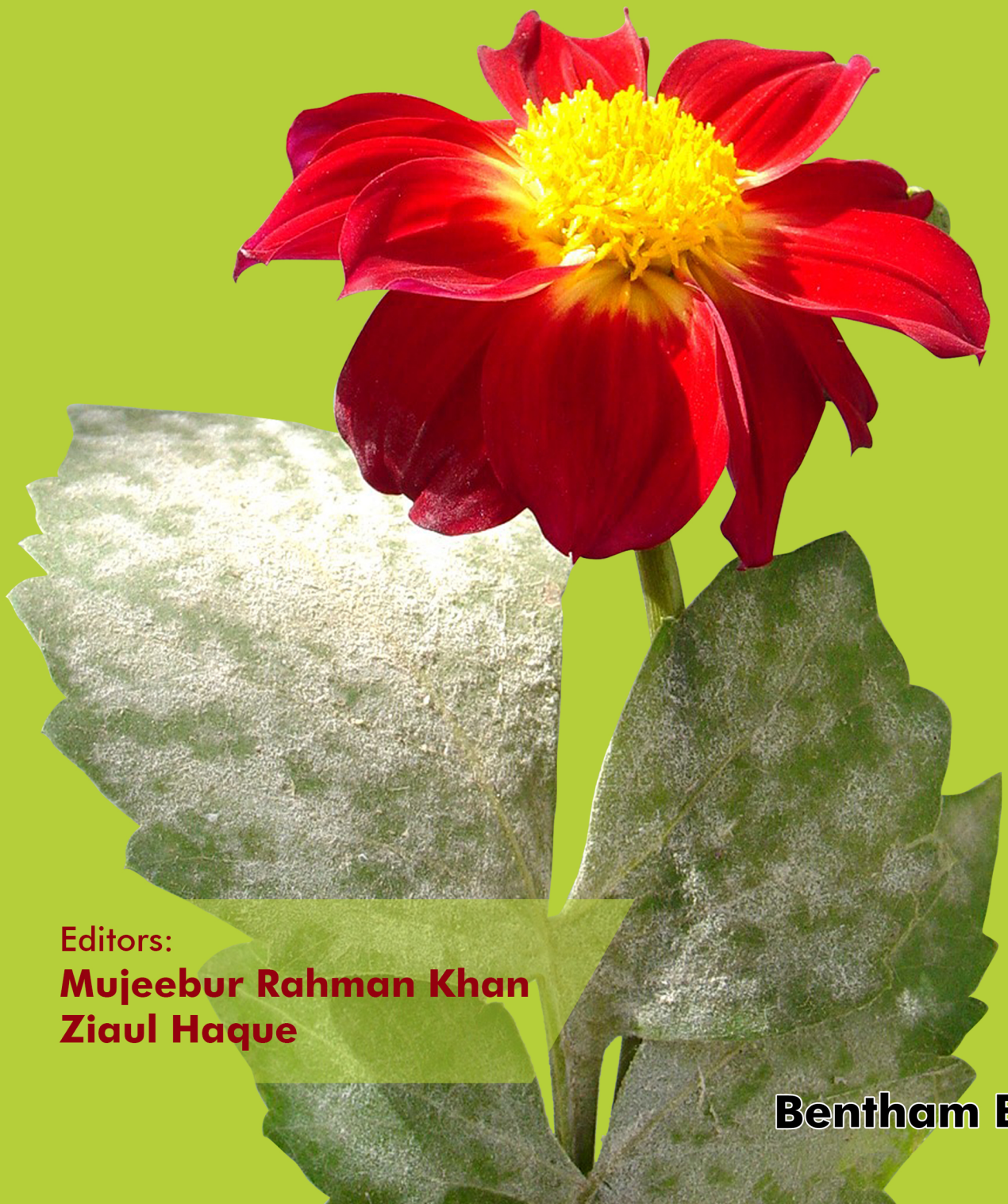
DISEASES OF ORNAMENTAL, AROMATIC AND MEDICINAL PLANTS



Editors:
Mujeebur Rahman Khan
Ziaul Haque

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Diseases of Ornamental, Aromatic and Medicinal Plants

Edited by

Mujeebur Rahman Khan
Department of Plant Protection
Faculty of Agricultural Sciences
Aligarh Muslim University
Aligarh, India

&

Ziaul Haque
Department of Plant Protection
Faculty of Agricultural Sciences
Aligarh Muslim University
Aligarh, India

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Cover Photo Acknowledgement: Branch of a dahlia plant infected with powdery mildew fungus © M. R. Khan.

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CONTENTS

FOREWORD

Plant diseases in ornamental, aromatic, and medicinal crops are common in occurrence and account for up to 12-20% yield losses. The book "***Diseases of Ornamental, Aromatic and Medicinal Plants***" by Prof. M. R. Khan and Dr. Z. Haque presents exclusive and comprehensive information on the major diseases and nematode problems in important ornamental plants (cut flowers, potted flowers, and flowering geophytes, turfs), medicinal plants (tuberous and non-tuberous) and aromatic plants. The present book aims to fill the knowledge gap and provides up-to-date relevant information in one place. It embodies nine chapters highlighting the aetiology, symptoms, disease cycle, economic importance, distribution, and management aspects with advanced and sustainable approaches. The present book shall serve as an important reference source to UG/PG students, academics, professionals, gardeners, scientists, researchers, and extension personnel in universities and institutes, bureaus, directorates, research stations, etc. dealing with plant diseases and nematode problems in ornamental, aromatic and medicinal plants. I wish to congratulate the editors of the book and contributors of the chapters for putting together their efforts to bring out this volume.

T.R. Sharma
Indian Council of Agricultural Research
Krishi Bhavan, New Delhi, India

PREFACE

The cultivation of ornamental plants such as cut flowers, potted flowers, and flowering geophytes has become an emerging commercial sector due to the continuously rising demand for flowers throughout the world. This sector also provides enough opportunities for employment generation as well as foreign earnings. The global trade of florists' crops has been projected to be more than $100 billion annually. Medicinal plants are essential to human life and are utilized in both ancient and modern medical practices all over the world. India is a rich habitat for medicinal and aromatic plants, and accounts for about 9.18 lakh tonnes of production annually. Similarly, aromatic plants assume eminence and economic significance for containing high-value aromatic compounds. However, diseases in these plants are major factors, that destroy around 10-20% of crop produce during pre-harvest and post-harvest stages. A book presenting exclusive and comprehensive information on "Diseases of Ornamental, Aromatic and Medicinal Plants" is lacking in the market, as a result, potential readers are deprived of up-to-date relevant information. The present book aims to fulfill the gap of knowledge and embodies nine chapters covering major diseases and nematode problems in ornamental (such as, anthurium, azalea, begonias, caladium, carnation, china aster, chrysanthemum, coleus, cyclamen, daffodils, gardenia, gerbera, gladiolus, lily, marigold, poinsettia, tulip, turfgrasses, *etc*.), aromatic (such as, basil, citronella, eucalyptus, Geranium, mint, rose, orchid, tuberose, *etc*.) and medicinal crops (such as, aloe vera, ashwagandha, asparagus, isabgol, liquorice, noni, patarchur, safed musli, rosa grass, turmeric, *etc*.), highlighting the aetiology, symptoms, disease cycle, economic importance, distribution, and management aspects with advanced and sustainable approaches. The present book shall serve as an important reference source to UG/PG students, academics, professionals, scientists, researchers, kitchen gardeners, horticulturalists, and extension personnel dealing with plant diseases in the above crops.

Mujeebur Rahman Khan
Department of Plant Protection
Faculty of Agricultural Sciences
Aligarh Muslim University
Aligarh, India

&

Ziaul Haque
Department of Plant Protection
Faculty of Agricultural Sciences
Aligarh Muslim University
Aligarh, India

List of Contributors

Archana Singh	Noida International University, Gautam Budh Nagar, Greater Noida, Uttar Pradesh, India
Abdus Samad	CSIR, Central Institute of Medicinal and Aromatic Plants, Lucknow, India
Deepak Kumar	Department of Nematology, CCS Haryana Agricultural University, Hisar, Haryana, India
Fayaz A. Mohiddin	Mountain Research Centre for Field Crops, SKUAST Kashmir, Khudwani, Anantnag (192102), Kashmir, India
Faheem Ahamad	Center for Agricultural Education, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India
Harjot Singh Sidhu	Maharana Pratap Horticultural University, Karnal, Haryana, India
Heena Altaf	Mountain Research Centre for Field Crops, SKUAST Kashmir, Khudwani, Anantnag (192102), Kashmir, India
Irfan Ahmad	Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India
Kartikey Pandey	Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India
Mujeebur Rahman Khan	Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India
Mohammad Akram	Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India
M. Shahid Anwar Ansari	Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India
Mohammad Haniph Shah	Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India
Mohammad Zuhaib	Noida International University, Gautam Budh Nagar, Greater Noida, Uttar Pradesh, India
Rakesh Pandey	Microbial Technology and Nematology Division, CSIR-Central Institute of Medicinal and Aromatic Plants, CIMAP, Lucknow, Uttar Pradesh, India
Suriya Jan	Division of Plant Pathology, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura (193201), Kashmir, India
Shugufta Parveen	Central Institute of Temperate Horticulture, Rangreth, Srinagar (190007), Kashmir, India
Seemab Zamir	Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India
Sabiha Saeed	Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India
Ziaul Haque	Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India

Zakir Amin Division of Plant Pathology, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura (193201), Kashmir, India

CHAPTER 1

Major Diseases of Cut Flowers

Harjot Singh Sidhu[1,*] and **Deepak Kumar**[2]

[1] *Maharana Pratap Horticultural University, Karnal, Haryana, India*

[2] *Department of Nematology, CCS Haryana Agricultural University, Hisar, Haryana, India*

Abstract: Flower cultivation at the commercial level has attained immense significance in the area of crop diversification and contributes a lot to the cultivator's economy. With the worldwide boom in the floriculture trade, the production of high-quality and disease-free flowers has become an important challenge in commercial floriculture. Various biotic and abiotic factors affect flower production in open fields and controlled environments. Among the cut flowers, anthurium, carnation, china aster, chrysanthemum, gerbera, marigold, orchid, rose, *etc.* are covered in this chapter with regard to their plant diseases. Anthracnose, black spot, botrytis blight, crown rot, leaf spot, powdery mildew, mosaic, root-rot, rust, twig blight, stem necrosis, stump rot, white rust, wilt *etc.* are important diseases of the above cut flowers that shall be discussed in detail and suitable management strategies shall also be presented in the chapter.

Keywords: Anthurium , Carnation, Chrysanthemum, Disease aetiology, Gerbera, Management, Orchid, Rose, Symptoms.

INTRODUCTION

Floriculture involves the growing of loose-cut flowers with stems and long leaves, dried flowers, decorative plants, nurseries, flower seeds and propagative materials. The cultivation of cut flowers has become an emerging sector due to multiple uses, satisfying the aesthetic needs of the people, employment-generating, a source of higher income for people and facilitating more foreign earnings. In addition, flowers are used as raw material in the manufacturing of essence, perfumes, medicines and confectioneries. Cut flowers are cultivated worldwide and the largest producer of cut flowers is China followed by India and the USA. However, by value, the largest importer and exporter is the Netherlands. In India, cut flowers are grown in an area of around 0.32 mha with the production of 1.96 MMT and 0.82 MMT (FAOSTAT, 2022).

[*] **Corresponding author Harjot Singh Sidhu:** Maharana Pratap Horticultural University, Karnal, Haryana, India; E-mail: harjotsingh@hau.ac.in

Mujeebur Rahman Khan and Ziaul Haque (Eds.)

Cut or loose flowers such as anthurium, carnation, chrysanthemum, gerbera, marigold, orchid, rose and some other annuals are extensively grown to fulfil the demands of regional and national markets around the world. Cultivation of flowers and ornamental crops are viewed as a growing field but the export and import of flowers and other related products have come across many infrastructural problems like inadequate cooling systems during transportation, bad storage facilities and poor road conditions, especially in developing countries.

Other constraints with the production and handling of commercial cut flowers are shortage of trained manpower and poor phytosanitation. Various biotic and abiotic factors also affect cut flower production under open fields and protected conditions. Flowers are mostly grown in monoculture and so there are more chances to be attacked by various plant pathogens such as fungi, bacteria, viruses, phytoplasma, plant-parasitic nematodes *etc.* Sometimes, extensive economic loss to floriculture occurs due to disease occurrence. The qualitative and quantitative loss of flowers due to diseases greatly affect the economy of the farmers/growers and their products are rejected in the floriculture market. Important diseases associated with cut flowers are enlisted in Table **1**. Major diseases of economically important cut flowers are described under:

Table 1. Estimated losses caused by pathogens in cut flower plants (McGovern and Elmer, 2018).

Crop	Disease/Pathogen	Country	Loss (%)
Anthurium	Bacterial blight (*Xanthomonas axonopodis* pv. *dieffenbachiae*)	USA (Hawaii)	50–100
Caladium	Fusarium tuber rot (*Fusarium solani*)	USA (Florida)	80–100
Carnation	Sclerotinia stem rot (Sclerotinia sclerotiorum)	India	38.5
	Root knot (*Meloidogyne incognita*)	India (Bangalore)	40–60
Celosia	Yellows (*Candidatus Phytoplasma* spp.)	Israel	up to 100
China aster	*Fusarium wilt* (*F. oxysporum* f. sp. *callistephi*)	USA (Connecticut)	up to 70
	Tobacco rattle virus	Japan	up to 63
	Tomato spotted wilt virus	Greece	37.7
Chrysanthemum	White rust (*Puccinia horiana*)	Turkey (Izmir)	80
	Bacterial wilt (*Dickeya chrysanthemi*)	Hungary (Budapest)	~100
	Tomato spotted wilt virus, Impatiens necrotic spot virus	Colombia	up to 80
Geranium	Bacterial blight (*Xanthomonas hortorum* pv. *pelargonii*)	USA	up to 100

(Table 1) cont.....

Crop	Disease/Pathogen	Country	Loss (%)
Gerbera	Tomato spotted wilt virus	Serbia, Venezuela	up to 30
Gladiolus	Fusarium corm rot (*F. oxysporum* f. sp. *gladioli*)	India	60–80
Gypsophila	Powdery mildew (*Erysiphe buhrii*)	Korea (Iksan City)	~100
Lily	Fire (*Botrytis* spp.)	Most lily growing areas	up to 100
Lisianthus	Fusarium crown and stem rot (*F. avenaceum*)	USA (Florida)	up to 70
Orchid	Bacterial brown spot (Burkholderia gladioli)	China	10–25
	Foliar nematodes (*Aphelenchoides besseyi* and *A. fragariae*)	USA (Hawaii)	up to 90
Rose	Crown rot (*Phytophthora nicotianae*)	Argentina	10–25
	Crown gall (*Agrobacterium tumefasciens*)	Kenya	5–60
	Gray mould (*Botrytis cinerea*)	Ethiopia (East Shoa Zone)	up to 31 (postharvest)
Snapdragon	Downy mildew (*Peronospora antirrhini*)	USA	up to 100
	Phytophthora stem rot and wilt (*Phytophthora* spp.)	USA	50
Multiple crops (Gerbera, Lisianthus, Rose)	Gray mould (*Botrytis cinerea*)	The Netherlands (Flower Exchange)	15–30 (postharvest)

DISEASES OF AZALEA

Anthracnose

Aetiology

Anthracnose of anthurium is caused by *Colletotrichum gloeosporioides* (Penz.) Sacc. The disease is also known as black nose or spadix rot.

Symptoms

The spadix's individual flowers are the main targets of the disease. The infection begins as little, black spots that subsequently become larger. Under damp conditions, a general rot of the entire spadix may happen in the advanced stages.

CHAPTER 2

Major Diseases of Potted Flowers

Ziaul Haque[1] and **Mujeebur Rahman Khan**[1,*]

[1] *Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India*

Abstract: Ornamental crops have deceptively benefited humankind since very early times and the importance of ornamental crops is being recognized by every individual from birth to death. It may be cultivated for cut flowers, dry flowers, live or dried plants, bulbs, and tuber, gardening/landscaping and also used in perfume, medicines, flavouring and colouring agents. Plant diseases are a major bottleneck in flower production and the losses caused by plant pathogens in important potted flowers have been estimated to be as high as 100%. Phyto-pathogens directly reduce the production and marketability of potted flowers. In this chapter, diseases of important potted flowers *viz*., azalea (*Rhododendron obtusum*), begonias (*Begonia* spp.), coleus (*Plectranthus scutellarioides*), gardenia (*Gardenia jasminoides*) and poinsettia (*Euphorbia pulcherrima*) are discussed with detailed emphasis given to disease aetiology, diagnostic symptoms, disease cycle and their management.

Keywords: Aetiology, Begonia, Coleus, Disease, Economic loss, Gardenia, Management, Poinsettia.

INTRODUCTION

The importance of ornamental crops is recognized by every individual and it has been cultivated for various purposes since very early times. They may be cultivated for cut flowers, dry flowers, live or dried plants, bulb tubers and gardening/landscaping. Flowers are generally used for making garlands, bouquets, wreaths, hair adornment, buttonholes, religious offerings, decorations, exhibitions, *etc*. They are also used for the production of perfume and oils. The oils are also used in the soap and cosmetic industry. Flowers and other parts are also used in medicines as flavouring and colouring agents. Potted flowering plants are now a vibrant, fast-growing, very profitable and estimated to be over $100 billion global industry (McGovern and Elmer, 2018).

[*] **Corresponding author Mujeebur Rahman Khan:** Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India; E-mail: mrkhan777in@yahoo.co.in

Plant diseases are a major bottleneck in flower production and even a minor decline in quality might render the crop unmarketable. The crop losses in representative floriculture crops have been projected to be as high as 100%. The pathogenic infections reduce the ornamental value by 10%, which leads to a $10 billion yearly loss in monetary terms. Besides, postharvest diseases also inflict substantial losses (10–30%) in overall florists' crops across the world (McGovern and Elmer, 2018). The flowers, as well as propagative material, are immediately affected by plant pathogens, which limit productivity and marketability. The global demand of flowers leading to their movement across countries has greatly contributed to the spread of diseases and their vectors. This may also influence disease scenario on other crops.

In this chapter, important diseases enlisted in Table **1** of potted flowers *viz*., Azalea (*Rhododendron obtusum*), Begonias (*Begonia* spp.), coleus (*Plectranthus scutellarioides*), Gardenia (*Gardenia jasminoides*) and Poinsettia (*Euphorbia pulcherrima*) are discussed with detailed emphasis on disease aetiology, diagnostic symptoms, disease cycle and their sustainable management.

Table 1. List of some important diseases associated with potted flowers.

Potted Flowers	Important Diseases
Azalea (*Rhododendron obtusum*)	Phytophthora Root Rot, Dieback, Wilt, Pythium Root Rot, Cylindrocladium Blight, Leaf And Flower Gall, Rhizoctonia Root Rot, Web Blight and Witches' Broom.
Begonia (*Begonia* spp.)	Fusarium Wilt, Botrytis Blight, Powdery Mildew, Pythium Root Rot, Bacterial Spot and Viral Diseases.
Coleus (*Plectranthus scutellarioides*)	Botrytis Blight, Downy Mildew, Crown Rot, Pythium Root Rot, Rhizoctonia Root Rot and Viral diseases.
Gardenia (*Gardenia jasminoides*)	Gardenia Canker, Myrothecium Leaf Spot, Powdery Mildew Rhizoctonia Root Rot, Phytophthora Root And Stem Rot, Pythium Root Rot And Bacterial Leaf Spot.
Poinsettia (*Euphorbia pulcherrima*)	Alternaria Leaf Spot, Anthracnose, Botrytis Blight, Powdery Mildew, Scab, Stem Rot, Root Rots, Bacterial Leaf Spot And Poinsettia Mosaic Virus.

AZALEA AND ITS DISEASES

Azalea [*Rhododendron obtusum* (Lindl.) Planch] is one of the most often used flowering plants (Fig. **1**) and is grown for decorative purposes all over the world. Though they are evergreens, their cold hardiness varies, hence, some form of winter protection is necessary. Large and varied flower sizes and colours are two of the most common horticultural traits and are considered in the development of new cultivars. The major diseases of azalea are as follows:

Fig. (1). Azalea plant with flowers. [Courtesy: Dow Gardens, Bugwood.org].

Phytophthora Root Rot, Dieback and Crown Canker

Azaleas are susceptible to infection from *Phytophthora* spp. worldwide (Linderman, 2018). Depending on the species, *Phytophthora* can cause dieback, crown canker, and root rot. While some species only affect the roots and crown, others might produce all of these symptoms. The majority of these diseases harm plants in the ground or in pots or containers, whether they are in nurseries or fields.

Causal Organism

Typically, *Phytophthora cinnamomi* and *P. nicotianae* (syn. *P. parasitica*) are responsible, but in some regions, *P. citricola* is also found to infect azaleas (Linderman, 2018).

Symptoms

Azaleas are susceptible to root infections from the time they are propagated through cuttings to the time they are planted in the ground. In below-ground parts, brown, necrotic spots can be seen on infected roots. When the root system is severely infested, the leaves may become chlorotic and subsequently necrotic, but they hardly ever wilt. As a result, the leaves and sometimes the entire plant shrink in size. In some cases, the infection from the roots can spread to the lower stem tissue, causing fatal crown cankers. When the bark is peeled away, the brownish internal wood is exposed, revealing the cankers.

CHAPTER 3

Major Diseases of Flowering Geophytes

Fayaz A. Mohiddin[1,*], Zakir Amin[2], Heena Altaf[1], Suriya Jan[3], Shugufta Parveen[4] and **Ziaul Haque[5]**

[1] *Mountain Research Centre for Field Crops, SKUAST Kashmir, Khudwani, Anantnag (192102), Kashmir, India*

[2] *Division of Plant Pathology, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura (193201), Kashmir, India*

[3] *Department of Botany, University of Kashmir, Shrinagar (191121), Kashmir, India*

[4] *Central Institute of Temperate Horticulture, Rangreth, Srinagar (190007), Kashmir, India*

[5] *Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India*

Abstract: Flowering geophytes are important ornamental or florist crops that mainly have tuberous roots, tuberous stems, true tuber and rhizomes or corms. The global trade of florists' crops including flowering geophytes is projected to be more than $100 billion annually. Plant pathogens have a direct impact on the production and marketability of flowering geophytes. In this chapter, important flowering geophytes *viz*., caladium, cyclamen, daffodils, gladiolus, lily, tuberose and tulip and their major diseases are described with special emphasis on disease aetiology, symptoms/signs, biology, disease cycle and management.

Keywords: Caladium, Cyclamen, Daffodils, Gladiolus, Lily, Tuberose, Tulip.

INTRODUCTION

Flowers have a good impact on our emotions in a variety of ways (Haviland-Jones *et al.,* 2005). The use of flowers in graves has been reported as far back as 60,000 years, during the Neanderthal epoch (Solecki, 1975). For thousands of years, humans has been actively growing flowers (Ackerson, 1967), but in recent times, the flower production has become a highly profitable industry worldwide. It has been reported that the annual global trade for flower crops is over $100 billion annually (African Business Magazine, 2012).

[*] **Corresponding author Fayaz A. Mohiddin:** Mountain Research Centre for Field Crops, SKUAST Kashmir, Khudwani, Anantnag (192102), Kashmir, India; E-mail: famohiddin@rediffmail.com

Mujeebur Rahman Khan and Ziaul Haque (Eds.)

Flowering geophytes are important ornamental or florist crops that mainly have tuberous roots, tuberous stems, true tuber and rhizomes or corms. Plant pathogens have a direct impact on the production and marketability of these flowering geophytes, as well as propagative material. It has been observed that global movement of flowering geophytes from their permanent production facilities to newer ones caused the spread of diseases along with their vectors. In this chapter, we are describing the major diseases of important flowering geophytes *viz*., caladium, cyclamen, daffodils, gladiolus, lily, tuberose and tulip with special emphasis on disease aetiology, symptoms/signs, biology, disease cycle and management.

CALADIUM AND ITS DISEASES

Caladium (*Caladium* x *hortulanum*, Araceae; syn. *C. bicolor*) is a favourite crop among indoor and outdoor florists and is distinguished by its vibrant leaf (Fig. **1**). Florida (USA) produces over 95% of the caladiums in the world. All phases of the growth of caladium, including field production and storage, are susceptible to pathogen infection and diseases. Pathogens that often infect caladium include *Pythium spp., Fusarium solani, Sclerotium rolfsii, Rhizoctonia solani, Xanthomonas axonopodis, Pectobacterium carotovorum, Meloidogyne* species and *Dasheen mosaic virus*. Brief descriptions of the important diseases affecting caladium are as follows.

Fig. (1). Caladium (*Caladium bicolor*) plant. [Courtesy: Deena Sharon Chadi, Bugwood.org].

Fusarium Tuber Rot

Causal Organism: *Fusarium solani*

The disease is the major issue impacting the quality and quantity of caladium plants, especially tubers (McGovern, 2004). This disease has progressively reduced the tuber production of several cultivars in Florida over the past ten years. Additionally, it has partially led to the elimination of some important commercial cultivars (McGovern, 2004). The infection of *Fusarium* on the tubers of commercial cultivars has been increased significantly with a disease incidence ranging from 90-100% (Gilreath *et al.,* 1999; McGovern, 2004).

Symptoms

The pathogen infiltrates the caladium tuber's base, causing the infection to advance towards the upper region of the plant. The fungus first causes a light brown discolouration on the tubers, but with time it darkens. A distinctive and early indication of the disease is individual brown spots on infected tuber fibres. Once the *F. solani* infection is over, the only thing left is a tuber that has entirely dried and is powdery in nature.

Disease Cycle and Epidemiology

Although the epidemiology and pathogenic disease cycle are not completely understood, however, it appears that plants or plants' tissues serve as the primary habitat for the fungus survival and spread. The fungus produces different types of spores like micro- and macroconidia in addition to the resting spores in the form of chlamydospores for long-term survival in case of unfavourable periods in the soil. Amongst these, micro and macroconidia may move through the air, however, it is unclear how they affect Fusarium tuber rot. The diseases are shown up in the field and in storage. Mycelium and chlamydospores found in seed tubers are the best modes of *F. solani* survival. The disease can linger on objects, utensils, machinery, and soil between crops (especially wood or abraded plastics). *Fusarium* survives as resistant chlamydospores for years without a living host. The pathogen may infect plants through wounds left behind by harvesting methods.

The optimal temperature range for the mycelial growth in culture ranges between 25- 30.5 °C and the optimal soil temperature requirements range from 26-28 °C to allow maximal pathogen development (Goktepe *et al.,* 2007). Deng *et al.* (2007) found that experimentally infected tubers decomposed more quickly at temperatures ranging from 13–18 °C. Because caladium is a tropical crop, it

CHAPTER 4

Major Diseases of Turf

Faheem Ahamad[1] and **Mujeebur Rahman Khan**[2,*]

[1] *Center for Agricultural Education, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India*

[2] *Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India*

Abstract: Turf grasses are extensively planted for ornamental landscaping or decorative purposes and for upgrading outdoor grounds in tropical and warm temperate regions. Most of the important turf is known by various common names such as Bermuda, couch, kweek and Doob. They are also valuable for soil stabilizing and livestock herbage. Turfgrass experiences a variety of disease problems, many of which result in a significant damage to turf appearance. In many instances, diseases are considered for low-quality turf, although other factors may also be responsible for this. Turfs are affected by several algal, fungal, and bacterial pathogens. This chapter provides a detailed account of the symptomatology, aetiology, biology, and management of a few important prevalent turf diseases *viz*., algae problem, anthracnose, Rhizoctonia patches, leaf and sheath spot, blight, Pythium damping off, rust and powdery mildew.

Keywords: Aetiology, Economic loss, Management, Symptom.

INTRODUCTION

Turfgrasses are among the most extensively planted ornamental grasses. The production of turfgrass constitutes a promising economic industry worldwide (Mwamula and Lee, 2021). In addition to its inherent function in soil stabilization, turfgrass is crucial in making suitable surfaces for outdoor sports (Ignatieva *et al*., 2020). The turf is also equally important for lawns in commercial places such as malls, hotels, parties, gardens, residential compounds, cemetery lawns, *etc.* (Clayden *et al*., 2018). Turfgrass, for instance, is used to cover the lawns of homes, schools, and cemeteries, in addition to playing a more significant part in the upgrading of outdoor grounds (Chawla *et al*., 2018). The cushioning effect decreases the impact of a jerk as well as injuries due to falling, slipping, bruising,

* **Corresponding author Mujeebur Rahman Khan:** Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India; E-mail: mrkhan.amu@gmail.com

Mujeebur Rahman Khan and Ziaul Haque (Eds.)

etc. compared to non-turf or wooden surfaces (Chang *et al*., 2017). The most lucrative market is found on golf courses (Larson *et al*., 2012).

From an ecological point of view, turf grasses play an important role in soil and water conservation, as well as providing recreational and aesthetic benefits (Hayden *et al*., 2015). They are also versatile in their ability to grow under a wide range of environmental conditions and are used for various purposes, including landscaping, sports fields, and wildlife habitats (Hempson *et al*., 2015). In addition to their functional benefits, turf grasses also provide numerous environmental benefits, such as reduced soil erosion, improved soil health, and carbon sequestering. Overall, turf grasses play an important role in sustainable land management and are an important component of many urban and rural landscapes (Monteiro, 2017).

Frequently, inadequate fertilizer, phytotoxicity, mower issues, animal damage, dry or damp patches, thatch, competition from other plants, or any other inappropriate management, results in dead and dying grass. Correct diagnosis of the issues is necessary for effective management of turf (Dernoeden, 2020). Unfortunately, there is still a lack of study on efficient sod production, particularly in relation to common turfgrass pests and diseases. A variety of disease problems, primarily algal, fungal, bacterial, and nematode pose a significant threat to turf fields and challenge their proper maintenance (Poinar and Georgis, 2020). Some of the important diseases of turf are discussed below.

ALGA (EUKARYOTIC ALGAE AND CYANOBACTERIA)

Eukaryotic algae are widespread in soils (Metting, 1988). There are a number of examples of visually visible algal growths on the soil surface in natural or semi-natural grassland ecosystems such as *Zygogonium* especially on acidic soils (West and Fritsch, 1927) and cyanobacteria (mostly *Nostoc*) on grassland soils (Booth, 1941). Cyanobacteria can also occasionally be seen adhering to the bottom parts of grass stems, as in the case of *Nostoc ommune* var. *flagelliforme* (Whitton *et al*., 1979). *Oscillatoria* is reported to make slime on golf greens (Hodges, 1987a,b). *Cosmarium, Cylindrocystis, Dactylothece, Klebsormidium, Mesotaenium,* and *Ourococcus* are one of the important genera of green algae identified as slime-producing algae in grasses (Baldwin, 1988). All of them except *Klebsormidium* and *Ourococcus* can make a lot of mucilage (Bourrelly, 1966). *Klebsormidium*, which is one of the most common filamentous green algae on land, is often found in groups of algae from other genera.

Symptoms

Although algae can damage turf around the year, in damp winter weather it can be frequently observed. The symptoms are scum and slime surface layer green-brown-black in colour or blue-green in case of *Nostoc* interaction (Dawson, 1968). Although cyanobacteria or *Zygogonium* is commonly associated with infestation forms of 'scums', its identification is difficult on the basis of a dark surface. The texture of wet "scum" is either sticky (Wise, 1961) or rubbery (Daniel and Freeborg, 1979). It can develop a parchment-like crust when it dries out (Beard, 1975; Decker and Decker, 1988), although this crust may later break, peel, and become detached from the soil (Shirtleff and Randall, 1978).

The formation of the black layer, which is also referred to as the "black plug layer", is an issue in turf. It generally arises in a root zone that is mainly comprised of sand. Affected turf areas generally thin out and turn into golden colour (Hodges, 1987b). The organic substances like mucilage produced by algae, bind with sand particles and fill pores making it harder for water to get through the turf profile (Kershasky, 1987). According to Hall (1987), dead algae trapped in the turf profile may cause the establishment of false water tables, which can result in waterlogging and, ultimately, anoxic conditions.

There have been three types of algae problems, symptoms in turf grasses *i.e*., scum, slime and black layer. Due to the enormous growth of alga, surface 'scum' is formed which leads to the generation of profuse mucilaginous 'slime'. The hardened slime layer forms a black layer which causes impediment of water penetration through the grass profile. Apparently, the scum and slime frequently overlap, but their identification by turf managers is difficult. They may not have the skill to identify the species of this potential so algal growths may or may not contain species that generate enough quantity of mucilage which may put people at danger of sliding on them (Baldwin and Whitton, 1992).

Favourable Environmental Conditions

Algae usually grow where the turf is bare (Fig.**1**) (Shildrick, 1990) or where it is thin and weak (Shiels, 1984). The amount of water defines the growth of algae. Algae cause problems when the turf surface is wet, waterlogged, poorly drained, or flooded. Algae problems are also linked to compacted soil. This is partly because compacted soil hurts the overall grass growth and also makes it hard for water to get through (Baldwin, 1988).

CHAPTER 5

Nematode Problems in Ornamental Plants

Mujeebur Rahman Khan[1], Ziaul Haque[1,*], Mohammad Akram[1] and **M. Shahid Anwar Ansari[1]**

[1] *Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India*

Abstract: Nematode infestation in ornamental crops affects the quantity and quality of flower yield, reducing flower size, total flower number, and the productive life of the plant. The most devastating nematode genera affecting ornamental crops are root-knot nematode, *Meloidogyne* species; foliar nematode, *Aphelenchoides* species; stem and bulb nematode, *Ditylenchus* species and root-lesion nematode *Pratylenchus* species. Nematode management in ornamental plants is difficult for many reasons, but practising nematode-free planting material, using cultural methods like a nursery or field cleanliness and application of nematicides can reduce the nematode populations. Hot water treatment of planting material is effective in eliminating nematode infection in vegetatively propagative materials. The use of resistant cultivars and biocontrol agents may also limit nematode damage in the plants. In this chapter, the problem of nematodes in important ornamental plants *viz*., Chrysanthemum, tuberose, crossandra, orchid, anthurium, gladiolus, gerbera, jasmine, lilies, narcissus, tulip and hyacinth are described, and information on general approaches of nematode management are discussed.

Keywords: Chrysanthemum, *Ditylenchus* spp., Economic importance, Gladiolus, *Meloidogyne*, *Pratylenchus* spp.

INTRODUCTION

Nematodes are multicellular animals and one of the most widespread organisms present in the soil. However, only a small portion of these organisms are plant parasitic, while the rest are free-living and survive on a different substrate (Khan, 2023c; Haque and Khan, 2021). The nematode body is thin, thread-like, bilaterally symmetrical, flexible, fusiform to cylindrical, and tapering at both ends (Khan, 2008). The majority of nematodes remain vermiform throughout their life, but some nematodes, such as reniform nematodes, root-knot nematodes, and cyst nematodes, assume sedentary life at maturity, and mature females develop to

[*] **Corresponding author Ziaul Haque:** Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India; E-mail: zia_haq07@yahoo.com

saccate forms (Khan, 2016). Generally, the adults of plant nematodes are 0.3 to 11 mm long with a specific gravity slightly greater than water (Khan, 2023b). Due to their microscopic size (~1/100 to 1/8 inch) and their subterranean habit, nematodes cannot be seen by the naked eye; hence, their crop damage generally remains hidden from the farmers (Sasser, 1989; Khan *et al*., 2021). Plant parasitic nematodes (PPN) infect almost all kinds of agricultural as well as ornamental crops and plants throughout the world, and inflict significant yield loss (Khan, 2007). The estimated crop production loss is about 10 percent worldwide due to the nematodes (Bahadur, 2021); however, in a broader range, the nematodes may cause 9-15% yield loss to the different crops and plants (Khan, 2023a). Nematode invades young emerging lateral roots, root hairs, cortical cells, epidermal cells and vascular tissue, which lead to the disfunctioning of the root system and, subsequently, the significant suppression of plant growth (Khan and Jairajpuri, 2012a, 2012b). Plant nematodes use the stylet to perforate the host surface and inject enzymes and hormones originating from the oesophageal glands. The enzymatic secretions and feeding by sedentary nematodes transform the host tissue into the large multinucleate specialized nutritive cells (as by root-knot nematode), syncytia (as by cyst nematodes) and nurse cells (by citrus nematode) for the establishment of their permanent feeding site. The feeding leads to the creation of wounds on the root surface, and this also exposes the roots to infection by soil pathogens (Khan and Sharma, 2020).

Nematodes cause damage to all parts of the plant, from belowground parts (root, tubers, bulb, rhizomes) to aboveground (stem, leaves, inflorescence, seed, fruits *etc*.) (Khan, 2016). The extent of host damage and crop loss caused by plant nematodes is determined by their soil population reproductive potential, plant species and, environmental conditions. (Khan, 2008). Cereals (Owen *et al*., 2023; Khan *et al*., 2023c), oil seed crops (Singh and Campos, 2023), vegetables (Correia *et al*., 2023), fruit crops (Mokrini *et al*., 2023), fibre crops (Mukherjee *et al*., 2011), beverage crops (Mohotti *et al*., 2023), and ornamental crops (Khan *et al*., 2023c) are all known to be severely damaged by the nematodes (Haque and Khan, 2021). The present chapter describes nematode infestation in important ornamental plants and offers practical solutions for their management.

Nematode Problems in Ornamental Plants

Ornamental plants, including cut flowers, potted flowers, flowering geophytes and decorative plants, are important sources of income for millions of people worldwide. Currently, the global market size of flower and ornamental plants is around $ 44 billion (CAGR, 2023). The estimated area under ornamental production is about 142 mha with 2980.05 MT global production. India is one of the leading producers and consumers of ornamental plants.

PPNs attack almost all types of ornamental crops that are grown in the home garden, modern landscape industry, and protected and open-field cultivation systems. In this chapter, important ornamental plants *viz*., Chrysanthemum, tuberose, crossandra, orchid, anthurium, gladiolus, gerbera, jasmine, lilies, narcissus, tulip and hyacinth are severely attacked by plant nematodes problems in protected as well as in open field conditions (Khan *et al*., 2023c). Monoculture of the ornamentals provides a crucial environment for the invasion of nematodes and other pathogens, which severely reduce the quality of the flowers to an extent that makes them unmarketable. The infected planting materials serve as the potential nematode inoculum.

The nematode species which frequently attack ornamental plants include endoparasites such as *Meloidogyen* spp*., Pratylenchus* spp., *Aphelenchoides* spp., *Ditylenchus* spp., as well as semi-endo and ectoparasites *viz*., *Rotylenchulus*, *Tylenchorhynchus*, *Xiphinema, Helicotylenchus, Hoplolaimus, Trichodorusetc.* (Table **1**). Among them, root-knot nematodes are the most notorious and widely occurring nematodes and attack almost all kinds of ornamental plants.

Table 1. List of some important diseases associated with potted flowers.

Crops	Nematode Species	References
Aster (*Aster* sp.)	*Aphelenchoides ritzemabosi, A. fragariae, D. dipsaci, M. hapla, Meloidogyne* spp.	Intrama, 1962; Gill and Sharma 1976
Carnation (*Dianthus* sp.)	*M. incognita, M. arenaria, M. javanica, M. hapla, Pratylenchus* spp., *P. coffeae, T. nanus, H. multicinctus, L. elongates, X. basiri, Criconemeides xenoplax, C. curvatum*	Dabaj *et al.,* 1994; Johnson *et al*. 2006
China Aster (*Callistiphus chinensis*)	*Meloidogyne* spp.	Krishnappa *et al.* 1980; Khan and Parvatha Reddy, 1992
Chrysanthemum (*Chrysanthemum* sp.)	*Aphelenchoides ritzemabosi, Apratylenchoiaes homoglans, Helicotylenchus crenatus, Hopolaimus indicus, Meloidogyne incognita, M. indica, M. javanica, Pratylenchus penetrans, P. coffeae, P. chrysanthus, R. reniformis, Tylenchorhynchus dubius*	Rashid and Khan,1975; Gill and Sharma, 1976; Sen and Dasgupta, 1977 Khan *et al*., 2005a and 2006
Crossandra (*Crossandra* sp.)	*Pratylenchus delattrei, M. incognita, Longidorus, africanus*	Khan and Parvatha Reddy, 1994
Gerbera (*Gerbera* sp.)	*M. incognita, P. coffeae, T. nanus, H. multicinctus, H. indicus, Hoplolaimus indicus, R. reniformis, L. elongates, X. basiri*	Nagesh and Parvatha Reddy, 2000 and 2005; Johnson *et al*. 2006

CHAPTER 6

Major Diseases of Aromatic Plants

Abdus Samad[1] and **Sabiha Saeed**[2,*]

[1] *CSIR, Central Institute of Medicinal and Aromatic Plants, Lucknow, India*

[2] *Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India*

Abstract: Aromatic plants provide the chief raw materials for cosmetics, perfumery and food industries. In recent years, with the rising need for therapeutic herbal medicines, attention towards aromatic plants has increased. Because of inherent and remedial pharmacological characteristics, aromatic plants are also exploited as natural medicines, and are mainly used for the extraction of essential oils, which have tremendous application in various industries. Aromatic plants become infested with many diseases that cause degradation of the quality and quantity of the required economic product. Considerable success has been achieved in managing the disease through cultural practices and biological and chemical control. The present chapter focuses on major diseases caused by fungi, viruses and bacteria threatening the bioactive potential, biomass, yield and various plant products of important aromatic plants, *viz*., basil (*Ocimum* spp.), citronella (*Cymbopogon* spp.), eucalyptus (*Eucalyptus* spp.), Geranium (*Geranium* spp.), mint (*Mentha* spp.), rose (*Rosa* spp.), orchid (*Orchis* spp.), tuberose (*Polianthes tuberosa*), *etc*. To enhance metabolite productive potential and raw material quality, necessary strategies of management for diseases have been defined, which are presented in the chapter.

Keywords: Basil, Citronella, Diseases management, Eucalyptus, Geranium, Mint, Rose.

INTRODUCTION

Aromatic plants assume immense economic significance for containing aromatic compounds. Different parts of the aromatic plant, like stem, wood, fruit, flower, and foliage, secrete fragranced volatile substances in the form of essential oil, green exudate, oleoresin and balsam. Among these, essential oils are secondary metabolites that are highly concentrated and perform diverse functions in the plant system. These oils are volatile, odorous, highly concentrated and hydrophobic compounds. Essential oils are a mixture of secondary metabolites that contain

* **Corresponding author Sabiha Saeed:** Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India; E-mail: sabihasaeed106@gmail.com

Mujeebur Rahman Khan and Ziaul Haque (Eds.)

terpenes and phenylpropenes (Greathead, 2003). Aromatic plants (Fig. **1**) such as basil (*Ocimum* spp.), citronella (*Cymbopogon* spp.), eucalyptus (*Eucalyptus* spp.), geranium (*Geranium* spp.), mint (*Mentha* spp.), rose (*Rosa* spp.), orchid (*Orchis* spp.), tuberose (*Polianthes tuberosa*), *etc*. have characteristic fragrance and flavour properties, which contain biological activities and are extensively employed in healthcare and aromatherapy as well as in many industries such as flavouring and fragrance, pesticides and repellents, cosmetics, spices, and herbal beverages (Samarth *et al.,* 2017).

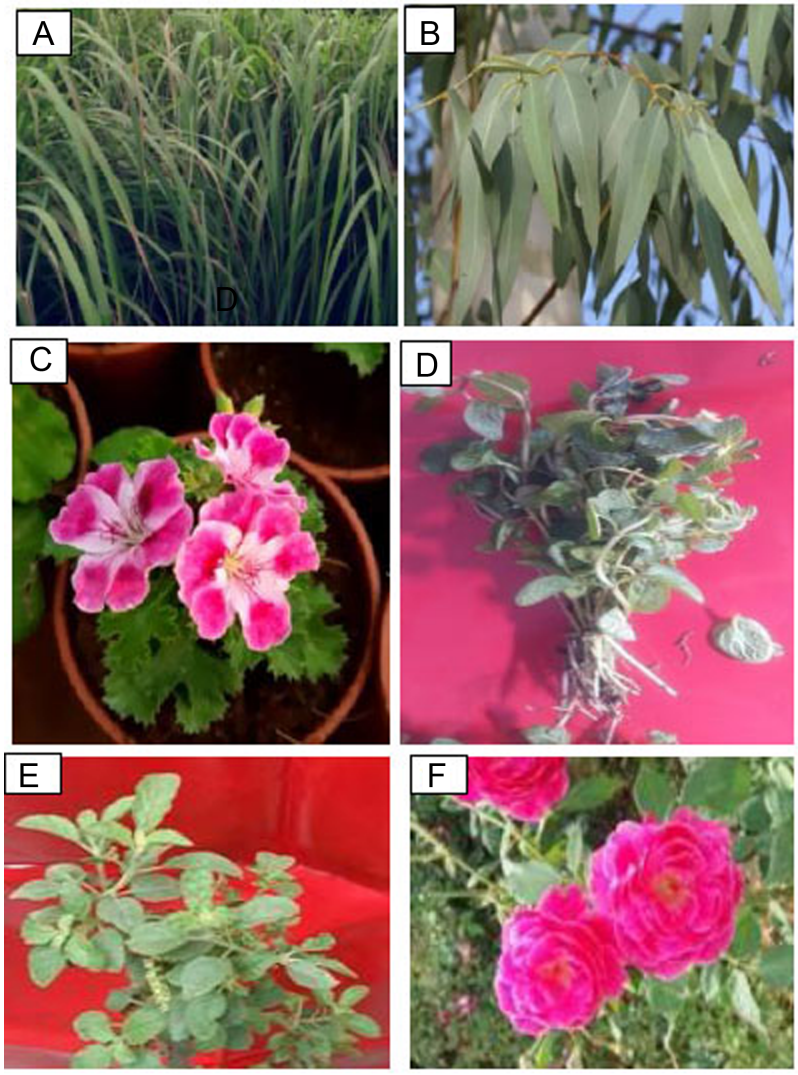

Fig. (1). Photographs of some important aromatic plants. **A**: Citronella, **B**: Eucalyptus, **C**: Geranium, **D**: mint, **E**: Ocimum, **F**: Rose.

Aromatic plants possess antimicrobial and antioxidant activity, which have been found to have several health applications in preventing and reducing disease risk like cardiovascular, inflammation, atherosclerosis and cancer (Gutteridge and Halliwell, 2010; Ndhlala *et al.,* 2010). They are comprised of hundreds of organic compounds, which include benzenoids, organic sulphur, terpenoids and nitrogenous compounds, which perform at several levels. Aromatic oils, herbs, and aroma chemicals are considerably used in cosmetic, flavoring, perfumery and drug industries. Additionally, they have become vital components of human activity.

The production of aromatic compounds is affected by several abiotic and biotic constraints. Among the biotic constraints, several viral, fungal, and bacterial diseases are a serious threat to the bioactive potential, biomass and yield of aromatic plants. The loss caused by the phytopathogens not only suppresses the plant yield but also affects the secondary metabolites, and the quality of raw material, which consequently reduces the market value of the produce. In this chapter, major fungal, viral, and bacterial diseases of economically important aromatic plants such as mint, basil or *tulsi*, geranium, citronella, rose, eucalyptus, orchid and tuberose (Table **1**), along with management strategies are discussed.

Table 1. Major diseases of some aromatic plants with their causal organism.

Aromatic Plants	Diseases	Causal Organism
Mint (*Mentha* spp.)	Rust	*Puccinia menthae*
	Powdery mildew	*Erysiphe cichoracearum*
	Wilt	*Verticillium alboatrum*var. menthae
	Aerial blight	*Rhizoctonia solani*
	Stolon and root rot	*Theilavia basicola, Rhizoctonia bataticola*
	Mosaic disease	*Tobacco mosaic virus*
Basil (*Ocimum* spp,)	Downy mildew	*Peronospora belbahrii*
	Fusarium wilt	*Fusarium oxysporum* f. sp. *basilicum*
	Anthracnose	*Colleotrichum gleosporioides* and *C. capsica*
	Gray mold	*Botrytis cinereal*
	Cercospora leaf spot	*Cercospora ocimicola*
	Bacterial leaf spot	*Pseudomonas cichorii*

CHAPTER 7

Diseases of Tuberous Medicinal Plants

Mohammad Zuhaib[1,*] and **Archana Singh**[1]

[1] *Noida International University, Gautam Budh Nagar, Greater Noida, Uttar Pradesh, India*

Abstract: Tuberous medicinal plants (TMP) are an important group of plants in which roots are modified into tubers and used for medicinal purposes. Many TMPs *viz*., Ashwagandha (*Withania somnifera*), safed musli (*Chlorophytum borolivianum*), Patarchur (*Coleus forskohlii*), asparagus (*Asparagus adscendens*), turmeric (*Curcuma longa*), *Holostemma adakodien, Typhonium trilobatu, etc*. are currently used in the preparation of stimulants, tonics, carminatives and expectorants. Plant diseases especially those caused by fungi, bacteria and viruses pose a serious threat to the profitable cultivation of tuberous medicinal plants. Important diseases of tuberous medicinal plants include root rot, wilt, tuber rot, rhizome-rot *etc*, which are mainly caused by soil-borne pathogens such as *Fusarium, Verticillium, Sclerotium, Rhizoctonia* and *Pythium* species. Growers generally use fungicides/pesticides to control these diseases. However, chemical residues in the plant tissue resulting from pesticide application make TMP medicine unsafe for human health. Biological control using antagonistic fungi and bacteria is a good substitute for chemical pesticides. In this chapter, we present an elaborate description of the important diseases of TMPs along with their sustainable management options.

Keywords: Asparagus, Ashwagandha, *Fusarium* spp., *Pythium* spp., *Rhizoctonia* spp., Safed musli, *Sclerotium* spp., *Verticillium* spp.

INTRODUCTION

Medicinal plants are essential to human life and are utilised in both ancient and modern medical practises worldwide. They aid in disease prevention, health maintenance, and the treatment of various diseases. Despite enormous progress in modern allopathy's research and development, 80% of the world's population still relies on herbal medicine to treat their health issues (Goto *et al.,* 1998). It is interesting to note that in developed nations, the demand for herbal remedies has multiplied, mainly due to the side effects of modern medication. In India, over 7500 species of higher plants have been identified as having therapeutic benefits (Shiva, 1996; Kala *et al.,* 2006). About 9.18 lakh tonnes of medicinal and aroma-

* **Corresponding author Mohammad Zuhaib:** Noida International University, Gautam Budh Nagar, Greater Noida, Uttar Pradesh, India; E-mail: zuhaib06@gmail.com

Mujeebur Rahman Khan and Ziaul Haque (Eds.)

tic plants are produced in India annually on 5.57 lakh hectares of land (Ashashri *et al.,* 2015). More than 5000 different types of medicinal plants, employed in 10,000 different herbal preparations, are found in India. The natural ecosystem's forests provide 90% of the raw materials that the herbal business needs, leading to the brutal exploitation and destruction of the ecosystem's natural habitats (Mathivanan *et al.,* 2016).

Typically, a particular component of a medicinal plant, such as its seeds, leaves, flowers, roots, *etc*., has therapeutic significance. Some medical plants have evolved their roots into tubers, which make up a significant group of therapeutic plants known as tuberous medicinal plants (TMPs). The underground storage organs of plants are known as tubers. Plant tubers have two important biological functions: first, as a storage organ, and second, as propagules to get through the dormant phase before they sprout and produce a new plant. The primary component of tuberous plants contains starch, and proteins and is used as a staple diet in most nations. Currently, a variety of TMPs that are high in dietary fibre, carotenoids, steroids, saponins, polyphenolics, and anthocyanins are utilised to make stimulants, tonics, carminatives, and expectorants (Sharma and Ramawat, 2013; Edison *et al.,* 2006). Ashwagandha (*Withania somifera*), safed musli (*Chlorophytum borolivianum*), patarchur *(Coleus forskohlii*), asparagus (*Asparagus adscendens*), turmeric (*Curcuma longa*), *Holostemma adakodien*, and *Typhonium trilobatu* are some of the tuberous medicinal plants frequently used in India to prepare herbal formulations for healthcare.

Plants that are crucial for medicine are regularly attacked by pests and pathogens which might lower their biomass and oil content (Gupta *et al.,* 2008). This lowers the therapeutic value of the plant and has a negative impact on the quality of its medicinal components. The use of these contaminated parts as medicine may also have a damaging effect on the human body (Chavan and Korekar, 2011). The lucrative and profitable cultivation of TMPs *viz*., Ashwagandha (*Withania somifera*), safed musli (*Chlorophytum borolivianum*), Patarchur (*Coleus forskohlii*), asparagus (*Asparagus adscendens*), turmeric (*Curcuma longa*), *etc*. is seriously threatened by root rot and wilt pathogens, especially *Fusarium, Verticillium*, *Sclerotium, Rhizoctonia*, and *Pythium* species. In this chapter, the description of the important diseases of the above TMPs along with their sustainable management options is discussed in detail.

ASHWAGANDHA AND ITS DISEASES

Ashwagandha (*Withania somnifera*, fam. Solanaceae), commonly known as “Indian Winter cherry” or “Indian Ginseng” is an important TMP. It is cultivated mostly in Africa, the Mediterranean region and Middle East Asia (Pati *et al.,*

2008). This medicinal plant's roots, leaves (Fig. **1**), and fruits possess tremendous therapeutic value, especially roots that contain an important alkaloid called withanolide-A. In India, the roots of Ashwagandha are processed as powder and extracts are exported to the countries like USA, Canada, U. K., Sweden, Czech Republic, Australia, Italy and Germany (Annonymous 2017). It is one of the most significant herbs in *Ayurveda*, the traditional medical system in India, and has been used for thousands of years as a *Rasayana* because of its wide-ranging health advantages. Ashwagandha roots are used in more than 200 Ayurvedic formulations as the main ingredient (Ashashri *et al.,* 2015). It possesses immense therapeutic value against several ailments such as mental diseases, asthma, inflammation, arthritis, rheumatism, tuberculosis, and various other diseases, including cancer (Sreeramu and Farooqi, 2004). *Withania somnifera* is prone to several pests and diseases. Fusarium wilt and Leaf spot diseases are the most prevalent diseases, which occur in a severe form in major cultivation areas of the countries as described below.

Fig. (1). Ashwagandha plant.

Fusarium Wilt

A wilt of Ashwagandha is an important and widely spread disease in nurseries as well as the commercial fields (Farooqui and Sreeramu, 2001). Sometimes, the infection causes complete failure of the crop (Sharma and Trivedi, 2010). Root rot and wilt of Ashwagandha are also reported from Bangladesh (Rehman *et al.,* 2014).

CHAPTER 8

Diseases of Non-Tuberous Medicinal Plants

Mujeebur Rahman Khan[1], Ziaul Haque[1,*], Mohammad Haniph Shah[1], Seemab Zamir[1] and **Kartikey Pandey[1]**

[1] *Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India*

Abstract: Medicinal plants constitute an important group of horticultural crops and many non-tuberous medicinal plants *viz*., aloe vera (*Aloe vera*), basil (O*cimum sanctum*), mentha (*Mentha arvensis*), noni (*Morinda citrifolia*), isabgol (*Plantago ovata*), *mulethi* or liquorice (*Glycyrrhiza glabra*), rosa grass (*Cymbopogan nardus*), *etc*. are currently used to prepare stimulants, tonics, carminatives, and expectorants. Various biotic and abiotic stresses affect the production of these medicinal crops. Among the biotic stresses, diseases caused by fungi, bacteria, viruses, and nematodes are major constraints. Diseases of aloe vera (such as anthracnose, dry rot, rust, soft rot), noni (dry rot, leaf blight, soft rot, root-knot), basil (anthracnose, leaf spot. powdery mildew, wilt), mentha (leaf spot, root-rot, rust, wilt), isabgol (Downey mildew, wilt), rosa grass (leaf blight. Red leaf spot), liquorice (leaf spot, root-rot) pose a serious risk to the successful cultivation of these medicinal plants. The economically significant diseases of non-tuberous medicinal plants are discussed and the relevant information is described in this chapter.

Keywords: Aloe vera, Basil, *Glycyrrhiza glabra*, Isabgol, Mentha, *Morinda citrifolia*.

INTRODUCTION

Medicinal plants play an important role in modern science as well as conventional medical practices around the globe and help people stay healthy, prevent sickness, and treat diseases. Generally, a specific part of the medicinal plants *e.g*. seeds, leaves, flowers, roots, *etc*. has medicinal value. Many non-tuberous medicinal plants *viz*., aloe vera (*Aloe vera*), basil (*Ocimum sanctum*), mentha (*Mentha arvensis*), noni (*Morinda citrifolia*), isabgol (*Plantago ovata*), *mulethi* or liquorice (*Glycyrrhiza glabra*), rosa grass (*Cymbopogan nardus*), *etc*. are currently used to prepare stimulants, tonics, carminatives, and expectorants.

[*] **Corresponding author Ziaul Haque:** Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India; E-mail: zia_haq07@yahoo.com

Most African, Asian and Latin American countries use conventional medication to assist in meeting some of their basic healthcare requirements. Up to 80% of people in Africa use traditional medicine as their primary form of healthcare (Payyappallimana, 2010). Around 158 million people utilise supplemental medications in the United States, where around US$18 billion was spent on conventional medicine in 2016. (Ghorbanpour *et al.,* 2017). The UK spends about US$230 million annually on alternative medicine. The industry for herbal medicines is already worth more than US$60 billion annually and is continuously expanding (Anonymous, 2023). Various biotic and abiotic stresses affect the production of these non-tuberous medicinal crops (Farooqui and Sreeramu, 2004). Major challenges include plant diseases caused by various pathogenic microbes. Important diseases of non-tuberous medicinal plants and their sustainable management are presented under:

ALOE VERA AND ITS DISEASES

Aloe vera is a semi-tropical plant that originated in India and is used in a wide range of therapeutic procedures. The plant is a perennial succulent member of the Asphodelaceae family that can tolerate drought. The word "*aloe*" is derived from the Arabic or Hebrew word "*alloeh*" which both mean bitter shining stuff. '*Ghee kunwar*' is its Sanskrit name. It plays a significant historical role in indigenous medical systems such as *Ayurveda*, *Siddha*, *Unani*, and homoeopathy (Baby and Justin, 2010). The genus contains around 250 species, among them *Aloe barbadensis* and *A. vera* are medicinally important. The plant has lance-shaped, pointy leaves with jagged edges. *Aloe barbadensis* contains more than 200 different substances, roughly 75 of which have biological effects. Chromones, anthraquinones (such as aloe-emodin), anthrones, and their glycosides are just a few of the numerous substances found in aloe vera leaves. Aloe vera also contains lipids, sugars, vitamins, minerals, proteins, glycoproteins, amino acids, and organic acids in addition to these substances. (Roy *et al.,* 2012; Saeed *et al.,* 2004; Patidar *et al.,* 2012). Aloe vera is quite susceptible to plant pathogens and important diseases that hamper its production, are described below.

Anthracnose

One of the most serious aloe vera diseases is anthracnose and a widespread problem for aloe growers (Kumar, 2014). It has been recorded in severe form in Europe, South America, and Western Australia since 1996. The disease is caused by *Colletotrichum* spp. which may grow and develop to infect a variety of hosts due to the varied climatic conditions in the Indian subcontinent. Due to the destruction of medicinally valuable plant components Alovera, it is a severe issue in India that causes a sizable loss (Avasthi *et al.,* 2011).

Causal Organism

Aloe vera anthracnose disease is caused by *Colletotrichum gloeosporioides.* The sexual stage of the fungus is (*Glomerella cingulata:* teleomorph). On infected plant leaves, the fungus rapidly produces conidia, acervuli, setae, and appressoria (Alam *et al.,* 2007).

Symptoms

The deep sunken lesions with an oval or circular form are the most typical anthracnose symptoms. Small, round to oval, dark green, water-soaked lesions are the first signs; later, they transform into circular lesions with tan to light brown centres. The lesion's centre changes colour from reddish-brown to brown as the patches mature (Fig. **1**). As the condition is severe, the lesions collapse to produce a large necrotic region (Rajendran and Gnanavel, 2011).

Fig. (1). *Colletotrichum gloeosporioides* symptoms on *Aloe vera*.

CHAPTER 9

Nematode Problems in Medicinal Plants

Rakesh Pandey[1], Mujeebur Rahman Khan[2,*], Ziaul Haque[2] and **Irfan Ahmad[2]**

[1] *Microbial Technology and Nematology Division, CSIR-Central Institute of Medicinal and Aromatic Plants, CIMAP, Lucknow, Uttar Pradesh, India*

[2] *Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India*

Abstract: Medicinal plants are regularly attacked by the plant parasitic nematodes, which can seriously harm these crops. However, only a few medicinal plants have been reported with regard to the extent of crop damage caused by the nematode. Root-knot nematodes (*Meloidogyne* spp.), root lesion nematodes (*Pratylenchus* spp.), and stunt nematodes (*Tylenchorhynchus* spp.) are major nematode pests that affect medicinal plants and significantly reduce their yield. The economically significant medicinal plants that are infected by nematodes include Ashwagandha (*Withania somnifera*), Basil (*Ocimum* spp.), Brahmi (*Bacopa monnieri*), Coleus (*Coleus forskohlii*), Henbanes (*Hyoscyamus* sp.), Noni (*Morinda citrifolia*), Menthol mint (*Mentha* spp.), Safed Musli (*Chlorophytum borivillianum*), *etc*. In the present chapter, nematode infestation in the above medicinal plants has been described in detail, and appropriate management options are suggested to avoid yield losses.

Keywords: Ashwagandha, Basil, Brahmi, Coleus, Henbanes, Mentha, Safed musli.

INTRODUCTION

Plants produce various chemical compounds for different purposes. Medicinal plants have been used in traditional medicine since prehistoric times, also called medicinal herbs. The herbal system of medicine is widespread in most Asian countries like India, China, Japan, Sri Lanka, Pakistan, and Thailand. On a global scale, there is a growing interest in the use of various medicinal plants such as henbanes, ashwagandha, Brahmi, Safed Musli, menthol mint, coleus, basil, opium poppy, *etc*., for therapeutic, cosmetic, colouring, flavouring, and dyeing purposes, as well as the production of nutraceuticals and food supplements, and other products (Pandey, 2003; Gupta, 2012; Ahn, 2017). Medicinal plants are used in the raw form in medicines, or their oils, alkaloids, and other components are

* **Corresponding author Mujeebur Rahman Khan:** Department of Plant Protection, Faculty of Agricultural Sciences, Aligarh Muslim University, Aligarh, India; E-mail: mrkhan777in@yahoo.co.in

extracted as pharmaceutical, cosmetic, and homeopathic use (Pandey, 2010). The efficiency of medicinal plants must be of high quality due to active principles to meet the required purpose (Lubbe and Verpoorte, 2011). Traditional medicines derived from medicinal plants have gained more credibility and have become useful in supporting herbal medicine systems for human health and care.

In the last few decades, a significant increase in the frequency and severity of plant diseases caused by fungi, bacteria, viruses, phytoplasma and nematodes in medicinal crops has been recorded, apparently due to mono-culturing because of the high market value (Palombo, 2006; Sharma, 2013). Plant nematodes constitute a major group of pathogens that attack medicinal plants and are among the important bottlenecks in the production and protection of these plants (Panday, 2017; Costa *et al*., 2019). Almost all medicinal plants have been subjected to attack by plant parasitic nematodes, but only in a few medicinal plants, significant crop damage has been recorded (Abtahi and Bakooie, 2017; Eapen and Pandey, 2018; Nguyen *et al*., 2019, Pandey *et al.*, 2023). Various nematodes include ecto parasites (*Tylenchorhynchus* spp.), semi-endo parasites (*Rotylenchuslus reniformis*), and endo-parasites (*Meloidogyne* spp.) occurring frequently in the root zones of medicinal plants (Pandey, 2017; Khan *et al*., 2019; Nguyen *et al*., 2019). In the present chapter, nematode infestation in common medicinal plants *viz*., Ashwagandha (*Withania somnifera*), Basil (*Ocimum* spp.), Brahmi (*Bacopa monnieri*), Coleus (*Coleus forskohlii*), Henbanes (*Hyoscyamus* sp.), Noni (*Morinda citrifolia*), Menthol mint (*Mentha* spp.), Safed Musli (*Chlorophytum borivillianum*), *etc.* have been detailed describing the distribution, symptoms, biology, life cycle, host parasites relationship, and management options to avoid yield losses.

ASHWAGANDHA (*WITHANIA SOMNIFERA*)

Ashwagandha, *Withania somnifera*, also referred to as Indian Ginseng or Indian Winter cherry, belongs to the family Solanaceae. It is one of the most significant herbs of Ayurveda (Singh *et al*., 2011). The chemical components of ashwagandha include alkaloids *viz*., anaferine, anahygrine, cuseohygrine, isopelletierine, steroidal lactones (withaferins, withanolides) and saponins (Mishra *et al*., 2000). The plant is also known to produce withasteroids (Ray and Gupta, 1994), which have been linked to a variety of health benefits, including antioxidant, anti-tumor, adaptogenic, anti-stress, anti-convulsant, immuno-modulatory, and neurological properties (Jayaprakasam *et al*., 2003; Budhiraja *et al*., 2000; Furmanowa *et al*., 2001). The roots of *W. somnifera* can be used as a sedative in cases of senile debility and to control hiccups, cough, dropsy, rheumatism, and female disorders. It is beneficial for inflammatory conditions, ulcers, and scabies when applied externally. As a febrifuge, leaves are applied to

lesions, throbbing swellings and itchy eyes (Misra, 2004). There have been numerous phytonematodes that attack the ashwagandha; however, only root-knot nematode is considered to be an economic one and has been studied in detail.

Root-knot Nematode

The root-knot disease of ashwagandha, predominantly caused by the *Meloidogyne incognita* and *M. javanica*, is widely spread, and more than 80% of plants are infested in India. The nematode-infected plant is stunted and chlorotic, with sparse branching and fewer, smaller leaves. These signs typically are not apparent until the nematodes have caused significant damage to the root system. The infected roots of such plants are heavily galled (Fig. **1**; Eapen and Pandey, 2018). A host differential test was used to identify the *Meloidogyne* races and found that race-2 predominantly attacks ashwagandha (Pandey and Kalra, 2003).

Fig. (1). Ashwagandha plant infected with root-knot nematode, *Meloidogyne incognita*. [Courtesy: NASI, India].

For root-knot management, the application of neem extract (*A. indica*), marc from *Artemisia annua*, and distillates from *M. arvensis* and *Bergera koengii* (syn. *Murraya koenigii*) were found to prevent the development of root knots on *W. somnifera* roots and decreased the population of *M. incognita* (Pandey and Kalra, 2003; Pandey *et al*., 2003). The application of bio-control agents was less successful in controlling root-knot in *W. somnifera* than organic materials; this could be because the hosts reacted negatively to the bio-control agents. However,

SUBJECT INDEX

D

E

F

G

H

I

L

M

N

O

P

R

S

T

V

W

Mujeebur Rahman Khan

Prof. Mujeebur Rahman Khan is a professor and chairperson at the Department of Plant Protection, Aligarh Muslim University (AMU), India, and has served as the dean of the Faculty of Agricultural Sciences, AMU. He obtained Ph.D. in botany (plant pathology & nematology) from AMU, and worked as postdoc at the North Carolina State University, California Department of Food and Agriculture, USA, and the Commonwealth Institute of Parasitology, UK. He has to his credit more than 300 research publications and review articles, 18 books, 2 patents on biopesticides (USA and India), and 10 major research projects. He has guided 14 Ph.D. and 52 MSc students. Dr. Khan is a fellow of the National Academy of Agricultural Sciences (India), Indian Phytopathological Society, etc., and editor of Indian Phytopathology. He is a recipient of various awards such as, Dr. K. C. Mehta Award (NAAS), B. B. Mundukar Award (IPS), Outstanding Scientist Award (AMU), Prof. H. L. Chakraborti Award (ISCA), Out-standing Scientist Award (SPSS), etc. His research interests include plant disease management, impact of climate change and environmental contamination on plant disease development, and biosynthesis of nanoparticles and their effects on plants and microbes.

Ziaul Haque

Prof. Ziaul Haque is presently serving as assistant professor in the Department of Plant Protection at Aligarh Muslim University. He did Ph. D. (Ag.) plant pathology & nematology from AMU, Aligarh and has ten years of teaching and research experience in the area of plant pathology and nematology. He also qualified ICAR-NET and his research studies focus on the management of plant pathogens by integrating basic and applied science. He contributed 21 research papers in peer-reviewed journals, and published eight books. He is a reviewer of over 20 reputed journals and conferred with Sir Syed Ahmad Khan Memorial Award from AMU for his outstanding contribution to academic research. He has worked as research scientist at PI Industries, fellow at NIF-India, senior research fellow at NBAIM, Mau, India; research associate at NIPHM, Hyderabad.