchida (Hao et al., 2010), and *Colletotrichum dematium* (Pers.) Grove. (McMillan and Graves, 1996). The disease caused due to *C. dematium* occurred as severe twig blight affecting over 80% of plants potted in nursery. The effective control of *C. dematium* was achieved by spraying Duosan, Zyban, and Clearry's 3336 fungicides (McMillan and Graves, 1996; Machowicz-Stefaniak, 2010). Fungal diseases like twig blight (top rot or die-back) caused by *Phytophthora nicotianae* Breda de Haan., *Pythium debaryanum* R. Hesse, *P. butleri* Subraman. and *P. aphanidermatum* (Edson) Fitzp.; leaf spot due to *Alternaria tenuissima* (Kunze) Wiltshire, *A. alternata* (Fr.) Keissl., *Rhizoctonia solani* J.G. Kiihn and *Ophiobolus catharanthicola* V.G. Rao & A. Pande also affect *C. roseus*. However, the damage caused to the crop is not very serious (Prajapati et al., 2003; Joy et al., 1998). Foot-rot and wilt disease in *C. roseus* caused by pathogens *Sclerotium rolfsii* Sacc. and *Fusarium solani* (Mart.) Sacc. are also a major problem (Prajapati et al., 2003). In *C. roseus*, three viral diseases causing different type of mosaic symptoms and phyllody or little leaf disease due to phytoplasma have also been reported. The disease spread could be managed by uprooting and destroying the infected plants and by applying pesticides (Prajapati et al., 2003; Joy et al., 1998).
Rauvolfia serpentina is a commercially important medicinal plant used in the treatment of piles (Shivanna et al., 2008), snake bite (Parinitha et al., 2004; Shivanna and Rajkumar, 2011), cancer (Achar et al., 2010), and ringworm (Shivanna and Rajkumar, 2011). The plant was reported to be infected by Fusarium oxysporum Schltdl. causing wilt (Janardhanan et al., 1964). Initially, the disease appeared as darkening of collar region and as the disease advanced, the root portion below ground level were affected and finally caused death of the whole plant. Other common diseases reported in R. serpentina are leaf spot (Cercospora rauvolfiae, Corynespora cassiicola (Berk. & M.A. Curtis) C.T. Wei., leaf blotch (Cercospora serpentinae Pandotra & A. Husain), leaf blight (Alternaria tenuis Nees), anthracnose (Colletotrichum gloeosporioides (Penz.) Penz. & Sacc.), die-back (Colletotrichum dematium (Pers.) Grove), powdery mildew (Leveillula taurica (Lév.) G. Arnaud), root-knot (Meloidogyne sp.), mosaic and bunchy top virus diseases. Field sanitation, pruning and burning of diseased parts and repeated spraying of 0.2% Dithane Z-78 or Dithane M-45 are recommended for controlling various fungal diseases (Prajapati et al., 2003; Joy et al., 1998).

Asteraceae

Artemisia pollens is a well known aromatic and medicinal plant species cultivated for its essential oil - Davana oil. This oil is mainly used as the flavouring agent and is a good source of antioxidants (Ruikar et al., 2009). Singh et al. (2009) reported the root knot disease caused by nematodes Meloidogyne incognita and M. javanicai in this plant.

Cannabinaceae

Cannabis sativa is a plant known for its psychoactive property and this is also used in the treatment of cancer (Aggarwal et al., 2006) and plant is diuretic, anti-emetic,
Cucurbitaceae

Momordica charantia another climber, used for medicinal and vegetable purposes. The plant is highly useful in the treatment of diabetes (Chaudhary et al., 2010). The climber is vulnerable to infection by powdery mildew disease caused by Sphaerotheca fuliginea (Schltldl.) Pollacci. Spraying of infected plants with Nimrod [bupirimate] @ 0.8 litres ha⁻¹ reduced the disease intensity and increased the yield (Gupta and Singhvi, 1980). The bitter gourd fruits are also proven to attack by Botryodiplodia theobromae Pat which caused rot symptom (Rao, 1964).

Euphorbiaceae

Emblica officinalis one of the medicinally important tree species in ayurvedic medicine which is used in treating chronic dysentery, bronchitis, diabetes, fever, diarrhoea, jaundice, dyspepsia, and cough (Pathak, 2003). The tree is infected with several fungal pathogens. Ravenelia emblicae Syd. caused rust which could be controlled by three sprays of wettable sulphur (0.4%) at an interval of one month during rainy season. Sooty mould which covers the entire leaf lamina, twig and flower by their growth could be managed by spraying starch (2%), monocrotophos (0.05%) or wettable sulphur (0.2%) (Pathak, 2003). In E. officinalis soft fruit rot is caused by Phomopsis phyllanthi Punith. which can be controlled by treating fruits with difolatan (0.15%), dithane M-45 or bavistin (0.1%), just after the harvest (Pathak, 2003).
Phyllanthus amarus is a traditionally important herb is well known for its hepatoprotective activity (Srirama et al., 2010). The plant (identified as P. niruri) is reported to be affected by blight disease caused by soilborne pathogen Rhizoctonia solani J.G. Kühn (Dubey and Pandey, 2008). Infection by the pathogen started with dark elliptical lesions on the root surface which rapidly coalesced and spread to stem and leaf surface. On leaf surface, initially dull green and water-soaked lesions appeared which later turned to light brown and imparted a burnt leaf appearance.

Fabaceae

Glycyrrhiza glabra is a common medicinal shrub used as laxative, emmenagogue, contraceptive, galactagogue, antiasthmatic drug, and antiviral agent (Anon., 1999a). The plant is found to be infected with wilt pathogen Fusarium sp., Rhizoctonia bataticola and Sclerotium sp. which caused root-rot and collar rot, respectively. Soil treatment or aerial spray with Bavistin or Benlate (0.05%) helped in controlling diseases (Farooqi and Sreeramu, 2001).

Singh and Khare (1975) reported wilt disease caused by Sclerotium rolfsii Sacc in Psoralea corylifolia which is used in the treatment of vitiligo and skin diseases (Shivanna et al., 2008).

Saraca asoca is an endangered medicinally important historical tree species which is cultivated in gardens and parks. The plant is very useful in uterine, and gynaecological problems, haemorrhoids and haemorrhagic dysentery (Anon., 2007a). Colletotrichum gloeosporioides (Penz.) Penz. & Sacc. caused the anthracnose disease. Santa et al. (2008) studied the control of anthracnose of asoka tree by biocontrol agents
such as *Trichoderma* sp. or *Pseudomonas fluorescence* and in combination with carbendazim. A combination of the above three agents was very effective.

*Tephrosia purpurea* is a medicinal herb used in the treatment of piles (Shivanna and Rajakumar, 2011), with anthelmintic, and alexipharma properties (Joy *et al.*, 1998). The plant is infected with the powdery mildew fungus *Microsphaera trifolii* (Grev.) U. Braun (Bagyanarayana, 1989) and leaf spot causing fungus *Pseudocercospora tephrosiae* A.N. Rai & Kamal (Rai and Kamal, 1989) and leaf blight causing fungus *Alternaria tenuissima* (Kunze) Wiltshire. The symptoms caused by *A. tenuissima* appeared as small dark spots which later coalesced to form irregular patches, later brown to black spots leading to necrosis and finally shot hole are formed. Spraying of infected plants with Carbendazin (0.15%) or mancozeb (0.3%) controlled the disease (Farooqi and Sreeramu, 2001).

**Iridaceae**

*Crocus sativus*, the ‘Kesar’, cultivated in sub-Himalyan or Kashmir valley in India, is the rich source of antioxidants (Vaidya and Devasagayam, 2007). The crop is affected with the corm rot disease caused by *Rhizoctonia crocorum* (Pers.) DC., *Fusarium moniliforme var. intermedium* Neish & M. Legg., *Macrophomina phaseolina* (Tassi) Goid., *Fusarium oxysporum* f.sp. *solani* Bilaï., *F. pallidoroseum* (Cooke) Sacc., or *Sclerotium rolfsii* Sacc., or species of *Mucor* and *Penicillium*. The corm rot disease caused the loss up to 70-85%. The use of *T. harzianum* @ 1kg with 20kg well-dried Farm Yard Manure acre⁻¹, and treatment of corms with Bavistin @ 2gL⁻¹ of water resulted in the successfull management of the corm rot disease (Kalha and Gupta, 2009).
Lamiaceae

*Coleus forskohlii* is another high-value medicinal herb used in the treatment of constipation, glaucoma, cardiac problems, and cancer (Singh et al., 2011). *Coleus forskohlii* is used as antihypertensive, and for weight management (Samy et al., 2008). The plant is affected with many diseases - leaf spot caused by *Corynespora cassiicola* (Berk. & M.A. Curtis) C.T. Wei, and blight caused by *Rhizoctonia solani* J.G. Kühn. This plant is affected by *Fusarium solani* (Mart.) Sacc. which caused root rot, and collar rot disease complex with root knot nematode i.e., *Meloidogyne incognita*, and fungal pathogens *Sclerotium rolfsii* Sacc., *Fusarium chlamydosporum* Wollenw. & Reinking and *Rhizoctonia bataticola* (Taubenh.) E.J. Butler (Shresti, 2005; Singh et al., 2011). Singh et al. (2011) recommended the use of carbendazim, and benomyl, or biocontrol agents like *Trichoderma* sp. to control these diseases.

Wilt disease is caused by *Fusarium solani* (Mart.) Sacc. in *Pogostimon patchouli* (Chavan, 2007) which is one of the important commercial aromatic crops grown mainly for its essential oil. Fungicides like carbendazim and carbendazim 12% + mancozeb 63% were highly effective *in vitro* in inhibiting the growth of *F. solani*. In field, spraying infected plants with carbendazim, carbendazim+mancozeb, carboxin + thiram, propiconazole, or mancozeb completely controlled the disease.

*Ocimum sanctum* is a holy plant for Indians and is highly medicinal. It is used in the treatment of diabetes, and also used as antiasthemitic, antistress, antitumor, gastric antiulcer, antioxidant, antimutagenic and immunostimulant (Modak et al., 2007). The plant is commonly infected with the powdery mildew fungi *Erysiphe biocellata* Ehrenb. (Sharma et al., 1981) and *Euoidium labiatarum* Y.S. Paul & J.N. Kapoor (Paul and
Kapoor, 1987), and leaf spot causing fungus *Cercospora ocimum* R.K. Srivast., Narayan & N. Kumari (Srivastava et al., 2001). *Alternaria* sp. and *Colletotrichum capsici*. (Syd.) Butler and Bisby are other serious pathogens that caused leaf blight, and defoliation. Spraying of Dithane Z-78 or Dithane M-45 is recommended to control these diseases (Farooqi and Sreeramu, 2001).

**Liliaceae**

*Allium cepa* is extensively cultivated for its culinary use and also for its medicinal use including cancer (Galeone et al., 2006). The plant is reported to be affected with the bacterial blight caused by *Xanthomonas campestris*. The use of resistant verities is more useful than applying bactericides (O’Garro, and Paulraj, 1997). The soft rot disease is caused by *Pseudomonas gladioli* pv. alliicola (Wright et al., 1993). Another herb of the same genera *Allium*, *A. sativum* is also well known for its culinary and medicinal uses. This plant is also useful in treating cancer (Galeone et al., 2006). This plant is reported to be infected with Onion Yellow Dwarf and Leak Yellow Stripe virus (Brunt et al., 1996).

*Chlorophytum borivilianum* commonly called as ‘safed musli’ is used in Ayurvedic medicines for enhancing strength and vigour (Biswa and Temburnikar, 2003). The plant species is severely infected by *Corticium rolfsii* Curzi which caused collar rot (Singh et al., 2001). Raghavendra et al. (2005) recorded the tuber-rot due to *Fusarium oxysporum* Schltdl. The spray of combination of a phytotonic solution with carbendazim reduced the infection considerably.

*Gloriosa superba* is one of the important medicinal plants useful in the treatment of ulcers, leprosy, piles, inflammations, abdominal pains, itching and thirst (Oudhia, 2011). *Curvularia lunata* (Wakker) Boedijn. caused leaf blight. The cloudy weather
associated with high humidity favoured high disease incidence. The disease could be controlled by spraying Dithane M-45 @ 0.3% (Farooqi and Sreeramu, 2001).

**Malvaceae**

*Abelmoschus moschatus* commonly called as ‘musk mallow’ is used for its cardioprotective, antiseptic, diuretic, and carminative properties (Joy *et al.*, 1998). *Colletotrichum hibisci* Pollacci. is reported to cause anthracnose, while *Alternaria hibiscum* and *Phytophthora* sp. caused leaf spot. These diseases were controlled by seed treatment with Agrosan Gn or CeraSon before sowing and spraying with Bordeaux (Farooqi and Sreeramu, 2001). In *A. moschatus*, powdery mildew caused by *Erysiphe polygoni* DC could be controlled by the repeated spray of Dithane Z-78 @ 0.5% at one-month interval (Panda, 2002). Bacterial leaf spot and blight caused by *Pseudomonas syringae* is seed-borne and favoured by low temperature (20-25°C) (Brown and McCarter, 1991).

**Meliaceae**

*Azaadirchta indica* a traditionally valuable medicinal tree is known for anti-inflammatory, immunomodulatory and adaptogenic properties (Tewari *et al.*, 2011). The tree is affected by die-back disease caused by *Phomopsis azaadirchtae* sp. nov. (Sateesh *et al.*, 1997). The disease is shown to be more pronounced during August to December, and occur throughout the year. Symptoms of infection started appearing with the on-set of rainy season and became progressively severe in later part of the rainy season and early winter season. The terminal branches are mainly affected. The disease resulted in the progressive death of tree, year after year (Girish and Bhat, 2008). They reported that
Bavistin was most effective, among six fungicides tested, in controlling the disease. *Bacillus subtilis* was also shown to suppress the pathogen *in vitro*.

Papaveraceae

*Papaver somniferum* a cultivated plant, is used for the treatment of headaches, arthritis and inducing sleep (Samy and Gopalakrishnakone, 2007). Pathogens like *Cochliobolus spicifer* R.R. Nelson and *Erysiphe cruciferarum* Opiz ex L. Junell., that caused leaf spot disease (Kishore *et al.*, 1985; Kar and Das, 1988). *Pythium ultimum* Trow., *P. mamillatum* Meurs. and *P. dissotocum* Drechsler. caused seedling blight and damping-off. Treatment of seeds with Ridomil MZ-72, Captan (0.3%), or Mancozeb controlled the blight and damping-off in seedlings (Prajapati *et al.*, 2003). *Papaver somniferum* is also affected by the leaf spot pathogen *Xanthomonas papavericola* (Duke, 1983).

Piperaceae

*Piper betle* L., used by people in Asian countries for mastication and medicine purpose, is employed in the treatment of skin diseases (Jeeva *et al.*, 2007; Shivanna *et al.*, 2008). This climber is affected by *Phytophthora palmivora* (E.J. Butler) E.J. Butler (Johri and Devi, 1998), and *P. nicotianae* Breda de Haan (Dasgupta *et al.*, 2008). Fungicides like bordeaux mixture, Ridomyl, Chlorothalonil, or Dithane M-45 inhibited spore germination and mycelial growth *in vitro*. In field, bordeaux mixture showed promising result in controlling *Phytophthora* (Dasgupta *et al.*, 2008). Raut and Bhattacharya (1999) reported *Curvularia lunata* (Wakker) Boedijn. which caused leaf spot disease.
Another climber species of the same genus, *Piper longum* L. is a very important spice and medicinal plant. Fruits are used for curing diseases of the respiratory tract, as sedative, as emmenagogue, as digestive, appetizer and carminative, as general tonic and haematinic, applied locally on muscular pains and inflammations (Khare, 2007). Many reports are available on the diseases of *P. longum*. It is infected by *Pseudocercospora piperis* (Pat.) Deighton (Nayak, 1990) and *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. (Wathore et al., 2010). Gawandee et al. (2006) studied the in vitro efficacy of bordeaux mixture @1% followed by carbendazim @ 0.1%, and mancozeb @ 0.25% on *C. gloeosporioides*. Patil et al. (2009) showed that mancozeb + carbendazim (0.2%), and *Trichoderma viride* effectively inhibited *C. gloeosporioides* in *P. longum*.

Yet another important spice plant, *Piper nigrum* is one of the most valuable spice yielding medicinal climber plant much sought-after by the world over. It is considered as the 'King of spices'. The fruits are used in indigestion, dysentery, cough, asthma, pimples, night-blindness, excessive sleep, obesity, fistula, piles, headache and jaundice (Shiddamallayya et al., 2010). The climber is commonly affected by foot and collar rot in nursery by *Phytophthora capsici* Leonian. The disease could be controlled by proper sanitation and two sprays of bordeaux mixture @ 1% and soil drench with copper oxychloride @ 0.2% (Anandaraj and Sarma, 1995). *Piper nigrum* is reported to be affected by 17 diseases (Anandaraj and Sarma, 1995). Some of the important diseases are leaf rot and blight caused by *Rhizoctonia solani* J.G. Kühn., *Pythium* sp., *Colletotrichum* sp., and anthracnose by *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. Two sprays of bordeaux mixture @ 1% control diseases (Anandaraj and Sarma, 1995). The species is also affected by phyllody caused phytopalsma and stunted disease caused by
CMV virus. Selection of healthy cutting for cultivation and proper sanitation is recommended for the control of these diseases (Anandaraj and Sarma, 1995).

**Plantaginaceae**

*Plantago ovata*, commonly called blond psyllium is used in the treatment of dysentery, constipation and disorders of the digestive system (Sahu, 2011). Russel (1975) reported the wilt disease in *P. ovata* caused by *Fusarium oxysporum* Schltdl. Rathore (2002) reported downy mildew disease caused by *Peronospora alta* Fuckel. Initially small yellow patches were observed on the under-surface of leaf lamina, which later spread to the entire leaf. The chlorotic areas developed on the upper surface of the leaf, and ash-white frost-like mycelial growth developed on the lower leaf surface. Infected leaves became brownish, followed by curling up of leaves. Later in 2009, Rathore studied the epidemiological factors responsible for the development of downy mildew disease; sufficient inoculum, age of the plant, and low temperature with high relative humidity correlated with disease development. Downy mildew could be effectively controlled by spraying with bordeaux mixture, copper oxychloride, Dithane M-45, or Dithane Z-78 (Farooqi and Sreeramu, 2001).

**Poaceae**

*Cymbopogon citratus* an important aromatic plant, yielding citronella oil is reported to have analgesic, antiseptic, antispasmodic, carminative, depurative, diaphoretic, digestive, diuretic, emmenagogue, expectorant, pectoral, and stimulant properties (Duke *et al.*, 2003). It is reported to be infected with leaf blight pathogen *Curvularia andropogonis*. The disease symptom started as small, brownish spots which enlarged into long patches along the tip and margin of the leaves. The disease is
controlled by spraying with Dithane M-45 or Dithane Z-78 (Farooqi and Sreeramu, 2001). The plant is also infected with *Rhizoctonia solani* J.G. Kühn, which caused sheath-rot disease (Zengping, 2011).

**Rutaceae**

*Murraya koenigii* is a well known culinary as well as medicinal tree used in the treatment of high fever (Shivanna and Rajakumar, 2011), diabetes, and in anti-inflammation (Khare, 2007). This tree is infected by *Ascochyta murrayae* M.S. Ali, Saikia & N. Ahmed, and *Phyllosticta murrayicola* Aa. (Rao et al., 1989; Ali et al., 1996).

**Solanaceae**

*Datura inoxia* Mill. is well known in the treatment of skin diseases (Jeeva et al., 2007), dog bite (Shivanna et al., 2008). *Corticium solani* (Prill. & Delacr.) Bourdot & Galzin, caused seedling damping-off and root and foot wilt (Thakur, 1974; Joy et al., 1998). Mature plants of *D. inoxia* Mill. is infected by *Alternaria alternata* (Fr.) Keissler, which caused dark-brown spots of various size, which gradually enlarged with concentric rings and became necrotic and at later stages withering and drooping of the leaves (Janardhanan and Husain, 1983). Leaf spot is also caused by *Alternaria tenuissima* (Nees) Wiltshire which is characterized by brown round to oval spots, which became necrotic at a later stage and caused withering and dropping of leaves. *Sclerotium rolfsii* Sacc is another major wilt pathogen in *D. inoxia* which resulted in drooping of leaves and finally wilting of the entire plant (Thakur, 1974). Thakur and Sastri (1970) reported 15-20% loss of *D. inoxia* plants due to root rot caused by *Sclerotium rolfsii* Sacc. in Kashmir. Among the viral diseases, Datura distortion mosaic in *Datura* sp., is characterized by the yellowing of veins followed by inward rolling and distortion of
leaves with a reduction in plant size. For reducing the impact of these diseases, field sanitation, use of resistant varieties, crop rotation for 3-4 years and pesticide application are recommended (Joy et al., 1998).

*Withania somnifera* commonly known as Indian Ginseng, is used as adaptogen or vitalizer, anti-stress and anxiolytic, and anti-depressant agents (Nasreen and Narayana, 2011). Seedlings of *W. somnifera* expressed rot and blight symptoms under high temperature and humid conditions. The use of disease-free seeds and treatment with thiram or deltan at 3-4g kg⁻¹ seed before sowing reduced seedling disease. Spraying of diseased plants with 0.3% fytolan, dithane Z-78 or dithane M-45 helped in controlling the disease incidence (Joy et al., 1998).

**Zingiberaceae**

*Costus speciosus* is a threatened medicinal plant used in the treatment of chicken pox, and other skin diseases (Padal et al., 2010). The seedlings of this plant are affected by blight caused by *Thanatephorus cucumeris* (A.B. Frank) Donk (Shukla et al., 1982), and leaves affected by blight caused by *Drechslera maydis* (Y. Nisik. & C. Miyake) Subram. & B.L. Jain (Janardhanan et al., 1981). Leaf blight caused by *Curvularia* sp. (Thakur et al., 1980) is controlled by spraying 0.3% Dithane M-45 (Farooqi and Sreeramu, 2001). It is also infected by many fungal pathogens. *Pythium* sp. is a soilborne fungal pathogen which caused rhizome rot (Thakur et al., 1978). The disease could be controlled by dipping the rhizome in bavistin or dithane-Z-78 (Farooqi and Sreeramu, 2001).

*Curcuma longa* is traditionally important spice with lot of medicinal properties; and used in the treatment of hydrocele, scabies (Rajkumar and Shivanna, 2009), and
cancer (Balachandran and Govindarajan, 2005). This plant is infected by several pathogens like *Fusarium pallidoroseum* (Cooke) Sacc., *Phoma medicaginis* Malbr. & Roum., *Beltrania rhombica* Penz. (Singh and Kang, 1989), and *C. curcumae* (Syd. & P. Syd.) E.J. Butler & Bisby (Damm et al., 2009). Koche et al. (2009) studied the control of foliar diseases caused by *Colletotrichum dematium* (Pers.) Grove and *Taphrina maculans* E.J. Butler. with propiconazole (0.1%), hexaconazole (0.1%), pencyclocazole (0.1%) or carbendazim (0.1%). Among the botanicals tested, seed extract of *Azadirachta indica* was more effective in controlling the diseases. The plant is affected by rhizome rot caused by *Pythium graminicola* Subraman. in the field. The disease control was achieved by drenching soil with mancozeb 0.3% or by spraying Bordeaux mixture (Panhwar, 2005; Joy et al., 1998).

*Zingiber officinale* is the most valuable medicinal and culinary herb used in the treatment of fever (Achar et al., 2010), tympanites (in veterinary) (Rajakumar and Shivanna, 2009), and as anti-inflammatory agent (Wiart, 2006). The plant species is reported to be infected with leaf spot disease caused by *Phoma exigua* Desm. (Rai, 1993), *Phomopsis zingiberis* M.S. Ali & Saikia (Ali and Saikia, 1993), and *Curvularia lunata* (Wakker) Boedijn (Sinha et al., 1987). Rhizome rot is a serious constraint in ginger cultivation. Ekka et al. (2009) reported that *Pythium* sp., *Fusarium* sp. and *Ralstonia solanacearum* were associated with the rhizome rot.

**Diseases of Wild medicinal plants**

Wild medicinal plants are in great demand by pharmaceutical companies, nationally and internationally. These medicinal plants have not been put into cultivation or prompt attempts were not made to cultivate them, as they are not domesticated. Some
of them require specialized ecological conditions such as swamps or specific soil nutrient requirement, rainfall, elevation or temperature. Since these plants are also available in plenty in forests, no attempts were made to cultivate them. This resulted in pushing these plant species to near extinction or threats. This warranted the cultivation of such medicinal plants for international trade and consumption. Although many wild plants are documented for their diseases (Patil, 1988; Ram and Mallaiah, 1996), a detailed study of these diseases is lacking. This is in contrast to the knowledge available for cultivated medicinal plants. Some of the medicinal plants in wild that attracted the attention of plant pathologists are described below. A survey of literature pointed out that a limited information is available on the diseases of wild climbers of medicinal importance. Most of these reports concentrated mainly on the documentation of diseases that occur in such plants.

Acanthaceae

* Asteracantha longifolia *(L.) Nees. a medicinal herb used for treating diseases of the urinogenital tract, and spermatorrhea (Khare, 2007). This plant is affected by leaf spot pathogen *Synchytrium asteracanthae* M.S. Patil (Patil, 1988).

Alangiaceae

* Alangium lamarckii* Thwaites, a tree species, has been reported for its astringent, spasmylic, antipyretic, and hypoglycaemic activities (Khare, 2007). The plant is infected with leaf spot disease caused by *Colletotrichum capsici* (Syd.) Butler and Bisby (Kar and Mahapatra, 1981).
Apiaceae

*Anethum graveolens* L. is a herb employed to relieve digestive problems, and used as galactagogue; it possess antihyperlipidemic, and antihypercholesterolemic activities (Dembitsky, 2005). Upadhyaya and Gupta (1992) reported powdery mildew pathogen *Erysiphe heraclei* DC. on this plant.

Apocynaceae


Asclepiadaceae

*Daemia extensa* R. Br. is a climber used in the treatment of amenorrhoea, and dysmenorrhoea (Khare, 2007). The plants are reported to be infected with *Colletotrichum capsici* (Syd.) Butler and Bisby (Kar and Mahapatra, 1981).

*Hemidesmus indicus* (L.) W. T. Aiton known as 'Indian sarsaparilla' is recommended for its diuretic, biliousness, emetic, expectorant, astringent, antidote, laxative and antidiabetic properties (Anon., 1987; Shetty *et al.*, 2002). Parinitha *et al.* (2003) studied the foliar fungal diseases caused by *Pestalotiopsis* sp. in Bhadra Wildlife Sanctuary, Karnataka.

*Tylophora indica* (Burm. f.) Merr. another valuable medicinal climber in international trade is used extensively in the treatment of asthma (Parinitha *et al.*, 2004).
It is affected by powdery mildew disease caused by *Oidium* sp. in *T. indica* (Verma and Gupta, 2006). The infection appeared in the form of powdery patches on the adaxial surface of the leaf. At later stages, the entire lamina is covered by patches of powdery mass and the affected area turned reddish-brown and infected leaves became chlorotic.

**Asteraceae**

*Ageratum conyzoides* is a herbaceous medicinal plant possessing haemostatic and muscle relaxant activity (Khare, 2007). Singh and Singh (1986) reported stem rot caused by *Sclerotinia sclerotiorum* (Lib.) de Bary. in this plant.

**Burseraceae**

*Boswellia serrata* is a medicinal tree species with immunomodulator property (Vaidya and Devasagayam, 2007). This tree is infected by *Cercospora boswelliae* Harsch, V. Nath, C.K. Tiwari & Rehill that caused leaf spot disease (Harsha et al., 1989). It is also reported to be affected by foot rot disease caused by *Fusarium oxysporum* Schltdl. (Dadwal and Jamaluddin, 1996).

**Celastraceae**

Hosagoudar *et al.* (2008) reported *Schiffnerula celastri* sp. nov., a black mildew fungus, on medicinally important climber *Celastrus paniculatus* Willd. *Celastrus paniculatus* is reported to possess anti-inflammatory, intelligence promoting properties and is used in the treatment of Alzheimer's disease (Dastmalchi *et al.*, 2007).

**Combretaceae**

Most of the species of *Terminalia* are economically important tree species growing in the subtropical regions of India. *Terminalia chebula* and *T. bellirica* are
important medicinal plants used in ayurveda to treat cold, cough, and dysentery (Mohan et al., 2008). Shivanna & Mallikarjunaswamy (2009) reported the leaf spot disease caused by *Phoma herbarum* Westend. in *T. arjuna* and *T. paniculata*, *Colletotrichum dematium* (Pers.) Grove. in *T. bellirica*. *Pestalotiopsis versicolor* (Speg.) Steyaert. in *T. chebula* and *Macrophomina phaseolina* (Tassi) Goid in *T. tomentosa*.

**Convolvulaceae**

*Convolvulus arvensis* L. is a herb that possess hypotensive, and anticonvulsant activities (Khare, 2007). Singh and Singh (1986) reported that *Sclerotinia sclerotiorum* (Lib.) de Bary. caused rot disease.

**Cyperaceae**

*Cyperus rotundus* L. possess carminative, astringent, anti-inflammatory, antirheumatic, hepatoprotective, diuretic, antipyretic and analgesic properties (Khare, 2007). Singh and Singh (1986) reported that *Sclerotinia sclerotiorum* (Lib.) de Bary. caused rot in this plant.

**Euphorbiaceae**

*Acalypha indica* is a medicinal herb is used to treat skin diseases, constipation, ulcers, bronchitis, otalgia and croup (Deshpande et al., 2008). Hasija et al. (1989) reported leaf spot disease caused by *Exosporium ampullaceum* (Petch) M.B. Ellis. from Jabalpur M.P. Another pathogen, *Mycocentrospora acalyphae* K. Srivast. & A.K. Srivast. was reported by Srivastava et al. (1995). There are also reports of *Cercospora acalyphae* and *Ramularia acalyphae* affecting this plant in other countries (Anon., 2011g).
Fabaceae

*Abrus precatorius* is known to the world for its historical commercial applications. The seeds are poisonous but are used to treat snake bite (Achar *et al.*, 2010), skin disease and poor eye-sight (Tirkey, 2006). Subhedar and Rao (1986) reported the leaf spot disease in *A. precatorius* caused by *Physalospora abri* Subhedar & V.G. Rao.

*Cassia tora* is a medicinal herb used in skin diseases (Khare, 2007). Sathya and Rajalakshmy (1964) reported *Leptosphaerulina trifolii* (Rostr.) Petr. which caused leaf spot disease in *C. tora*. Other pathogens include *Alternaria alternata* (Fr.) Keissl., *A. tenuissima* (Kunze) Wiltshire., *Cercospora canescens* Ellis & G. Martin., *Phomopsis cassiae* Sousa da Cámara., and *Corynespora cassiicola* (Berk. & M.A. Curtis) C.T. Wei. (Lenne, 1990). Neeraj and Verma (2010) in their review reported the control of *Alternaria* disease by the use of Thiram in different concentration followed by other fungicides like bavistin, dithane Z-78, blitox or Bordeaux mixture.

*Caesalpinia bonducella* a prickly shrub, used to control blood sugar and skin diseases by ethnic people (Modak *et al.*, 2007). Majumdar and Agnihotri (1988) reported *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. and *Fusarium solani* (Mart.) Sacc. which caused leaf spot and wilt, respectively.

*Senna angustifolia* (Vahl) Batka. is identified as the promising plant for the treatment of constipation (Agarwal and Bajpai, 2010). Saroj *et al.* (2011) reported pod rot disease in *S. angustifolia* caused by *Bipolaris australiensis* (M.B. Ellis) Tsuda & Ueyama.
Lamiaceae

*Clerodendrum inerme* (L.) Gaertn. is used to cure psoriasis, scabies and ringworm (Mohan *et al.*, 2008). Bagyanarayana *et al.* (1998) reported the occurrence of rust pathogen *Prospodium tirumalense* Bagyan., Ravinder & P. Ramesh. on leaves of *C. inerme*.

Loganiaceae

*Strychnos nux-vomica*, a highly poisonous and medicinal tree is used for snakebite treatment (Vijayan *et al.*, 2007). The foliages of the tree were found infected with the leaf spot pathogen *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc.

Oleaceae

*Jasminum sambac* (L.) Aiton. is employed in treating wounds, headaches, and insomnia (Sen *et al.*, 2011). This plant is infected with leaf spot disease caused by *Colletotrichum capsici* (Syd.) Butler and Bisby (Kar and Mahapatra, 1981).

Rubiaceae

*Anthocephalus cadamba* (Roxb.) Miq., one of the important endemic medicinally important trees, is used as a tonic and as mouth gargle and to relieve fever (Orwa *et al.*, 2009), and skin problems (Achar *et al.*, 2010). The tree species is infected by *Scytalidium lignicola* Pesante. (Orwa *et al.*, 2009).

Solanaceae

*Solamum nigrum* L., a common medicinal herb possesses anti-inflammatory, antispasmodic, sedative, diuretic, laxative, and antiseptic activities (Khare, 2007); it is also used in the treatment of bone fracture (Shivanna and Rajakumar, 2011). Bhardwaj
and Paul (1987) reported *Cercospora nigri* Tharp var. *microsporae* var. nov. which caused leaf spot disease.

**Ulmaceae**

*Holoptelea integrifolia* (Roxb.) Planch is a tree species, bark of which is used to treat fever (Shivanna *et al.*, 2008). *Phyllosticta* sp. is reported to cause leaf spot disease in this plant.

**Verbenaceae**

*Vitex negundo* L. is a shrubby plant used for its anti-inflammatory and analgesic activities (Wiart, 2006). The pathogen *Pseudocercospora viticigena* J.M. Yen, A.K. Kar & B.K. Das. is reported to cause leaf spot disease (Kar and Das, 1982).

**Disease symptomatology**

Disease symptoms in plant vary depending on the pathogenic microorganism(s) associated with the host plant. Often, they produce unique symptoms of disease, very specific to the pathogen. For example, mosaic, phyllody and root knot for diseases caused by viruses, phytoplasma and nematodes, respectively. Canker and bushy stunt are other unique examples of disease symptoms produced by bacterial and viral pathogens, respectively (Riley *et al.*, 2002). Among the diseases, those caused by fungal pathogens are unique and could be identified either by naked eye looking into the reproductive propagules produced on infected plant part or by simply observing under low power hand held-lens (×10).

The commonest way of symptom expression by fungal pathogen(s) is by the manifestation of leaf spots that vary in size and shape and spread. The leaf spot symptom
may appear as black tiny spots or lesions which may enlarge over a period of time into a large spots, which may coalesce to produce a larger one and finally the blight (Cooper, 2007). Leaf spot might generally initiate from the leaf lamina, margin or tip and advance towards petiole and finally stem. Where hypersensitive reactions are commonly observed, shot holes of varying sizes are also observed. Incubation of the infected foliages often yield reproductive propagules that are produced abundantly in the infected area, which paves the way for the identification of fungal pathogen based on morphological characteristics. Such of the propagules could be cultured on PDA or any specific media to obtain colony culture, which can be again used for identification and isolation. Many leaf spots produced by rust, downy mildew and powdery mildew pathogens are identifiable by naked eye/light microscopes and can not be confirmed by culture techniques as they are biotrophic pathogens.

Diseases are also produced on the stem, near the growing point or in region towards the soil. Spots are specifically produced as in case of Ascochyta. The disease may be manifested as the fruit spot, stem tip blight, dry and wet stem rot. The stem tip blight might end up in die-back if the disease progresses rapidly towards stem base. Root diseases are also very common, often identified as root rot. The storage parts like underground corm, tuber, bulb, rhizome, stolon are also affected by diseases caused by fungi (Timothy et al., 1999).

Seedborne diseases are unique and contribute to the fungal transmission in plants, systematically or asystematically. Soilborne diseases as well as seedborne diseases generally affect seedlings and cause seedling damping-off and also wilt. Other than the
above diseases, smut is very commonly observed in graminaceous species causing head smut, loose smut, and covered smut diseases (Elmer, 2001).

In contrast to the fungal diseases, the bacterial diseases are predominantly characterized by rotting and canker and also wilt. Viral disease symptoms are also diverse, often with many host species. Examples for viral diseases include common Tobacco Mosaic Virus (TMV) to bushy stunt, golden yellow ring spot, crinkle, chlorotic, curling, stunting and other symptoms (Mahy and Regenmortel, 2008). As for as the phytoplasma diseases are concerned, the disease could be identified only when the prominent disease symptoms are observed on plant. For example, sandal spike, little leaf of brinjal, grassy shoot of sugar cane, and witches’ broom (Lee et al., 2000).

Most of the fungal diseases could be detected by conventional techniques with the aid of light microscope, culturing on media and baiting. This is done based on the morphological characteristics of propagules produced in the infected tissues before or after incubation on the blotter or culture medium. Specialized or selective medium has been designed for the isolation of specific fungal species from soil substrata contaminated with various other culturable fungal species; for example Komada medium and Malachite-captan agar for the detection of Fusarium sp., Kerr’s Medium for the detection of Fusarium solani and Phoma betae selective medium for the detection of P. betae (Dhingra and Sinclair, 1993). These techniques take a minimum of 7-8 days and often the fungal species could be identified upto the generic or species level. Recent modern techniques including the serological analysis and nucleotide assays help in the quick identification of the fungal species (Bridge et al., 1998; Lievens and Thomma, 2005). The molecular biological technique, however, require sophisticated laboratory facility
and analytical instruments. As for as the detection of bacteria, virus and phytoplasma are concerned, only molecular biological tools can bring about the reliable results (López et al., 2007). The nematodal diseases are generally identified by symptoms like root knots or galls, root lesions, excessive root branching, injured root tips, and stunted root systems and presence of eggs and cysts of nematodes in the gall region (Sarah et al., 2008).

Disease assessment

Any pathogen attack on plant alters its fitness by affecting its ability to survive, growth and reproduction. However, the effect of different degrees of infection range from a small lesion to death of the whole plant. This again depends upon the aggressiveness of the pathogen and the resistance of host plant and environmental conditions. The effect of infection on host plant is primarily important in agricultural crops since the yield is the quantitative measure which depicts the real effect of host-pathogen interaction. It is important to quantify the effect of pathogen infection on host plant by some numerical values. The prediction using the numerical value gives the clear-cut idea of what happened due to infection. The quantitative assessment of disease is one among the important parameters used to study the effect of pathogens on the host plant. According to Kranz, “Without quantification of disease no studies in epidemiology, no assessment of crop losses and no plant disease surveys and their application would be possible” (Madden and Hughes, 1995). The quantitative assessments of disease are of two types – disease incidence (DI) and disease severity (DS). Disease incidence is the number of plants that are visibly diseased, relative to the total number of assessed plants or proportion of diseased plants or plant parts. Disease severity is the area of plant tissue that is visibly diseased and is relative to the total plant tissue assessed (Madden and
Hughes, 1995). For foliar disease symptoms like leaf spot, lesion, and blight and those caused by viruses, disease incidence give the better characterization of the population dynamics rather than the disease severity (Madden and Hughes, 1995). Since the disease incidence is a binomial variable (plant is either diseased or healthy) and is much easier to determine than severity, and therefore, it is more conveniently used in the disease epidemiology surveys. Usually in epidemic studies, the progress of the disease in time and space called spatio-temporal analysis was used for the prediction of disease distribution. Spatio-temporal analysis of epidemics provide valuable information on pathogen dissemination and epidemic progress, and it also helps in the prediction of plant disease losses (Pethybridge et al., 2005). The spatial disease analysis can be done by using i) point pattern analyses (binomial or beta-binomial distribution models) or ii) Correlation based analyses (spatial analysis by distance indices - SADIE, runs analysis) for the distribution of disease incidence in the particular geographical area. Madden and Hughes (1995) opined that beta-binomial model provided a good fit to the incidence of foliar disease caused by viruses, fungi and bacteria. The derivation of beta-binomial model based on the binary Taylor’s power-law was used to assess the degree of heterogeneity; it is useful in establishing the relationship between observed and theoretical variances during the development of an epidemic or to compare data from different experimental treatments (Maanen and Xu, 2003). Many reports were available on the distribution of disease incidence based on the beta-binomial distribution. Spatial aggregation of foliar diseases of strawberry caused by Phomopsis obscurans and Mycosphaerella fragariae in Ohio State, based on both beta-binomial and SADIE was studied by Turechek and Madden (2000). The spatial pattern of virus disease in lettuce
and tobacco plants using the above tool was studied by Madden et al. (1982, 1995). Similarly, spatial heterogeneity of the grape downy mildew incidence was studied by Madden and the group during 1995 in Ohio. Gent et al. (2008) studied the spatial pattern of powdery mildew in *Humulus lupulus*, using the beta-binomial tool. By using both beta-binomial and SADIE tools, Pethybridge et al. (2005) studied the spatial distribution of the *Phoma ligulicola* in *Pyrethrum* fields at Tasmania. Madden and Hughes (1995, 1999) reviewed the application of the beta-binomial and other tools in detail and discussed the comprehensive details of tools used in the assessment of plant disease incidence.

**Effect of disease on plant metabolites**

Microbial pathogens cause a profound effect on various physiological mechanisms of plant system. They interfere in their metabolic processes. As regard to the respiration, pathogen affects the respiratory apparatus; as a result the rate of respiration increases (Akhkha *et al.*, 2003), thereby lot of energy is utilized. The activation of pentose pathway results in the production of ‘polyols’, which is metabolized in the fungus (Thornton & Cooke, 1974; Loescher and Everard, 2004).

Infection by a pathogen interferes in the enzymatic processes of photosynthesis, and calvin cycle, in particular and electron transport and carboxylation, in general (Rahoutei *et al.*, 2000; Garavaglia *et al.*, 2010). Decreased carbon dioxide diffusion into infected leaves reduced photosynthesis (Guo *et al.*, 2005). The net assimilation rate decreased with increase in severity. Chlorophyll content was drastically affected by pathogens (Mandal *et al.*, 2009) and so also the structural changes in chlorophyll (Aldea *et al.*, 2006). Pathogen toxins also inhibited enzyme systems of photosynthesis (Agrios,
During pathogenesis, carbon and nitrogen are diverted away from primary metabolism to produce secondary metabolites and activate defense genes (Aldea et al., 2006; Major et al., 2010).

In healthy host cells, metabolism progresses in a well balanced manner, but under adverse conditions they are capable of adjusting their metabolism to a new circumstance. The presence of pathogen, for example, can induce the formation of new metabolic pathway(s). This could be illustrated as follows:

\[
\begin{align*}
K_1 & \quad X \\
A & \quad K_2 \\
B & \quad K_3 \\
& \quad C \\
K_4 & \quad Y
\end{align*}
\]

A is normally concerted through intermediates B and C. If the velocity of reaction \( K_1 \) is equal to that of \( K_2 \), then A is connected to C without the accumulation of B. However, if \( K_1 \) is proceeding much faster than \( K_2 \) or the velocity of \( K_2 \) is negligible, then B will accumulate, and sometime new reaction sequence may be induced. \( K_3 \) and \( K_4 \) indicate those alternative or shunt pathways leading to the production of new abnormal metabolites X and Y. This type of metabolic alteration has been observed in diseased tissue or organs (Chandniwala, 1996). Park et al. (2009) reported that the infection due to anthracnose pathogen in \textit{Capsicum annuum} fruit cause increases in the tryptophan decarboxylase (TDC) activity which subsequently increased the serotonin (neurotransmitter) biosynthesis. They suggested that the increase in TDC levels is caused in response to the pathogen infection. The potato virus -Y (PVY) infection in \textit{Datura metal} led to a decrease in total alkaloids and out of 15 alkaloids found in healthy leaves, only 12 were found in the infected ones. The PVY infection caused a noticeable decrease
in the hyoscyamine (alkaloid) content of different organs of both healthy and infected plants (El-Dougdoug et al., 2007). Plant pathogens like viruses could also alter the biosynthetic pathway. Gutha et al. (2010) reported that modulation of the flavonoid biosynthetic pathway was altered due to GLRaV-3-infection in Vitis vinifera and synthesized certain other flavonoids which were not produced previously in plants. In addition to this, infection reduced the chlorophyll and carotenoid content. Muth et al. (2009) reported the increase in flavonoid and isoflavonoid contents in Colletotrichum infected Lupinus angustifolius plants. The infection by pathogen affected the carbohydrate metabolism, which in turn targeted the signal transduction and promoted the synthesis of several enzymes both in the plant and pathogen. This enzymatic activity triggered the synthesis of many secondary products through unknown mechanism(s) (Berger et al., 2007).

Plant pathogenic fungi like Colletotrichum species secreted ammonia during plant pathogenesis, which increased the pH in the infected area (Prusky et al., 2001). The mycelia of C. dematium were found to contain 0.8–1.28% cholesterol (Pajon et al., 2003).

**Plant-pathogen interaction**

The development of disease in a host plant is a struggle for existence between the host and pathogen. For their survival, they employ chemical weapons. The pathogen causes a disturbance in structural integrity and physiological processes of the host by producing chemical substances; mainly, enzymes, toxins, growth regulators, and polysaccharides. These are nothing but the chemical weapons of pathogens to fight against the host defense system. In biochemical defense mechanism, the plant produces
certain chemical entities, which are toxic to the pathogen. In response to this, pathogen(s) also produce certain chemicals capable of detoxifying plant toxins (Luckner, 1984). During this ‘war of chemicals’, many enzymatic and chemical reactions take place. This process might lead to the conversion of one chemical compound into another, through the process of biotransformation.

Most of the chemicals produced during the plant pathogen interaction are toxic substances. The pathogen may interrupt the pathway leading to secondary metabolite synthesis and trigger the production of some other chemical compound (Gutha et al., 2010). During the process of infection, active chemical production in the host plant was reduced which is coupled with the production of new chemicals from pathogens as studied in Zizipus mauritiana fruit (Singh and Sumbali, 1998). The secondary chemicals produced by fungi and other microorganisms have been studied to some extent, (Thines et al., 2006). The schematic representation of the secondary chemical production in fungi based on Thines et al. (2006) and Deacon (2006) is detailed in ANNEXURE IV.

Plants often wait until pathogens are detected before producing toxic chemicals or defense-related proteins because of the high-energy costs and nutrient requirements associated with their production and maintenance (Freeman and Beattie, 2008). Following detection of the pathogen, plant produces secondary metabolites, which acts as toxic chemicals, and pathogen-degrading enzymes. Major groups of these secondary metabolites include alkaloids, flavonoids, phenols, steroids, and terpenoids (terpenes).

Alkaloids: Many categories of alkaloids like pyrrolidine, tropane, piperidine, quinolizidine, isoquinoline, indole and pyrrolizidine alkaloids (PAs) are toxic to some
degree and appear to serve primarily in defense against microbial infection (Mazid et al., 2011; Freeman and Beattie, 2008; Cseke et al., 2006).

**Flavonoids:** It include chalcones, flavanones, flavones, flavonols and isoflavonoids. These flavonoids protect plants from infection by phytopathogenic organisms and UV radiation (Hahlbrock, 1981; Luckner, 1984; Schwinn and Davies, 2005; Mazid et al., 2011). Some of the flavonoids associated with plant defence are - Nobelitin (flavonoid) – pre-infectional fungitoxic chemicals in the *Citrus* leaves, phloridzin (flavonoid) synthesized as post-infectional fungitoxin in apple leaves, luteone (isoflavones) – pre-infectional fungitoxic substance inhibiting germination and germ tube development of *Helminthosporium* spores, and pterocarpan, medicarpin, pisatin, phaseollin (isoflavones) in legumes with phytoalexin properties (Luckner, 1984).

**Phenols:** One of the major biological properties of phenol is ‘antimicrobial property’ and act as protectant against pathogens (Friend, 1979). P-hydroxybenzoic acid, protocatechuic acid, vanillic, syringic, salicylic, caffeic, gallic, and p-coumaric acid, hydroquinone, catechol, orcinol, eugenol, myristicin, scopoletin, chlorogenic, medicarpin, rishitin, and camalexin are some of the phenolic compounds present in plants or synthesized during pathogen attack. These phenols successfully prevented germination, penetration and establishment of pathogens in their hosts (Friend, 1981; Cseke et al., 2006; Freeman and Beattie, 2008; Mazid et al., 2011).

**Steroids:** Plant sterols are known for their role in growth, and development and protection against stress conditions (Martin and Kish, 2006) and signal transduction (Wang and Chory, 2006). Signal transduction play a very essential role during the
process of pathogenesis. The plant prepares to fight against pathogens after receiving the signals. Brassinosteroids are the plant steroids involved in acclimation to environmental stresses, promote cell elongation, and enhance resistance to pathogens (Sun et al., 2010).

Plant sterols also have the antifungal properties (Roddick, 1987).

**Sulphur containing secondary metabolites:** They include phytoalexins, thionins, defensins (cysteine-rich proteins) and allinin which are produced in plants under defense to pathogens. Phytoalexins are synthesized in response to infection by pathogens and limit the spread of the invading pathogens by their accumulation around the site of infection (Singh, 2005; Mazid et al., 2011).

In addition to the above, plants also produce enzymes which act upon the invading pathogens. Hydrolytic enzymes produced by plants in response to pathogens degrade cell walls of pathogenic fungi. For example, chitinases catalyze the degradation of chitin of fungal cell walls and lysozymes degrade bacterial cell walls (Freeman and Beattie, 2008).

**Metabolites produced by fungi**

Toxins are extremely poisonous metabolic substances in very low concentration produced by phytopathogenic microorganisms inside the host plant system during the course of their attack. The fungus resides in the center of the lesion, which is surrounded by an un-invaded chlorotic halo, a symptom that is commonly observed during the infection process of necrotrophic pathogens. This zone is created by the diffusion of fungal toxins. Pathogens secrete phytotoxic secondary metabolites to kill the host tissue and avoid the initiation of defense responses by the host. The phytotoxins produced by
plant pathogens belong to either host-specific (HS-toxins) or non-host-specific toxins (NHS-toxins). The NHS toxins are poisonous to all plant species (Leuven, 2003).

The toxins produced by plant pathogenic fungi act on plant physiology by detoxifying the plant toxins produced against pathogens and damage the cell organelles. In addition, the fungal toxins also have toxic effects on other organisms. One of the best examples is the ergot alkaloid produced by *Claviceps purpurea*, which caused ergotism leading to the death of organisms including human beings (Agrios, 2005). Similarly, many other mycotoxins also showed toxicity to human system and other organisms. The AAL-toxin produced by *Alternaria* species induce apoptosis in experimental monkey kidney cells (Wolpert *et al.*, 2002). This toxin also caused the depletion of complex sphingolipids and in the disruption of sphingolipid metabolism leading to the death of mammalian cells (Thomma, 2003; Abbas *et al.*, 1994). T-2 toxin, the trichothecene type of toxin produced by *Fusarium* sp. depressed the immune system and caused nausea and vomiting in man; the fumonisin produced by the same fungus caused abdominal pain, borborygmus and diarrhoea (Peraica *et al.*, 1999) and induced liver and kidney tumours in rodents. Fumonosins are classified as Group 2B ‘possibly carcinogenic to humans’, with ecological studies showing a possible link to increased oesophageal cancer (Wild and Gong, 2010). Clerocidin, also produced by *Fusarium* modified the gyrase-DNA gate to induce irreversible and reversible DNA damage in animals (Pan *et al.*, 2008). Colletotrichin, a toxin isolated from *Colletotrichum capsici*, markedly inhibited the oxidation of succinate and those substrates with NAD-linked dehydrogenases in liver and kidney (Foucher *et al.*, 1974). Cercosporin produced by *Cercospora* sp. generated highly toxic singlet oxygen (¹O₂), an extremely toxic compound to humans and other organisms.
Topopyrones produced by Phoma sp. are highly toxic, and damaged DNA by trapping the covalent binary complex formed between topoisomerase and DNA substrate in humans (Khan et al., 2008). Phomalactone produced by Phomopsis sp. exhibited potent cytokine production inhibitory activity, which badly affect immune responses in humans (Wrigley et al., 1999). Similarly, Phenochalasin produced by the same fungus inhibited the formation of lipid droplets in experimental animals (Tomoda et al., 1999). The toxins produced by fungi are listed in ANNEXURE V.

**Biotransformation**

Biotransformation is ‘the bioconversion of one compound into another due to the activity of a microorganism’. During the process of pathogenesis, many chemical reactions involving several enzymatic reactions takes place which might lead to the conversion of one chemical compound into compound through bio-conversion. Pathogens have been reported to exhibit the property of biotransformation (Amadio and Murphy, 2010; Andryushina et al., 2010).

Microorganisms like fungi, and bacteria have been used for the biological transformation of organic compounds. Recently, the use of either the whole microorganism or their enzymatic system alone resulted in steriospecific and sterioselective reactions that are of greater significance. These reactions have demonstrated their usefulness in the asymmetric synthesis of molecules with important biological activities and industrial applications (Pajon et al., 2003). Through biotransformation, it is possible to synthesize compounds which are otherwise difficult to be synthesized by chemical methods; for example some steroid compounds (Liu et al.,
The biotransformation allows the production of regio- and stereoselective compounds under mild conditions. These products may be labeled as ‘natural’ rather than chemical (Carvalho and Fonseca, 2006). Biotransformation could also be done by using enzymes, however, enzymes are expensive but the whole cell biocatalysts such as bacteria, fungi are cheaper and simpler. Microbial biotransformation has the advantage over other systems in that the production of biomass that could be achieved quickly and it might mimic mammalian catabolism. It might allow the production of useful intermediates or metabolites in large enough quantities to allow the identification and use in drug toxicity studies (Rathbone and Bruce, 2002).

The above findings suggest that the plant-microbe interaction might induce the production of some secondary metabolites in the host plant which is more useful than the original chemical. Thus, the disease in the plant is also useful in terms of bio-conversion. Much of work is restricted to biotransformation *in vitro*. There are no reports available on the biotransformation studies in naturally occurring plant diseases.

Preliminary studies have shown that the medicinal climbers occur abundantly in the sanctuary forests located in Chikmagalur and Shimoga districts of Karnataka and are affected by diseases caused by fungal and bacterial pathogens and phytoplasma. However, the review of literature revealed that not much information on diseases caused in certain climbing medicinal plants like *Clitoria ternatea, Dioscorea alata, Dioscorea bulbifera, Gymnema sylvestre, Naravelia zeylanica* and *Tinospora cordifolia* is available in India.
Botanical description of selected climber species

Clitoria ternatea

*Clitoria ternatea* belongs to the subfamily Papilionaceae of the family Leguminaceae. It is a pretty, hardy perennial climber and grows up to 2-3m in height. Leaves are pinnate, 6-13 cm long; leaflet ovate or oblong, 2-5 cm long; flowers axillary, solitary; pedicel 8-13 mm long papilionaceous white or bright blue with yellow or orange centre. Calyx 1.3-2.0 cm, corolla 3.8-5.0 cm. Fruit of *Clitoria ternatea* is a pod, which is linear to oblong and flattened. Measures about 4-13 x 0.8-1.2 cm, sparsely pubescent, pale brown when mature. Pods dehisce completely along both sutures and twisted to release the seeds. There are about 8-11 seeds present per pod. Seeds are oblong, somewhat flattened, measures 4.5-7 x 3-4 mm, olive brown to almost black, shiny, often patterned, and minutely pitted. The roots fix atmospheric nitrogen, therefore this plant could be used to improve soil fertility.

Dioscorea alata

*Dioscorea alata* belongs to the family Dioscoreaceae. It is vigorously twining herbaceous vine, from massive underground tuber. Stems to 10 m or more in length, freely branching above; internodes square in cross section, with corners compressed into "wings," these often red-purple tinged. Aerial tubers (bulbils) formed in leaf axils (not as freely as in *D. bulbifera*), elongate, to 10 x 3 cm, with rough, bumpy surfaces. Leaves long petioled, opposite (often with only 1 leaf persistent); blades to 20 cm or more long, narrowly heart shaped, with basal lobes often angular. Flowers small, occasional, male and female arising from leaf axils on separate plants (i.e., a dioecious species), male
flowers in panicles to 30 cm long, female flowers in smaller spikes. Fruit a 3-parted capsule; seeds winged.

*Dioscorea bulbifera*

*Dioscorea bulbifera* is also belongs to the family Dioscoreaceae. It is vigorously twining herbaceous vine, with small or absent underground tubers. Stems to 20 m or more in length, freely branching above; internodes round or slightly angled in cross section, not winged (as in *D. alata*). Aerial tubers (bulbils) freely formed in leaf axils, with mostly smooth to surfaces. Leaves long petioled, alternate; blades to 20 cm or more long, broadly heart shaped, with basal lobes usually rounded. Flowers small, fragrant, male and female arising from leaf axils on separate plants (i.e., a dioecious species), in panicles or spikes to 11 cm long. Fruit a capsule; seeds partially winged.

Coursey (1967) reported two phases in the growth of *Dioscorea* species - repeated cycle of growth and dormancy. In the active phase, the plant is represented by the above ground parts like stem and leaf and the dormant phase by the subterranean tuber. The growth of the stem at the beginning of the active phase is very rapid, up to 15 cm per day (Masterson, 2012). *Dioscorea bulbifera* reproduce through asexual method by means of underground tubers or aerial bulbils. Sexual reproduction via seed is still likely of secondary importance. Seeds of *D. bulbifera* and other members of the genus are believed to undergo an obligate dormancy period of several months before they germinate (Masterson, 2012). A single vine may produce as many as 200 bulbils, through which means the plant regenerates.
The continuous variation in anthracnose is resistance observed in the natural population of *D. alata* in field (IITA report) (Asiedu, 2001). Bhattacharjee *et al.* (2011) opined that genetic erosion was observed in *Dioscorea* species due to intensive cultivation of improved cultivars. He also suggested that domestication of wild species is useful in breeding program since they are believed to be the reservoir of resistance genes including anthracnose disease. This suggestion supports the study of diseases in wild population to select of plants more resistant to the particular disease.

**Gymnema sylvestre**

*Gymnema sylvestre* belongs to the family Asclepiadaceae. It is a slow growing, perennial, twining/woody climber, much-branched, rooting at nodes. Leaves 3-6×2-3 cm, ovate or elliptic-oblong, apiculate, rounded at base, sub-coriaceous. Flowers minute, greenish-yellow, spirally arranged in lateral pedunculate or nearly sessile cymes. Corolla lobes imbricate. Follicles solitary, upto 8×0.7 cm, terete, lanceolate, straight or slightly curved, glabrous. Seeds ovate-oblong, glabrous, winged, brown. Flowering and fruiting during October-March.

**Naravelia zeylanica**

*Naravelia zeylanica* belongs to family Ranunculaceae. Stem striate, subglabrous. Lateral leaflet petiolules 1.5-2.5 cm; central leaflet petiolule 3-7 cm, shallowly striate; leaflet blade ovate, 6-11 × 6-10 cm, abaxially sparsely curved hairy to subglabrous, adaxially glabrous, base rounded to cordate; 5-veined from base. Inflorescences terminal or axillary, to 40 cm, velutinous; bractlets borne at middle of pedicel, scaly. Flowers 1 cm in diam. Sepals pale yellow, narrowly obovate to elliptic, 5-7 × 3 mm, sparsely
pubescent. Petals 8-10, clavate, obovate, or spatulate, 5-7 × 1-1.5 mm. Stamens linear, 2.5-3.5 mm; anthers yellow, linear, glabrous, apex rounded. Pistils linear, lanate-villous. Persistent styles 3 cm. Achenes fusiform, 4 mm, pilose. The plant was regenerated through the seeds. Even though plant produced large number of fruits, not all the fruits produced viable seeds.

*Tinospora cordifolia*

*Tinospora cordifolia* belonging to Menispermaceae is a big climber (glabrous) shrub generally climbs on large trees. It is a twining, succulent-stemmed, fast growing with tuberous roots. Its branches are grey-green, up to 40 mm in diameter, becoming brown with age. The leaves are heart-shaped and 100 ×100 mm. Its flowers are tiny creamy-greenish and male and female flowers are formed on different branches. It flowers and fruiting during November - February. The female flowers are followed by oval red fruit up to 10 mm in diameter Bark is thin, greyish or creamy white in colour, when peeled fleshy stem is exposed. Its seeds are curved, pea sized.

The active principles and the therapeutic values of the above climbing medicinal plants are detailed in Table 2.1.
<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Plant species/common name/family</th>
<th>Therapeutic property/biological activity</th>
<th>Active principle</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td><em>Clitoria ternatea</em> L. Shankapushpi (K), ‘Aparajita’ (S) Butterfly pea (E) Papilionaceae</td>
<td>Antimicrobial</td>
<td>Cliotides (cyclotides)</td>
<td>Nguyen <em>et al.</em>, 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Uterotonic activity and anti-HIV activity insecticidal activity</td>
<td>Cyclotides (plant-derived proteins)</td>
<td>Poth <em>et al.</em>, 2011</td>
</tr>
<tr>
<td>02</td>
<td><em>Dioscorea alata</em> L. Noorele genasu (K) ‘Kaashtaaluka’ (S) Greater Yam (E) Dioscoreaceae</td>
<td>Antisthmatic</td>
<td>Flavonoids or saponins.</td>
<td>Taur and Patil, 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antimicrobial and insecticidal</td>
<td>'Finotin' (protein from seeds)</td>
<td>Kelemu <em>et al.</em>, 2004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Immunomodulatory</td>
<td>Dioscorins</td>
<td>Lin <em>et al.</em>, 2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Estrogenic compounds</td>
<td>Hydro-Q(9) chromene (1) gammatocopherol-9 (2)</td>
<td>Cheng <em>et al.</em>, 2007</td>
</tr>
<tr>
<td>03</td>
<td><em>Dioscorea bulbifera</em> L. Heggenasu (K) ‘Vaaraahikanda’ (S) Potato Yam (E) Dioscoreaceae</td>
<td>Free radical scavenging</td>
<td>1,1-diphenyl-2-picrylhydrazyl</td>
<td>Chen <em>et al.</em>, 2004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hypertension</td>
<td>Dioscorin and its hydrolysates</td>
<td>Hsu <em>et al.</em>, 2002</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antifungal</td>
<td>Beta-sitosterol</td>
<td>Aderiye <em>et al.</em>, 1964</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cause Hepatotoxicity</td>
<td>Diosbulbin B</td>
<td>Xu <em>et al.</em>, 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cardioprotective effect</td>
<td>Flavonoid rich fraction (FRF)</td>
<td>Jayachandran <em>et al.</em>, 2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antibacterial</td>
<td>8-epidosbulbin E acetate</td>
<td>Shriram <em>et al.</em>, 2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antitumour</td>
<td>Polysaccharide</td>
<td>Zhang <em>et al.</em>, 2007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anti-salmonellal</td>
<td>Bafoudiosbulbins A, and B</td>
<td>Teponno <em>et al.</em>, 2006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anticancer</td>
<td>Pet eth extract</td>
<td>Yu <em>et al.</em>, 2004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anti tumour</td>
<td>Kaempferol-3,5-dimethyl ether, (+)-catechin, myricetin, and diosbulbin B</td>
<td>Gao <em>et al.</em>, 2002</td>
</tr>
</tbody>
</table>

Contd...
<table>
<thead>
<tr>
<th>No.</th>
<th>Species</th>
<th>Activity</th>
<th>Compound</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>04</td>
<td><em>Gymnema sylvestre</em> R.Br. ex Schult. Madhunashini (K) 'Meshashringi' (S) Gymnema (E) Asclepiadacea</td>
<td>Larvicidal</td>
<td>Gymnemagenol</td>
<td>Khanna et al., 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leishmanicidal</td>
<td>Sapogenin, gymnemagenol</td>
<td>Khanna et al., 2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radioprotective efficacy</td>
<td>Gymnemic acid</td>
<td>Sharma et al., 2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Weight control</td>
<td></td>
<td>Preuss et al., 2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increases fecal cholesterol and CA-</td>
<td></td>
<td>Nakamura et al., 1999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>derived bile acid excretion</td>
<td></td>
<td>Shimizu et al., 1997;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inhibit the intestinal absorption of</td>
<td></td>
<td>Wang et al., 1998</td>
</tr>
<tr>
<td></td>
<td></td>
<td>glucose and also oleic acid</td>
<td></td>
<td>Murakami et al., 1996</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hypoglycemic</td>
<td>Gymnemic acid- gymnemosides a and b gymnemoside b and gymnemic acid V</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antihyperglycemic</td>
<td>Gymnemic acid IV</td>
<td>Sugihara et al., 2000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Selectively inhibits responses to sweet substances</td>
<td>Gurmarin (sweet-suppressive Peptide(protein))</td>
<td>Murata et al., 2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hyperlipidemic</td>
<td>Gymnemate</td>
<td>Luo et al., 2007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antisweet activity</td>
<td>Sodium salt of alternoside II</td>
<td>Ye et al., 2001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inhibition of sweet taste responses</td>
<td>Gurmarin</td>
<td>Ninomiya and Imoto, 1995</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antisweet principles</td>
<td>Gymnemagenin - gymnemic acid-III, -IV, -V, -VIII, and -IX,</td>
<td>Liu et al., 1992</td>
</tr>
</tbody>
</table>
Table 2.1 contd...

<table>
<thead>
<tr>
<th></th>
<th>Plant Name</th>
<th>Activity</th>
<th>Compounds</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>05</td>
<td><em>Naravelia zeylanica</em> (L.) DC. Talevodetada balli (K) ‘Dhanavalli’ (S) Ranunculaceae</td>
<td>Antimicrobial</td>
<td>Taraxerol and β-sitosterol</td>
<td>Naika <em>et al</em>., 2005</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anticancer</td>
<td>Berberine</td>
<td>Naika and Krishna, 2008</td>
</tr>
<tr>
<td>06</td>
<td><em>Tinospora cordifolia</em> (Willd.) Miers ex Hook.f. &amp; Thomson Amruthaballi (K) ‘Guduuchi’ (S) Tinospora (E) Menispermaceae</td>
<td>Hypoglycemic effects by insulin releasing and insulin-mimicking activity</td>
<td>Palmatine, jatrorrhizine and Magnoflorine</td>
<td>Patel and Mishra, 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antiosteoporotic effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hypoglycemic</td>
<td>Saponarin</td>
<td>Seidlova-Wuttke <em>et al</em>., 2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chemopreventive</td>
<td>Epoxy clerodane diterpene</td>
<td>Sengupta <em>et al</em>., 2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antiangiogenic</td>
<td>Octacosanol</td>
<td>Dhanasekaran <em>et al</em>., 2009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Immunomodulatory</td>
<td>Arabinogalactan polysaccharide from stem</td>
<td>Thippeswamy <em>et al</em>., 2008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Immunostimulating</td>
<td>(1,4)-alpha-D-glucan (RR1)</td>
<td>Nair <em>et al</em>., 2006</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Antioxidant</td>
<td>Arabinogalactan polysaccharide</td>
<td>Subramanian <em>et al</em>., 2002</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Polyclonal mitogenic activity</td>
<td>Polysaccharide -arabinogalactan</td>
<td>Chintalwar <em>et al</em>., 1999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anticomplementary and Immunomodulatory on guinea pig</td>
<td>Syringin (TC-4) and cordiol (TC-7)</td>
<td>Kapil and Sharma, 1997</td>
</tr>
</tbody>
</table>

K=Kannada name; S= Sanskrit name; E= English name
The above climber medicinal species have not been studied for diseases caused in them in forests of Bhadra Wildlife Sanctuary which is situated in Chikmagalur and Shimoga districts of Karnataka. Further the literature survey suggested that there is no published work on seedborne nature, transmission, incidence and severity of diseases, spatial distribution of diseases, control of seed mycoflora and the effect of disease on secondary metabolite content in foliages of these medicinal plants.