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## Chapter

# Diseases of Medicinal Plants Cultivated in Karnataka and Their Management

P. Swetha and R. Sundararaj

## Abstract

A broad spectrum of fungal diseases infecting selected 10 medicinal plants surveyed in Karnataka, India, was studied in the present research. We present a detailed review on previously reported as well as our present investigation's details of fungal diseases, etiology, symptoms, and its management. Some of the commonly observed diseases are Anthracnose disease, Blight disease, Leaf spot, Root rot, Powdery mildew, Downy mildew, and Wilt disease. The detailed analysis of medicinal plants revealed that the medicinal plants are susceptible to diverse fungal phytopathogens. Therefore, sustainable management of the diseases is necessary for the successful cultivation of disease-free medicinal plants.

**Keywords:** diseases, medicinal plants, Karnataka

## 1. Introduction

India is a cradle for diverse medicinal plants and has an immense repository of traditional medicinal knowledge. There are valuable resources that aid in treating various illnesses. About 90% of the medicinal herbs in India are accessible only from the forest, and hence, there is an imminent need for the commercial cultivation of medicinal plants. Karnataka one of the Indian states is known for the major biodiversity hotspots of India, *viz.*, the Western Ghats, which boasts a huge diversity of medicinal plants in the country. Plant diseases create challenging problems in commercial plantations and pose economical threats. Medicinal plants are not an exception and are vulnerable to the attack and invasion of several pathogens resulting in huge crop loss as well as degradation of their medicinal properties. Toxins produced by these pathogens are also of a great concern in case of medicinal plants. Therefore, the prevention of the diseases of medicinal plants should be the utmost priority. In this context, diseases of the 10 important medicinal plants cultivated in Karnataka *viz.*, Sweet flag (*Acorus calamus* L.), Adosa (*Adhatoda vasica* (L.) Nees), Safed musli (*Chlorophytum borivilianum* Sant. & Fern.), Gurmar (*Gymnema sylvestre* (Retz.) Schult.), Hibiscus (*Hibiscus rosa-sinensis* L.), Noni (*Morinda citrifolia* L.), Velvet bean

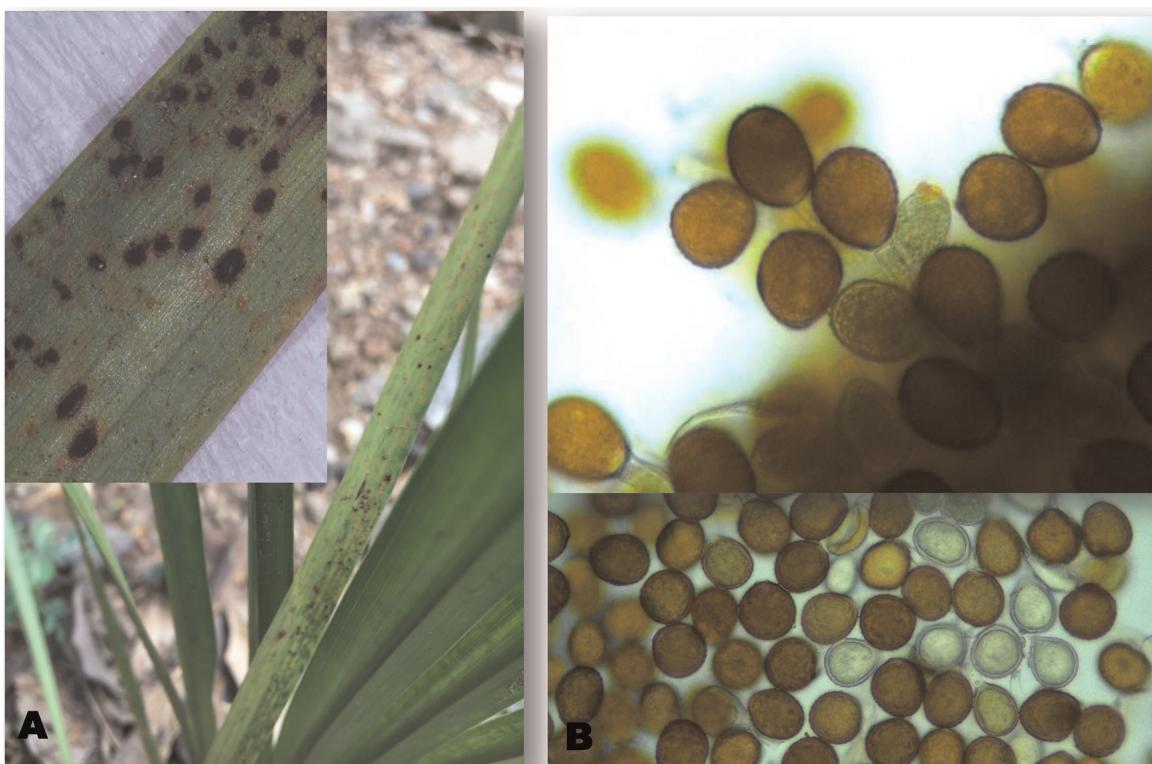
(*Mucuna pruriens* (L.) DC.), Tulsi (*Ocimum sanctum* Linn.), Long pepper (*Piper longum* Linn.), and Crepe jasmine (*Tabernaemontana divaricata* & *Tabernaemontana coronaria* (L.) R. Br. ex Roem. & Schult.), and their management measures are reviewed and presented.

### 1.1 Sweet flag (*A. calamus* L.)

Rust caused by *Uromyces acori* [1]; leaf spot disease by unidentified pathogen [2] and bacterial leaf blight caused by *Xanthomonas campestris* P.V.O. *Oryzae* [3] have been reported on *A. calamus*. In this plant, rust disease caused by *U. acori* was prevalent in Tumkur district during the winter months, with the highest disease index of 69.4% in December, and the extent of infection ranged from 3 to 4% (**Figure 1**).

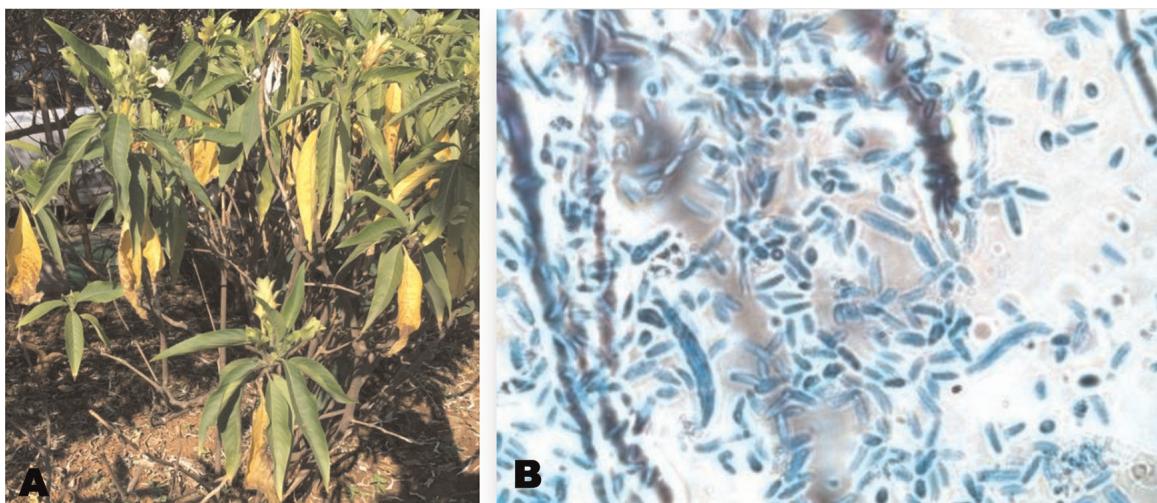
### 1.2 Adosa (*A. vasica* (L.) Nees)

There are relatively few reports of disease on *A. vasica*; these include leaf spot caused by *Rhizoctonia solani* [4, 5]; Alternaria blight [6] and rust by *Puccinia thwaitesii* [7]; leaf spot by *Alternaria alternata*, anthracnose disease by *Colletotrichum capsici*, leaf rust by *Aecidium adhatodae* [8]; leaf necrotic spots by *Colletotrichum gloeosporioides* [4, 9]; and wilt by *Fusarium oxysporum* Schlect [10]. Wilt disease by *F. oxysporum* occurs during high humidity conditions and the highest disease index and death of 7% of the plants were observed during the month of September and the extent of infection ranged from 3 to 7% in Bangalore (**Figure 2**).



**Figure 1.**

Rust symptoms in *Acorus calamus* (A) caused by *Uromyces acori* (B).



**Figure 2.**  
Wilt symptoms in *Adhatoda vasica* (A) caused by *Fusarium oxysporum* (B).

### 1.3 Safed musli (*Chlorophytum borivilianum*)

Leaf blight disease caused by *A. alternata* [11] and *Colletotrichum chlorophytum* [12]; red spot disease by unidentified pathogen [11]; root rot disease by a *Rhizoctonia solani*, *Aspergillus flavus*, *Fusarium oxysporum* complex [13] and *Haemoponectira haematococca* [14]; and anthracnose disease by *Colletotrichum chlorophyti* [15] are the major diseases reported so far in *C. borivilianum*. Leaf spot disease in this plant by the pathogen *A. alternata* was observed in Bangalore during March (Figure 3).

### 1.4 Gurmar (*G. sylvestre* (Retz.) Schult.)

Powdery mildew and leaf spot caused by *Colletotrichum* sp. [16] and *Pseudomonas syringae* [17] are the major diseases so far reported in *G. sylvestre*. Leaf



**Figure 3.**  
Leaf blight symptoms in *Chlorophytum borivilianum* (A) caused by *Alternaria alternata* (B).



**Figure 4.**

Leaf spot symptoms in *Gymnema sylvestre* (A) caused by *Colletotrichum gloeosporioides* (B).

spot symptoms due to the pathogen *C. gloeosporioides* occur during January in Bangalore (**Figure 4**).

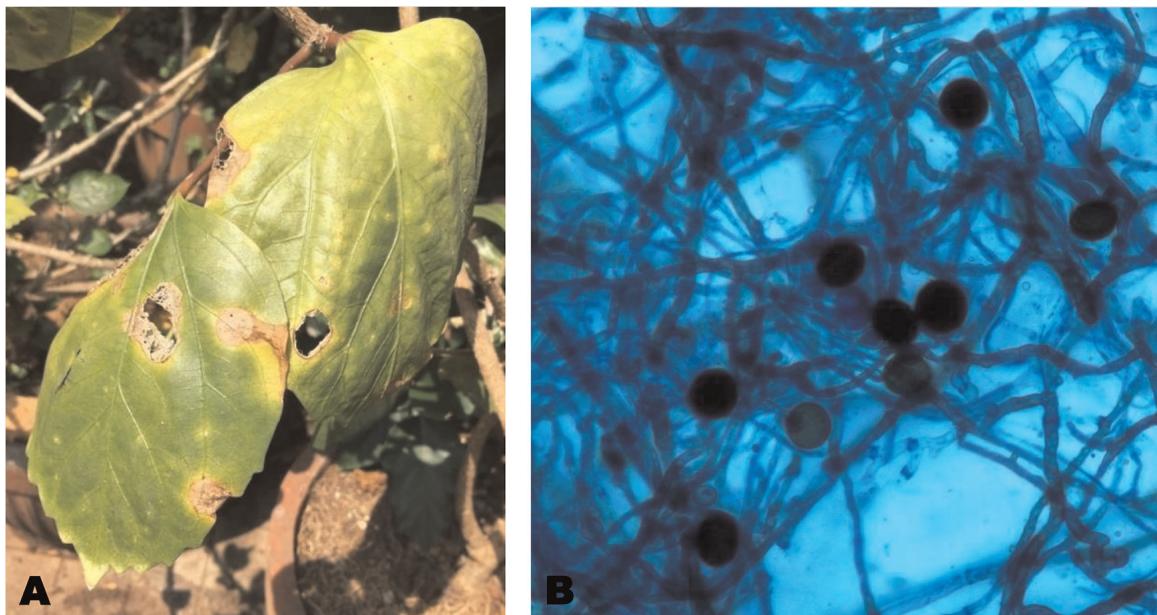
### 1.5 *Hibiscus (H. rosa-sinensis L.)*

A number of fungal diseases commonly infect hibiscus plants; in addition, physiological disorders also occur [18]. Leaf spots caused by several species of fungi cause brown or black circular or irregular shaped spots on the leaves [18]. Sooty mold is a black fungus on the upper surfaces of leaves, growing in the secretion of aphids, mealybugs, many scales, and immature whiteflies. The mold spoils the appearance of foliage but is not particularly injurious to the plant [18]. Root rots and collar rots, one of several species of fungi causing soft rotting of roots and sometimes also stems. Infected plants often wilt as though they are short of water [18]. Anthracnose by *Colletotrichum gloeosporioides* (*Glomerella cingulata*) [19]; powdery mildew by *Podosphaera* sp. [20]; dieback disease by *Botrytis* sp. and *Erwinia* sp.; wilt disease by *Fusarium oxysporum* and *Verticillium*; Choanephora blight caused by *Choanephora infundibulifera* [21]; botrytis blight by *Botrytis cinerea* [22]; hibiscus witches broom disease caused by *Candidatus Phytoplasma brasiliense* [23]; Phytophthora disease by *Plagithmysus nicotianae* var. *nicotianae* [24] and rust by *Kuehneola malvicola* were also reported [25].

Incidence of Leaf blight disease by *Nigrospora sphaerica* was observed in December (**Figure 5**) and anthracnose disease by the pathogen *C. gloeosporioides* was observed from August that gradually declined in the month of December on *H. rosa-sinensis* in Bangalore. Anthracnose disease exhibited the highest disease index of 29.4% in October and the extent of infection ranged from 2 to 4% (**Figure 6**).

### 1.6 Noni (*M. citrifolia L.*)

This plant is known to be susceptible for some fungal diseases. Anthracnose caused by *C. gloeosporioides*, by which small brown-shaped spots of varying size (0.5–2.5 cm) appear on the leaves that gradually enlarge and coalesce. The center of the coalesced lesion turns grayish white leaving a shot hole symptom. Under humid conditions,

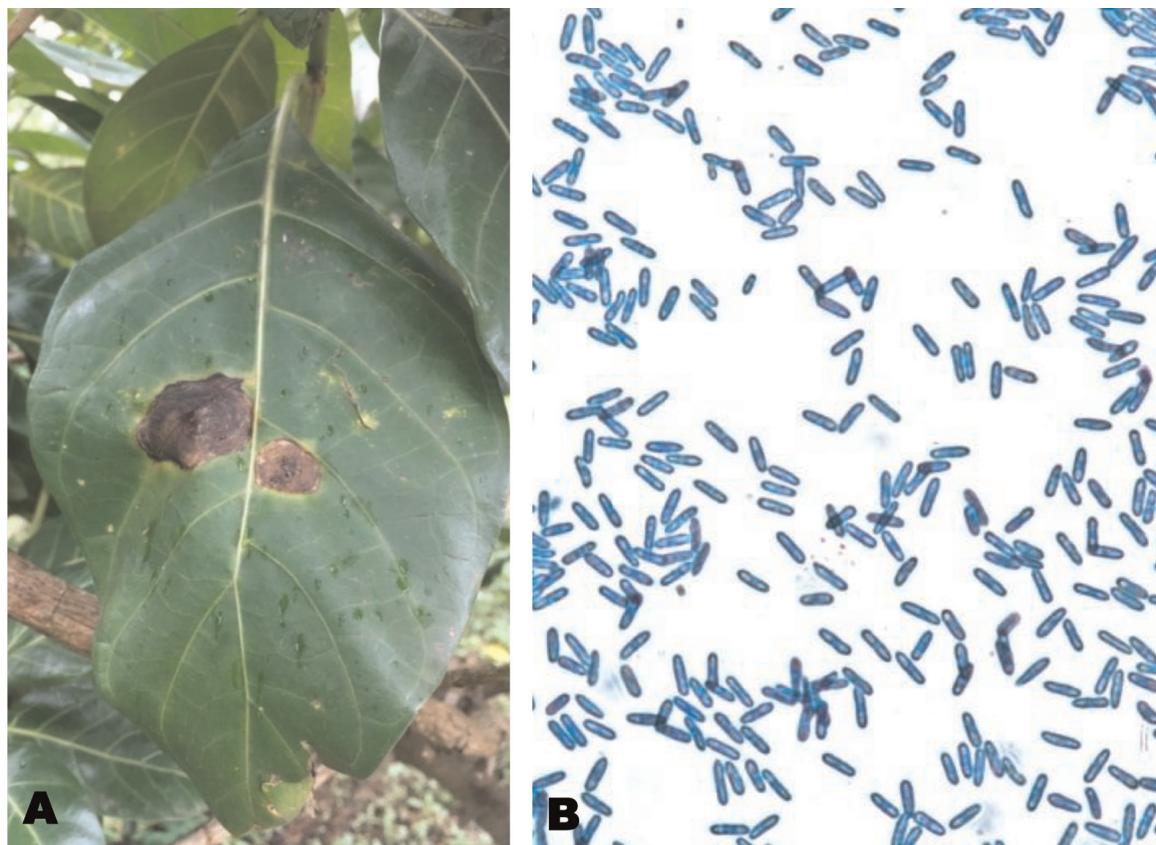


**Figure 5.**  
Leaf blight symptoms in *Hibiscus rosa-sinensis* (A) caused by *Nigrospora sphaerica* (B).



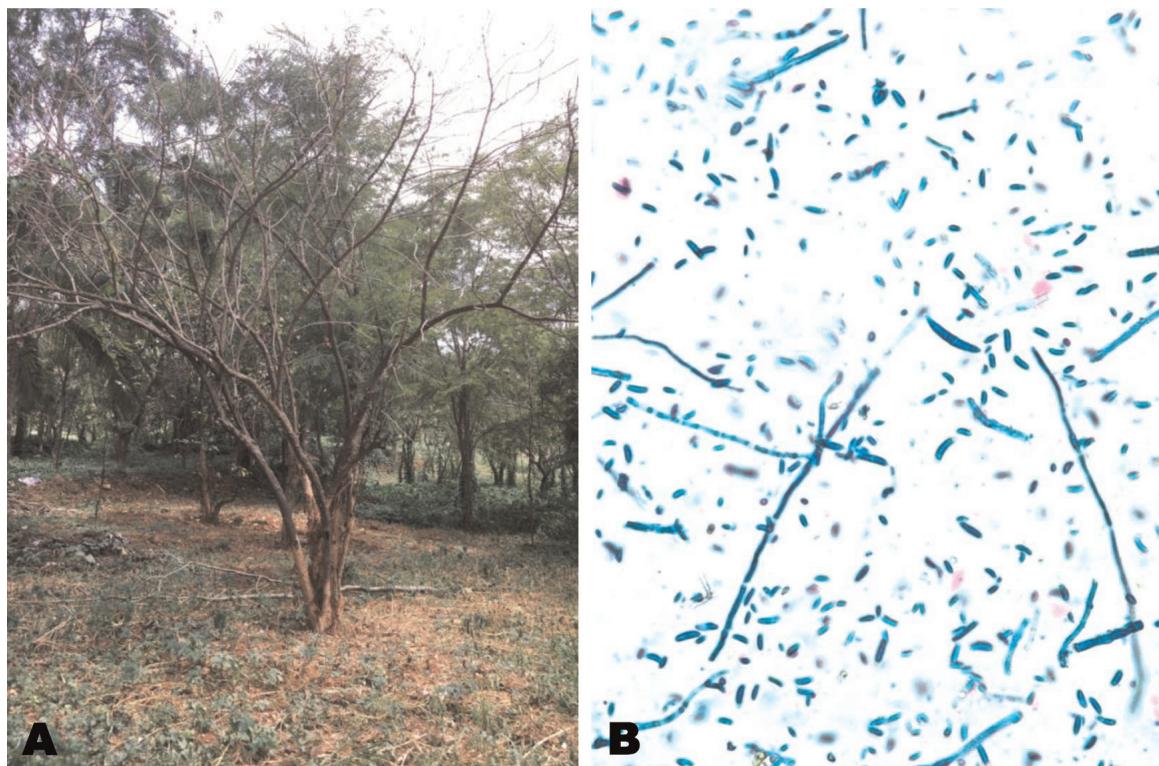
**Figure 6.**  
Anthracnose symptoms in *Hibiscus rosa-sinensis* (A) caused by *Colletotrichum gloeosporioides* (B).

acervuli with pink masses of spores emerged on the lesions [26, 27]. *C. gloeosporioides* infect all parts of the plant like twigs, flowers, and fruits irrespective of stages of the crop growth. Symptoms of the infection on the flowers appear as dull brown lesions, and the infected flowers dry off within 48 h after infection. The twigs infected by *C. gloeosporioides* are characterized by the presence of necrotic brown lesions with yellow halo. The necrotic lesions spread gradually toward fruits through peduncle that leads to the development of infection on flowers and fruits. Later, the infected fruits shrink, dry off, and get mummified. After mummification, the infected fruits are



**Figure 7.**  
Anthracnose symptoms in *Morinda citrifolia* (A) caused by *Colletotrichum gloeosporioides* (B).

colonized by saprophytic molds like *Aspergillus* and *Penicillium* [26]. Tamil Nadu and Karnataka states in southern India witnessed a severe outbreak of leaf blight, during 2008–2009 by the infection of *A. alternata* [27]. The same pathogen was reported to cause dry fruit rot, which is characterized by the presence of black necrotic sunken spot of 2 to 3 mm diameter on the green unripe fruits [28]. *Pantoea agglomerans* causes soft rot of fruits with the typical symptoms of soft rot of fruits with brown water-soaked lesions on the surface of matured but unripe fruits. The lesion spread quickly within one or two days to the entire fruit, and the infected fruits emit a bad odor. The affected tissue becomes softened and rots subsequently [26]. It is also infected by a wide range of other fungal pathogens such as *Phytophthora* sp. and *Sclerotium rolfsii* (black flag and stem, leaf and fruit blights), *Guignardia morindae* (leaf spot), *Phellinus noxius* (brown root rot), *A. alternata* (dry fruit rot) and *Phytophthora morindae* [29]; *P. agglomerans* (wet fruit rot); and *Collectotrichum* sp. (anthraconose) [28]. The pathogenic alga, *Cephaeluros minimus* has been reported to cause leaf spot and occurrence of mold infection by *Rhizopus* sp. in the post-harvested fruits [28]. Fusarium wilt disease by *Fusarium oxysporum* [30] and phytoplasma disease caused by phytoplasmas (mycoplasma like organisms or MLOs) [31] were also reported. Among these diseases, anthracnose disease by *C. gloeosporioides* was observed in *M. citrifolia* at Bangalore throughout the year with the highest disease index of 13.79% in December and the extent of infection ranged from 10 to 15% (**Figure 7**). Wilt disease on *M. citrifolia* by *F. oxysporum* is prevalent in Bangalore during high humidity conditions and the highest disease index and death of 10% of the plants during September and the extent of infection ranged from 8 to 10% (**Figure 8**).



**Figure 8.**  
Wilt symptoms in *Morinda citrifolia* (A) caused by *Fusarium oxysporum* (B).

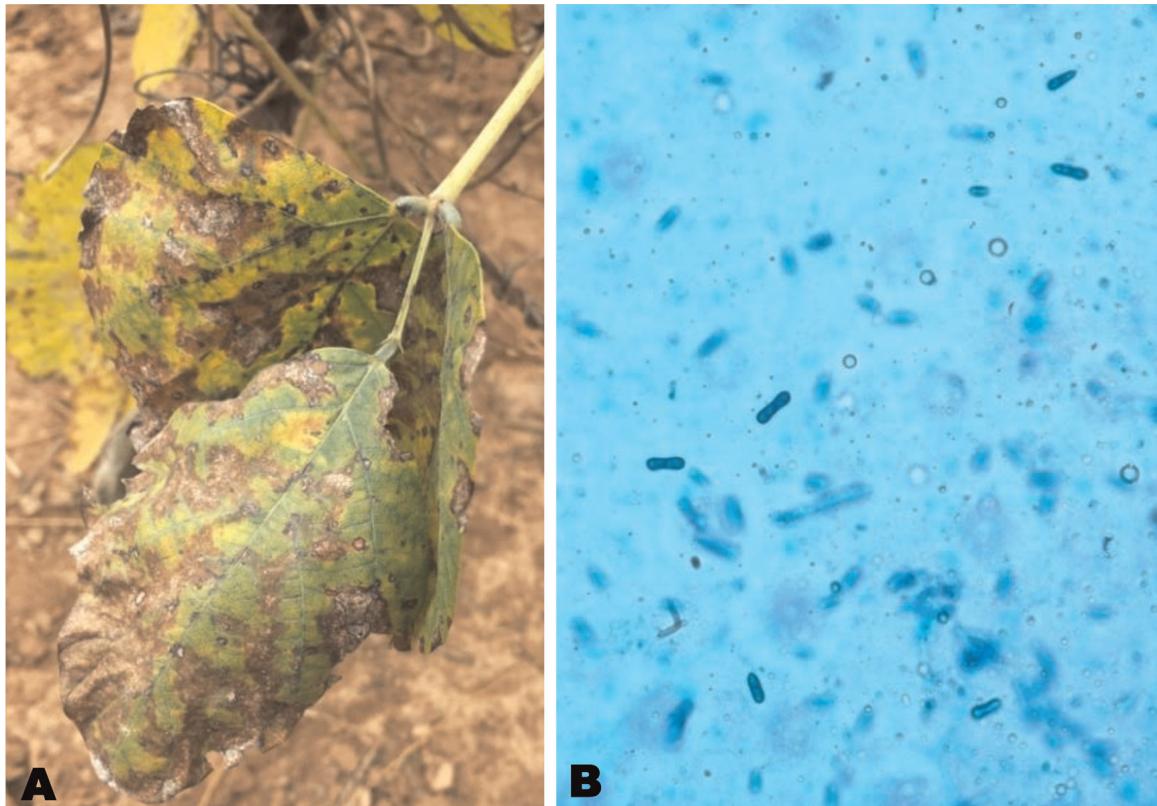
### 1.7 Velvet bean (*M. pruriens* (L.) DC.)

Necrotic crowns and numerous necrotic lesions along the roots and runners of *M. pruriens* caused by *Macrophomina phaseolina* are considered as a serious threat in Nigeria [32]. Foliar fungal diseases (*Cercospora* leaf spot and angular leaf spot, *Phaeoisariopsis griseola*) were also reported in the USA as substantially reducing the biomass of *Mucuna* [33]. Charcoal rot caused by *Modiolula phaseolina* was reported by [34]. Incidence of Leaf blight disease caused by *C. gloeosporioides* occurs in Bangalore in September while in December in Gadag (Figure 9). Also, incidence of Rust disease caused by *Uromyces mucunae* was observed in the month of January in Gadag district (Figure 10).

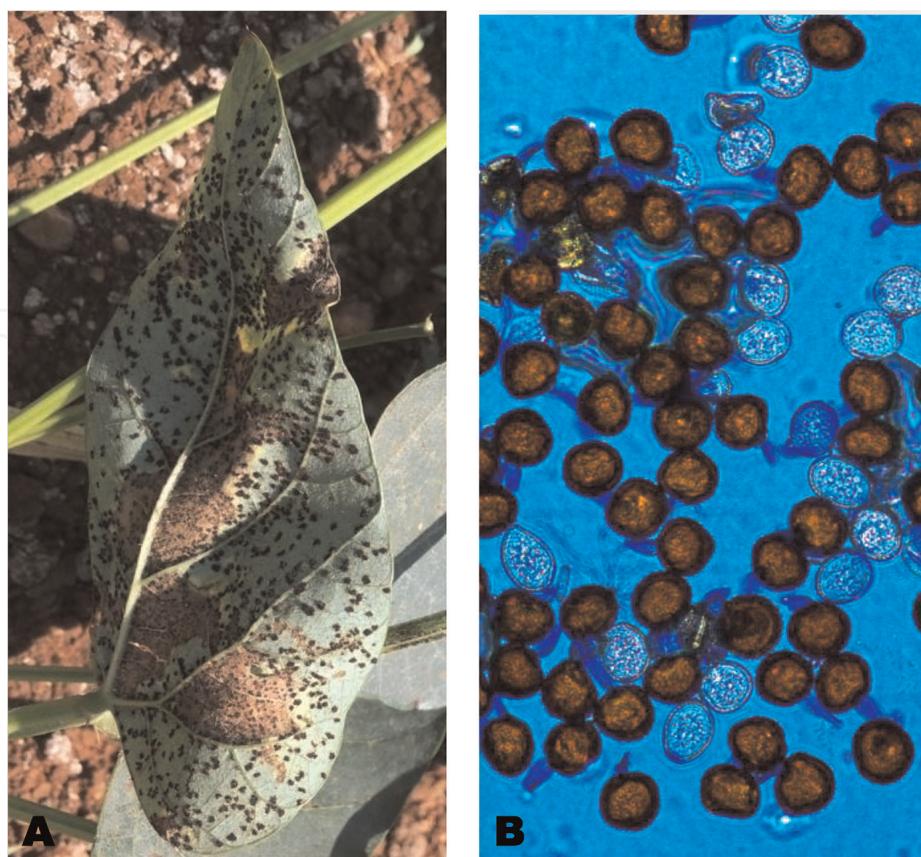
### 1.8 Tulsi (*O. sanctum* L.)

There are several diseases that could cause leaf damage leading to yield loss, such as Fusarium wilt (*Fusarium oxysporum* f. sp. *basilicum*) [35]. Other destructive diseases include bacterial leaf spot (*Pseudomonas cichorii*), gray mold (*Botrytis cinerea*), fungal leaf spot by *Alternaria* sp., *Cercospora ocimicola* and *C. gloeosporioides* and damping off or root rot (*Rhizoctonia solani*; *Pythium* sp.), root rot by *Rhizoctonia solani* and *Pythium* sp. [36]; leaf blight by a species of *Alternaria* [37]; Gray mold caused by *Botrytis cinerea* [38]; and powdery mildew caused by *Erysiphe biocellata* [39]. Downy mildew (*Peronospora belbahrii*) is also very destructive and widespread disease in this plant [35].

Wilt disease of Tulsi by *F. oxysporum* is severe during December causing complete mortality in January in Bangalore, and the extent of infection of this disease ranged



**Figure 9.**  
Leaf blight symptoms in *Mucuna pruriens* (A) caused by *Colletotrichum gleosporoides* (B).



**Figure 10.**  
Rust symptoms in *Mucuna pruriens* (A) caused by *Uromyces mucunae* (B).



**Figure 11.**  
Wilt symptoms in *Ocimum sanctum* (A) caused by *Fusarium oxysporum* (B).

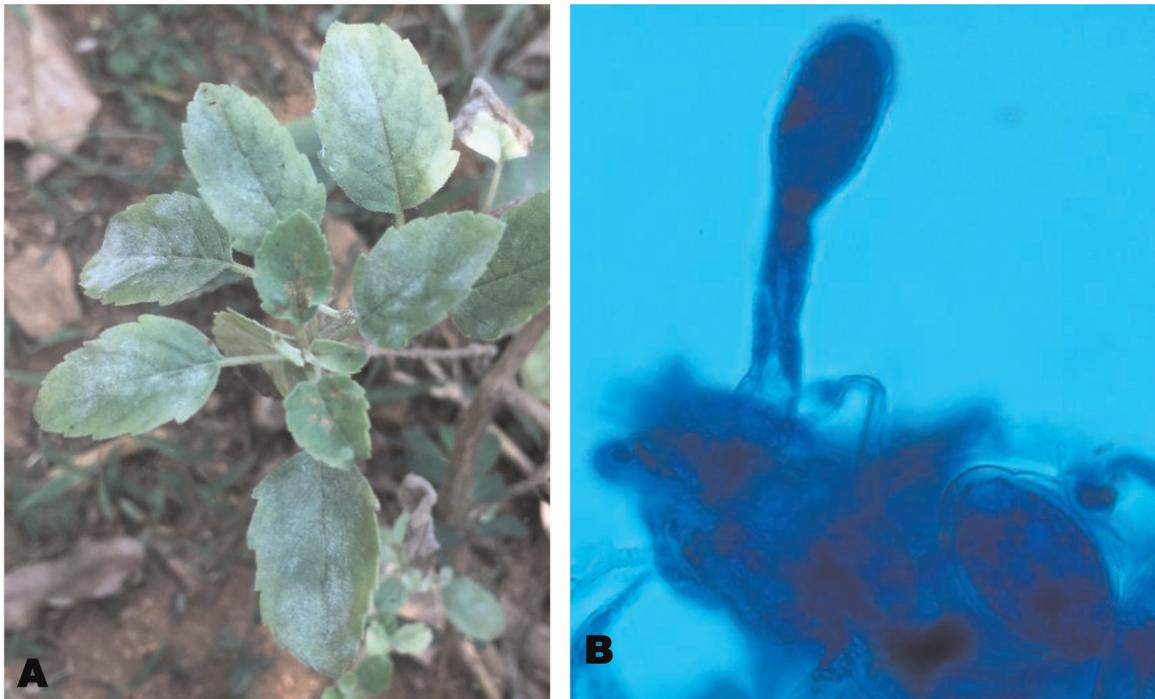
from 80 to 100% with the death of most of the plants (**Figure 11**). Incidence of powdery mildew by *Erysiphe biocellata* occurs in January causing complete mortality in March, and the extent of infection of this disease ranged from 70 to 100% with the death of 100% of the plants (**Figure 12**). Fungal leaf spot disease by *C. gloeosporioides* is noticed in August (**Figure 13**).

### 1.9 Long pepper (*P. longum* L.)

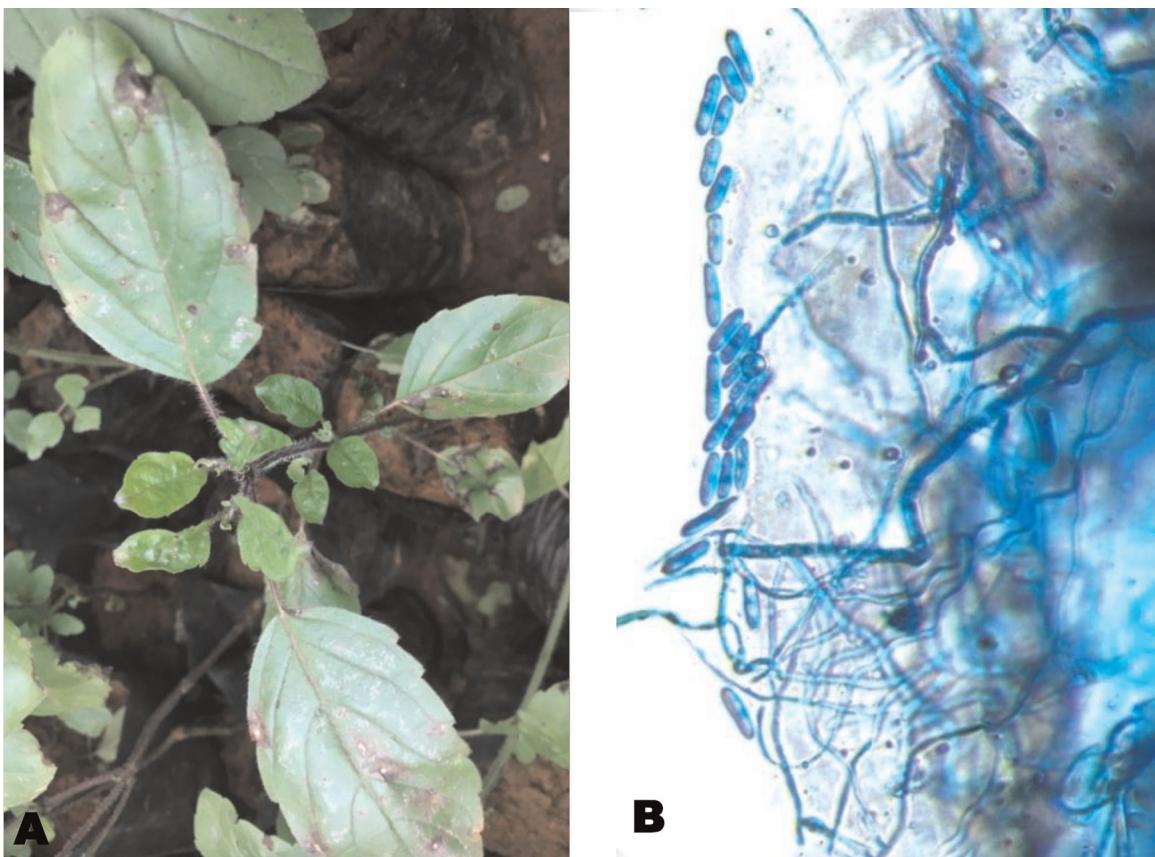
Known to be affected by the number of fungal diseases like showing symptoms of rotting of leaves and vines and by *C. gloeosporioides* [40], necrotic spots and blights on leaves by *Collectotrichum* sp. and *Cercospora* sp. [41]; leaf spot by *Botryodiplodia theobromae*, leaf rot by *Fusarium pallidoroseum* [42] and *Rhizoctonia solani* [40]; *Cercospora* leaf spot by *C. piperata* [43, 44] and *Phytophthora* rot by *Phytophthora capsici*, basal wilt by *Sclerotium rolfsii*, *Phytophthora* Foot rot by *Phytophthora capsici*, and phyllody disease by phytoplasma [40]. In Bangalore, the onset of the anthracnose disease caused by *Colletotrichum boninense* was observed in June with the highest disease index of about 17.5% in September. It gradually decreased during the subsequent months and was found vanish during April and May and the extent of infection of this disease ranged from 29 to 35% (**Figure 14**).

### 1.10 Crepe jasmine (*T. divaricata/coronaria* (L.)

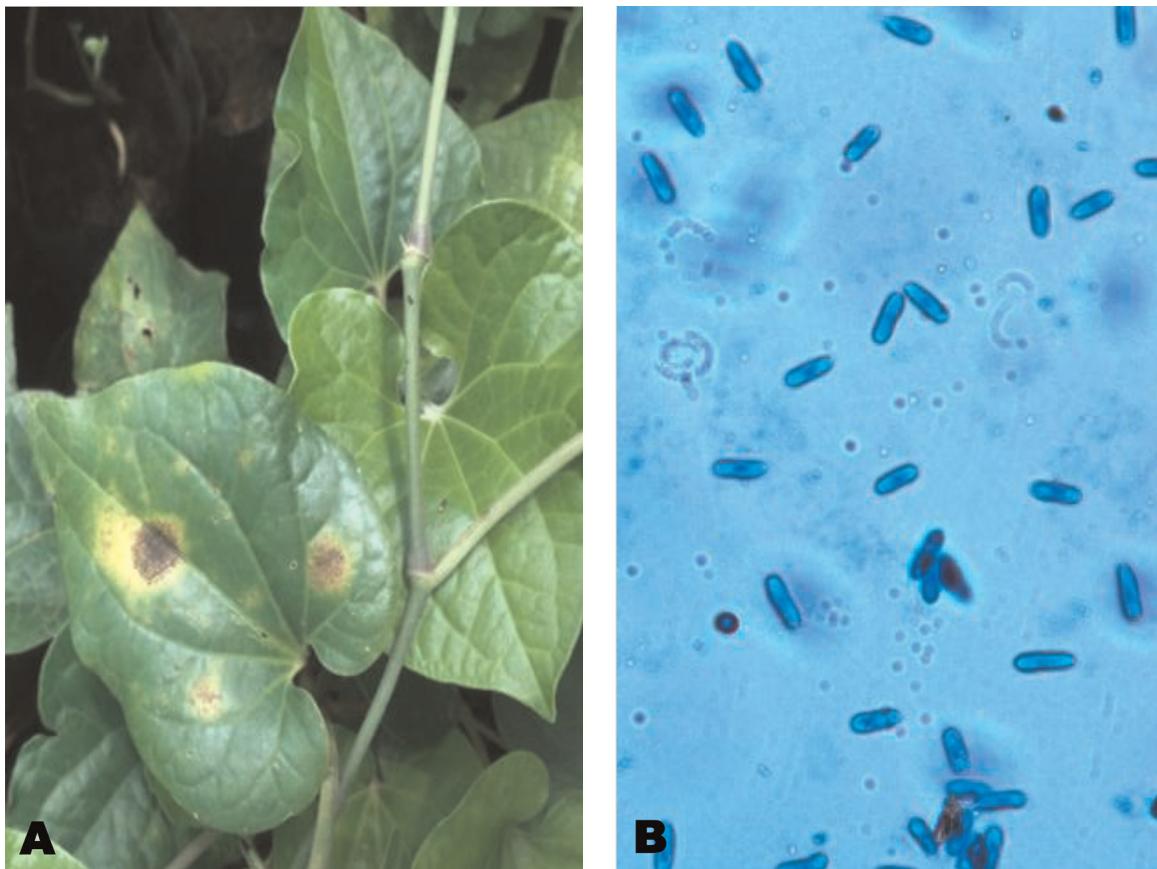
Leaf brown or black spots caused by *Phytophthora citrophthora* in which brown or black spots and patches may be either ragged or circular, with a water-soaked or



**Figure 12.**  
Powdery mildew symptoms in *Ocimum sanctum* (A) caused by *Erysiphe biocellata* (B).



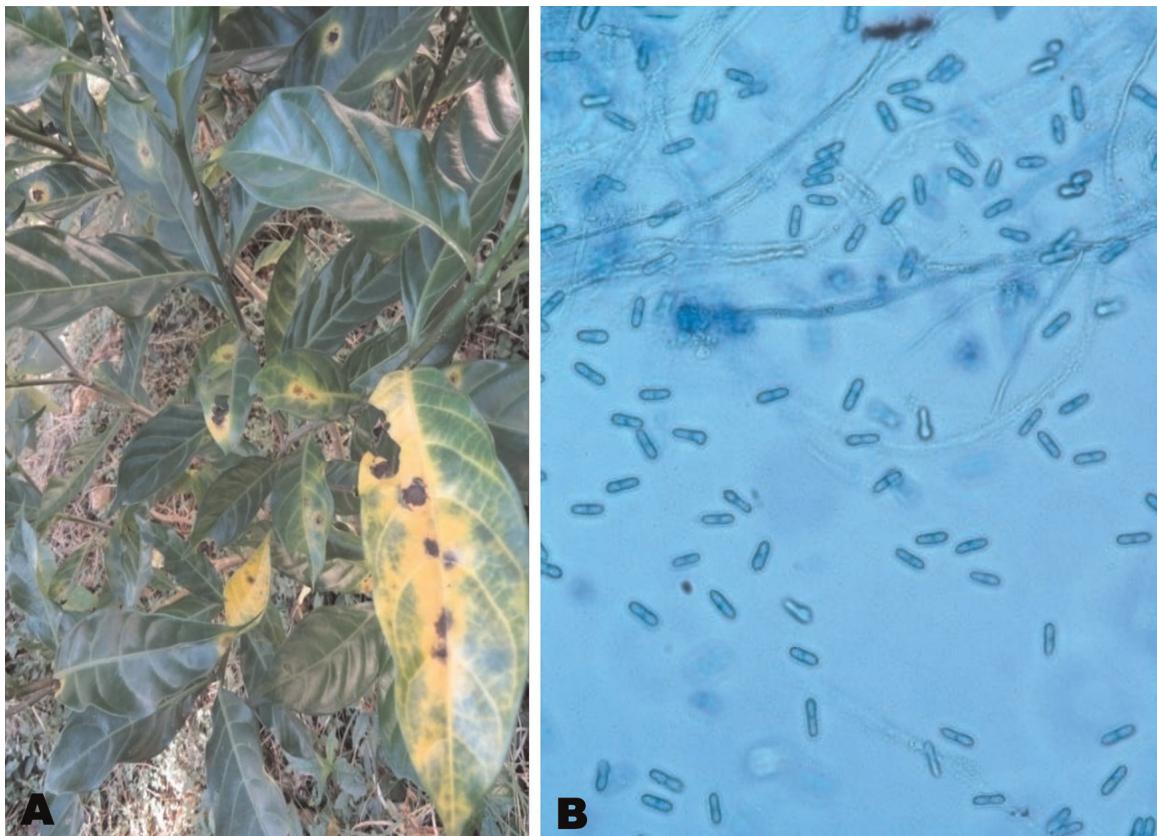
**Figure 13.**  
Leaf spot symptoms in *Ocimum sanctum* (A) caused by *Colletotrichum gleosporoides* (B).



**Figure 14.**  
Leaf spot symptoms in *Piper longum* (A) caused by *Colletotrichum boninense* (B).



**Figure 15.**  
Wilt symptoms in *Tabernaemontana divaricata* (A) caused by *Fusarium oxysporum* (B).



**Figure 16.**  
Leaf spot symptoms in *Tabernaemontana coronaria* (A) caused by *Colletotrichum boninense* (B).

yellow-edged appearance. Insects, rain, dirty garden tools, or even people can help its spread of this disease [44]. *T. divaricata* is also affected by wilt disease by *Fusarium oxysporum* [45] and rust disease by *Uredo manilensis* [46]. It was found to be affected by *Fusarium oxysporum* with wilting symptoms from September to November, causing death of plants in November and the extent of infection of this disease ranged from 10 to 20% (**Figure 15**). *T. coronaria* with leaf spot disease caused by *Colletotrichum gloeosporioides* was observed from November to January with the highest disease index of 9.7% in the month of January and the extent of infection of this disease ranged from 40 to 50% (**Figure 16**).

## 2. Management of diseases

On the basis of the experiments conducted and the results obtained in our studies and the reports of earlier researchers the following management measures are recommended for the economically important diseases of medicinal plants in Karnataka.

#Disease recorded in Karnataka for the first time.

\*Disease recorded for the first time on the host plant.

Diseases of *A. calamus*.

Disease and its pathogen	Symptoms	Management practices
<b>Rust disease</b> [1] <i>Uromyces acori</i>	<ul style="list-style-type: none"> <li>Infected leaves shows reddish brown pustules on both surface of leaves with ruptured epidermis.</li> <li>Severe infection consisting of yellow brown-coalesced pustules at the center, circular rings of brown pustules at the periphery and brown to black-coalesced raised spots at the center was observed.</li> <li>Formation of yellow and brown pustules in a scattered pattern in advanced stages.</li> <li>On stems, affected tissues showed necrosis and death of plants [1].</li> </ul>	<p><b>Cultural method</b> [46]</p> <ul style="list-style-type: none"> <li>Removal of weeds from bunds and channels.</li> <li>Avoid application of excess nitrogen.</li> <li>Apply N in three doses (50% during basal, 25% during the tillering phase and 25% N in panicle initiation stage).</li> </ul> <p><b>Chemical Method</b> [46]</p> <ul style="list-style-type: none"> <li>Application of Carbendazim 50WP @ 500 g/ha (or) Tricycloazole 75 WP @ 500 g/ha (or) Metominostrobin 20 SC @ 500 ml/ha (or) Azoxystrobin 25 SC @ 500 ml/ha.</li> </ul> <p><b>Biological control</b> [46]</p> <ul style="list-style-type: none"> <li>Dipping seedling root, soil application, and foliar spray with TNAU Pf 1liquid formulation (500 ml for one-hectare seedlings) are recommended [47, 48].</li> </ul>
<b>Leaf spot disease</b> [2] Unidentified	<ul style="list-style-type: none"> <li>Occurrence of discolored spots on the leaves of the plant [2].</li> </ul>	<ul style="list-style-type: none"> <li>Application of Captan @10 g and Chloryrifos @20 ml/10 L will help in the mitigation of the disease [2].</li> </ul>
<b>Bacterial leaf blight disease</b> [3] <i>Xanthomonas campestris</i> P.V. <i>O. Oryzae</i>	<ul style="list-style-type: none"> <li>Bacterial leaf blight produces tannish-gray to white lesions along the veins and characteristic symptoms of yellow lesions with wavy margins on leaf blades that may extend to the sheath.</li> <li>Symptoms are observed at the tillering stage, disease incidence increases with plant growth, peaking at the flowering stage.</li> <li>Leaves of the entire plant turn pale yellow and wilt during resulting in a partial or total crop failure.</li> <li>Occurrence of bacterial ooze from infected leaves has been observed in warm and humid climates, which contributes to the spread of this disease [3].</li> </ul>	<ul style="list-style-type: none"> <li>Application of Bordeaux mixture with or without sugar, copper-soap mixture, copper-mercury fungicides, copper oxychloride and streptomycin solution. Spraying synthetic organic bactericides such as nickel dimethyl dithiocarbamate, dithianone, phenazine and N oxide techlofthalam [3].</li> <li>Chlorinating irrigation water with stable bleaching powder.</li> </ul>

### Diseases of *A. vasica*.

Disease and its pathogen	Symptoms	Management practices
<b>Wilt Disease#*</b> <i>Fusarium oxysporum</i> Schlect. emend. [10]	<ul style="list-style-type: none"> <li>The leaves slowly wilt and die; they usually do not turn yellow, the leaves tend to stay green they begin to darken and turn brown, or blackish color and chlorosis occur and the plant dies [10].</li> </ul>	<ul style="list-style-type: none"> <li>Use Safer Yard &amp; Garden Insect Killer to control many garden insects.</li> <li>Avoid application of excess nitrogen fertilizers that may increase susceptibility to the disease.</li> <li>Deweeding using a weed flamer or natural herbicide.</li> </ul>

Disease and its pathogen	Symptoms	Management practices
<b>Leaf spot disease [4, 5]</b> <i>Rhizoctonia solani</i> & <i>Colletotrichum gloeosporioides</i>	<ul style="list-style-type: none"> <li>Initially, symptoms appear as minute, round, light brown spots but later the spots grow and acquire a round to irregular shape with coalescence of some spots.</li> <li>Fully developed spots are water-soaked dark brown to blackish, scattered all over the leaf lamina with margins of the spots diffusing and at the center.</li> <li>Severe infection resulted in defoliation [5].</li> <li>Concentric grey-brown spots appear on the leaves and join together to create large necrosed patch. Fruiting fungal bodies are observed in the middle of the spots [50].</li> </ul>	<ul style="list-style-type: none"> <li>Application of Mycostop (1–2 g/100 sq. ft.), biological fungicide that with sufficient watering protect crops against wilt caused by <i>Fusarium</i>.</li> <li>If the disease persists, removal of the entire plant and solarization of the soil before planting again is essential [49].</li> <li>Spraying with Benomyl 0.1% (or) Mancozeb 0.2% (or) Carbendazim 0.1% is recommended [51].</li> </ul>
<b>Leaf spot disease [8]</b> <i>Alternaria alternata</i>	<ul style="list-style-type: none"> <li>Initially, symptoms appear as minute, round, light brown spots but later the spots grow and acquire a round to irregular shape with coalescence of some spots.</li> <li>Fully developed spots are water-soaked dark brown to blackish, scattered all over the leaf lamina with margins of the spots diffusing and at the center.</li> <li>Severe infection resulted in defoliation [5].</li> <li>Concentric grey-brown spots appear on the leaves and join together to create large necrosed patch. Fruiting fungal bodies are observed in the middle of the spots [50].</li> </ul>	<ul style="list-style-type: none"> <li>Spraying with Benomyl 0.1% (or) Mancozeb 0.2% (or) Carbendazim 0.1% is recommended [52].</li> </ul>
<b>Anthracnose disease [8]</b> <i>Colletotrichum capsici</i>	<ul style="list-style-type: none"> <li>Large expanding leaf spots with dark to tan centers and diffuse, irregular margins.</li> <li>Expansion of individual lesions results in their “target spot” appearance; that is, concentric rings become visible in the lesions as the lesions grow each day.</li> <li>Lesions may coalesce to form large, blighted areas on leaves, often at</li> </ul>	<ul style="list-style-type: none"> <li>Sanitation by removal of severely diseased leaves of the plant and destruction of fallen infected leaves is recommended.</li> <li>Management of moisture and humidity by ensuring good drainage, dewatering, adequate plant spacing, pruning, minimize leaf wetness, and overhead irrigation.</li> </ul>

Disease and its pathogen	Symptoms	Management practices
	<p>leaf margins. Infected leaves may abscise (drop) prematurely.</p> <ul style="list-style-type: none"> <li>• Symptoms are often most severe within dense noni canopies and/or on the lower leaves.</li> <li>• Fruits and stems are not susceptible to infection [53].</li> </ul>	<ul style="list-style-type: none"> <li>• Avoid mechanical spread of the pathogen on hands and tools during harvesting operations [53].</li> <li>• Spraying of <i>P. fluorescens</i>, <i>Bacillus subtilis</i> were found to be effective [54].</li> <li>• Most studies have evaluated the leaf extracts of various plants to control <i>C. capsici</i>. Leaf extracts of neem, <i>Datura</i>, <i>Ocimum</i>, <i>Polyalthia</i>, <i>Vinca rosea</i> were found fungitoxic against <i>C. capsici</i> [55].</li> <li>• Yeasts strains isolated from rhizosphere were found to be antagonistic to <i>C. capsici</i> by inhibiting the mycelia growth of <i>C. capsici</i> to the extent of 40.6 to 43.1%, which intern found to control the anthracnose to the tune of 60% [56].</li> <li>• There are several species of <i>Trichoderma</i>, of which the major ones are <i>Trichoderma asperellum</i>, <i>T. viridae</i>, <i>T. harzianum</i>, and <i>T. longibrachiatum</i>. Isolates of <i>T. longibrachiatum</i> found to inhibit the mycelia growth of <i>Colletotrichum capsici</i> up to 66% due to the volatile compounds released by <i>Trichoderma</i> [57].</li> <li>• Use disease-free seeds.</li> <li>• Seed treatment with thiram 2 kg/ha or zineb 2.5 kg/ha.</li> <li>• Spraying of captan 0.2% with sufficient interval.</li> <li>• Essential oil of <i>Nigella sativa</i> is shown to have antimicrobial activity [51].</li> </ul>
<b><i>Alternaria blight</i> [6] <i>A. alternata</i></b>	<ul style="list-style-type: none"> <li>• The <i>Alternaria</i> leaf blight infects all aerial parts of plant.</li> <li>• Initially, the disease appears in the form of small, scattered brown spots on the leaf lamina, which later increases in size and coalesces covering the entire area with dark brown margin and yellow halo.</li> <li>• Linear necrotic lesions appear on stem, petioles, and sepals. In severe cases, the head and seeds also get infected [58].</li> </ul>	<ul style="list-style-type: none"> <li>• The fungicide Indofil M-45, Ridomil at 0.5% and bio agents like <i>Trichoderma harzianum</i>, <i>T. viride</i>, <i>T. pseudokoningii</i>, <i>T. koningii</i>, <i>Aspergillus niger</i>, and <i>A. flavus</i> reduced the growth of <i>A. alternata</i> [59].</li> </ul>
<b><i>Leaf rust</i> [7] <i>Puccinia thwaitesii</i></b>	<ul style="list-style-type: none"> <li>• The disease starts as circular brown or reddish brown, granular.</li> <li>• Sori or a group of sori were observed in chlorotic areas, which soon die.</li> </ul>	<ul style="list-style-type: none"> <li>• <i>Trichoderma harzianum</i> was found to be effective against rust pathogen <i>Puccinia thwaitesii</i> [60].</li> </ul>

Disease and its pathogen	Symptoms	Management practices
	<ul style="list-style-type: none"> <li>As the disease advances, the red pustules become black spots circular and small and later coalesce to form large patches [7].</li> </ul>	
<b>Leaf rust [8]</b> <i>Aecidium adhatodae</i>	<ul style="list-style-type: none"> <li>The postules are circular or elliptical, smaller than those of stem rust, and they do not coalesce and contain masses of orange-brown Urediospores.</li> <li>Infection sites primarily are found on the upper surfaces of leaves and leaf sheaths and occasionally on the neck.</li> <li>They survive on stubbles and volunteer crops [61].</li> </ul>	<ul style="list-style-type: none"> <li>Mixed cropping with suitable crops is recommended.</li> <li>Avoid application of excess dose of nitrogenous fertilizers.</li> <li>Spraying of Zineb at 2.5 kg/ha or Propiconazole @ 0.1% is recommended [61].</li> </ul>

### Diseases of *Chlorophytum borivilianum*.

Disease and its pathogen	Symptoms	Management practices
<b>Leaf blight [11]</b> <i>Alternaria alternata</i>	<ul style="list-style-type: none"> <li>Initially, reddish-brown lesions on the leaves, forming longitudinal streaks along the midrib, veins and margin of the infected leaves. Finally, rotting and death of leaves is observed [11].</li> </ul>	<ul style="list-style-type: none"> <li>Spraying biocontrol agents like <i>Trichoderma</i> sp.</li> <li>Spraying with Benomyl 0.1% (or) Mancozeb 0.2% (or) Carbendazim 0.1% IS recommended [52].</li> </ul>
<b>Colletotrichum chlorophytumi [12]</b>	<ul style="list-style-type: none"> <li>Yellowing of leaves leading to withering and ultimately death of the whole leaf [12].</li> </ul>	<ul style="list-style-type: none"> <li>Application of Bavistin solution @1 g in 1 liter of water at the interval of 25 days twice [12].</li> </ul>
<b>Red spot [11]</b> Unidentified	<ul style="list-style-type: none"> <li>Occurrence of red, orange, and yellow leaf spots on plants [11].</li> </ul>	<ul style="list-style-type: none"> <li>Application of Bavistin solution @1 g in 1 liter of water at the interval of 25 days twice [11].</li> </ul>
<b>Root rot disease [13]</b> <i>Rhizoctonia solani, Aspergillus flavus, Fusarium oxysporum</i> [13]	<ul style="list-style-type: none"> <li>Initially gradual drying of leaves of affected plants.</li> <li>The basal portion of the root appears watery and soft and root system is very much reduced and its tissues are also affected. In advanced stages, the infection spreads to roots, and the roots decompose and turn into a decaying mass of tissues resulting in poor and stunted development of roots [62].</li> </ul>	<ul style="list-style-type: none"> <li>Fungicides, neem-based formulations, organic cakes and a biocontrol agent <i>Trichoderma viride</i>.</li> <li>Application of mancozeb 63% + carbendazim 12% (SAAF-75WP), carbendazim 50WP, propiconazole 25EC, 0.1% tebuconazol (250EC), and hexaconazole 5EC are highly effective.</li> <li>Root dipping for 15 min. in a mixture of 0.3% thiram (80WP) + 0.15% carbendazim (50 WP).</li> <li>Application of <i>Trichoderma viride</i> at 5 g kg<sup>-1</sup> soil before planting.</li> <li>Field application of a mixture of NC + mustard cake (1:1) before planting at the rate of 4 q h<sup>-1</sup>.</li> </ul>

Disease and its pathogen	Symptoms	Management practices
<i>Haemofonectira haematococca</i> sp. nov. [14]	<ul style="list-style-type: none"> <li>Initially gradual drying of leaves of affected plants.</li> <li>The basal portion of the root appears watery and soft and root system is very much reduced and its tissues are also affected. In advanced stages, the infection spreads to roots, and the roots decompose and turn into a decaying mass of tissues resulting in poor and stunted development of roots [62].</li> </ul>	<ul style="list-style-type: none"> <li>Soil drenching 45 days after sowing (DAS), with a mixture of 0.3% thiram + 0.15% carbendazim + 0.5% <i>T. viride</i> + 0.4% NC + 0.4% mustard cake.</li> <li>Spraying of 0.2% carbendazim (50WP).</li> <li>Neem-based formulations and six oil cakes extracts, neem oil, neem formulation no 2 at 3% and neem, jatropha cakes extract at 40% were highly inhibitory to <i>Rhophitulus solani</i> [13].</li> </ul>
<b>Anthracnose</b> [15] <i>Colletotrichum chlorophyti</i>	<ul style="list-style-type: none"> <li>Initially, small brownish spots on lamina, more prominent on margin or tip, are observed.</li> <li>Typical symptoms of Anthracnose like sunken lesion that range from dark red to tan black [15].</li> </ul>	<ul style="list-style-type: none"> <li>Root dipping for 15 min. in a mixture of 0.3% thiram (80WP) + 0.15% carbendazim (50 WP).</li> <li>Application of <i>Trichoderma viride</i> at 5 g kg<sup>-1</sup> soil before planting and field application of a mixture of NC + mustard cake (1:1) before planting at the rate of 4 q h<sup>-1</sup>.</li> <li>Soil drenching 45 days after sowing (DAS), with a mixture of 0.3% thiram + 0.15% carbendazim + 0.5% <i>T. viride</i> + 0.4% NC + 0.4% mustard cake.</li> <li>Spraying of 0.2% carbendazim (50WP) [14].</li> </ul>

#### Diseases of *G. sylvestre*.

Disease and its pathogen	Symptoms	Management measures
<b>Leaf spot #</b> [16] <i>Colletotrichum gloeosporioides</i>	<ul style="list-style-type: none"> <li>Appearance of minute black or brown points surrounded by a pale green ring visible on both the surfaces of the leaf.</li> <li>As the spots enlarge, the center turns pale brown and then greyish-white surrounded by a deep brown band.</li> <li>The fructifications of the fungus appear as tiny black dots in the white center.</li> <li>The diseased spots are scattered over the leaf and are roundish when young but may become irregular when mature.</li> </ul>	<ul style="list-style-type: none"> <li>Spraying 3 g of water soluble sulfur in one liter of water at an interval of 10–15 days [16].</li> </ul>

Disease and its pathogen	Symptoms	Management measures
<b>Leaf spot [17]</b> <i>Pseudomonas syringae</i>	<ul style="list-style-type: none"> <li>Leaf tissue withers and large brown patches of dried leaf may result [16].</li> </ul>	
<b>Powdery mildew [16]</b> <i>Unknown</i>	<ul style="list-style-type: none"> <li>Initial symptoms were small, angular, water-soaked lesions observable on both adaxial and abaxial surfaces.</li> <li>Lesions enlarged, became tan to light brown, and were often surrounded by chlorotic haloes [64].</li> </ul>	<ul style="list-style-type: none"> <li>Extracts of seaweeds (<i>Sargassum wightii</i>, <i>Turbinaria conoides</i>, <i>Ulva lactuca</i>) possess an antimicrobial activity against the pathogen [17].</li> </ul>
	<ul style="list-style-type: none"> <li>Typical mildew growth is generally confined to the under-surface of the leaf.</li> <li>Severe infection leads to infection on the upper-surface [16].</li> </ul>	<ul style="list-style-type: none"> <li>Spraying 3 g of water soluble sulfur in one liter of water at an interval of 10–15 days [65].</li> </ul>

### Diseases of *H. rosa-sinensis*.

Disease and its pathogen	Symptoms	Management practices
<b>Blight*# <i>Nigrospora sphaerica</i></b>	<ul style="list-style-type: none"> <li>Initial symptoms were yellow-to-brown, irregular-shaped lesions on the leaf margin, or tip later lesions expanded along the mid-vein until the entire leaf was destroyed.</li> <li>Blighted leaves turn grayish to dark brown and wither, and ultimately affected plants died.</li> </ul>	<ul style="list-style-type: none"> <li>In areas where the disease may cause yield loss, applying captan, captafol, fentin hydroxide, and mancozeb can inhibit conidial germination and carbendazim fungicide and copper base fungicide can effectively control the disease.</li> <li>Spraying with Mancozeb 1 kg or Iprobenphos 500 ml or Carbendazim 250 g/ha is recommended [66].</li> </ul>
<b>Anthracnose # <i>Colletotrichum gloeosporioides</i> [Glomerella cingulata] [19]</b>	<ul style="list-style-type: none"> <li>Appearance of yellowish brown to dark brown irregular spots present with a chlorotic yellow halo on leaves.</li> <li>Progression of the disease leads the spots to coalesce and the leaves dry up.</li> <li>The center of the lesions was covered by black acervuli [19].</li> </ul>	<ul style="list-style-type: none"> <li>Spray Bordeaux mixture 1%, such that the spray solution reaches the lower surface of the leaves.</li> <li>Spray Bordeaux mixture 1% or carbendazim + mancozeb 0.1% with the onset of pre-monsoon showers on the new foliage and spikes.</li> <li>Regulate shade in the plantation with the onset of pre-monsoon showers.</li> <li>Adopt integrated nutrition management practices in the plantation.</li> <li>Spray <i>P. fluorescens</i> (FP 7) at 3-week interval.</li> <li>Before storage, treat with hot water, (50–55°C) for 15 minutes or dip in Benomyl solution (500 ppm) or Thiobendazole (1000 ppm) for 5 minutes [63].</li> </ul>
<b>Bacterial Leaf Spot <i>Pseudomonas cichorii</i> [67]</b>	<ul style="list-style-type: none"> <li>Lesions range from 2 to 10 mm in diameter and are usually surrounded by a two-color border with necrotic lesion center surrounded by yellowish halo.</li> </ul>	<ul style="list-style-type: none"> <li>Starting new plants using pathogen-free cuttings and</li> <li>Application of fertilizer affect severity of many bacterial diseases of ornamental plants.</li> </ul>

Disease and its pathogen	Symptoms	Management practices
	<ul style="list-style-type: none"> <li>The central necrotic portions of the lesions are tan to whitish and sometimes fall out, creating a “shot-hole” appearance.</li> <li>Severe spotting may cause premature defoliation.</li> <li>Other parts of the hibiscus plant (e.g., flowers, petioles, stems) are not susceptible to the disease [67].</li> </ul>	<ul style="list-style-type: none"> <li>Sanitation and removal of diseased plant organs such as leaves from the vicinity of healthy leaves is recommended.</li> <li>Routine pruning and destroying branches with heavily diseased leaves.</li> <li>Minimizing leaf wetness and relative humidity in the plant canopy can manage the disease effectively.</li> <li>Ensure that soil is completely aerated.</li> <li>Trim weeds around hibiscus plants to reduce relative humidity ensure plant spacing, intercropping, non-host plants between hibiscus plants to block the spread of bacteria between plants [67].</li> </ul>
<b>Powdery Mildew</b> [20] <i>Podosphaera</i> sp. [20]	<ul style="list-style-type: none"> <li>Initially begins as white spots that turn gray or tan as the fungus grows and covers more of the foliage.</li> <li>The fungus causes stunted growth and in severe cases, the leaves may wither and fall off the plant [68].</li> </ul>	<ul style="list-style-type: none"> <li>Watering hibiscus at the base of the plants and not directly on the leaves is recommended.</li> <li>Avoid high-nitrogen fertilizers and ensure proper spacing.</li> <li>Trim affected growth immediately and dispose of diseased plant material carefully.</li> <li>A mixture of neem oil and water is a safe, at a rate of 2 tablespoons neem oil to 1 gallon of water has shown to effectively manage the disease [68].</li> </ul>
<b>Dieback Disease</b> <i>Botrytis</i> sp., <i>Erwinia</i> sp. [69]	<ul style="list-style-type: none"> <li>The rot will cause a change of color on the stem and sometimes it appears as a light brown dry rot.</li> <li>The leaves begin to wilt as water does not progress in rotted stem [69].</li> </ul>	<ul style="list-style-type: none"> <li>Removal of infected part of the stem from the plant and early spotting of the disease will help in mitigating the disease.</li> <li>Application of diluted Phyton (Copper biocide) on the wound is recommended [69].</li> </ul>
<b>Wilt Disease</b> <i>Fusarium oxysporum</i> and <i>Verticillium</i> [69]	<ul style="list-style-type: none"> <li>Characteristic symptoms of leaves slowly wilting and death of the entire plant are observed.</li> <li>Initially, leaves will tend to stay the green and later may slowly darken as they wilt to a dark green, brown, or blackish color.</li> <li>Wilt disease affects the entire plant, not just one tip or branch [69].</li> </ul>	<ul style="list-style-type: none"> <li>Application of 1 pint of household bleach with 2 quarts of warm water is recommended.</li> <li>Sanitation and removal of the wilted plant will ensure the prevention of the spread [69].</li> </ul>
<b>Choanephora Blight</b> <i>Choanephora infundibulifera</i> [21]	<ul style="list-style-type: none"> <li>Initial symptoms began as reddish purple spots at the tip of flowers and expanded to encompass entire flowers.</li> <li>Infected lesions appeared water-soaked, reddish brown, and were followed by rapid rotting of infected tissues [21].</li> </ul>	<ul style="list-style-type: none"> <li>Good sanitation practices including grooming the plants and removing spent or senescing flowers can minimize the potential for infection.</li> <li>It is also important to avoid wetting the flowers when watering and crowding plants.</li> </ul>

Disease and its pathogen	Symptoms	Management practices
<b>Botrytis blight</b> <i>Botrytis cinerea</i> [22]	<ul style="list-style-type: none"> <li>Lesions initially occur on the tips of stems and rapidly moved downward when environmental conditions are cool and humid.</li> <li>No lesions are observed on leaves; however, flowers became blighted, turn brown, and abscise prematurely.</li> <li>Diseased stems occasionally are colonized by <i>C. gloeosporioides</i> is reported [22].</li> </ul>	<ul style="list-style-type: none"> <li>Adequate spacing between the plants can promote good air circulation.</li> <li>Use of potassium bicarbonate, mancozeb, copper hydroxide, and thiophanate-methyl is recommended [70].</li> </ul>
<b>Hibiscus witches' broom disease</b> <i>Candidatus Phytoplasma brasiliense</i> [23]	<ul style="list-style-type: none"> <li>Witches' brooms disease affected leaves and shoots display distorted, dwarfed, and discolored symptoms.</li> <li>This disease results from a multitude of diseases such as powdery mildew or rusts, mistletoe, or from insect and mite feeding [72].</li> </ul>	<ul style="list-style-type: none"> <li>Sanitation and aeration reduce humidity levels around plants and appropriate fungicide applications are recommended for disease control.</li> <li>Fallen leaves and petals should be carefully removed from production areas.</li> <li>Regular fungicide applications will reduce losses on especially susceptible hosts grown in humid environments [71].</li> </ul>
<b>Viral disease</b> Rhabdovirus-like particles and hibiscus ring spot virus [73]	<ul style="list-style-type: none"> <li>Chlorosis along with vein yellowing mottling, vein banding and clearing, vein enation, rosetting, leaf distortion, flower abortion, distortion, and stunting are the characteristic symptoms [73].</li> </ul>	<ul style="list-style-type: none"> <li>The best way is the prevention of the disease.</li> <li>Selection of virus free seed should be done from credible sources. This includes Cuttings, bulls, rhizomes, tubers, and seeds.</li> <li>Eradication of the diseased plant will eliminate the inoculum from the field.</li> <li>Insect vectors must be efficiently managed through eradication of weeds that harbor them and via sowing of trap crops.</li> <li>Similarly, soil fumigation and nematicides can be applied against nematode-transmitted viruses to control nematodes [74].</li> </ul>
<b>Phytophthora disease</b> <i>Plagithmysus nicotianae</i> var. <i>nicotianae</i> [24]	<ul style="list-style-type: none"> <li>Production of brownish to black lesions [24].</li> </ul>	<ul style="list-style-type: none"> <li>Chemical control includes the use of metalaxyl or its near-identical twin mefenoxam used in single or multiple applications.</li> <li>The use of soil fumigants such as chloropicrin may reduce pathogen populations, and fumigant nematicides such as 1,3-dichloropropene reduce nematode populations that enhance black shank incidence and severity [75].</li> </ul>

Disease and its pathogen	Symptoms	Management practices
Rust <i>Kuehneola malvicola</i> [25]	<ul style="list-style-type: none"> <li>Initially, minute orange-brown pustules typical of most rusts develop on the underside of leaves.</li> <li>Upper leaf surface appear slightly larger yellow-orange spots and do not develop pustules.</li> </ul> <p>Premature defoliation may occur [25].</p>	<ul style="list-style-type: none"> <li>Appropriate chemicals may be tried on prized plant specimens [76].</li> <li>Sanitation measures, including removal of dead fallen foliage and pruning infected flowering branches following bloom, should provide adequate control in many cases [25].</li> </ul>

### Diseases of *M. citrifolia*.

Disease and its pathogen	Symptoms	Management measures
Noni anthracnose <i>Colletotrichum gleosporoides</i> [27]	<ul style="list-style-type: none"> <li>Large expanding and diffusing leaf spots with dark to tan centers with irregular margins are observed.</li> <li>Expansion of individual concentric lesion rings results in the “target spot” appearance.</li> <li>Lesions coalesce to form large, blighted areas on leaves and leaf margins. Infected leaves may abscise prematurely.</li> <li>Symptoms are severe within dense noni canopies and/or on the lower leaves; however, fruits and stems are not susceptible to infection [53].</li> </ul>	<ul style="list-style-type: none"> <li>Sanitation by removal of severely diseased leaves of the plant and destruction of fallen infected leaves is recommended.</li> <li>Management of moisture and humidity by ensuring good drainage, dewatering, adequate plant spacing, pruning, minimize leaf wetness, and overhead irrigation.</li> <li>Avoid mechanical spread of the pathogen on hands and tools during harvesting operations [53].</li> <li>Spraying of <i>P. fluorescens</i>, <i>Bacillus subtilis</i> was found to be effective [54].</li> <li>Most studies have evaluated the leaf extracts of various plants to control <i>C. capsici</i>. Leaf extracts of neem, Datura, <i>Ocimum</i>, Polyalthia, <i>Vinca rosea</i> were found fungitoxic against <i>C. capsici</i> [55].</li> <li>Yeast strains isolated from rhizosphere were found to be antagonistic to <i>C. capsici</i> by inhibiting the mycelia growth of <i>C. capsici</i> to the extent of 40.6 to 43.1% which interns found to control the anthracnose to the tune of 60% [56].</li> <li>There are several species of <i>Trichoderma</i>, of which the major ones are <i>Trichoderma asperellum</i>, <i>T. viridae</i>, <i>T. harzianum</i>, and <i>T. longibrachiatum</i>. Isolates of <i>T. longibrachiatum</i> found to inhibit the mycelia growth of <i>Colletotrichum capsici</i> up to 66% due to volatile compounds released by <i>Trichoderma</i> [57].</li> <li>Use disease-free seeds.</li> </ul>

Disease and its pathogen	Symptoms	Management measures
<b>Wilt disease#</b> <i>Fusarium oxysporum</i> Schl.f.sp. <i>morindae</i> [30]	<ul style="list-style-type: none"> <li>The leaves slowly wilt and die; they usually do not turn yellow, the leaves tend to stay green they begin to darken and turn brown, or blackish color and chlorosis occurs, and the plant dies [10]. The fungal disease develops during hot weather and is most destructive when soil temperatures approach 80°F.</li> <li>Dry weather and low soil moisture encourage this plant disease [77].</li> </ul>	<ul style="list-style-type: none"> <li>Seed treatment with thiram 2 kg/ha or zineb 2.5 kg/ha.</li> <li>Spraying of captan 0.2% with sufficient interval.</li> <li>Essential oil of <i>Nigella sativa</i> is shown to have antimicrobial activity [51].</li> </ul>
<b>Black Flag disease [78]</b> (Presently recorded) <i>Phytophthora</i> species, <i>Phytophthora morindae</i> [29]	<ul style="list-style-type: none"> <li>Severely diseased plants have characteristic “black flags,” which describes the blackened, wilted, withered, or completely necrotic leaves hanging from blackened petioles and stems.</li> <li>Initially, infection of the leaves, petioles, and stems may have blackened streaks or stripes along the veins.</li> <li>Later, entire stems and petioles may collapse after being girdled by black lesions.</li> <li>Fruit symptoms, common at the stem end, consist of a progressive soft rot with a water-soaked appearance and chocolate-brown or dark brown to black color.</li> <li>Advanced stages of fruit infections result in dry, shriveled fruit “mummies” that may have a fuzzy or silvery surface [29].</li> </ul>	<ul style="list-style-type: none"> <li>Disease can be controlled by following integrated cultural and preventive methods such as pruning, sanitation, avoidance, and an appropriate cropping system.</li> <li>Regular monitoring for black flag disease must be carried out during periods of extended rain.</li> <li>Pruning, removal, and destroying symptomatic foliage and fruits will reduce the pathogen inoculum levels and disease incidence.</li> <li>Promoting good air circulation within the noni plant canopy will ensure rapid drying of leaves and fruits.</li> <li>Reduction of relative humidity within the noni canopy, ensuring adequate soil drainage and controlling weeds around the noni plants are recommended.</li> <li>Maintain good plant nutrition with foliar sprays of fertilizers derived from phosphorus acid, such as Phosgard® [29].</li> </ul>
<b>Algal leaf spot [53]</b> <i>Cephaleuros minimus</i>	<ul style="list-style-type: none"> <li>Initial leaf spots are characterized by a light brown color and surrounded by a conspicuous, diffuse, yellow halos.</li> </ul>	<ul style="list-style-type: none"> <li>Sanitation and removal of severely diseased leaves from the plant and destruction of fallen-infected leaves.</li> </ul>

Disease and its pathogen	Symptoms	Management measures
<b>Noni shot hole</b> [53] Unidentified	<ul style="list-style-type: none"> <li>The effect of these symptoms may be minor; the disease is not fatal but some premature defoliation may occur [53].</li> </ul>	<ul style="list-style-type: none"> <li>Moisture and humidity management ensuring good drainage, controlling weeds, adequate plant spacing, pruning, minimizing leaf wetness, and overhead irrigation.</li> <li>Growing noni in full sun is recommended [53].</li> </ul>
<b>Noni stem canker</b> Unidentified [53]	<ul style="list-style-type: none"> <li>Initial spots are tiny, maroon-colored specks on leaves and bracts that develop into lesions (2–10 mm diameter) with bleached or tan centers and maroon margins, often surrounded by or accompanied by yellowing of leaf tissue around lesions.</li> <li>As the lesions mature the centers drop out, leaving the typical “shot hole” appearance. Infected leaves may abscise prematurely. However, stems and fruits display no symptoms [53].</li> </ul>	<ul style="list-style-type: none"> <li>Sanitation and removal of severely diseased leaves from the plant and destruction of fallen infected leaves.</li> <li>Moisture and humidity management ensuring good drainage, controlling weeds, adequate plant spacing, pruning, minimizing leaf wetness and overhead irrigation.</li> <li>Protective spray applications of approved fungicides and avoiding spreading of the pathogen on hands and tools during harvesting operations are recommended [53].</li> </ul>
<b>Noni stem blight</b> <i>Sclerotium rolfsii</i> , and root-knot nematodes [53]	<ul style="list-style-type: none"> <li>Initial characteristic symptom observed is rot of stem at the interface between woody and green stem tissues.</li> <li>Stem may be girdled and collapsed, leading to plant death.</li> <li>Stem lesions are irregular in shape with roughened, dark borders and an overall corky appearance [53].</li> </ul>	<ul style="list-style-type: none"> <li>Pruning the diseased stem at least 1 inch below the stem canker is recommended.</li> <li>For humidity management through plant spacing and pruning, weed control, good drainage is recommended.</li> <li>Applications of protective or therapeutic fungicides will help mitigating the disease [53].</li> </ul>
<b>Sooty mold</b> Sooty mold is caused by a ubiquitous, airborne fungus [53].	<ul style="list-style-type: none"> <li>Foliar chlorosis, wilting, stem girdling at or near soil line; internal stem necrosis, stem rot, defoliation leading to plant death [53].</li> </ul>	<ul style="list-style-type: none"> <li>Avoid planting in low-lying areas with poor drainage, undue plant stresses.</li> <li>Avoid plant-parasitic nematodes, injuring stems with weed-whackers.</li> <li>Do not pile rocks around the base of noni plants, as they may injure the stem [53].</li> </ul>
<b>Phytoplasma disease</b> Phytoplasmas (mycoplasma-like organisms or MLOs) [31]	<ul style="list-style-type: none"> <li>Diseased plants usually express various growth and flowering abnormalities, together with chlorosis, stunting, and sometimes dieback symptoms [31].</li> </ul>	<ul style="list-style-type: none"> <li>To control sooty mold, one must control the sap-feeding insects (scales, aphids) which infest the noni plant.</li> <li>Sooty mold may in some cases be washed off noni leaves with a strong spray of soapy water [53].</li> <li>Controlling phytoplasma diseases usually begins with controlling insect vectors that starts with good weed removal practices and clearing brush that can host insect vectors.</li> </ul>

Disease and its pathogen	Symptoms	Management measures
<b>Root rot disease [80]</b> <i>Fusarium proliferatum</i>	<ul style="list-style-type: none"> <li>Initially, typical yellowing and root rot symptoms are observed.</li> <li>Dark brown to black, discolored, decaying or completely rotted roots is observed [80].</li> </ul>	<ul style="list-style-type: none"> <li>Removal of an infected plant is necessary to contain the pathogen.</li> <li>Dry weather seems to increase leafhopper activity, so it is important to keep the plant watered.</li> <li>Good cultural care and practices will increase plant resistance and spread of the disease [79].</li> </ul> <p><b>Chemical/Biological Control</b></p> <ul style="list-style-type: none"> <li>Seed is treated with fungicide may protect seedlings from root rot for a short time.</li> </ul> <p><b>Cultural Practices</b></p> <ul style="list-style-type: none"> <li>Rotating crops may help reduce the severity of Fusarium root rot.</li> <li>Herbicide injury, foliar diseases, hail damage, or drought may make it more susceptible to root rot [81].</li> </ul>

### Diseases of *M. pruriens*.

Disease and its pathogen	Symptoms	Management measures
<b>Leaf blight*# <i>Colletotrichum gleosporioides</i></b>	<ul style="list-style-type: none"> <li>The symptoms on leaves began as dark brown lesions surrounded by chlorotic halos, and later became larger, round or irregular spots with gray to off-white centers surrounded by dark brown margins.</li> </ul>	<ul style="list-style-type: none"> <li>Destroy all affected branches and spray the plants with 0.5% Bordeaux mixture or Mancozeb 0.25%.</li> </ul>
<b>Rust disease # <i>Uromyces mucuna</i> [47, 48]</b>	<ul style="list-style-type: none"> <li>Small, irregular black spots occur on mature leaves covering the lower surface.</li> <li>Yellow brown-coalesced pustules at the center, severe infection consisting of circular rings of brown pustules at the periphery and brown to black-coalesced raised spots at the center.</li> <li>On stems, affected tissues showed softening, necrosis, and death of plants [47, 48].</li> </ul>	<p><b>Cultural method</b> [46]</p> <ul style="list-style-type: none"> <li>Removal of weeds from bunds and channels.</li> <li>Avoid application of excess nitrogen.</li> <li>Apply N in three doses (50% during basal, 25% during tillering phase and 25% N in panicle initiation stage).</li> </ul> <p><b>Chemical Method</b> [46]</p> <ul style="list-style-type: none"> <li>Application of Carbendazim 50WP @ 500 g/ha (or) Tricyclozole 75 WP @ 500 g/ha (or) Metominostrobin 20 SC @ 500 ml/ha (or) Azoxyystrobin 25 SC @ 500 ml/ha.</li> </ul> <p><b>Biological control</b> [46]</p> <ul style="list-style-type: none"> <li>Dipping seedling root, soil application, and foliar spray with TNAU Pf 1liquid formulation (500 ml for one hectare seedlings) are recommended [47, 48].</li> </ul>

Disease and its pathogen	Symptoms	Management measures
<b>Collar rot of seedling</b> Unidentified [82]	<ul style="list-style-type: none"> <li>Localized lesion at or about the collet between the stem and the root is observed.</li> <li>The lesions develop around the stem eventually forming a “collar” [82].</li> </ul>	<ul style="list-style-type: none"> <li>Applications of 2 kg Trichorich (a formulation of <i>Trichoderma</i> in neem cake) and 2 kg <i>Pseudomonas fluorescens</i> mixed with 500 kg FYM to the root region is recommended [82].</li> </ul>
<b>Velvet bean severe mosaic virus disease.</b> Velvet bean severe mosaic virus (VbSMV) [83]	<ul style="list-style-type: none"> <li>Naturally infected velvet bean plants shows diffused yellow spots on the young leaves, which turn into severe mosaic and yellowing symptoms in the older leaves.</li> <li>Seeds from diseased plants showed poor germination.</li> <li>The symptoms succession included chlorosis of the primary veins on the abaxial leaf surface, extending gradually to the secondary and tertiary veins to form a network of dark green veins [83].</li> </ul>	<ul style="list-style-type: none"> <li>The use of insecticides for vector control and resistant cultivars is recommended [83].</li> </ul>
<b>Charcoal rot</b> <i>Macrophomina phaseolina</i> [34, 84]	<ul style="list-style-type: none"> <li>Diseased plants are wilted and dead pre-maturely with patches similar to those of sudden death syndrome (SDS).</li> <li>Discoloration in cortex tissues of taproot and lower stems is typical and when stems are split, piths of diseased plants have brown stem rot like browning in the lower part of the stem.</li> <li>In some plants, however, no pith browning can be found [34, 84].</li> </ul>	<ul style="list-style-type: none"> <li>Crop rotation with small grain, such as wheat or barley, helps to reduce population levels of the fungus.</li> <li>Excessive seeding rates should be avoided so that plants do not compete for moisture, which increases disease risk during a dry season [34, 84].</li> </ul>

### Diseases of *O. sanctum*.

Disease and its pathogen	Symptom	Management measures
<b>Wilt disease #</b> <i>Fusarium oxysporum</i> [35]	<ul style="list-style-type: none"> <li>The affected plants had stunted growth with wilting symptoms.</li> <li>Chlorosis of leaves with brown spots and streaks on the stem, vascular discoloration of roots, severely twisted stems, and leaf drop was observed [35].</li> </ul>	<ul style="list-style-type: none"> <li>There is no remedy for <i>Fusarium</i> wilt of basil. Destroy infected plants and do not plant basil or other mint plants in that area for two to three years [35].</li> </ul>
<b>Powdery mildew disease #</b> <i>Erysiphe biocellata</i> [39]	<ul style="list-style-type: none"> <li>The white mycelia covered leaves and stems are observed on the upper surface of lower leaves.</li> <li>These white patches soon joined together to form larger white greyish powdery coating discernible on the severely affected leaves.</li> </ul>	<ul style="list-style-type: none"> <li>Spraying NSKE 5% or neem oil 3% twice at 10-day interval from initial disease appearance, eucalyptus leaf extract 10% at initiation of the disease, and 10 days later and Carbendazim 500 g or wettable sulfur 1500 g/ ha is recommended [85].</li> </ul>

Disease and its pathogen	Symptom	Management measures
<b>Fungal Leaf Spots #</b> <i>Colletotrichum gloeosporioides</i> and a complex of three fungal pathogens: <i>Alternaria</i> spp., <i>Cercospora</i> spp., and <i>Colletotrichum</i> spp. [86]	<ul style="list-style-type: none"> <li>Leaves finally show necrosis resulting in withering, drying, and defoliation [39].</li> </ul>	
<b>Bacterial Leaf Spot or Basil Shoot Blight</b> <i>Pseudomonas cichorii</i> [87]	<ul style="list-style-type: none"> <li>These leaf spots show brown to black in color, with yellow halo around it.</li> <li>The spots are irregular in shape and as the disease progressed, the spots coalesced and the entire leaves turned necrotic.</li> <li>They occur when the leaves stay wet or damp for an extended period [86].</li> </ul>	<ul style="list-style-type: none"> <li>Removing all diseased foliage, avoiding overhead watering, treating the holy basil plant weekly with a potassium bicarbonate fungicide will help prevent the fungal pathogen from spreading.</li> <li>Some brands of potassium bicarbonate fungicide recommend mixing 2 teaspoons of the product with 1 gallon of water and applying the solution thoroughly to the foliage with a pump sprayer [86].</li> </ul>
<b>Downy Mildew</b> [87] <i>Peronospora belbahrii</i>	<ul style="list-style-type: none"> <li>Black or brown spots that appear on the leaves and streaking on the stems of the plant [87].</li> </ul>	<ul style="list-style-type: none"> <li>While there is no fix for bacterial leaf spot, you can minimize the damage by making sure that your basil plants have plenty of air circulation and avoiding overhead watering is recommended [87].</li> </ul>
<b>Cercospora leaf spot</b> <i>Cercospora ocimicola</i> [36]	<ul style="list-style-type: none"> <li>Symptoms include yellow leaves that have fuzzy, grey growth on the undersides of the leaves [87].</li> </ul>	<ul style="list-style-type: none"> <li>In the United States, mono- and dipotassium salts of phosphorous acid provided the best control, whereas moderate disease suppression was provided by mandipropamid, cyazofamid, and fluopicolide [88].</li> <li>One of the most effective measures for disease control is via genetic manipulation of the host, namely introgression of resistant genes. The objectives of this study were to expand on what others have reported on potential sources of resistance to BDM in some species of <i>Ocimum</i> [89, 90].</li> <li>Downy mildew is aggravated by overly wet conditions, so ensuring avoiding overhead watering and ensuring the basil plants have good drainage and good air circulation is recommended.</li> <li>Spraying with 0.3% wettable sulfur is recommended [87].</li> </ul>

Disease and its pathogen	Symptom	Management measures
<b>Root rot</b> <i>Rhizoctonia solani</i> , <i>Pythium</i> spp. [36]	<ul style="list-style-type: none"> <li>Failure of seeds to germinate, germinated seedlings collapses brown, shriveled area at base of stem, roots brown, and water-soaked.</li> <li>Disease promoted by high humidity and poor air circulation [36].</li> </ul>	<p>around the plants to reduce water splash, removal and destroying any symptomatic leaves; minor infections can be controlled by spraying weekly with a fungicide containing potassium bicarbonate [36].</p> <ul style="list-style-type: none"> <li>Complete control of root rot caused by infection of <i>Rhizophitus solani</i> in <i>Ocimum</i> sp. was achieved with seed treatment of tolclofos-methyl (50SC) at 3 g kg<sup>-1</sup>. Soil solarization and drenching of dazomet (98G) at 40 g active ingredient per m<sup>2</sup> around plants reduced incidence of root rot from 70.6% to 4.1% [91].</li> <li>Root rot can be controlled by drenching the nursery beds with a 0.1 per cent solution of mercurial fungicide and adopting phytosanitary measures [36].</li> </ul>
<b>Viral disease</b> Yellow mosaic virus [92]	<ul style="list-style-type: none"> <li>Symptoms included leaf mosaic or mottling, yellowing, ring spots, stunting, and distortion of leaves, flowers, and fruits are observed [92].</li> </ul>	<ul style="list-style-type: none"> <li>Seeds are to be treated with insecticides like carbosulfon at 30gm or monocrotophos at 5 ml per one kg seed before sowing.</li> <li>Follow crop rotation and maintain soil health management. Grow suitable region wise resistant varieties. Use seeds collected from disease-free plants.</li> <li>Infected plants should be removed and destroyed.</li> <li>Control of white fly by spraying insecticides viz., dimethoate 0.03 per cent or monocrotophos 1.6 per cent or metasystox (0.1 per cent) or triazophos 1.25 ml/l at the initial stage of disease proves effective.</li> <li>Foliar sprays of methyl demeton 2 ml/l also control the vector spread [93].</li> </ul>
<b>Leaf blight</b> <i>Alternaria</i> sp. [37]	<ul style="list-style-type: none"> <li>Early blight is first observed on the plants as small, black lesions mostly on the older foliage.</li> <li>Spots enlarge, and by the time they are one-fourth inch in diameter or larger, concentric rings in a bull's eye pattern can be seen in the center of the diseased area.</li> </ul>	<ul style="list-style-type: none"> <li><i>L. lactis</i> subsp. <i>lactis</i> LABW4 can be used as a prospective agent to control leaf blight disease of <i>Ocimum</i> plant and to increase its medicinal properties [37].</li> </ul>

Disease and its pathogen	Symptom	Management measures
	<ul style="list-style-type: none"> <li>Tissue surrounding the spots may turn yellow.</li> <li>The fungus also infects the fruit, generally through the calyx or stem attachment.</li> <li>Lesions attain considerable size, usually involving nearly the entire fruit; concentric rings are also present on the fruit [37].</li> </ul>	
Gray mold <i>Botrytis cinerea</i> [38]	<ul style="list-style-type: none"> <li>Infected organs produce profuse off-white to gray mycelia covered with dark conidia disseminated in wind currents or by rain splashing from plant to plant.</li> <li>The disease then progresses, killing all leaves and secondary buds leading to the death of the entire plant.</li> <li><i>B. cinerea</i> may also develop on the packed bunches during shipment to market, resulting in rot of the entire package [38].</li> </ul>	<ul style="list-style-type: none"> <li>Cultural methods, particularly reduction of relative humidity and leaf wetness, and reduce black spot and gray mold incidence.</li> <li>Thiram reduces gray mold incidence, which also controls black spot.</li> <li>A formulation based on <i>Trichoderma harzianum</i>, which is active against gray mold, soon will be registered, possibly for basil [38].</li> </ul>

Diseases of *P. longum*.

Disease and its pathogen	Symptoms	Management measures
<b>Anthracnose #</b> <i>Colletotrichum boninense</i>	<ul style="list-style-type: none"> <li>Initially, the lush green color of healthy leaves gradually changed to pale yellow.</li> <li>These symptomatic leaves primarily showed brown concentric ring shaped spots, which later developed yellow halo around it.</li> <li>Subsequently in the later stages, the leaves wilt and abscise.</li> </ul>	<ul style="list-style-type: none"> <li>Spraying Bordeaux mixture 1% or carbendazim + mancozeb 0.1% is recommended.</li> <li>Regulation of shade and adoption of integrated nutrition management practices in the plantation is recommended.</li> <li>Spraying <i>P. fluorescens</i> (FP 7) at 3-week interval [63].</li> </ul>
<b>Leaf spot</b> <i>Botryodiplodia theobromae</i> [ <i>Lasiodiplodia theobromae</i> ] [42]	<ul style="list-style-type: none"> <li>Oval, round to irregular or angular, necrotic, surrounded with the concentric rings.</li> <li>Later, these spots increase in size and coalesce covering larger leaf area with dark brown margin and yellow halo [42].</li> </ul>	<ul style="list-style-type: none"> <li>Collection and removal of fallen leaves.</li> <li>Spraying with Carbendazim 0.1% and Mancozeb 0.25% [42].</li> </ul>
<b>Rot</b> <i>Fusarium pallidoroseum</i> [42]	<ul style="list-style-type: none"> <li>Occur in patches</li> <li>on the Leaves—turn yellow and then dry up slowly</li> <li>Entire plant shows complete drying of the foliage</li> <li>Whitish mold growth is observed [42].</li> </ul>	<ul style="list-style-type: none"> <li>Field sanitation by destruction of infected plant debris.</li> <li>Soil drenching—COC—0.25% and Pre planting treatment of bulbs with benomyl 15% + mancozeb 60% is recommended.</li> <li>Local Bellary, Poona Red Globe, Patna Red, White Large—resistant varieties are recommended [42].</li> </ul>

Disease and its pathogen	Symptoms	Management measures
<b>Cercospora leaf spot</b> <i>Cercospora piperata</i> [43, 94]	<ul style="list-style-type: none"> <li>Round or irregular greyish spots</li> <li>Dark brown or blackish borders appear on older leaves [43, 94].</li> </ul>	<ul style="list-style-type: none"> <li>Remove and destroy the infected plant residues.</li> <li>Spray Mancozeb or Copper oxychloride at 2 kg/ha at the intimation of the disease.</li> <li>Two to three sprays may be given at 15-day interval [43, 94].</li> </ul>

### Diseases of *Tabernaemontana divaricata*.

Disease and its pathogen	Symptoms	Management measures
<b>Anthracnose Leaf blight disease*#</b> <i>Colletotrichum gloeosporioides</i>	<ul style="list-style-type: none"> <li>Primarily, blight start as minute, round, light brown spots, and the spots grow and acquire a round to irregular shape and some spots coalesce.</li> <li>Fully developed spots were water soaked, dark brown to blackish, scattered all over the leaf lamina.</li> <li>The spots were equally visible on lower and upper leaf surfaces.</li> <li>Grey-brown spots made up of concentric markings appear on the leaves and can join together to create large dead patches.</li> </ul>	<ul style="list-style-type: none"> <li>Spraying biocontrol agents like <i>Trichoderma virens</i> chemical fungicides like Benomyl 0.1% (or) Mancozeb 0.2% (or) Carbendazim 0.1% is recommended [52].</li> </ul>
<b>Wilt disease*#</b> <i>Fusarium oxysporum</i>	<ul style="list-style-type: none"> <li><i>Fusarium</i> sp. clogs the vascular tissues in roots and stem restricting water flow causing the foliage to wilt and turn yellow.</li> <li>Chlorosis often appear later in the growing season and are first noticed on the lower (older) leaves.</li> <li>As the disease progresses, the younger leaves will also be affected and the plant eventually dies.</li> </ul>	<ul style="list-style-type: none"> <li>Use Safer Yard &amp; Garden Insect Killer to control many garden insects.</li> <li>Avoid application of excess nitrogen fertilizers that may increase susceptibility to the disease.</li> <li>Deweeding using a weed flamer or natural herbicide.</li> <li>Application of Mycostop (1–2 g/ 100 sq. ft.), biological fungicide that with sufficient watering protect crops against wilt caused by <i>Fusarium</i>.</li> <li>If the disease persists, removal of the entire plant and solarization of the soil before planting again is essential [49].</li> </ul>
<b>Leaf blight disease</b> <i>Phytophthora citrophthora</i> [44]	<ul style="list-style-type: none"> <li>Brown or black spots and patches may be either ragged or circular, with a water soaked or yellow-edged appearance [95].</li> </ul>	<ul style="list-style-type: none"> <li>Use disease-free planting material.</li> <li>Removal of infected leaves when the plant is dry.</li> <li>Leaves that collect around the base of the plant should be raked up and disposed.</li> <li>Overhead irrigation must be avoided.</li> <li>Treatment of the seed with benomyl + thiram 1 g each per kg of seed is recommended [95].</li> </ul>

Disease and its pathogen	Symptoms	Management measures
<b>Wilt disease</b> <i>Fusarium oxysporum f. sp. tabernaemontanae</i> [45]	<ul style="list-style-type: none"> <li><i>Fusarium</i> sp. clogs the vascular tissues in roots and stem restricting water flow causing the foliage to wilt and turn yellow.</li> <li>Chlorosis often appears later in the growing season and is first noticed on the lower (older) leaves.</li> <li>As the disease progresses, the younger leaves will also be affected and the plant eventually dies.</li> </ul>	<ul style="list-style-type: none"> <li>Use Safer Yard &amp; Garden Insect Killer to control many garden insects.</li> <li>Avoid application of excess nitrogen fertilizers that may increase susceptibility to the disease.</li> <li>Deweeding using a weed flamer or natural herbicide.</li> <li>Application of Mycostop (1–2 g/ 100 sq. ft.), biological fungicide that with sufficient watering protect crops against wilt caused by <i>Fusarium</i>.</li> <li>If the disease persists, removal of the entire plant and solarization of the soil before planting again is essential [49].</li> </ul>
<b>Viral infection</b> Plant Virus [96]	<ul style="list-style-type: none"> <li>Disrupts the cell's functionality, outward signs of a viral infection result in a plant disease with symptoms such as abnormal or stunted growth, damaged fruit, discolorations, or spots [96].</li> </ul>	<ul style="list-style-type: none"> <li>Keep vectors such as aphids, leafhoppers, and thrips under control.</li> <li>Viruses can also be introduced by infected pollen or through plant openings (as when pruning).</li> <li>New plants should be checked, as well as tools and existing plants.</li> <li>Use of certified seed that is deemed disease-free is recommended [96].</li> </ul>
<b>Viral disease</b> Tobacco mild green mosaic virus [97]	<ul style="list-style-type: none"> <li>Symptoms on naturally infected <i>T. divaricata</i> are highly varied and include chlorotic ringspots, chlorotic banding, vein clearing, oak-leaf patterns, and mosaic on the younger leaves.</li> <li>During the late winter, after the cold season, the yellow spots usually become necrotic and, as the surrounding tissue expands, the leaves become buckled and distorted.</li> <li>The necrotic zones, in severely affected fully expanded leaves, disintegrate, leaving "shot holes" from which small or large areas of necrotic tissue have fallen out</li> <li>Severely affected leaves wither, leaving the plant naked [97].</li> </ul>	<ul style="list-style-type: none"> <li>Keep vectors such as aphids, leafhoppers, and thrips under control.</li> <li>Viruses can also be introduced by infected pollen or through plant openings (as when pruning).</li> <li>New plants should be checked, as well as tools and existing plants.</li> <li>Use of certified seed that is deemed disease-free is recommended [96, 97].</li> </ul>
<b>Rust disease</b> <i>Uredo manilensis</i> [98]	<ul style="list-style-type: none"> <li>Leaf lesions began as chlorotic flecks that expanded into necrotic spots with orange-to-reddish brown, sub epidermal uredinia.</li> <li>Brown telia developed on the abaxial side of leaves [45].</li> </ul>	<ul style="list-style-type: none"> <li>Select rust-resistant plant varieties when available.</li> <li>Removal and destruction of infected leaves and fallen debris are recommended.</li> <li>Drip irrigation and soaker hoses can be used to help keep leaves dry.</li> <li>Use a slow-release, organic fertilizer on crops and avoid excess nitrogen.</li> </ul>

Disease and its pathogen	Symptoms	Management measures
		<ul style="list-style-type: none"><li>• Apply copper sprays or sulfur powders to prevent infection of susceptible plants. For best results, apply early or at first sign of disease.</li><li>• Effectively treat fungal diseases with SERENADE Garden®.</li><li>• Containing sulfur and pyrethrins.</li><li>• Removal of weeds to improve air circulation is recommended.</li><li>• Use a thick layer of mulch or organic compost to cover the soil after you have raked and cleaned it well.</li><li>• Burn or bag-infected plants after the growing season and do not compost [99].</li></ul>

### 3. Conclusion

The review and our study on the diseases of medicinal plants cultivated in Karnataka endorsed the fact that the medicinal plants are not free from diseases. Among the medicinal plants cultivated in Karnataka maximum of 12 diseases are reported in *H. rosa-sinensis* followed by 10 diseases each in *M. citrifolia* and *O. sanctum*, 7 diseases each in *A. vasica* and *T. divaricata/T. coronaria*, 5 diseases each in *C. horvillianum* and *M. pruriens*, 4 diseases in *P. longum*, and 3 diseases each in *A. calamus* and *G. sylvestre*. It includes 12 diseases that were recorded for the first time in Karnataka and 5 diseases recorded for the first time on the respective host plant. Since medicinal plants are for human consumption and animal welfare the usage of chemical pesticides for the management of diseases should be strictly avoided. The option of the extraction and purification of the secondary metabolites produced by the fungal antagonists for their biocontrol activities against fungal diseases to be explored. The genes conferring to antagonistic effect toward the pathogen could be genetically engineered into medicinal plants thereby producing resistant varieties or transgenic plants that are resistant to diseases. The biocontrol agent *T. virens* can be scaled-up for talc-based formulations and mass production of fungal bio pesticides for controlling fungal diseases of medicinal plants. All such efforts will pave way to produce medicinal plants in a more sustainable eco-friendly way and will prove to be beneficial not only to the producers but also to the consumers.



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