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Forest, "A peculiar organism of unlimited kindness and benevolence, that makes no demands for its sustenance. But, extends protection to all beings. Offering shade even to all the man with the axe, who destroys it".

- Gautam Buddha, 487 BC.
The Western Ghats are regarded not only as ‘biological treasure troves’ but are also considered to be one of the major ‘hotspots’ of biodiversity regions of the world. Springing from the Arabian sea coast to the montane heights of over 2,000 m and having rainfall ranging from less than 1,000 mm to over 6,000 mm, the landscape is very heterogeneous. The Western Ghats, boasts of biologically diverse forests and consists of a variety of forest types and spreads over states of Maharashtra, Karnataka, and Kerala. The Western Ghats harbours around 5500 species of flowering plants alone. Globally, flowering plants are estimated to constitute 2.5% of the total number of species of all groups, this leads to an estimate of 2,20,000 species over the Western Ghats (Utkarsh et al., 1998).

The biodiversity areas are under a high degree of threat due to slash and burn cultivation, savannization and forestry operations, and the latter favours deciduous timber species thus reducing endemic plants in the Western Ghats (Chandran, 1993). Most of the endemic plants in the Western Ghats are associated with evergreen forests (Myers, 2000).

The Western Ghats located in Karnataka is a unique biological entity and forests covers an area of 30,755.73 sq km and are perhaps the most productive region, with large tracts of pristine forests, well wooded areas and unspoilt coastline in the Peninsula. The region straddles the districts of Uttara Kannada, Dakshina Kannada, Shimoga, Chikkamagalore, Hassan and Kodagu and perhaps has the largest combination of plantations, agrifloriculture, fishery and other economic produces.
In India, out of an estimated 45,000 species of plants, 17,000 species are the flowering plants. More than 7,500 species are used for human and veterinary health care by 4,635 ethnic communities in India (Kareem, 1999). On the other hand, mining in the Western Ghats is a major factor causing forest fragmentation and many large and small dams are constructed for irrigation and hydroelectric power. In addition to this, pests and diseases have resulted in the elimination of the virgin forest cover. It is estimated that around 10% of the flora is threatened with extinction.

In the heart of the Western Ghats of Karnataka lies, Bhadra Wildlife Sanctuary which is located in the districts of Chikkamagalore and Shimoga. The area is well drained by Bhadra river and all these areas are ecologically more or less distinct and almost contiguous except a few patches of private coffee cultivation in between. Karnataka’s highest mountain peak Mullaiagnagiri, lies just outside the southern boundary of Muthodi forests.

There is an iron ore mine at Kemmannugundi in the Bababudangiri hills. Inside the sanctuary, there were about 736 families in 16 villages who were growing paddy and coffee for almost a century and depended on the surrounding forests for their requirements. In 2002, villagers were offered a good resettlement, package and were moved into the resettlement sites outside the sanctuary.

Bhadra Wildlife Sanctuary is the paradise of wildlife, more particularly bison’s (now, a few) and other larger animals like elephants, leopards, sloth bear, sambar and, deer and reptiles like python, king cobra, and amphibians and, birds like king fisher. Ibis, Malabar pied horn bill, myna and bulbul. However, due to various reasons wildlife is reduced to a few countable populations.
Plants are used by people for many purposes other than food. Many medicines are obtained from plants to treat a variety of ailments. Rural and primitive cultures around the world still depend on native plants to relieve pain and cure illness. Based on the traditional knowledge, that was used to treat human ailments, researchers have developed many modern medicines. Each of the 20 best selling drugs in the world is either extracted directly from a plant or linked to a plant in another way.

The bioactive molecules of plant origin are the chemical substances of promise used in the therapy of a wide range of diseases including aids, cancer and hepatitis. Over 95% of the medicinal plants used by the Indian industry today are collected from the wild. Over 70% of the plant collections involve destructive harvesting because of the requirement of large quantities of root, bark, wood or stem and even whole plants. Increasing human populations and growing demand for land for socio-economic development has led to increasing rates of destruction and degradation of natural habitats and putting many medicinal plants under risk of genetic erosions and even extinction.

There has been considerable work on the floristic biodiversity of the Western Ghats of Karnataka and Bhadra Wildlife Sanctuary. The work of Cameron deserves more attention, as he has managed to publish several lists as well as a book on the Forest Trees of Mysore and Coorg (1894), while Subramanyam and Nayar (1974) brought out a book on the vegetation of the Western Ghats. However, a good general account of forests of the state was given by Hussain (1974; 1975 a,b,c,d) and Rao and Razi (1973-74). Similarly, several lists have emanated due to the efforts of several workers like, Lavery (1888) on Shimoga trees and Yoganarasimhan et al. (1977a,b) on vegetation and plants of Chikkamagalore district. Several books and pamphlet based on plants of
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the state have been published and these include Mallikarjunappa’s (1973) list of botanical and Kannada names, Narasimhachar’s (1949) on botanical and Kannada names, Ramaswamy’s (1969) Kannada book on forest trees of Karnataka, Ramaswamy et al. (2001) flora of Shimoga district, Gamble’s (1997) flora of Presidency of Madras, Ramaswamy’s and Razi’s (1973) flora of Bangalore district and Saldanha and Nicholson’s (1976) flora of Hassan. Even, geographical and ecological studies of plants have got their due share of attention from several workers. Among them, Pascal’s (1988) wet evergreen forests of the Western Ghats; ecology, structure, floristic composition and succession and bilingual list of 500 medicinal plants (Anon, 1922) are note worthy.

Recently, Bhat and Murali (2001) studied phenology of the under storey species of tropical moist forests of the Western Ghats region of Uttara Kannada district in South India. Utkarsh et al. (1998) worked on the patterns of the diversity in the Western Ghats of India. Shivaraj et al. (2000) worked on the mapping of forests based on the biological diversity to identify conservation sites, a case study from Udupi and South Canara districts of Karnataka; tree communities and human influence in the Western Ghats, India by Achar et al. (2000) and Western Ghats : A life scape, Gadgil (1996). All these works highlight different aspects of the Western Ghats.

Diseases of medicinal herbs

Beginning of the knowledge concerning plant diseases are in the very remote past. However, often-strange mixtures of facts and fancy have little scientific value.

The green leaves exhibit a phenomenon of removing some of the microbes normally carried by wind. Once the leaves comes in contact with microbes, a series of complex events follow due to interaction between leaf surface exudates and microbes,
whose spores happen to colonize the leaf. In conjunction with the microbial and host metabolism, physical factors (light, temperature, air current and humidity) also interact with ecological niche of the leaf (Sharma and Mukerji, 1974) and the resultant disease might reduce the quality and are responsible for major productive losses of forests and are more destructive. Fungi, bacteria, viruses and mycoplasmas are mainly responsible for causing diseases (Kumar et al., 1991). Among them, fungal pathogens are known to pose major threats to plant species including the medicinal plants (Bisht et al., 1997).

Bilgrami (1997) conducted an exclusive work on the fungal wealth of India. More than 2000 fungal genera have been reported from the country, amongst which 185 are new genera. A large number of Indian fungi have also been reported on the basis of their habitat. Maximum number of fungi belong to the group deuteromycotina of which, hyphomycetes constitute the largest class represented by 600 genera and 4000 species and soil is the richest habitat for fungal organisms followed by forest and crop litter. They found that species of Cercospora, Fusarium, Alternaria and Helminthosporium cause serious plant diseases in different parts of the country. Also, the members of class Coelomycetes like species of Colletotrichum, Pestalotiopsis, Phoma and Botryodiplodia are very well distributed and cause field and storage diseases.

Diseases of crop plants have been studied to a great extent as compared to the other groups of plants. Fungal diseases of some important medicinal plants have also been studied to some extent. In this part of the thesis, attempts were made to collect literature on the occurrence, symptomology, disease severity, epidemiology, detection methods, pathogenicity and disease management in herbaceous medicinal plant and
qualitative and quantitative changes in phytochemicals following infection by fungal pathogens.

Fungal diseases of plants gained due scientific attention rather very late. The important contribution of fungal pathology of herbaceous medicinal plants includes those of Stevenson (1942) on the drug plant *Atropa bellodona* grown in 32 acres as a war emergency project in Virginia. The leaf spots caused considerable injury and the fungus was identified as *Cercospora atropae*. The Indian workers such as Ganguley *et al.* (1962) reported leaf necrosis on *A. bellodonna* caused by *Aschochyta kashmiriana* and, in 1970, Janardhanan *et al.*, observed severe root rot both in young and old plants of belladonna in the farms of Jammu and Kashmir, which was due to the causal organism *Pythium butleri*.

Grogan and Kimble (1959), reported decline and replant problem of *Asparagus racemosus* in California due to *Fusarium oxysporum f. sp. asparagi*. They suggested that the organism is seed borne and a vascular parasite and is a major factor for the rapid killing of seedlings in infested soil. Bakel and Kerstens (1974) observed yellowing and dying of mature stem combined with reddish lesions on the stem or below soil level in *A. officinalis*. Results of the study showed that the stem death was due to the infection/lesion at the base of the stem at the soil level with *Fusarium culmorum*. They proved that fungus is mainly spread through the soil and also demonstrated the spread of the fungus by air which is dependent on other factors such as length of the humid period and the presence of wounds. In 1979, Johnston *et al.* observed extensive crown rot and stem pith discoloration of asparagus which resulted in the decline and replant problem in the production fields of North America. In addition to *F. oxysporum f. sp. asparagi*, *F. moniliforme* was also isolated from asparagus plants. Based on the isolation and
pathogenicity studies, *F. moniliforme* was reported as the pathogen of a distinct disease of asparagus, *Fusarium* stem and crown rot. Results of this study indicated that *F. moniliforme* was predominantly isolated from old plantings, where it caused extensive stem and crown rot.

Similarly, Falloon *et al.* (1987) isolated *S. vesicarium* from asparagus throughout California. Most California isolates from spears, green fern or debris, as well as three isolates of *S. vesicarium* from Switzerland and two isolates resembling the conidal state of *S. majusculum* from England were pathogenic on young asparagus seedlings. All penetrations of tissue from germinated spores of *Stemphylium* and *Pleospora* were exclusively through stomata. However, reproduction of spear symptoms failed unless water stress was relieved or prevented before inoculation. Pseudothecia of *Pleospora* on fern debris were shown to be an important source of inoculum for purple spot of asparagus spears.

Tripathi in 1985 described two diseases of asparagus caused by the pathogens *Cercospora asparagi* and *Phomopsis asparagi* on needles and branches and, on the stem, respectively, from Garhwal, Himalayas which caused 30-35% of damage to the crop.

Schreuder *et al.* (1995) isolated three dominant fungi viz., *F. oxysporum* and *F. proliferatum* and to lesser extent *F. solani* from crown, root and stem lesions of symptomatic U.c. 157 F₂ asparagus plants and also from soil debris from a declining asparagus field at South Africa. Three *Fusarium* species isolated were pathogenic to asparagus. However, they differed significantly in their disease causing ability. In an *in vitro* assay, *F. proliferatum* caused a mean disease rating class of 4 as compared to a class of 3 for *F. oxysporum* and 2 for *F. solani* on a scale of 1-5. The high frequency of
isolation and virulence of both *F. oxysporum* and *F. proliferatum* indicated that both species are important pathogens associated with asparagus decline in South Africa.

Ikediugwu and Juliana (1978) described the leaf and flower disease of *Acalypha* species in Nigeria, that was most prevalent during the wetter part of the year i.e., July to September on *A. hispida, A. wilkesiana var. macafeana* and *A. godseffiana*. *Botrytis* sp. was isolated from all the diseased leaf tissues and from the infected floral parts of *A. hispida*. Artificial inoculation with *Botrytis* sp. resulted in a lesion by the sixth day that resembled those of naturally infected plant. *Acalypha* species appear to be a possible reservoir of this important pathogen of crops.

Nath and Bhargava (1980) conducted a survey of fungi causing leaf spot disease of *Achyranthus aspera* in the Gorakhpur area. They identified the causal organism as *Colletotrichum dematium* or *Vermicularia*. However, *Cercospora achyrathina* was the leaf spot causing organism in *Achyranthus aspera* from Kurukshetra (Aneja and Kaushal, 2000).

In 1961, Lall et al. described *Cercospora stachytarphetae* on *Averrhoa carambola* and fungus produce spots that varied in size, with distinct color and the conidia.

Khutua et al. (1981) reported new diseases of vegetables, ornamental and plantation crops, caused by *Colletotrichum capsici* causing leaf spot and anthracnose on *Amorphophallus campanulatus* in the rainy season.

Mallaiah et al. (1981) identified *Oidium* sp. as the causal organism of powdery mildew of *Aeschynomene indica* near Nagarjunasagar.

Aneja and Kaur (1995) carried out surveys for pathogenic fungi associated with infected materials collected from Kurukshetra and adjoining areas of Haryana during
1992 and 1993. Totally, about 12 fungal pathogens were identified and pathogenicity of a few to their respective hosts was proved. *Cercospora calotropidis* on *Calotropis procera*; *Cercospora* sp. on *Amaranthus viridis*; *Oidium* state of *Leveillula taurica* on *Medicago lupulina*; *Ramularia rubella* on *Rumex dentatus*; *Bremia* sp. on *Sonchus oleraceus*; *Pseudocercospora afromarginalis* (*C. agramarginalis*) on *Croton borplandianum* are the pathogens reported from Haryana. However, *Curvularia lunata* disease on *Parthenium hysterophorus* was reported for the first time from India.

In 2001, Srivastava *et al.* collected species of *Cercospora* from Gorakhpur and adjoining areas of North Eastern UP from infected leaves of *Aerva scandens* with distinct symptoms. Study revealed the occurrence of a new species - *Cercospora aervae*.

Plants with medicinal and aromatic value are cultivated in large scale for the production of drugs, perfumes and essential oils in Karnataka. More often, these crops are reported to be infected by various disease causing organisms. During 2001, Khan *et al.*, observed different diseases like damping-off by *Rhizoctonia solani*, rust by *Uromyces hohsoni*, leaf spot by *Cercospora jasminicola, A. alternata* and *Phoma herbarum*, leaf blight by *Glomerella cingulata* and wilt by *Sclerotium rolfsii* on *Artemisia parviflora* (Davana).

In 1987, Sickinger *et al.*, reported *Verticillium* wilt of *Abutilon theophrasti* (velvet leaf). The symptom of the disease - chlorosis, necrosis and darkening of the stele of roots and stems was produced due to *Verticillium dahliae* during mid-July. A decline in plant vigour was noted near the end of the life cycle. In advanced stages of the disease, a reduction in seed, pod size and number was observed; many pods produced aborted
seeds. Field experiments showed that *V. dahliae* was specific for velvet leaf and failed to induce disease in cabbage and pepper.

Venkatasubbaiah *et al.* (1992) isolated *Stagonospora apocyni* from leaf spot disease symptoms on *Apocynum cannabinum* L. (hemp dogbane) and proved Koch’s postulate. The 4 phytotoxins like Citrinin, (S)–Mellein, tyrosol and L-acetylorcinol were isolated and identified from culture filtrate of *S. apocyni*. All these 4 toxins from the genus *Stagnospora* caused necrotic lesion on hemp dogbane leaves similar to that in naturally infected plants. Of these toxins, Citrinin received attention because of its toxicity to humans and livestock.

Purushothaman (1971) observed leaf blight disease on *Barleria cristata*, due to *A. tenuis* in many parts of Tamil Nadu, India. Disease was manifested as brown to dark-brown specks of about 5 mm dia. on young leaves. In older leaves, lesions coalesced into larger blighted areas with concentric rings. Finally, leaves curled and dropped-off.

In 1981, Khatua *et al.*, reported leaf blight of *Brassica oleracea* var. *botrytis* caused by *R. solani*. Khangura (1999) reported *Rhizoctonia* sp. from hypocotyl rot of *Brassica napus* (Canola, an oil seed crop in Western Australia). Their findings revealed that pectic enzyme differentiated the pathogen isolates into six distinct zymogram groups like 54% ZG5, 8% ZG6, 1% ZG9, 12% CZG1, 4%, CZG4 and 6% CZG5, amongst which ZG5 was found to be the most pathogenic and virulent.

In 1981, wilt of *Basilla alba* was reported due to *Sclerotium rolfsii* and *Meloidogyne incognita* by Khatua *et al.*, during rainy season.
Manoharachary et al. (2003) collected sooty molds growing in the living leaves of *Bassia latifolia* and *Bougainvillea spectabilis*. They identified the pathogen as *Polychaeton bassiae* and *Polychaeton bougainvilleae*.

Keim (1977) established the pathogenicity of *Phytophthora parasitica* on *C. roseus* in a production nursery. Infection initiated in the shoot apex, and portions of foliage were later wilted, and leaves showed a dull grey colour. Subsequently, the wilted leaves became severely necrotic, followed by shriveling and necrosis of the stem. However, there were no lesions found on plant tissues at or below the surface of the soil. The practice of pruning *C. roseus* in container stock nurseries was shown to increase the opportunities for diseased foliage and suggested that nurseries engaged in the production of *C. roseus* in containers should exercise special care to avoid splashing of foliage. Khatua et al. (1981) reported that foot and root rot of *C. roseus* was caused by *M. phaseolina* in India.

Ganguly and Pandotra (1962) described powdery mildew (*Erysiphe cichoracearum*) on leaves of *Chenopodium ambrosioides* from the state of Jammu and Kashmir.

*Cassia occidentalis* (coffee senna) has been used for a variety of medicinal purposes and as a potential source of gum. Gudauskas et al. (1977) observed severe disease during summer in Agronomy Farm at Auburn University, Alabama, on plantings of *C. occidentalis*. Disease symptoms were noted in July when the weeds were about 25 cm in height. Based on characteristics observed in infected tissues and on artificial culture, the fungus associated with coffee senna was identified as *C. dematium*. They
found the disease to be a limiting factor to seed production of coffee senna. Coffee senna was reported to be a source of inoculum of the fungus for soybeans and other hosts, as they are susceptible to anthracnose caused by *C. dematium f. truncata*. However, soybeans were not examined extensively. Further, they suggested that, the potential value of *C. dematium f. truncata* as a mycoherbicide is a consideration that warrants additional studies. During surveys of pathogenic fungi of Kurukshetra in 2000 (Aneja and Kaushal), a typical disease symptom produced by non obligate pathogen *Curvularia lunata* on *Cassia obtusifolia* and *Cercospora sp.-I*, on *C. occidentalis* were reported in this region.

Singh and Bhalla (2000) explored the fungal foliar diseases in natural as well as planted forests of Mirzapur district (UP). Observations revealed that the hyphomycetous form genus *Pseudocercospora* was the potent causal agent; *P. cassiae sophorae* and *P. cocculicola* occurred on *C. sophera* and *Cocculus hirsutus*, respectively. *Cassia angustifolia* (senna) a medicinal plant grown in Karnataka was found infected by *A. alternata* on leaves. The disease was controlled by using Iprodione or Mancozeb (Khan *et al.*, 2001).

Muniyappa *et al.* (1979) reported an undescribed white leaf disease of *Cynodon dactylon* (Bermuda grass) in India. Disease occurred singly or in small patches, with small white leaves, shorter rhizomes and internodes, excessive sprouts from nodes or base of the diseased plant. Electron microscope study revealed the association of pleomorphic mycoplasma like organisms (MLO) in the phloem tissues of infected plant materials and not in healthy leaves which suggested that MLO are the probable cause of

Palmarosa - *Cymbopogon martini* var. *motia* and other species of *Cymbopogon*, the essential oil bearing plants of poaceae, are cultivated on commercial scale in India. A number of pathogens have been reported to cause severe diseases on palmarososa and considerable work has been carried out to identify the pathogen(s). Leaf blight disease of palmarosa caused by *Curvularia trifolii* significantly affected the essential oil yield (Gupta *et al.*, 1977; 2000).

Similarly, Janardhan *et al.* (1980) reported leaf blotch disease caused by *Curvularia andropogonis*. The disease caused a significant reduction in total essential oil as well as the geraniol content of plants. The leaf spot disease caused by pathogen *Helminthosporium leucostylum* was reported on lemon grass (*C. fexuosus*) plants by Santra (1981). Singh *et al.* (1999) identified 15 resistant and one susceptible accession, among the available genetic stocks of lemon grass against rust pathogen *Puccinia nakanishikii*. The behaviour of F₁ generation plants arising from spontaneous cross(es) between the resistant and susceptible accessions showed that the, susceptible accession harboured recessive allele(s) of the gene(s) present in dominant allelic form(s) in the resistant accessions.

Alam *et al.* (1994) observed collar rot and wilt disease affecting commercial plantings of Java citronella (*C. winterianus*) in Lucknow, Patnagar and the adjoining areas. In field, infected plants exhibited leaf curling, and dried leaves with basal rotting. Infection spread from one plant to another and caused premature drying and death in large number of plants. Isolates recovered from infected plants were identified as
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F. moniliforme and a less frequency of Pythium sp. The isolates differed in their pathogenicity under green-house conditions. There were also differences in growth rate, pigment production and sporulation between isolates. The causal organism was finally identified as Fusarium moniliforme, the anamorph of Gibberrella fujikuroi.

Cymbopogon jwarancusa grows wild in Kashmir (India), the leaves of this perennial grass on distillation yield an aromatic oil, which is of great pharmaceutical utility. Dhar and Rekha (1996) observed a new smut disease on the flowering racemes of some plants in the experimental farm during 1984. The fungus was identified as Sphacelotheca cymbopogonis. Reduction in the height of the infested spike was reported. Smut pathogen Tolyposporium christensenii on Cymbopogon was studied by Khan et al. (2001) in Karnataka. They recommended the use of Mancozeb, Dithane-M, Rovaral, Bavistin, Karathane, and neem-based nematicides either by spraying or applying or by treating.

Nath and Bhargava (1980) surveyed leaf spot diseases in the Gorakhpur area. They isolated Colletotrichum dematium belonging to family Melanconiales on leaves of Clitoria ternatea (Leguminosae).

Douglas and Mac Hardy (1981) have worked on the pathology of Chrysanthemum morifolium. Their work revealed the relationship between vascular alterations and symptom development in chrysanthemum due to V. dahliae, a wilt pathogen. Investigations showed that the pathogen secreted certain wall degrading enzymes suggesting the possibility of an altered wall developmental pattern or enzymatic activity on the vessel wall of inoculated plants. Vessels of uninoculated plant always had smooth
walls and unobstructed pits. Result also revealed that the development of disease symptom was closely related to coating of vessel walls and plugged vessels.

Mallaiah et al. (1981) reported powdery mildews fungus *Oidium* sp. in *Clerodendrum inermi*, near Nagarjunasagar and surroundings.

Oval shaped large whitish grey coloured necrotic leaf spots caused by *Pestalotiopsis* sp. on *C. longa* in the HRS, Gauhati during 1984 was reported by Borborua (1987). Palarpawar and Ghurde (1990) observed leaf spot disease of turmeric caused by *Colletotrichum curcumae*. Further study revealed that the pathogen remained viable for eight months in leaf debris.

Parasadji et al. (2004) studied the pathogen, *Taphrina maculans* and disease development in *C. longa*. Infection lead to the appearance of pale yellow specks on leaves that turned into large orange brown lesions which coalesced to produce leaf blotch. Histopathological observations on blotched leaf tissue revealed the octosporous colonies of ascospores in asci.

Verma (1984) studied powdery mildew of *Convolvulus arvensis* caused by species of *Oidium* and has given the complete description of the pathogen and its pathogenecity. Ormeno-nunez et al. (1988) reported *Phomopsis convolvulus* from the infected leaf of bindweed (*C. arvensis*) and has made a detailed study of disease severity and mortality in relation to the environmental conditions. These results suggested that this fungus has potential as a mycoherbicide. *Fusarium pallidoroseum* on *C. arvensis* was reported for the first time by Aneja and Srinivas (1992) from different parts of Haryana, while surveying for plant pathogenic fungi associated with aquatic weeds. Typical
disease symptoms were caused by the isolated pathogens on both wounded and unwounded, detached leaves *in vitro* and thereby confirming the pathogenicity.

*Chenopodium album*, a common leafy vegetable, cultivated during winter in Orissa was affected by leaf spot diseases due to *Phoma exigua*. Numerous black submerged pycnidia were present in the necrotic spots and the infected leaves dried and fall off, in the experimental plots at the Central Research Form of the University (Mishra, 1987).

Bilgrami *et al.* (1981) studied the damping-off disease of *Cannabis sativa* caused by *F. solani* f. sp. *solani*. Later in 1987, Mishra reported similar result and he also suggested chemical measures to control this pathogen.

*Croton tiglium* (Euphorbiaceae) is a herb grown extensively all over India for herbal medicine. During the southwest monsoon season, Nath *et al.* (1992) observed twig blight disease on 2-3-year-old plants. Usually infection started from the lower surface of the leaf and gradually spread to the twigs. The causal organism has been identified as *C. dematium*.

Bera and Purkayastha (1992) isolated a phytopathogenic fungus *Pestalotiopsis versicolor* from infected leaves of *Ceriops decandra*, an economically important mangrove plant of Sundarbans, West Bengal. Fungus was found to grow abundantly on the same species at different localities and exhibit differential growth characteristics.

Manoharachary *et al.* (2003), observed living leaves of *Centella asiatica* affected with spots having chestnut brown margins and pale central region in the botanical garden of Osmania University, Hyderabad. The pathogen was identified as *Cercospora centellae*. 
Chlorophytum borivilianum (safed musli), a commercially important medicinal plant valued as general tonic, was affected by a leaf spot disease due to *M. phaseolina* during 1999 at a research farm of National Research Centre for Medicinal and Aromatic Plants, Madhya Pradesh (Mandal *et al.*, 2004). Severity of disease of about 52% was recorded in the commercial fields of Khargone region of Madhya Pradesh during 2001.

Agarwal *et al.* (2001) observed three major diseases - wilt, blight and powdery mildew caused by *F. oxysporum*, *Alternaria burnsidei* and *Erysiphe polygoni*, respectively, in cultivated *Cuminum cyminum* (cumin). These pathogens affected the quality and yield of cumin, which varied from 70 to 80%. Among the disease, wilt caused by *F. oxysporum* was not manageable since fusaria can survive in soil for several years.

*Coleus* sp. cultivable in dry area is used to extract essential compounds, particularly, forskolin from roots. Forskolin is used as hormone sensitive enzyme in biological system. It is also being used for heart diseases and respiratory disorders. Siddaramaiah *et al.* (2001) observed root rot of *C. barbatus*, in Bangalore and the causal organism was identified as *Fusarium chlamydosporum*.

Powdery mildew (*Erysiphe cinchoracearum*) on leaves of *Chenopodium ambrosioides* from the state of Jammu and Kashmir was reported by Ganguly and Pandotra (1962).

Kar and Mehapatra (1981) recorded *Colletotrichum* species on *Cestrum diurnum* from India, Incidence of the pathogenic infection was severe during rainy season.

In 1974, Thakur observed root and foot rot of *D. innoxia* in Regional Research Laboratory plantation (Jammu). The disease affected plants at all stages of growth but was more in young plants. The seedlings showed damping-off within a few weeks of
sowing. Rot and foot rot is observed near the soil line showing dirty brown colour and complete separation of the bark. Identification indicated that *Corticium solani* caused root and foot rot of *D. innoxia*.

Alam *et al.* (2000) observed fruit rot, in the experimental fields of *D. innoxia* at CIMAP, Lucknow. Isolations from necrotic tissues and seeds of infected fruit samples invariably produced six fungal cultures and were identified as *A. alternata, A. solani, Bipolaris zeae, B. hawaiensis, C. lunata* and *F. pallidoroseum* were highly pathogenic. Microbial deterioration of tropane alkaloids viz., hyoscyamine and scopolamine was recorded. Maximum deterioration in hyoscyamine and scopolamine content due to *B. zeae* and *F. pallidoroseum*, respectively, was recorded; *C. lunata* and *A. alternata* showed minimum deterioration.

Sattar *et al.* (1982) observed leaf blight disease of *D. innoxia* caused by *Phytophthora nicotianae* in the vicinity of National Botanical Research Institute, and experimental field of CIAMP, Kukrali, Lucknow. Rakholiya and his associates (1998) reported new leaf spot disease of *D. innoxia* characterized by a number of spots on leaves. The fungus was identified as *Alternaria crassa*.

Filoda *et al.* (1998) reported *Fusarium* species - *F. solani* and *F. equiseti, F. avenaceum, F. coeruleum* and *F. oxysporum* were more frequent than *F. avenaceum, F. coeruleum* and *F. oxysporum* on medicinal plants and condiments like *Coriandrum sativum, D. innoxia, Hyssopus officinalis, Nigella sativa, Papaver somniferum* and *Hypericum perforatum*.

*Datura metel* var. muricata plants growing in plots of the division of Plant Introduction at Volcani Center were found to be infected with the fungus *A. crassa*.
Examination of seeds from infected pods revealed that a large number of seeds carried the fungus and the infected seeds were generally gray, whereas fungus-free seeds were brown and seedlings germinating from the infected seeds produced about 22% chlorotic cotyledons. The fungus the reduced seed quality and caused pre-emergence killing, seedling blight. The mycelium was located beneath the seed coat in most infected seed treatment (Aliza Halfon-Meiri, 1973). *Alternaria* leaf spot disease and heavy defoliation in winter was documented in *D. stramonium*, *D. metel* and *D. innoxia* plants in experimental plots at Regional Research Laboratory, Jammu. Treatment with thiram yielded good results (Ganguly and Pandotra, 1962). During storage of seeds of *D. metel*, *A. flavus* deteriorated the quality of the drug and also contaminated the drug by elaborating aflatoxins (Roy *et al.*, 1988). Kar and Mehapatra (1981) recorded *C. capsici* on *D. stramonium* from India.

Yams (*Dioscorea* spp.) are a staple food and medicine throughout the world. However, production is being constrained by the increased prevalence of the fungal disease. Prasad and Singh (1960) described *C. gloeosporioides* as the causal organism of anthracnose of *Dioscorea alata*.


Garg and Kumar (1987) worked on the charcoal rot and ashy stem blight of *Euphorbia lathyris*. The pathogen was identified as *M. phaseolina* which caused charcoal rot infection at the seeding stage and ashy stem blight and root rot in the late season and
the severely infected plants succumbed to death. Young and Alcorn (1984) observed infection of roots of *E. lathyris* in Southern Arizona by *M. phaseolina*. New weed hosts of *M. phaseolina* were also detected on *E. hyssopifolia* and *E. prostrate*.

Chaudhari and Patel (1987) observed blight of *Foeniculum vulgare* (fennel) that was incited by *A. alternata* and *Ramularia foeniculi*.

*Glycyrrhiza glabra*, known as “Mullathi” an important medicinal herb, cultivated in the research farm of Regional Horticultural Research Station, Himachal Pradesh, was affected with a leaf spot disease caused by *Cylindrosporium glycrrhizae* (Bharat et al., 2002).


*Hibiscus moschatus* is widely cultivated in parts of India, for manufacturing high grade perfumery from seeds and leaves. Roots are also used in traditional and unani systems to cure gonorrhoea, leucoderma and itch and also used as tonic. Shukla *et al.* (1981) observed defoliation and death of these plants due to leaf blight disease in experimental plantations of Central Institute of Medicinal and Aromatic plants, Lucknow and Pantnagar. The causal organism was identified as *Phytophthora nicotianae*. In Kalyani, India, anthracnose of *H. abelmoschus*, was reported to be caused by *Colletotrichum capsici* which was virulent in rainy season (Khusuwa *et al.*, 1981). Kar and Mehapatra (1981) reported *C. capsici* on *Hibiscus rosa-sinensis* from West Bengal, India.
Ganguly and Pandotra (1962) described some commonly occurring diseases like rust (*Puccinia menthae*), powdery mildew (*Erysiphe cichoracearum*) and leaf blight (*Alternaria* sp.) on *Mentha arvensis* in the experimental plots at Regional Research Laboratory, Jammu. On *Mentha piperita* (peppermint), rhizome and stem rot caused by *Phoma* sp. was observed in Western Oregon peppermint plantings (Homer, 1971). Disease was characterized by black cankers and lesions on stems and rhizomes. Pathogen was identified as *P. strasesti* and all five isolates were pathogenic and caused symptoms identical to those in naturally infected plants.

In 1981, Roberts and Homer worked on the sources of resistance to *Puccinia menthae* in mint. Rust of mint caused by *P. menthae*, caused severe crop losses. Mint strains immune to rust were identified from a 4-year study of a diverse collection containing 703 accessions. The study confirmed that immune and highly resistant strains of *Mentha* sp. existed.

Shukla *et al.* (1999) reported the occurrence of *A. alternata* on rust pustules of *M. arvensis* (menthol mint) leaves at the research farm of CIMAP, Pantnagar. Severe damage to the foliage of *M. arvensis* occurred on highly susceptible cultivars viz., Shivalik and Gomti leading to heavy defoliation in plants. The highly susceptible Shivalik had 45% dual infection of *P. menthae* and *A. alternata*, which increased the necrotic area of the affected leaves, thereby, reducing the essential oil yield by 55.1% from >75% in diseased leaf area in comparison to healthy leaves.

In 2001, Khan *et al.* reported stolon rot in *M. arvensis* (Japanese mint), by *M. phaseolina, Rhizoctonia bataticola* and *Thielavia basicola*. Leaf blight, wilt, rust and
powdery mildew were caused by *Alternaria* sp., *Verticillium albo-atrum*, *Puccinia menthae* and *E. cichoracearum*, respectively.

Shukla *et al.* (2001) observed the stem blackening and rot disease of *M. arvensis* caused by *B. theobromae* in Lucknow and Tari surrounding commercial cultivation fields of Uttar Pradesh. The disease incidence varied from 2-5%, however, sometimes, 10% incidence was observed in farmer’s fields in Lucknow. Initial symptoms appeared as black dots on stem internodes and later extended upwards. The blackening of stem branches and leaf midrib along the veins spread to entire plant and finally resulted in necrosis and mortality. Tests carried out to evaluate resistant cultivars of menthol mint indicated that MAS 1 and Shivalik showed mild reaction to *B. theobromae*.

Mallaiah *et al.* (1981) worked on leaf blight of *Manihot esculentus* (cassava) near Nagarjunasagar and found that it was caused by *Drechslera* state of *Cochliobolus spicifer*.

In 1998, Pratt *et al.*, evaluated pathogenicity of *M. phaseolina* by inoculating tissues of mature plants with infested tooth picks of 2 isolates of the pathogen collected from field grown plants. Stolons of white clover (*Trifolium repens*) and stems of alfalfa (*Medicago sativa*) showed a brown-black, basipetally progressive necrosis of vascular tissues, collapse of surrounding pith, epidermis and expanding lesions. In taproots and corms of Alfalfa, *M. phaseolina* caused dark discoloration in bands, above and below the inoculation points and subsequent death of cortical tissues, lateral roots and stems. Sclerotia were observed in all tissues of both species. Both isolates of *M. phaseolina* tested positive for pathogenicity.
French basil (*Ocimum basilicum* var. *difforme* Benth) finds extensive use in medicine and perfumery industry. This plant expressed severe and widespread leaf blight disease in the experimental plots of CIMAP, Lucknow and Gehru. The pathogen produced abundant acervuli on the surface of infected leaves. Consistent isolation and pathogenicity confirmed the causal agent, *C. capsici* (Alam *et al.*, 1979).

Keinath (1994) observed *Fusarium* wilt of *O. basilicum* in a commercial greenhouse in South Carolina. Four isolates of *F. oxysporum* from sweet or bush (cv. minimum) basil were found pathogenic on these hosts in greenhouse tests. Garibaldi *et al.* (1997) reported diseases like soil borne, wilt and crown rot by *F. oxysporum* f. sp. basilici, *R. solani* and species of *Sclerotinia* and *Pythium* and foliar disease like gray mold by *Botrytis cinerea*, black spot / leaf spot by *C. gloeosporioides* on basil.

In 2001, Srivastava *et al.*, collected *Cercospora acimigena* on *O. sanctum* from Gorakhpur and adjoining areas of North Eastern UP from infected leaves with distinct symptoms.

Aneja and Kaushal (2000) reported pathogenic fungi *Colletotrichum punctiformis* on *Oxalis latifolia* a terrestrial weed of Kurukshetra.

Species of *Rauwolfia* are important in traditional medicine and are mainly cultivated for the large scale production of alkaloids. Batista *et al.* (1996) studied the alkaloids of *R. sellowii* which is a rich source of indole alkaloids. More often, these crops are infected by various disease causing organisms.

*Rauwolfia serpentina* has been shown to be affected by diseases like wilt (*Fusarium* sp.), leaf blight and bud rot (*Alternaria tenuis*) and powdery mildew (*L. taurica*) from the state of Jammu and Kashmir (Ganguly and Pandotra, 1962).
Varadarajan (1966) reported severe leaf spot and premature defoliation of *R. serpentina* by *C. lunata* under cultivation in Ranoli-Gujarat state. Flowers and fruits were also infected and resulted in total loss of seeds. He suggested that high temperature and moisture favoured the *Curvularia* infection and could be controlled by spraying bordeaux mixture, two to three times a week, for about four to six weeks.

Lele and Ram (1968) recorded a fairly wide spread die-back disease of *R. serpentina* caused by *C. dematium* in the experimental plots of plant introduction division, Indian Agriculture Research Institute, New Delhi. Disease resulted in 25% mortality in the field. However, *R. canescens* grown in adjacent plots were unaffected. Spraying with dithane Z-78 (0.2%) at the advanced stage of infection subsequent to pruning of the affected parts partially controlled the spread of the disease in the field.

Khan *et al.* (2001) studied diseases of sarpagandha grown in Karnataka. Some of the common diseases were wilt by *F. oxysporum*, powdery mildew by *L. taurica*, leaf blight and bud rot by *A. tenuis*, and leaf spot and mosaic by *Cercospora rauwolfiae* and TMV strain, respectively. Reduction in total root weight and alkaloid content in infected plant resulted following disease. Application of Bavistin, Karathane, Dithane and seed treatment with any contact fungicide yielded good result.

Khan *et al.* (2001) reported die-back by *Diplodia rosarum*, black spot by *Diplocarpon rosea* and rust by *Phragmidium* spp. on an important commercial medicinal plant- *Rosa damascena* grown in Karnataka. They reported control of these diseases by using Mancozeb, Dithane-M, Rovaral, Bavistin and Karathane either by spraying or applying or by treating.
Leaf blight disease of rosemary, *Rosmarinus officinalis* was reported in Bangalore, India by Kalra *et al.* (1993). Leaves are the main source of an essential oil, with high medicinal properties. However, due to diseases, leaves were completely necrotic and resulted in heavy yield losses. The predominantly isolated fungus was identified as *R. solani*.

Malvaceae is one of the largest families and consists of important agricultural crops, ornamental species and some wide-spread weeds. Plants of this family as a whole are affected by several diseases. Bailey *et al.* (1996) studied the taxonomic status of isolates of *Colletotrichum* - *C. gossypii*; *C. gossypii* var. *cephalosporioides*; *C. gloeosporioides* f. sp. *malvae* and *C. malvarum* from cotton, *Lavatera trimestris*, *Malva pusilla* and *Sida spinosa*. Conidial morphology, differentiation, their affinity for the lectin *Bauhinia purpurea* agglutinin (BAP) and a monoclonal antibody (UB20), and the nature of their infection hyphae were assessed in association with the analysis of rDNA sequence data. Results revealed that all isolates and several other samples of *C. gloeosporioides* f. sp. *malvae* were forms of the *C. orbiculare* aggregate species. All isolates produced straight-cylindrical conidia that bound to BPA and remained aseptate after germination. The similarity of these forms to *C. orbiculare* species aggregate was confirmed by the examination of their initial infection process and by restriction digests of their rDNA. All forms of *C. orbiculare* aggregate showed a high degree of host specificity. *C. orbiculare* species aggregate provided excellent opportunities for dissecting the molecular basis of pathogen specificity.

Sharma and Mukerji (1974) studied the incidence of some pathogenic species of *Candida, Macrophomina, Colletotrichum, Alternaria, Fusarium* and *Phoma* on ageing,
senescing and decaying leaves of *Sesamum*. However, *Candida albicans* was represented by higher population on young leaves. It was evident that *C. albicans* is a well established member of the phylloplane. The study established two aspects that fully mature leaves exhibited highest fungal population, which decreased as the leaves underwent senescence. And, in addition to micro-and-macro climate, the nature of surface substrates on leaves at different stages of their development is also an important factor governing incidences of pathogenic fungi.

Kar and Mandal (1973) reported four new species of *Cercospora* from West Bengal. The species like *Cercospora midnapurensis* on *Tylophora asthmatica*; *C. tragiae-folii* on *Tragia involucrata*, *C. urariarum* on *Uraria lagopoides* and *C. tagetis* on *Tagetes patula* were isolated from plants belonging to Asclepiadaceae, Compositae, Leguminosae and Euphorbiaceae, respectively.

Saxena and Singh (1991) reported root rot of marigold (*Tagetes erecta*) caused by *R. bataticola* state of *M. phaseolina* in Taj garden, Agra and the incidence was found to be 20-25%. Pathogenicity test established that plants produced symptoms after 10-15 days after inoculation and mortality within 20-30 days.

Nath and Bhargava (1980) conducted a survey of leaf spot diseases in Gorakhpur area and found that fungus belonging to the family Melanconiales, *C. gloeosporioides* affected leaves of *Tecoma stans* (Bignoniaceae)

New species of dematiaceous fungi *Cercosporidium tinosporae* and *Corynespora calicioidea* are identified on *Tinospora cordifolia* (Kar and Ray, 1985). A complete description of their morphology, mode of infection and pathogenicity were described in their work.
Nema and Sharma in 1999, reported new leaf spot and blight disease of *Tabernaemontana coronaria* (Apocynaceae) from Jabalpur. The fungus was identified as *Phytophthora citrophthora*.

In 2001, Srivastava *et al.*, collected infected leaves of *Triumfetta rhomboidea* and isolated species of *Cercospora triumfettae* – *rhomboidea* from Gorakhpur and adjoining areas of North Eastern UP.

Khan *et al.* (2001) observed diseases on *Withania somnifera* (ashwagandha), in Karnataka and suggested control measures. Diseases like seedling rot, leaf blight and spot were caused by species of *Alternaria* and *M. roridum*. Reduction in total root weight and alkaloid content in infected plants was observed.

Rathaiah and Gogoi (2000) recorded banded leaf blight of ginger caused by *R. solani* cultivated at Sorhat, Assam. They conducted field experiments to study the disease incidence and found that higher calcium may be responsible for reducing the incidence of banded leaf blight of ginger.

Shivanna *et al.* (1986; 1988) worked on *Alternaria cyamopsisidis*, *Colletotrichum dematium* and *Myrothecium roridum* diseases in cluster bean and their disease development in different seasons in Karnataka. Symptomatology on leaves and pods and fungal pathogenicity and concerns of seed health of cluster bean were studied.

Mehrotra (2000) studied a number of foliage diseases of certain medicinal plants, in nurseries at New forest, Dehradun. Among foliage diseases, leaf web blight of *Tylophora indica* caused by *R. solani* was the most damaging as it defoliated plants almost completely. Other diseases recorded were leaf spotting and blight by *Cercospora* and leaf blight by *S. rolfsii* in *Gloriosa superba*, and leaf spot and fruit rot of...
W. somnifera by M. roridum. They also reported that Myrothecium leaf spot of 
W. somnifera, and Phytophora leaf blight of C. roseus were highly damaging, resulting 
in heavy defoliation.

Effect of environmental factors on disease development

Several findings have revealed that the time of planting and environmental factors 
like temperature, relative humidity, pH, and light intensity affects disease severity, 
growth, and sporulation. Associations of toxicogenic species with foodstuffs, herbal 
drugs, and their mycotoxins have pronounced effect on human and animal health. 
Lillehoj et al. (1970) and Campbell et al. (1974) reported that mycotoxins of Aspergillus 
and Penicillium are a cause for contamination of food stuffs and several of these toxins 
cause animal disorders and may similarly affect humans.

Verma and Kumar (1995) while working on Isariopsis indica var. zizyphi 
revealed that pathogens survive under natural conditions on infected leaves and get 
dispersed mainly by wind current and in result primary infection and secondary spread of 
the diseases.

Chase (1983) observed that disease on Crassulaceae members due to the fungal 
pathogen, C. gloeosporioides, are primarily caused though wounds, since, relatively little 
disease occurred in its absence. Plants easily get damaged in the wild due to 
environmental calamities and by man made activities. However, mycotoxin production is 
reported to be governed by some parameters suitable for active mold growth such as 
nutrients, temperature and relative humidity.

Dodd et al. (1991) conducted studies of C. gloeosporioides pathogenic to mango 
in the Phillippines at different temperature and humidities. It appeared that Philippine
isolate of *C. gloeosporoides* were adopted to higher mean temperature of the Philippines. Conidia germinated and formed appressoria at RH between 95 and 100% and free surface moisture was only visible at 100% RH. The information obtained was used to estimate infection levels and to evaluate pre and post harvest practices in the control of the disease.

Sharma *et al.*, (1996) investigated the effect of time of planting on the incidence of leaf blight disease of *Solanum khasianum*, an important medicinal plant used for the synthesis of steroidal drugs. Transplanting of seedling during November was found to be favourable for the development of leaf blight caused by *A. tenuissima* followed by transplanting in December, January and February. They also observed that the development of disease before flowering adversely affected the growth and vigour of plants, thereby reducing the yield of berries. They also observed that rainfall coupled with a temperature of 27-30° C and relative humidity of 63-89% could play an important role in disease development.

Bilgrami *et al.* (1997; 1981) reported cloudy weather with intermittent rain, high humidity and warm temperatures to favour the disease of *Cannabis sativa* due to *F. solani*.

Lodha *et al.* (1997) studied the efficacy of summer irrigation and soil solarization and combining with cruciferous residues against the dry root rot pathogen *M. phaseolina* in an arid climate. Combining cruciferous residues with polyethylene mulching or natural heating of moistened soil has been found to improve the reduction in population of *M. phaseolina* in hot arid climate. In irrigated amended soil, and polyethylene mulching during May, soil temperature increased to 57° C and 50° C at depths of 0-15 and
16-30 cm, respectively. As a result, *M. phaseolina* was almost eradicated (93-99%) by natural heating of irrigated soil (46-53° C) for 15 days after amending with cruciferous residues. Mulching alone was only partially effective (69-89% reduction). These results suggested a new approach in controlling soil borne pathogens in hot and arid region by combining summer irrigation with soil amendment. Amendment with residues alone or in combination with soil solarization also increased the population of lytic bacteria against *M. phaseolina*.

Alam *et al.* (1994) revealed that collar and wilt disease spread caused by *F. moniliforme* was high during summer and it indicated that the spread of the disease was favoured by high temperature. Cloudy weather with intermittent rain, high humidity and warm temperature was found to favour the disease of *Cannabis sativa* caused by *F. solani* (Mishra, 1987).

Verma and Kumar in 1995 studied the survival and dispersal of *Isariopsis indica* var. *zizyphi*, which caused mouldy leaf spot of ber. Their investigations revealed that the pathogen survived under natural conditions on infected leaves and are dispersed by mainly wind currents in the initiation of primary infection and secondary spread of the disease.

Increased concentrations of culture filtrate of *A. alternata* resulted in reduced seed germination and affected seedling growth of *Sesamum indicum*. They opined that reduction in seed germination and seedling vigour could be due to the presence of some inhibitory substances in the culture filtrate of *A. alternata*. 
Kumar *et al.* (1984) showed the involvement of toxic metabolites in 21-days-old culture of the pathogen (*A. alternata*) in pathogenesis. The toxin invariably developed spots on host leaf (*H. maticus*) within 6 h of applying the filtrate on pierced surface.

**Disease management in medicinal plants**

Many of the plant diseases can be controlled by the use of either chemicals or bioagents as antagonists or with plant extracts which inhibit pathogen’s growth or its pathogenesis.

An attempt was made by Amaresh *et al.* (2000) to know the efficacy of three botanicals and seven fungicides in the control of *Alternaria* blight. During *in vitro* evaluation, cyproconazole was found to be the most effective, than mancozeb, iprodione and tridemorph and, neem seed extract showed maximum inhibition. During *in vivo* evaluation, chlorothalonil, mancozeb and cyproconazole showed effective control and leaf extracts of *Ocimum cannum* and *Tridax procumbens* were less effective. Narasimhudu and Balasubramanian (2002) conducted studies to control *Colletotrichum capsici* in turmeric. Indofil M-45 had high fungicidal activity as compared to Bavistin, Topsin - M and neem.

Among the antagonists used in plant disease management, Bopaiah *et al.* (1991) reported the use of saprophytes like *Aspergillus niger*, *A. fumigatus* and *Penicillium islandicum* from phyllosphere of sorghum against pathogenic fungi *Helminthosporium oryzae*, *Phytophthora arecae* and *Pyricularia oryzae*. According to Jubina and Girija (1998), a bacterial isolate from the rhizosphere of pepper plants had the ability to suppress foot rot disease of pepper plant caused by *Phytophthora capsici*. The bacterial isolate showed moderate to high inhibition of the pathogen. *Trichoderma harzianum*
completely overgrew the pathogen in vitro. On treatment with bacterial / fungal antagonist on pepper shoot, isolates B5, B7 and B13 were highly effective and can be used as a biocontrol agent and two isolates B4 and B7 enhanced growth of pepper plants in the absence of pathogen.

A study was undertaken by Desai and Scholosser (1999) to generate the information on whether the sclerotial parasitization is species - or isolate-specific by taking different species of Trichoderma. It was demonstrated that sclerotia of S. rolfsii were first penetrated, colonized and later killed by the biocontrol agent. Rhizoctonia solani is one of the most destructive fungal diseases of patchouli. Mishra et al. (2000) conducted experiments to test the efficacy of T. harzianum, Glomus aggregatum and Gliocladium virens to find out the suitable biological control of Rhizoctonia wilt of patchouli, separately and in combination. Biswas and Sen (2000) used isolates of T. harzianum to control M. phaseolina which caused charcoal rot in a variety of crops including jute (Corchorus olitorius and C. capsularis). Certain isolates of T. harzianum, were found to be useful upon seed treatment.

Sinha et al. (1992) reported that chitosan, a polymer of β-1-4 linked glucosamine a derivative of chitin, is a strong elicitor and has antifungal activity. Seed treatment at concentrations between 0.1% and 1% provided protection to crops like rice, groundnut and chickpea from pathogens viz., Helminthosporium oryzae, Pyricularia oryzae, Cercospora arachidicola, Sclerotium rolfsii and F. oxysporum f. sp. ciceri. Chitosan did not have direct toxic action but induced changes in host metabolism by eliciting phenylalanine ammonia lyase, synthesis of many other proteins and phytoalexin production.
Experiments on chemical control of twig blight of *Croton tiglium* due to *Colletotrichum dematium*, using Bavistin, Dithane M-45, Dithane Z-78 or captan at 0.2% concentration suggested that foliar spraying with Dithane M-45 was found effective against the disease (Nath *et al*., 1992).

Fuńgicide Emisan-6 (0.1%) was found effective followed by Carbendazim (0.1%) and copper oxychloride (0.2%). Biological methods using antagonists- *T. viride* and *T. harzianum* were also found effective to root rot of *Coleus barbatus* caused by *F. chlamydosporum* (Siddaramaiah *et al*., 2001).

Rathiah (1982) worked extensively on the control of rhizome rot of *Curcuma longa* (turmeric) caused by *Pythium myriotylum*. His experiments revealed that ridomil @ 0.01% to the seed plots plus dipping of seed rhizome controlled the disease incidence and increased yield; Ceresan was found ineffective.

Falloon *et al*. (1985) determined the optimum time and rate of application of metalaxyl to control *Phytophthora* infection in *Asparagus*. Results of their study revealed that application of metalaxyl during winter months, when plants were dormant, had relatively little effect on production. However, yield losses due to the pathogen were greatest when infection occurred in the spring. A significant amount of spear and crown rot occurred below the soil surface, suggesting that the effect of *Phytophthora* on asparagus production in California has been underestimated in the past, especially in wet years.

Falloon *et al*. (1991) studied individual and combined effects of flooding, *Phytophthora* rot, and metalaxyl on asparagus. *Asparagus* crowns (cv. V.C. 157) were transplanted into non-infected plots or plots that had been infested with both
Phytophthora megasperma var. sojae and P. cryptogea before transplanting. Metalaxyl was sprayed over half of the infested and half of the non-infested plots immediately after transplanting. Plots were then flooded for 48 h every 2, 3, 4 or 8 week or not flooded at all. Disease severity in infested plots increased as flooding frequency increased but was reduced by metalaxyl. Metalaxyl was found more effective in controlling phytophthora rot as flooding frequency decreased. There was only a small advantage from dipping crown in solutions of metalaxyl at concentrations of 20-200mg or from in-furrow applications to seedling or crown transplants at 0.07-1.12 kg. Thus, phytophthora related establishment failures could be controlled with metalaxyl or avoided by transplanting crowns or seedling transplants, when field conditions are dry and warm.

Fungicide spray with Difolatan and Dithane M-45 at 10 days and 20 days interval was reported to be most efficacious in controlling A. alternata and R. foeniculi causing blight of fennel (Chaudhary and Patel, 1987).

Alam et al. (1998) studied the efficacy of five fungicides viz., metalaxyl plus mancozeb, fosetyl-Al, captan, propamocarb hydrochloride and triadimefon against the growth of Pythium dissotocum damping-off pathogen of Papaver somnifera (opium poppy) in vitro. Their findings suggested that the disease could be effectively managed either by seed treatment with metalaxyl plus mancozeb formulation or use of resistant varieties.

Bowers and Locke (2000) reported that the wilt of muskmelon by F. oxysporum f. sp. chrysanthemi could be controlled significantly by plant extracts like clove, pepper, mustard or cassia at 5-10% in the greenhouse conditions. An investigation by Babu et al. (2001) showed that the leaf extracts of some medicinal plants and weeds like Polyalthia,
vilvum, neem, tulsi, calotropis, rain tree or croton significantly reduced the mycelial growth of \( A. \) solani. Experiments conducted by Dubey (2002) showed that the application of karanj \((Pongamia glabra)\) and ground nut \((Arachis hypogea)\) cakes and foliar spray of karanj and saubabul \((Leucaena leucocephala)\) leaf extract separately resulted in the management of \textit{Thanatephorus cucumeris} which caused web blight of urd and mung bean.

Experiments were conducted to test the effect of some of the micro-nutrient and hormones on the development of the powdery mildew disease induced by \textit{Sphaerotheca pannosa} in rose \((Rosa indica)\) at Rajasthan (Sobti and Mathur, 1992). Application of micronutrients viz., zinc, copper, manganese and magnesium in the form of sulphates, boron and molybdenum as borax and ammonium molybdate and gibberillic acid significantly reduced the mildew infection and increased the flower yield. Singh et al. (2000) determined the role of biotic factors in upgrading plant vigour and survival.

The mycorrhizal fungi and PGPRs being mutualistic symbionts play a pivotal role in plant health. The axenically cultivable plant growth-promoting root endophyte \textit{Pirifoamospora indica} improved the growth and overall biomass production of medicinal plants like \textit{Bocopa monnera} and \textit{Artemia anna}. It colonized root cortex to obtain carbon, while assisting the plant with the improved and rapid uptake of phosphorous and mineral nutrients of low mobility from soil and their translocation to the host roots. Besides, it protected plants from pests, and relieved stress condition.

Plant growth promoting rhizobacteria (PGPR) are the best alternative to chemicals, to facilitate eco-friendly biological control of soil and seed-borne pathogens. PGPR are gram-negative and fluorescent pseudomonads are the most widely studied. According to Arora et al. (2001), the siderophores of fluorescent pseudomonads and their introduction into rhizosphere have been widely explored. Siderophore production in iron
stress conditions confers an added advantage in the exclusion of pathogen due to iron starvation. Use of antagonistic rhizobia has added advantage as they have ability to fix nitrogen. Of the 12 isolates of root-nodulating bacteria, *Rhizobium meliloti* isolated from medicinal plant *Mucuna pruriens*, only two produced siderophores.

Similarly, plant growth promoting fungi (PGPF) isolated from rhizosphere and rhizoplanes of *Zoysia tenuifolia* have been found to be effective in controlling fungal diseases caused in cucumber, wheat and soybean in addition to promoting plant growth in green house as well as in field. These fungi induced systemic resistance in cucumber by enhancing the host defense mechanisms and increased yield significantly. These organisms have also been shown to possess competitive colonization and saprophytic ability (Shivanna et al., 1994, 1995, 1996a,b,c; Meera et al., 1995a,b).

**Phytochemicals and their importance**

Man relied on natural products in general and plants in particular to promote and maintain good health and to fight sickness, pain and disease since time immemorial. With advances in experimental methods in phytochemistry and pharmacology, several medicinal plants were screened for active principles and biological activities (Rivier and Bruhn, 1979). For instance, solutions made by soaking the bark of willow tree, *Salix* were a traditional cure to aches and pains. The ingredients in willows that reduced pain was isolated in 1827 and named salicin. Today aspirin (acetyl salicylic acid), a derivative of salicin is the most widely used drug in the world. Similarly, in 1960, two cancer treatment drugs were discovered in a familiar garden plant, *C. roseus* (periwinkle), which is the natural source of vinblastine and vincristine. Vinblastin is used to treat Hodgkin’s disease, (cancer of lymphnodes) and vincristine is used to treat childhood leukemia. And,
reserpine, a drug obtained from *R. serpentina* is used to control high blood pressure (Rinehart and Winston, 1996).

In rural areas, parts of plants are used as crude drugs to cure the disease and to maintain their health. But, in modern times, such crude medicines are not accepted. Therefore, before marketed, they are subjected to various physico-chemical processes. This awakening has added impetus to multidisciplinary research, such as phytochemistry, pharmacology, pharmacognosy, and biochemistry to isolate the active substances of several species and unveil its therapeutic potency for adoption in modern medicine. In the last few decades, it has been possible to device economically feasible techniques for the extraction of several phytochemicals.

The phytochemical compounds are classified into primary and secondary metabolites. The primary metabolites such as carbohydrates, lipids, amino acids, proteins, chlorophyll and nucleic acid are common to all plants. They are inactive as medicine but are involved in the normal physiological process of the plant and these are utilized as food by man. Secondary metabolites are biosynthetically derived from primary metabolites but are more limited in distribution. Secondary metabolites are also called phytopharmaceuticals and include organic compounds such as alkaloids, steroids, terpenoids, phenols or glycosides. About 40,000 specimens were analyzed during the 1960’s to 1980’s by the National Cancer Institute, America, and this remains the most extensive screening programme of plants to date (Tyler, 1998). The database NAPRALERT in 1998 contained more than 88,000 secondary metabolites, and every year some 4000 new ones are being reported (Farnsworth, 1996).
These secondary metabolites were considered as waste product for a long time, however, with the advancement of knowledge in the field of plant chemistry, it is now realized that they are therapeutically active and are used as drug or source of drugs and these have a very important role to play in growth and development of plants. It is known to act as chemical adaptation to environmental stress and serves as a nitrogen source at the time of necessity. It also serves as defensive compounds against the pathogens and herbivores. Quantity of these organic compounds or secondary metabolites may vary (Sahu, 1982), with variation in altitude, soil condition, climatic condition, season of collection, habitat and other factors. For instance, the bark cinchona, collected in rainy season is reported to possess no quinine (Yaniv and Palevitch, 1982) and application of farmyard manure and nitrogenous fertilizers were found to increase the alkaloid contents in solanaceous plants apart from increasing the total yield of crude drugs.

Gershenzon (1983) has shown the significant influence of water and nutrient stress on the secondary metabolite production and concluded that a detailed study in understanding of the environmental factors regulating the synthesis of secondary compounds should be useful in maximizing the harvest of usable products in herb species and drug plants. Dicosmo and Towers (1983) have similar findings on the effect of stresses such as nutrition, light, temperature, pH, on the secondary metabolite production.

Effect of disease on phytochemicals

Much information has been gathered on effect of disease due to fungi on agricultural and horticultural crops and also on storage products. Unfortunately, literature on the effects of disease on uncultivated medicinal plants as compared to the medicinal
plants under cultivation is very limited. Some of the reports available are discussed below.

On the other hand, the primary and secondary metabolite content may vary between healthy and diseased plant samples, both quantitatively and qualitatively. This may be due to the association of particular fungal pathogens, which may produce toxic metabolites or may bring about modification in phytochemistry.

The crude drugs available in markets of our country are generally collected from the forest areas by the unskilled persons having no knowledge of the procedure and proper time of collection, drying and storage. Drugs are usually gathered without any reference to the climatic, and ecological condition and diseases of the collected material. This causes wide variation in the quality and degree of effectiveness.

Bohra and Purohit (2003) worked on the fungal toxicity and found that mycotoxin comprises a group of chemically unrelated fungal metabolites like polypeptide, alkaloid, benzoquinon, anthraquinone, xanthon, coumarin, terpene and their derivatives that result in significant illness, reduction in productivity and market price, loss of food, livestock mortality, reduced growth rate, and infertility. Hence, prevention, inactivation and detoxification have been adopted to control the adverse effect of mycotoxin.

Rao et al. (1982) reported that leaf spot pathogen eliminates the photosynthetic tissues resulting in the slow down and cessation of photosynthates like carbohydrates and proteins and impose the moisture level by indirectly affecting the secondary metabolitic synthesis.

Sindhan and Parashar (1996) studied changes in phenolic compounds, carbohydrates and mineral elements in resistant (M-147, G-201) and susceptible (NC-13,
GK-19) cultivars of groundnut to early and late leaf spots and observed high content of total phenols and ortho-dihydric phenols, K, Zn and Fe in all cultivars and increase in P, K, Zn and Cu in susceptible cultivars. In all cultivars, there was a reduction of total reducing and non-reducing sugars, N, P, Cu and Mn. Ten amino acids were detected in the resistant cultivars as compared to nine in the susceptible cultivars. N, Mn and Fe contents were low where as they were high in resistant as compared to the susceptible cultivars. The post infectional increase in phenolic compounds and decrease in carbohydrates was suggested to the enhanced synthesis of phenolic compounds and hydrolysis of phenolic glycoside by fungal glycosides to yield free phenols (Sharma et al., 1993) and reduction in N concentration after infection was attributed to disruption of all structural activity coupled with enhanced activity of proteolytic enzymes (Nayudu and Walker, 1961).

Prasad et al. (1997) observed a gradual decrease in mineral content, starch, total reducing sugar and all the individual sugars in downy mildew Peronospora lathyri-palustris affected Lathyrus sativus (khesari). Non reducing sugar tended to increase in diseased plants. The quantity of P, K and Ca remained unchanged, pointing out normal absorption and subsequent translocation of these ions. Alteration in mineral content has been interpreted as disease resistance and susceptibility (Gupta et al., 1985). Decrease in starch, total sugar, reducing sugar and increase in non reducing sugar with the progression in disease was assigned to the disturbed synthesis or utilization. The deficiency of the carbohydrate and mineral content in this host render it in a plight of hunger and metabolic derangement.
Nagaraja (1998) studied the mineral metabolism in *Dioscorea bulbifera* plants following infection. Elements such as K and Na increased due to their greater mobility that accumulated at metabolically active sites. Mn, Cu, Ni, Co, Cr and Pb content was also increased due to stimulation by the pathogen and the decrease in Ca content was attributed to rapid utilization. Similarly, the decrease in Mg was thought to be due to failure in translocation and rapid uptake by pathogen in infected leaves.

Chhabra *et al.* (2000) reported that the vitamin ‘C’ content remained constant at pre-infectional stage, and after infection, there was drastic reduction in ascorbic acid content in *Lycopersicon pinnellifolium* and *L. peruvianum* plants infected with early blight fungus, *Alternaria solani*.

Prasad and Sah (1991) observed decline in sterol content of infected leaves of *Achyranthus aspera* and *Vitex negundo* leaves after the inoculation and colonization by *Alternaria alternata*, *Botryodiplodia theobromae* and *Pestalotiopsis theae* that were isolated earlier from these hosts. The maximum fall in sterol content was observed in *V. negundo* due to *A. alternata*, followed by *B. theobromae* and *P. theae*; *P. theae* was a weak pathogen with respect to the decrease of total sterol.

Sharma *et al.* (1993) observed biochemical alterations in brinjal leaves and fruits due to infection by *Phomopsis vexans*. Due to infection, a progressive and significant decrease in the quantity of total non-reducing and reducing sugars, amino acids, phenol and orthodihydroxy phenols was observed. Decrease in sugar was attributed to the utilization of reducing sugars by the pathogen and conversion of non-reducing sugars to reducing sugars upon infection. Amino acid content also decreased due to their utilization by the pathogen.
Banik and Chatterjee (1995) quantitatively estimated the total chlorophyll and carbohydrate content of healthy and diseased leaves due to *Phytophthora palmivora* of rubber (*Hevea brasiliensis* var. RRIM 105) plants. Considerable reduction in both the contents was noticed in the host tissues during the course of infection as compared to the healthy ones. Loss of chlorophyll content coupled with increased respiratory activity in infected tissues by pathogen was attributed to the decline in the carbohydrate level.

D'Aulerio *et al.* (1995) studied *Melissa officinalis* infected by *Erysiphe galeopsidis* and *Septoria melissae* and *Salvia officinalis* and *Mentha piperita* infected by *Erysiphe salviae* and *Puccinia menthae*, respectively, for micro-morphological study of infected tissues and chemical investigation into the volatile fraction of secretory tissues of healthy and infected plants. They observed that the pathogenic fungal infection seriously damaged the secretory tissues and stomata, causing a decrease in the amount of essential oil contained in infected plants and modifying the composition of the volatile fraction. In *M. piperita* the increase in terpene and decrease in menthol and menthophuran affected the quality of oil and hence its market value, and in *M. officinalis*, decrease in neral and geranial aldehydes and increase in citronellal affected its aroma and fragrance. Increase in terpene related substances, which have allelopathic properties, could be a self defence reaction to pathogenic infection.

Kumar and Singh (1996) recorded biochemical changes of sun flower leaves due to leaf spot caused by *A. alternata* and observed drastic reduction in wax content, Chlorophyll ‘a’, ‘b’, polyphenol, sugar, N, P and K content in diseased leaves 40 and 70 days after inoculation. There was hardly any reduction in S content, but it was slightly reduced in necrotic tissues. Reduction in N, P and K was attributed to the utilization of
these nutrients by the pathogen during pathogenesis. The reduction of chlorophyll content was attributed to decreased synthesis of pigment in the infected tissues or destruction of a part of chlorophyll due to infection (Diener, 1963) and reduction in sugar to degradation metabolism in diseased tissues (Nema, 1983) or utilization by the pathogen (Padmanaban, 1973).

Hosagoudar et al. (1997) reported that infection of Santalum album with Asterina congesta, resulted in reduction in the total chlorophyll, chlorophyll ‘a’, chlorophyll ‘b’, soluble sugar, starch, peroxidase, protein and total amino acids and an increase in the proline, total phenol contents, amylase and protease enzyme activities in the infected leaves. The reduction of primary metabolites like starch, sugar and protein was thought to be due to the reduced synthesis or due to the increased utilization by fungus for its growth.

Various biochemical changes was investigated in safflower leaves infected with Puccinia calcitrapae var. centaureae (Singh et al., 1998). Higher amount of chlorophyll, amino acids and ortho-dihydric phenols were detected in cultivars tolerant of P. calcitrapae, whereas in susceptible cultivars total soluble and reducing sugars were more. Total chlorophyll, chlorophyll ‘a’ and ‘b’, total amino acids and soluble sugars declined while the total and ortho-dihydrlic phenol content increased after rust infection. Reduction in chlorophyll was attributed to destruction of chlorophyll or higher accumulation of sugar (Curtis and Clark, 1950), which would make the nitrogen unavailable for chlorophyll formation by binding it in the formation of protein (Subramanyam et al., 1976).
**Cymbopogan** is a source of valuable aromatic oil and has antiseptic properties. Saikia et al. (2002) observed severe attack of commercial plantation of *Cymbopogan martinii* var. motia (Palmarosa) by leaf rust disease (*Puccinia nakanishikii*) which caused severe losses to the herb and oil yield. Results of the study revealed that healthy leaves yielded 0.60% of oil while the leaves with 100% disease index (PDI) yielded 0.38% oil with 36.66% reduction in yield. Oil reduction is accompanied by decrease in geranyl acetate and an increase in the geraniol content. They opined that changes in major constituents might reduce the present market value.

Misra et al. (1998) observed the outbreak of leaf blight diseases in *Cymbopogon winterianus* in an experimental field causing serious loss to herb and the oil yield. Healthy leaves yielded 1.65% oil, while leaves with 74.20% disease index (PDI) yielded 0.8% oil, with a reduction of 47.27% yield. Reduction in oil yield was also found to be associated with decrease in citronellal and citronellyl acetate content and increase in the geraniol and geranyl acetate content of the oil. The decrease ultimately affected the total oil yield and its quality.

Janardhan et al. (1980) reported loss of about 31% total oil and 11.8% geranial in *C. martini* due to leaf blotch disease caused by *Curvularia andropogonis*. Similarly, in *C. martini* due to leaf blight (*C. trifolii*), significant yield loss was reported by Gupta et al. (1977; 2000). They observed that healthy and infected leaves contained 2.8% and 2.05% essential oil, respectively. But on dry weight basis, a reduction of 26.79% oil content in diseased leaves as compared to healthy ones and about 71.8% geranial loss was noted in infected plants. They concluded that infection and disease may probably
interfere with the essential oil biosynthesis in leaves and also pathogen affected the quantity and quality of essential oil.

Leaf blight of *Cassia angustifolia* and *Cassia acutifolia* (senna) due to the pathogen *A. alternata* reduces the quality and quantity of the produce (Patel and Pillai, 1979). Chemical analysis of leaves of infected plants revealed that content of sennoside, the active principle, was inversely proportional to the leaf blight intensity.

A report on changes in biochemical constituents of tea plants following infection by *Exobasidium vexans* was reported by Chakraborty et al. (2002). They observed changes in polyphenol oxidase, peroxidase and phenylalanine ammonia lyase activities after blister blight infection. The infection also caused changes in biochemical constituents like proline, protein and total phenol content and such biochemical changes ultimately affected the quality of tea.

An *in vitro* method was established to study degraded products of phytochemicals following biotransformation by using fungal species. The essential oil extracted from peel of *Citrus sinensis* and commercial limonene were subjected to biotransformation by various fungi such as *Epicoccum nigrum, Colletotrichum falcatum, F. moniliforme, F. oxysporum, Trichothecium roseum*, and *Curvularia pallescens* and an enzyme extract from *Musa paradisiaca*. The change in chemical composition was tested by HPLC and GC-MS. Results indicated that the most of the hydrocarbons of *C. sinensis* oil were found to be partially oxidized/hydroxylated to alcohol by *E. nigrum*. *M. paradisiaca* enzyme acted as ligases/peroxidases and oxidized terpene hydrocarbons to oxygenated monoterpenes and higher carboxylic acid and an unknown component I. *T. roseum* and
F. oxysporum also produced enzymes which could be used for biotransformation of various terpenoids contained in limonene (Singh et al., 2002).

Kiran et al. (2003) applied tissue culture technique to evaluate biochemical profile of calli susceptible and resistant brassicas like B. juncea and B. napus. The biochemical analysis of callus of hypocotyl raised on MS medium supplemented with 1 mg l\(^{-1}\) NAA and 1 mg l\(^{-1}\) BAP and sub cultured on the same medium but adjunct with culture filtrate (CF) of A. brassicae with incubation period of 4 weeks revealed that culture filtrate caused greater accumulation of total soluble and reducing sugars in susceptible B. juncea cv. kranti than in resistant B. napus CV GSH-1 and B. juncea CV RH-781. Phenolic content and flavonols were higher in CF treated calli of CVS GSH-1 and RH-781 than kranti. Protein content though increased in all the three cultivars, increase was more in resistant cultivars than in the susceptible ones. They suggested that the accumulation of phenolic and flavonols upon exposure of callus to CF could be used as an index of relative resistance of disease and higher protein content as a function of disease resistance.

Tripathi et al. (2003) carried out an investigation to estimate the qualitative and quantitative losses in coriander due to Protomyces macrosporus (stem gall disease). There was decrease in reducing sugars, non-reducing sugars, protein, oil, N, P, K, Ca, Mg, Fe, while Mn content increased in diseased seeds.

Height and leaf area of inoculated sweet basil plants were reduced by 30 and 40%, respectively, with isolates F. oxysporum compared with non inoculated plants of basil. F. oxysporum reduced fresh weights of sweet and lemon basil (cv. citriodorum) but had no effect on six other herbs of the family Lamiaceae (Keinath, 1994).
Janardhan and Husain (1974) reported the sudden wilting of *Pythium butleri* infected *Atropa belladonna*. Extensive disintegration following pathogenesis was due to the toxic metabolite and pectolytic enzymes produced by the pathogen. They also observed root rot of *Belladonna* caused by *Fusarium* sp. and the disease was a serious threat in the commercial plantations in Jammu and Kashmir and about 40% of plants were affected by the disease.

The fungi *A. crassa* and *A. alternata* are reported to produce a phytotoxic metabolite *in vitro*. The metabolite was isolated and identified as tenuazonic acid (Sattar *et al.*, 1986). This toxin was found to be responsible for chlorosis, necrosis and typical yellowing of infected leaves of *D. stromonium* and *D. innoxia*. The toxin showed significant phytotoxic activity against a number of plants. The toxin was reported to induce significant reduction in chlorophyll and protein contents in infected leaves. This activity is suggested to be the cause of chlorosis and necrosis found in infected leaves (Janardhahan and Husain, 1975; 1983; 1984).

Downy mildew disease caused by *Peronospora arborescens* on *Papaver somniferum* (opium poppy) caused 20-30% loss of yield of opium latex. The secondary infection by downy mildew was found to reduce 17-22% latex yield (Thakore *et al.*, 1983). On the other hand, observation made by Felklova (1977) indicated significant decrease in morphine, codeine and thebaine content in opium poppy capsule infected by *A. alternata*.

White rust disease caused by *Albugo candida* is one of the major diseases of *Brassica* in India. It causes heavy losses by affecting flowers and flower bearing branches and decreases the yield adversely. A study has been carried out by Khangura and Sokhi
(1995) to compare the levels of various phyto-hormones on stag heads and healthy flowers. The result indicated reduced levels of indole-3-acetic acid in malformed inflorescence in varieties RL-1359 and KLM-619 and in *B. campestris* var. TL-15 also showed increased levels of gibberillic acid, zeatin and abscisic acid along with reduced level of indole-3 acetic acid. The reduction in IAA was attributed to reduced rate of auxin biosynthesis.

Lopez *et al.* (1998) observed that infection with bitrophic fungi *Colletotrichum trichellum, Puccinia pelargonii-zonalis, Cercospora circumscissa* and *Phragmidium violaceum* on leaves of *Hedera helix, Pelargonium zonale, Prunus avium* and *Rubus ulmifolius* resulted in cell membrane damage, lipid accumulation and chloroplast disorganization, and affected membrane permeability. A partial aggregation of nuclear chromatin observed indicated decrease in DNA replication and transcription.

Shukla *et al.* (2000) carried out an experiment to determine the impact of foliar fungal diseases viz., rust (*Puccinia menthae*) and leaf blight (*Alternaria alternata*) of mint on essential oil content. Due to high infestation (>75% of leaf area) by *P. menthae* and *A. alternata*, drastic defoliation was observed which reduced the herbage and essential oil yield by 55% in comparison to healthy plants. They opined that the disease caused interference in the essential oil biosynthesis in infected leaves.

Similar experimental findings of Gupta *et al.* (1977; 2000) revealed that healthy and infected leaves of *C. martini* contained 2.8 and 2.05% essential oil, respectively. On dry weight basis, a reduction of 26.79% oil content in diseased leaves due to the pathogen *C. trifolii*, as compared to healthy ones was noted. Geraniol losses was as high as 71.8%
due to blight disease in infected leaves. Thus, the infection and disease development may probably be interfering with the essential oil biosynthesis in leaves.

Diseases even brought about changes in growth regulators and it was proved by Wiese and Devay (1970) while working on *Gossypium hirsutum*. The growth regulator IAA was increased, ABA contents doubled and ethylene level was increased by 2-5 folds during defoliation. He concluded that altered host metabolism in turn alter growth regulator content.

Analysis of the information available in the literature reveals that due to the inherent capability of microorganisms to produce toxins or other secondary metabolites and by altering metabolic pathways of host plants, the nutritional as well as the medicinal properties of biochemicals in such infected plants are expected to change drastically (Roy *et al.*, 1988, Roy and Kumari, 1991 and Shastri, 1969).

All these biochemical changes deteriorate the active ingredients of raw and stored plant samples of medicinal value by reducing their efficacy to treat the disorders. Thus, it is advisable to analyze the chemical composition of metabolites of healthy and diseased plant materials.