World Journal of Pharmaceutical and Life Sciences
WJPLS
www.wjpls.org
SJIF Impact Factor: 6.129

FUNGAL DISEASES OF MEDICINAL PLANTS IN FIELDS AS WELL AS UNDER STORAGE-A REVIEW

Mansoor A. Malik[1]*, Mehrajud Din Talie[2] and Nusrat Ahmad[3]

[1,2,3]*Section of Mycology and Plant Pathology, Department of Botany, University of Kashmir Srinagar, JK India-19006.*
[3]*Department of Environmental Science University of Kashmir Srinagar, JK India-19006.*

***Corresponding Author: Mansoor A. Malik**
Section of Mycology and Plant Pathology, Department of Botany, University of Kashmir Srinagar, JK India-19006.

Article Received on 29/01/2022 **Article Revised on 19/02/2022** **Article Accepted on 09/03/2022**

ABSTRACT

Fungal infections can infect medicinal plants. According to a survey, different fungal diseases can be found in the roots and shoots of several therapeutic plants. *Fusarium oxysporum* and *Fusarium solani* invaded the roots of the plants, causing withering and finally death. *F. culmorum* was isolated as well, although it was not harmful to these hosts. The sage plants (*Salvia officinalis*) were also heavily infected with *F. solani*. They were also infected with *Rhizoctonia solani* at the same time. Powdery mildews, downy mildews, and rusts were the most common aerial illnesses. On spinach, downy mildews were discovered. Rust illnesses were also found on medicinal plants such as estragon (*Puccinia absinthi*), peppermint (*Mentha piperita*), and mentha (*Puccinia menthae*). White rusts, *Albugo candida*, were also found on several of the plants.

KEYWORDS: Medicinal Plants, White Rust, Powder Mildews, Down Mildews.

1. INTRODUCTION

The medicinal plants are traditionally used worldwide as remedies for the treatment of various diseases, including asthma, gastrointestinal symptoms, skin disorders, respiratory and urinary problems, and hepatic and cardiovascular disease. Nowadays most people also rely on herbal medicine because they are less costly and are showing compatibility with human body with minimum side effects as compared to modern medicines. They are now in great demands in market and the number of patients consuming the herbal medicine is increasing exponentially (Pal and Shukla, 2002). These plants synthesize a diverse array of biologically active compounds that are important for them to survive and flourish in the natural environment. The composition of biologically active compounds of medicinal plants varies widely depending on the plant species, soil type and on their association with microbes. The bioactive compounds present in these medicinal plants have been studied for various pharmacological properties and now many of them are utilized in modern medicines examples include digoxin from *Digitalis*, aspirin from bark of *Salix*, quinine from *Cinnamomum* bark, morphine from *Papaver* (Vickers and zollman, 1999). The medicinal plants although are global source of herbal products that are compatible with human body but they are being exploited at a very high speed in nature as the number of people consuming herbal products is increasing exponentially. Various conservation strategies are being employed both in situ and ex situ for maintaining species equilibrium (McGowan et al., 2017). The article reviews about the fungal diseases of such plants that is also one of the main biotic factors responsible for limited supply of herbal products.

2. Fungal diseases of medicinal plants in fields

It is clear from the literature that there is a significant information on the incidence of fungal diseases on crop plants. But such information is very insignificant in case of medicinal plants under cultivation as well as naturally growing *Chlorophytum borivilianum* is commonly known as safed musli. It's an important medicinal plant for its energetic roots which contain saponins. Therefore, farmers have started cultivation of this crop on large scale in Maharashtra. The crop has been found to be attacked by number of fungal pathogens in the field. Ramakrishnan and Ramakrishanan (1948) observed incidence of leaf rust disease of this plant caused by *Uromyces Culiformis*. Similarly, Chandra and Tandon (1965) recorded leaf spot disease of the same plant, due to *Colletotrichum chlorophytumi*. Likewise, Narsimhan et. al., (1966) rust disease due to *Uromyces cligniyi* and Rao and Narendra (1974) reported anthracnose due to *Colletotrichum dematium*. Mukherji et. al., (1986) recorded leaf spot due to two species of *Colletotrichum* viz. *Colletotrichum chlorophyti* and *C. dematium* and

rust diseases due to two species of *Uromyces* viz. *Uromyces loculiformis* and *U. cligniyi* on the crop of Chlorophytum. Mandal et. al., (2004) recorded *Macrophomina phaseolina* for the first time on the crop causing severe diseases. *Rauwolfia serpentina* is another important drug plant used in ayurvedic medicines, but in Maharashtra its cultivation has been found in some private gardens. Its root contains various alkaloids of great medicinal value. The plant has been reported to be infected by number of fungi in the field. Ramakrishnan et. al., (1950) reported leaf spot disease of this plant caused by *Mycosphaerella rauwolfiae* and Mohanty and Addy (1957) reported another fungus *Cercospora rauwalfiae* responsible for leaf spot disease. Chandra (1957) reported *Cercospora rauwalfiae* casual organism of another disease that is leaf blotch disease. Mohanty (1958) reported target spot disease due to *Corynespora cassicola*. Similarly, Ganguly and Pandotra (1962) reported leaf spot due to *Alternaria alternata*, wilting due to *Fusarium oxysporum* and powdery mildew due to *Leveillula taurica*. Janardhanan et. al., (1964) also found wilting due to *Fusarium* sp. Varadrajan (1964) observed leaf spot due to *Pellicularia filamentosa* and anthracnose due to *Colletotrichum gloeosporioides*. Lal and Tandon (1966) reported leaf spot disease caused by *Colletotrichum* sp. Lele and Ram (1968) reported die-back due to *Collectotrichum dematium*. Mehrotra and Das (1976) also reported *Cercospora rauwalfiae* and *Fusarium* sp. responsible for causing disease of *Rauwolfia serpentine*. Varadarajan (1996) recorded leaf spot due to *Curvularia lunata*. *Aloe barbadense* is another important medicinal plant, and is a member of family Liliaceae. This plant has long been in use in traditional medicine for treatment of digestive system, wounds, burns and skin troubles. Aloe gel can be obtained from the leaves. It contains mixture of glycosides called aloin. The plant can be cultivated in almost all parts of Maharashtra, even under constant drought conditions. The leaves of Aloe plants were found to be infected by various pathogens in field. Ajrekar and Tonapy (1923) and Parndekar (1964) reported leaf rust due to *Uromyces aloes*. Roy (1976) observed *Colletotrichum gloeosporioides, Fusarium solani, Pestolotiopsis vesicular, Phoma sorghina, Phomopsis aloes*, and *Alternaria alternata* on leaves of the above cited plant. Kate et. al., (1997) and Gupta and Masood (2004) found leaf blight and leaf spot due to *Alternaria alternata*. *Adathoda vasica* is another important drug plant. Its cultivation on large scale around farm house in Konkan region. The leaves contain important alkaloid vasicine, used in various cough syrups. Leaves are found to be infected by some fungal pathogens. Sydow et. al., (1966) reported rust disease due to *Aecidium adhathode*. Chowdhary (1948) observed *Cercospora adhathode* on leaves, Pandotra and Ganguly (1964) leaf spot due to *Phyllosticta vasicae*. Similarly, Shreemali (1972) found new disease on stem due to *Phoma vasicae*. Roy (1976) and Roy et. al., (1988) observed leaf spot due to *Colletotrichum capsici, Alternaria alternata, Colletotrichum gloeosporioides* and *Curvularia lunata*, anthracnose disease due to *Drechslera speciferum*. *Centella asiatica* is commonly called as "brahmi" is a creeping medicinal plant. Now farmers have started cultivation of this crop under polyhouse condition in Maharashtra. Brahmi mainly contains saponins in the form of asiaticoside, madecassic acid. It is used as nerve tonic for improving memory power. This crop plant has been attacked by number of fungi. Singh et. al., (1973) recorded white rust fungus *Albugo* sp. on leaves. Reddy and Rao (1975) leaf spot due to *Cochliobolus geniculatus*. Manoharachary (2003) reported new species *Cercospora centellae* in Hyderabad. *Emblica officinalis* belonging to family Euphorbiaceae. Its fresh and dried fruits are used in various ayurvedic preparations like 'Triphala churn' and 'Chyawanprash'. Amla fruit is a rich natural source of vitamin 'C' and also contain tannins. Amla fruits are largely used in Indian medicine. Fruits and leaves of plant have been attacked by number of fungi in field. Joshi (1958) and Tyagi and Prasad (1972) recorded leaf, stem, fruit rust due to *Ravenelia emblicae*. *Zingiber officinale* is also called as ginger. It is medicinal as well as cash crop of Maharashtra. Its cultivated in almost all the areas. The fresh and dry rhizomes of ginger used in medicines and condiments. The crop is particularly susceptible to the disease and often heavy losses occur in different localities. leaves of ginger are infected by various fungal pathogens that include *Taphrina maculans* (Mix 1949), *Phyllosticta zingiberi* (Ramakrishnan, 1952., Shukla and Haware, 1972), *Colletotrichum zingiberis* (Neema and Agarwal, 1960., Jain et. al., 1960), *Septoria zingiberis* (Sundaram, 1961), *Cercospora zingibericola* (Kar and Mandal, 1969), *Piricularia zingiberis* (Rathaiah, 1979), *Cercoseptoria zingiberis* (Rathaiah, 1981), *Fusarium zingiberis* (Rana and Arya, 1991). Rathaiah and Gogai (2000) found banded leaf blight of ginger due to *Rhizoctonia solani*. *Hemidesmus indicus* is also called as 'Anantmul'. It is cultivated largely in Gujrat, Rajasthan, U.P. etc. But in Maharashtra plants have been found in Western Ghats in wild stages. The leaves of these plants are attacked by number of pathogens. Agarwal and Hasija (1961) recorded leaf spot due to *Pestalotiopsis carbonacea*. Kar and Mandal (1969) observed new *Cercospora* sp. in West Bengal. Khanna and Chandra (1977) leaf spot due to *Fusarium equiseti*. Recently, Pawar and Deotare (2001) reported white powdery mildew caused by *Oidium hemidesmi* from Gautala forest in Maharashtra. *Azadirachta indica* belonging to member of family Meliaceae. The plant is found throughout India. In India it is very common in Maharashtra, Rajasthan, M.P., U.P., and Tamil Nadu. The neem seed contains non-edible fixed oil. It also contains Nimbin, Nimbidin possess anti-viral activity. It also contains glycerides of saturated and unsaturated fatty acids. The leaf extracts are useful for blood purification. The leaves and fruits are infected by different fungi. Mitra (1935) recorded leaf spot due to *Cercospora subsessilis* and same pathogen was also observed by Mundkar (1938) and Rao (1962). Uppal et. al., (1935) found powdery mildew and leaf spot due to

Oidium sp. and *Cercospora leucosticta*. Chawdhary (1957) and Jain et. al., (1960) observed rust due to *Cercospora leucostica*, Narayanaswamy et. al., (1968) powdery mildew due to *Oidium azadirachtae* and same pathogen was observed by Sharma and Jain (1974). Recently, Pawar and Deotare (2001) found powdery mildew and rust due to *Oidium azadirachtae* and *Cercospora* sp. *Glycyrrhiza glabra* is commonly called as "liquorice". It is cultivated largely in Spain, England, Russia. But in India it is cultivated as a small scale in field. Nowadays, in Maharashtra it is also cultivated in agricultural sectors. Its root contains triterpenoid saponin known as "glycyrrhizin". The plant has been attacked by various fungi. Chona et. al., (1959) recorded leaf spot due to *Cercospora cavarae* and the same pathogen has been also observed by Banerjee et. al., (1966) on leaf. *Curcuma longa* (Turmeric) is multipurpose ayurvedic as well as spice plant in India. It is main species of commerce and is cultivated for its rhizomes. The extraction of powder is carried out from rhizomes. Turmeric contains chief yellow coloring substances curcuminoids is known as curcumin. Its official use in various pharmacopoeias. Turmeric plant is largely cultivated in Sangli district in Maharashtra. The leaves and rhizomes of plant has been attacked by number of fungi in field. Ramakrishnana (1954) recorded *Colletotrichum capsici* on leaves. Summanwar and Bhide (1962) leaf spot disease due to *Phyllosticta zingiberis*, Chowdhary (1966) found the species of *Alternaria tenuissima* on leaf. Patil and Moniz (1973) observed a pathogen *Colletotrichum capsici*. Pavgi and Upadhyaya (1976) found parasitic fungus *Cercospora curcumae-longae*. Rathaiah (1982) observed leaf gall due to *Taphrina maculans*. Prasadji et. al., (2004) leaf blotch due to *Taphrina maculans*. Palarpawar and Ghurde (1989) observed *Colletotrichum curcumae* on leaves of turmeric. *Andrographis paniculata* belonging to family Acanthaceae. Its common name is Kalmegh or Kirayat. It is cultivated throughout India. In Maharashtra, it is cultivated in small scale. The dried leaves and tender shoots are used in medicines. It contains active principles andrographolide. The plant affected by number of fungi in field. Thirumalachur and Govinda (1953) recorded leaf spot due to *Cercospora andrographidis*. Recently, Roy (1989) found incidence of *Alternaria alternata* and *Botrydiploidia theobromae* on stems of Kalmegh. *Datura metel* plant belonging to family Solanaceae. The plants are cultivated in agricultural field as well as in wild condition. The plant is attacked by different pathogens. Rao (1962) recorded leaf spot of *Datura* caused by *Alternaria crassa* and the same pathogen was recorded by Siddiqui (1963). Ganguly and Pandotra (1962) observed leaf spot due to *Alternaria tenuissima*. Rao (1967) found *Phyllosticta solani* on infected leaves. Narayanswamy and Ramakrishanan (1968) observed powdery mildew due to *Oidium cyparissiac*. Recently, Roy (1989) found *Sepegazzinia sundera* and *Cochliobolus specifer* on seeds, tubers and stems of *Datura*. *Solanum viarum* is commonly known as 'ringini'. The plants actually grow in wild condition, but nowadays, these plants grow on agricultural sector on large scale. The fruits contain high number of alkaloids. Kapoor and Hingorani (1958) recorded leaf spot and fruit rot of *Solanum* due to *Alternaria alternata*. Rao (1965) reported leaf blight due to *Phytophthora parasitica*. Singh and Seth (1970) observed *Alternaria tenuis* on leaves. *Asparagus officinalis* and *A. racemosus*, commonly known as Shataveri. *A. officinalis* is used as vegetables. Its tubers are used in preparation of 'Shataveri soup'. Another species *A. racemosus* is used in preparation of readymade energetic food. Both the species were attacked by number of fungi in field. Kheswala (1936) reported "Phoma" disease due to *Phoma asparagi* on stem. Thirumalachur (1947) rust on cladodes due to *Puccinia phyllocladiae*. Shreemali (1973) observed fungus on stem due to *Phomopsis armericae*. Falloon and Grogan (1988) observed *Phytophthora* sp. on stem. Recently, Roy (1989) observed fungi *Pestalopsis laprogena* and *Nigrospora sphaerica* on stems of *Asparagus racemosus*. *Abrus precatorius* is another important drug plant, it is commonly called 'Gunj'. Its leaves have medicinal properties. These plants generally grow as climbing habit. The leaves get infected by airborne pathogens. Ramakrishnan and Ramakrishnan (1948) reported leaf rust due to *Ravenelia ornate*. Sanwal (1951) found leaf rust due to *Ravenelia ornate*. Siddiqui (1957) and Tyagi and Prasad (1972) reported leaf rust due to *Ravenelia ornata*. Patwardhan (1966) reported powdery mildew due to *Acrosporium* sp. Likewise, *Withania somnifera* a member of family Solanaceaeis commonly called Ashwagandha. Its roots are used as tonic. The roots contain major amount of alkoloids viz. Withanine. The plant in field is infected by large number of pathogens. Sydow et. al., (1912) reported leaf rust disease of *Withania somnifera* caused due to *Aecidium withaniae*. Pavgi et. al., (1970) observed leaf spot due to *Cercospora withaniae*. *Mentha arvensis* is one of the important medicinal plant . Its leaves aromatic and scented due to volatile oil in their leaves. Ahmed (1990) recorded rust disease due to *Puccinia menthae*. Shukla et. al., (2001) observed stem blackening and stem rot due to *Botrydiploia theobromae*. *Tinospora cardifolia* is a member of family Menispermasae commonly called as 'Gulvel'. Its stem has medicinal value and used in Jaundice. Ajrekar and Oza (1932) reported *Glomaerella cingulata* on leaves. Mundkar (1938) and Thirumalachur and Chupp (1948) observed leaf spot due to *Cercospora tinosporae*, Thirumalachur and Lacy (1951) leaf spot caused by *Phyllachora dolichospora*. Tilak and Kale (1970) found parasitic stem fungus due to *Uleodothis indica*. Chandra (1974) reported *Cercospora verruculosacausinf* leaf spot disease. *Strychnos nux-vomica* plant, cultivated for its seeds. The seed contain alkaloids strychnine and brucine used in allopathic medicines. Seeds of plant is very hard. The leaves and seeds were infected by various pathogens in field. Stevens (1927) reported 'sooty mould' disease caused due to *Meliola stenospora*. Kapoor (1967) studied *Meliola petchii* on infected leaves. Nagaraja et. al.,

(1995) observed 'sooty mould' due to *Meliola strychonicola*. Besides, *Piper longum* another medicinal plant, commonly called as 'Pimpli'. It is a member of family Piperaceae. The fruit contains high amounts of phenolic compounds. Mundkar (1938) recorded leaf rot of *Piper longum* due to *Phytophthora parasitica*. Asthana (1946) observed leaf spot caused by pathogens *Cercospora piperata*. Rao (1962) recorded leaf spot due to *Cercospora piperata*. *Ocimum sanctum* is a 'sacred' plant of Hindu religion. Its cultivation is in Tulsi vrandavan and in field. It is a medicinal as well as aromatic plant, it contains volatile oil in their leaves. The leaves are infected by different fungal pathogens. Munjal et. al., (1959) reported leaf spot due to *Cercospora guatemalensis*, Munjal (1960) reported leaf spot caused by *Cercospora ocimicola*, Pandotra and Ganguly (1964) reported another fungus *Cercospora canescans* causing leaf spot disease. Ahmed (1990) observed powdery mildew due to *Oidium* sp. in Arunachal Pradesh.

3. Fungal pathogens of medicinal plant parts during storage

Medicinal plants undergo drastic chemical changes from field to factory due to microbial action. The plant samples collected from field or forests are stored in traditional warehouses where they are usually packed in gunny bags or spread as such as ground and have to face fluctuating environment and diverse range of microbes. During transport of medicinal plant parts to the market may involve various types of damages which may result into infections caused by various bioagents. These bioagents can be bacteria, fungi, insects, and viruses. Fungal pathogens not only attack medicinal plants in fields but also cause postharvest losses, studied by various workers Roy (1973) studied white rot disease on roots of *Chlorophytum borivilianum* caused by pathogen *Sclerotium rolfsii.* Cooke (1978) found that Aspergillus *phaeocephalus* was found on the roots of *Asparagus racemosus*. Malvia and Jain (1981) isolated root rot fungus Macrophomina phaseolina from roots of Rauwolfia serpentina. Roy et.al., (1988) isolated about seven fungi viz. *Aspergillus flavus, A. niger, A. candidus, A. luchuensis, A. ocharaceus, Fusarium moniliforme* and *Penicillium* sp., from infected roots of *Rauwolfia serpentina*. Chourasia (1990) reported that *Aspergillus flavus, A. niger, A. ocharaceus, Penicillium citrinum, Penicillium* sp. *Fusarium moniliforme* and *Fusarium* sp. were found to be associated on the surface of roots and seeds of *Withania somnifera*. Bordia et. al., (1995) observed that *Chlorophytum borivilianum* tubers are infected by fungus *Aspergillus* sp. and *Fusarium* sp. during the storage of fleshy tubers. Chourasia (1990) isolated fungal pathogens *Aspergillus flavus, A. niger, A. ocharaceus, Penicillium citrinum, Penicillium* sp., *Fusarium moniliforme, Fusarium* sp., from the roots of *Asparagus racemosus*. Chourasia (1990) reported rhizomes of *Acorus calamus* infected by saprophytic fungi *Aspergillus flavus, A. niger, A. ocharaceus, Penicillium citrinum, Penicillium* sp. *Fusarium moniliforme, Fusarium* sp. Rhizome rot of *Zingiber officinale* a postharvest disesaes caused by *Pythium myriotylum* (Bhagwat 1960), *Curvularia lunata* (Sahni 1966), *Fusarium oxysporum* (Rao 1966), *Diplodia notalensis* (Wilson and Balagopal, 1971), *Sclerotium rolfsii* (Haware and Joshi, 1973), *Macrophomina phaseolina* (Sarma and Nambiar, 1974). Roy et. al., (1988) isolated fungi *Aspergillus flavus, A. niger, A. ocharaceus, Chaetomium* sp., *Penicillium citrinum, Rhizopus stolonifer* from the rhizomes of *Zingiber officinale*. Dohroo (2001) reported fungal pathogens *Pythium ultimum, Fusarium oxysporum, Verticillium* sp. and *Chlamydosporium* sp. associated with storage rot of ginger. This disease was noticed in storage pits from January, which reached its maximum intensity in April at 18.5℃ temperature and 67.5% relative humidity. Setty (1959) reported *Penicillium islandicum* a fruit rot disease of *Emblica officinalis*. Fruit rot disease of *Emblica officinalis* was caused and reported by *Cladosporium herbarum, Pestalotia cruenta, Phoma* sp. (Tandon and Verma 1964), *Pestalotia cruenta* (Tandon and Srivastava 1964), *Pestalotia cruenta, Aspergillus niger* (Srivastava et. al., 1964, Srivastava and Tandon 1968), *Aspergillus niger, Fusarium* sp., *Penicillium oxalicum* (Rao 1966), Kulkarni and Sharma,1971), *Herdersonula toruloides* (Khanna and Chandra, 1975), *Cladosporium cladosporioides* (Jamaluddin,1978), *Phoma putaminum* (Pandey et. al., 1980). Manoharachary (1975) isolated fungus *Cladosporium oxysporum* from fruit rot of *Strychnos nux- vomica.* Rajiv Kumar et. al., (1979) made an extensive screening of fungi associated with stored samples of *Triphala* using blotter test and two culture media. They found Aspergilli were most frequent contaminant and *Aspergillus niger* was recorded in every sample and in all the tests. Chourasia et. al., (1987) reported *Aspergillus flavus, A. niger, A. ocharaceus, A. candidus, A. luchuensis, Chaetomium* sp., *Botrytis* sp. from fruits of Piper longum. Janardhanan and Ganguly (1963), studied fungal flora of seeds of *Belladona*, *Digitalis* and *Pyrethrum* and their data indicated that most of fungi associated with seeds of medicinal plants were apparently externally borne and could be substantially eliminated by surface sterilization. Narayan and Prasad (1981) reported the minimum number of fungi on fresh seeds of *Foeniculum vulgare* (Fennel) and their number was found to increase gradually in second year of storage and it remained constant in the third year. They further observed that Aspergilli invaded the seeds during the first year of storage and their frequency increased during successive years. Dutta and Roy (1987) showed association of *Aspergillus flavus, A. niger* and *Penicillium citrinum* with the seeds of *Strychnos nux-vomica* and *S. potatorum*. Roy et. al., (1988) isolated fungi from seeds of different medicinal plants. *Aspergillus flavus, A. niger, A. candidus, A. luchuensis, Alternaria alternata, Fusarium moniliforme* and *Penicillium citrinum* and *Rhizopus stolonifer* from seeds of *Emblica officinalis*. *Aspergillus flavus, A. niger, A. candidus, A. nidulans, Fusarium moniliforme, Penicillium* sp., *Trichoderma* sp. from the seeds of *Azadirachta indica. Aspergillus flavus, A. candidus, A.*

°Chraceus, Penicillium citrinum and *Trichoderma* sp. from seeds of *Datura* metal. *Aspergillus flavus, A. niger, A. candidus, Chaetomium* sp., *Fusarium moniliforme and Penicillium citrinum* from seeds of *Abrus precatorius. Aspergillus flavus, A. niger, A. candidus, A. luchuensis, A. nidulans, Alternaria alternata, Fusarium moniliforme, Penicillium citrinum, Penicillium sp., Rhizopus stolonifer* and *Trichoderma* sp. from the seeds of *Holarrrhena antidysendrica*. *Aspergillus flavus, A. candidus, A. nidulans, Fusarium moniliforme, Rhizopus stolonifer* from *Strychnos nux- vomica* seeds. Dhake (1994) isolated seventeen fungi, six species of *Aspergillus*,three species of *Fusarium*, two species of *Penicillium*, and one species each of *Alternaria*, *Rhizoctonia*, *Cladosporium*, *Rhizopus*, *Trichoderma* and *Chaetomium* from fruits and seeds of *Azadirachta indica*.

4. Mycoflora associated with Crude and Stored drugs of medicinal plants

The above literature review shows that the fungi are associated with various diseases of medicinal plants such as leaf spot, twig blight, root rots and various storage rots etc. However, the mycoflora associated with stored raw medicines or crude drugs which cure the human diseases have been poorly investigated so far. A number of drugs absorb moisture during their storage and become susceptible to the microbial growth. The environmental conditions like relative humidity, temperature, moisture and storage conditions have been reported to affect establishment of drug mycoflora, their role on biodeterioration and mycotoxin contamination.

4.1 Factors responsible for fungal contamination of crude or stored drugs of medicinal plants

Relative humidity: It has been observed in most of the cases that a large number of fungi have been associated with stored medicinal plants/plant parts (Roy et. al., 1987). The effect of different levels of relative humidity on fungal association and aflatoxin production in *Piper longum* fruits was reported by Chourasia and Roy (1989). Christensen (1974) recorded different levels of relative humidity affecting invasion of different storage moulds. Dutta et. al., (1987) reported 96% relative humidity as favourable for maximum incidence of fungi on *Strychnos potatorum* and *S. nux-vomica* seeds. Roy (1989) noted that relative humidity above 90% was highly favourable for the maximum incidence of *Aspergillus niger, A. flavus, Fusarium* sp. and *Penicillium* sp. on twenty-one crude herbal plant samples. Chourasia and Roy (1991) found 75% relative humidity as lowest limit and 96% relative humidity as highest limit for association of mycoflora on the seeds of Neem and Datura. Dohroo (2001) studied intensity of storage rot of ginger disease with relative humidity and found maximum intensity of diseases at 67.5% relative humidity. Another study on relation of intensity of fungi associate with stored drugs with humidity reported the highest incidence of fungi associated with herbal drugs under storage during mansoon season when the relative humidity ranged between 79-91% (Roy, 2003).

Temperature: The variation in the occurance of fungi as basic mycoflora and periodical mycoflora showed their appearance throughout the year due to wide range of temperature, which has been reported by Armolic et. al., (1956), Kennedy (1964), Sinha (1979) and Dutta (1988). Dutta (1988) reported maximum incidence of seed mould at 30℃ in the seed of *Strychnos potatorum* and *Strychnos nux- vomica*. Roy (1989) observed maximum incidence of seed fungi on number of medicinal plant parts and seeds stored at 28.1℃ to 33℃ temperature. Dahroo (2001) reported storage rot of ginger disease reached its maximum intensity at 18.5℃.

Moisture: Moisture is one of the prime factors in colonization of moulds. A number of drugs absorb moisture during their storage and become susceptible to the microbial growth. Some drugs absorb moisture to the extent of 25% of their weight. The moisture, not only increases the bulk of the drugs, but also causes impairment in the quality of crude drug. The excessive moisture facilitates enzymatic reactions resulting in decomposition of active constituents. Drug plant materials dried such as that moisture levels remain below to the limits might salvage from mould infestation reported by Bewly and Black (1985). Similarly, Chourasia and Roy (1991) reported that high moisture content of Neem seeds and Datura seeds allowed growth of maximum moulds along with *Aspergillus flavus*. Bagwan and Meshram (2004) reported that moisture content of 15-22% was found to be more suitable for mycoflora association and aflatoxin production.

5. Fungi in deterioration of drug quality

Medicinal plant parts are associated with a variety of fungi in field as well as during storage which cause various types of harmful effects to the plant parts and decrease the quality of active components of that plant part. The whole process is termed as biodeterioration. During storage, the fungal organisms thrive in plant parts such as root, rhizome, fruit, and seeds by utilizing various components of plant parts and cause degradation of protein, carbohydrates, lipids etc, whereas loss in medicinally active ingredients from the drug plant parts have been reported by few workers. the various constituents that are getting affected by fungi include:

a) **Protein:** Proteins are the important constituents of the drug plant parts. During storage, change in protein content of seeds of medicinal plants are influenced both by fungi as well as physical factor (Wallace *et.al*., 1976 and Mondal et. al., 1981). The decrease in protein content by fungi is due to their enzymatic degradation into simpler components which are then subsequently utilized by them (Cherry et. al., 1975). Loss in protein content of seed due to associated mycoflora has also been reported in case of different oil seeds as in groundnut (Nager and Chauhan, 1977), Sunflower (Ivanov, 1989) and safflower (Sandikar and Mukadam,1990), Mustard (Kumar and Prasad, 19930). Loss in protein content in the medicinal plants have also been reported by

some workers. Dutta et. al., (1987) found in case of *Strychnos potatorum* and *Strychnos nux--vomica* seeds stored for 60 days showed maximum loss in protein content due to high incidence of mycoflora. Roy (1989) observed that *Aspergillus flavus* caused maximum loss in protein content of *Strychnos nux-vomica*, *Strychnos potatorum*, *Datura metal* and *Piper longum* seeds. While *Penicillium citrinum* was found to be more destructive of protein in case of *Syzygium cumini* and *Azadirachta indica* seeds. Bavaji and Sreeramula (2002) observed decrease in protein content in infected sesame leaves is due to the utilization of protein by the pathogen**.**

b) Oil content: Seeds of some medicinal plants are mainly used for the extraction of oil for its further uses in ayurvedic medicines. Moulds associated with the seeds of some medicinal plants may cause degradation of oil both qualitatively and quantitatively. Degradation of oil content of the seeds due to mycoflora have been reported by different workers in case of different plants. Singh et. al., (1972) in sesame reported that association of mycoflora caused significant reduction in oil content resulting into increase in free fatty acid content. Loss in oil content of seeds has also been reported in case of mustard (Chahal and Kang, 1979), Sunflower (Singh and Prasad, 1985). Sharma and Bhawmik (1987) found that groundnut seeds infected with *Macrophomina phaseolina* showed loss in oil content and change in the oil colour. Among the total mycoflora *Aspergillus niger* and *A. flavus* were found to be highly destructive to oil in the seeds of sesame (Singh and Prasad, 1979). Similarly, Sharma (1981) found in case of sesame deterioration of oil due to *Aspergillus niger*, *A. flavus, A tamari, Penicillium citrinum, P. lilicenum, P. petulum and Cladosporium herbarum*. Prasad (1988) studied in case of safflower and reported that *Alternaria carthami, A. alternara* and *Aspergillus flavus* caused loss in oil content, change in colour and other physiochemical properties of oil.

c) Degradation of active ingredients: medicinal plant parts such as root, stem, fruit, and seeds show drastic chemical changes in its active components like alkaloids, glycosides, phenolic compounds, essential oils due to number of fungi associated with these plant parts. There are significant evidences to support those fungi cause degredation of active components of medicinal plants. Dutta and Roy (1987) in case of *Strychnos nux-vomica* and *S. potatorum* seeds found that degradation of alkaloids is due to *Aspergillus candidas*, *A. clavatus*, *A. flavus*, *A. luchuensis*, *A. niger*, *A. nidulans*, *A. ochraceus* and *A. sydowi*. Dutta (1988) also reported degradation of maximum alkaloids from *Strychnos* seeds due to *A. flavus*. His studies also revealed that *Aspergillus niger* effectively reduces strychnine. Roy (1989)., reported changes in alkaloid, phenol and protein content of seed, fruit, and root samples of different drug plants by *A. flavus, P. citrinum, A. niger, Fusarium moniliform*. The decrease in the concentration of all the important constituents (10-40%) was recorded under fungal infestation within 60 days of storage. Roy and Chourasia (1988) reported decrease in phenolic & alkaloid content of Mucuna pruriens seeds associated with *A.flavus*. Roy (1989) also reported reduction in alkaloid content of *Strychnos potatorum* & *Strychnos nuxvomica* seed due to storage fungi, *A. niger, A. flavus and Penicillium citrinum*. Roy (2003) reported degradation of alkaloids in *Strychnos potatorum* and *S. nux-vomica* seeds within 90 days of infestation by *A. flavus A. niger*, & *Penicillium citrinum Strychnine* & brucine were identified in the seeds as the major alkaliods, their concentration was significantly reduced under infestation.

6. Aflatoxin production and its role in contamination of medicinal plant parts: Aflatoxins are known to produce very commonly by two species of *Aspergillus* viz, *Aspergillus flavus* and *Aspergillus parasiticus*. The former is more common than latter. Aflatoxins have been identified as Bl and B2 from isolates of *Aspergillus flavus*, while B1, B2, G1 and G2 from *Aspergillus parasiticus* (Nagarajan and Bhat, 1973). Hasseltine et. al., (1966) reported Aflatoxigenic contamination in seeds of groundnut, maize, rice, wheat, rye, jawar, soyabean etc. due to attack of *Aspergillus flavus*. The growth of *Aspergillus flavus* was inhibited by a large number of medicinal plant extracts. Shivendra Kumar and A.K. Roy (1996) recorded an aqueous extxacts of twentyfour medicinal plants (parts) which have medicinal properties in curing different human diseases were screened for aflatoxin prevention. The root extracts of *Plumbago zeylanica* showed maximum aflatoxin B1 prevention (81.54%), followed by *Ocimum sanctum* (80.03%), *Moringa oleifera* (78.81%), *Piper longum* (75.95%), *Lawsonia inermis* (73.88%), *Curcuma aromatica* (71.45%) and *Azadirachta indica* (70.46%). Significant evidences are to support that the growth of *Aspergillus flavus* was reduced by medicinal plant extracts. But there are also many evidences to support its role in contamination and deterioration of drug quality of many medicinal plants. The growth of *A. flavus* under storage not only deteriorate the quality of drug plants but also contaminate it with aflatoxins. Roy et. al., (1988) isolated fifty *A. flavus* strains from drug plant seeds out of which 21 were aflatoxigenic. Roy et. al., (1988) reported 50 isolates of *Aspergillus flavus* obtained from different drug plants /plant parts, 21 isolates were found to be toxigenic, 12 isolates had potentiality to produce aflatoxin B1, only seven had both B1and B2 and only two produced B1, B2 and G1. Roy (1989) screened 33 plant part samples for aflatoxin and

found that all are aflatoxin contaminated. Bagwan and Meshram (2004) reported that ninetyseven samples of dried fig fruits were collected from different places. The aflatoxin contamination in 97 sample varied from 0.6 to 39.0 µg/Ka. The moisture content in 15-22% was found to be suitable for aflatoxin production. Chourasia and Roy (1989) reported aflatoxin contamination in fruits of *Piper longum* (Pippali) and stated that the level of aflatoxin B1 production was high when the relative humidity was between 75 and 96%. Chourasia. (1990) reported five drug plant samples used for the preparation of churna, four were aflatoxin B1 positive where its concentration ranged from 1.27 to 0.47 µg/g. of the 49 strains of *Aspergillus flavus* isolated from different drug plant samples, 22 were toxigenic and their potentiality to produce aflatoxin B1 was in the range of 0.09 to 0.88 µg/ml of culture filtrate, each drug contained aflatoxin B1.

CONCLUSION

From the current research it was concluded that diverse number of pathogenic fungal species cause various diseases to various important medicinal and other plants in fields as well as during storage conditions. Therefore, these fungi may reduce the production of metabolites and hence, therapeutic drugs and normal metabolism of these mentioned plants. The current research act as a basic platform and summarizes a detailed account of various severe diseases along with their casual organisms. Therefore, the study will help the researchers to combat these multiple illness by following proper management strategies.

ACKNOWLEDGEMENT

The authors are thankful to Head, Department of Botany, University of Kashmir for Assistance during manuscript preparation and multiple scholars for assistance in sample and metadata collection for the completion of this research article.

Conflict of interest

There are no conflicts of interest to declare related to this study.

REFERENCES

1. Agarwal, G. P. & Hasija, S. K. Fungi causing plant diseases at Jabalpur (MP)-VI. Some Cercosporae. *Pr℃. nat. Acad. Sci., India*, 1961; *31*: 355-359.
2. Ajrekar, S. L., & Tonapy, B. R. A note on life history of Uromyces aloës (Cook) Magn. *J Indian Bot S℃*, 1923; *3*: 267-269.
3. Allard, R. W., & Jain, S. K. Population studies in predominantly self-pollinated species. II. Analysis of quantitative genetic changes in a bulk-hybrid population of barley. *Evolution*, 1962; 90-101.
4. Andersson, J. O. N. A. S., & von SYDOW, E. R. I. K. The aroma of black currants II. Lower boiling compounds. *Acta chem. scand*, 1966; *20*(2): 522-528.
5. Bhabha, H. J., & Ramakrishnan, A. N. D. A. (September). The mean square deviation of the number of electrons and quanta in the cascade theory. In *Pr℃eedings of the Indian Academy of Sciences-Section A*, 1950; 32(3): 141. Springer India.
6. Bilgrami, K. S. (Ed.). *Fungi of India: List of References*. Today and Tomorrow Publisher, 1991.
7. Bresler, A. D., Joshi, G. H., & Marcuvitz, N. Orthogonality properties for modes in passive and active uniform wave guides. *Journal of Applied Physics*, 1958; *29*(5): 794-799.
8. Chandra, M. Ancient Indian Ivories. *Bulletin of the Prince of Wales Museum of Western India*, 1957; *6*: 4-63.
9. Chandra, Sudhir, and R. N. Tandon. "Three new foliicolous fungi." *Current Science*, 1965; 34(8): 257-260.
10. Chowdhary, S. Notes on fungi from Assam. *Lloydia*, 1948; *21*: 152-156.
11. Gergely, J., Hele, P., & Ramakrishnan, C. V. Succinyl and acetyl coenzyme A deacylases. *Journal of Biological Chemistry*, 1952; *198*(1): 323-334.
12. Gokulapalan, C., & Girija, V. K. Rhiz℃tonia solani-a new threat to ginger crop in Kerala. *Journal of Mycology and Plant Pathology*, 2000; *30*(1): 131-132.
13. Jain, S. A. (Ed.). *Reality*. Vira Sasana Sangha, 1960.
14. Janardhanan, K. K., Ganguly, D., & Husain, A. Fusarium wilt of Rauvolfia serpentina. *Current Science*, 1964; *33*(10): 313-313.
15. Javed, M., Charaya, M. U., & Sinha, P. Current status of anthracnose (Fruit-rot and die-back) disease in five bl℃ks of chilli growing areas of Ghaziabad district (UP) India. *Bulletin of Pure & Applied Sciences-Botany*, 2017; *36*(2), 72-77.
16. Joshi, P. S., & Bhaisare, K. A NEW PERSPECTIVE ON THE EARLY IRON AGE CULTURES OF VIDARBHA AND SOUTH INDIA. *Rethinking the Past*, 295.
17. Kar, A. K., & Mandal, M. New Cercospora spp. from West Bengal. II. *Transactions of the British Mycological S℃iety*, 1970; *54*(3): 423-433.
18. Khanna, K. K., & KK, K. CONTROL OF GUAVA FRUIT ROT CAUSED BY PESTALOTIA PSIDII WITH HOMOEOPATHIE DRUGS, 1977.
19. King, E. J., Harrison, C. V., Mohanty, G. P., & YOGA-NATHAN, M. The Effect of Aluminium and of Aluminium containing 5 per ce. nt. of Quartz in the Lungs of Rats. *Journal of Pathology and Bacteriology*, 1958; *75*(2): 429-34.
20. Kumar, S., Gupta, S., Chandra, S., Singh, B. B., Ali, M., & Dhar, V. Pulses in New Perspective. In *Pr℃eedings of the National Symposium on crop Diversification and Natural Resources Management, 20–22 December*, 2004; *2003;* 222-244.

21. LAL, B., & Tandon, R. N. Some new leaf spot diseases caused by Colle-totrichum.I. In *Pr℃. natn. Acad. Sci. India, Sect. B*, 1966; 36(2): 223-232.
22. Lele, V. C., Raychaudhuri, S. P., Bhalla, R. B., & Ram, A. Curvularia tuberculata, a new fungus causing die-back disease of citrus in India. *Indian Phytopathol*, 1968; *21*: 66-72.
23. Mandal, K., Maiti, S., Saxena, D. R., & Saxena, M. A new leaf spot disease of Safed musli. *Journal of Mycology and Plant Pathology*, 2004; *34*(1): 162-163.
24. Manoharachary, C. Biodiversity, taxonomy, ecology, conservation and biotechnology of arbuscular mycorrhizal fungi. *Indian Phytopathology*, 2004; *57*(1): 1-6.
25. McGowan, P. J., Traylor-Holzer, K., & Leus, K. IUCN guidelines for determining when and how ex situ management should be used in species conservation. *Conservation Letters*, 2017; *10*(3): 361-366.
26. Mehrotra, R., Pant, M. M., & Das, M. P. Electronic structure and adhesive energies at bimetallic interfaces. *Solid State Communications*, 1976; *18*(2): 199-201.
27. Mitra, M. Stinking smut (bunt) of wheat with special reference to Tilletia indica. *Indian Journal of Agricultural Sciences*, 1935; *5*: 51-74.
28. Mix, A. J. A monograph of the genus Taphrina. *University of Kansas Science Bulletin*, 1949; *33*(1).
29. Mohanty, N.N., & Addy, S. K. CERCOSPORA LEAF–SPOT OF RAUWOLFIA SERPENTINA BENTH. *Current Science*, 1957; *26*(9): 289-290.
30. Moran, K. *Investment appraisal for non-financial managers: A step-by-step guide to making profitable decisions*. Pitman, 1997.
31. Narasimhan, R. Syntax-directed interpretation of classes of pictures. *Communications of the ACM*, 1966; *9*(3): 166-173.
32. Narayanaswamy, P., & Pagnamenta, A. Accurate solution of Bethe-Salpeter equations for tightly bound fermion-antifermion systems. *Il Nuovo Cimento A*, 1968; *(1971-1996)*, *53*(3), 635-656.
33. Pandotra, V. R., & Ganguly, D. Fungi on medicinal and aromatic plants in the North-West Himalayas-II. *Mycopathologia et mycologia applicata*, 1964; *22*(2): 106-116.
34. Parmar, V. S., Jain, S. C., Bisht, K. S., Jain, R., Taneja, P., Jha, A., ... & Boll, P. M. Phyt℃Chemistry of the genus Piper. *Phyt℃hemistry*, 1997; *46*(4): 597-673.
35. Rana, K. S., & Arya, P. S. Rhizome rot and yellow disease of ginger in Himachal Pradesh. *Indian Journal of Mycology and Plant Pathology*, 1991; *21*(1): 60-62.
36. Rao, V. G., & Varghese, K. M. Forest microfungi. III. Some new taxa of ascomycetes. *Sydowia*, 1979; *32*: 252-259.
37. Rathaiah, Y. PIRICULARIA LEAF SPOT OF GINGER IN ASSAM, 1979.
38. Rathaiah, Y. A new species of Cercoseptoria causing a leaf spot of ginger. *Mycologia*, 1981; *73*(4): 774-777.
39. Rathaiah, Y., & Gogoi, R. Banded leaf blight of ginger in Assam. *Journal of Mycology and Plant Pathology*, 2000; *30*(2): 245-246.
40. Reddy, J. K., Scarpelli, D. G., & Rao, M. S. Experimental pancreatic carcinogenesis. *Advances in medical oncology, research and education*, 1979; *9*: 99-109.
41. Roy, A. G., Roy, R., & Bergeron, N. Hydraulic geometry and changes in flow vel℃ity at a river confluence with coarse bed material. *Earth Surface Pr℃esses and Landforms*, 1988; *13*(7): 583-598.
42. Roy, C. *Introduction to nursing: An adaptation model*. Prentice Hall, 1976.
43. Seshu, S., & Reed, M. B. Linear graphs and electrical networks, 1961.
44. Shah, G. L., & Suryanarayana, B. A NOTE ON THE DISTRIBUTION OF SEXES IN RHYNCHOSPORA WIGHTIANA (NEES) STEUD. *Current Science*, 1967; *36*(6): 157-158.
45. Shreemali, J. L. Some new members of Sphaeropsidales from India. *Indian phytopathology*, 1972.
46. Shukla, B. N., & Haware, M. P. Phyllosticta leaf spot of ginger (Zingiber officinale) in Madhya Pradesh. *Indian journal of mycology and plant pathology*, 1972.
47. Singh, T. N., Paleg, I. G., & Aspinall, D. Stress metabolism III. Variations in response to water deficit in the barley plant. *Australian Journal of Biological Sciences*, 1973; *26*(1): 65-76.
48. Singh, V., Sharma, M., & Jain, D. K. Trichomes in Salvia (Labiatae) and their taxonomic significance. *Nelumbo*, 1974; *16*(1-4): 27-34.
49. Sinha, D., Mukhopadhyay, S., & Mukherjee, D. A note on the direct calculation of excitation energies by quasi-degenerate MBPT and coupled-cluster theory. *Chemical physics letters*, 1986; *129*(4): 369-374.
50. Smith, C. G. Cross-in℃Culation experiments with conidia and ascospores of Erysiphe polygoni on pea and other hosts. *Transactions of the British Mycological S℃iety*, 1969; *53*(1): 69-IN10.
51. Towne, G., Nagaraja, T. G., Brandt, R. T., & Kemp, K. E. Dynamics of ruminal ciliated protozoa in feedlot cattle. *Appl. Environ. Microbiol*, 1990; *56*(10): 3174-3178.
52. Tylophora asthmatica W. and A. (Asclepiadace~e), Walayar, T. S. Ramakrishnan and K. Ramakrishnan, 28-8-1948.
53. Unger, E. C., Fritz, T. A., Matsunaga, T., Ramaswami, V., Yellowhair, D., & Wu, G. *U.S. Patent* Washington, DC: U.S. Patent and Trademark Office, 1996; *5,580,575*.
54. Varadarajan, P. R. Product diversity and firm performance: An empirical investigation. *Journal of Marketing*, 1986; *50*(3): 43-57.

55. Verma, R. K., & Pandro, V. Diversity and Distribution of Clavarioid Fungi in India, Three Fungi from Central India. *Int. J. Curr. Microbiol. App. Sci*, 2018; *7*(12): 2129-2147.