

Diseases of Medicinal and Aromatic Plants and their Management



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Diseases of aromatic grasses and their management

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The medicinal and aromatic plants (MAPs) are contributing a remarkable portion in the economy through their utilization in the formulation of synthetic drugs, herbal dietary supplements, functional foods and beauty products. As the demand is increasing, there is an urgent need to protect these plants from biotic and abiotic factors for optimum propagation and yield. Certain studies confirms the growth of MAPs in some abiotic stresses such as salinity, drought but they are unable to confront the fungal pathogens due to which severe quantitative and qualitative loss takes place.

Distribution of MAPs from from different vegetation has been depicted in Fig. 1. Besides that, MAPs also aids in sustaining livelihood of tribal communities as they gather raw material from wild and sell it in the local market.

In India, total 960 MAPs plant species are used for trading purposes in which around 170 are the most traded species in world herb market with 100 million tons per year of demand. The status of MAPs in India have been briefly reporeted by Chatterji *et al.* (2001) (Fig 2).

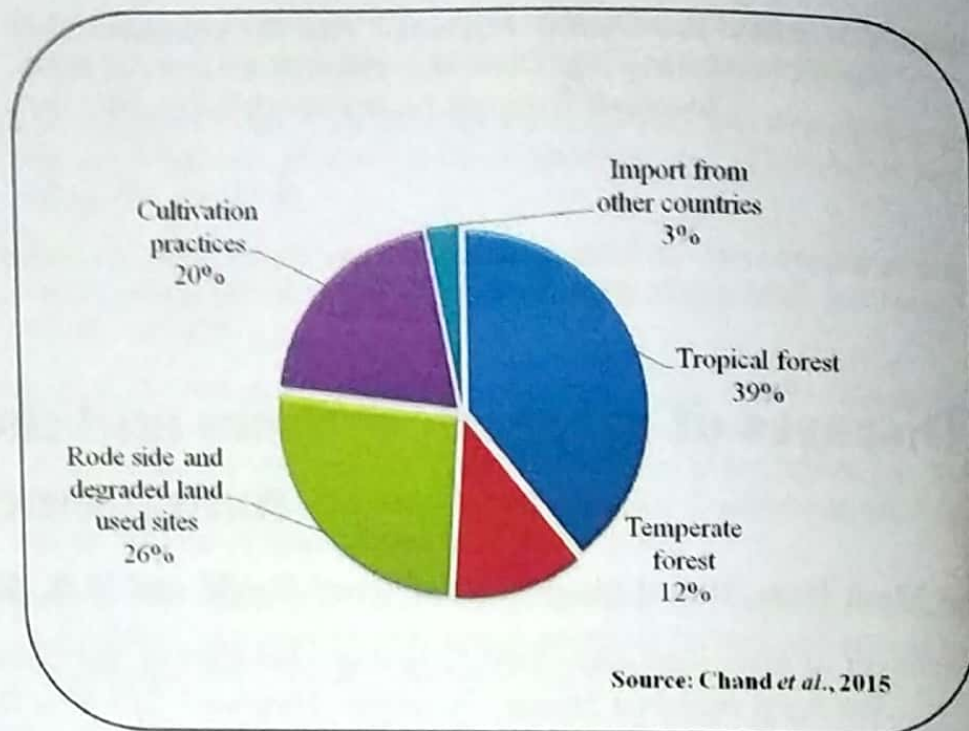


Fig. 1. Distribution of important trading MAPs species obtained by various area

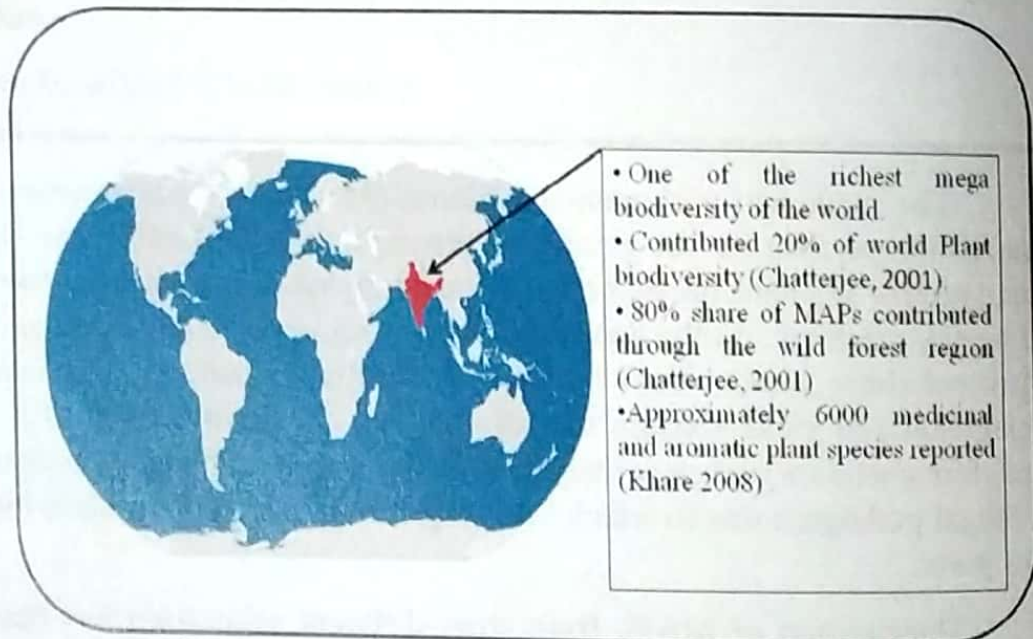


Fig. 2. Overview of MAPs status in India

Aromatic grasses such as lemongrass, palmarosa and vetiver are best suited for salt stressed. There are various biotic and abiotic factors which hinder the successful production of MAPs and causing considerable loss in yield (Singh *et al.*, 2004). Diverse group of fungi exhibit pathogenic invasions on different parts of MAPs causing several aerial, foliage and underground diseases (Ganguly and Pandotra, 1962). Despite of increased demand, their supply is insufficient due to low production and inferior quality as a result of damages done by pests and diseases (Nagpal and

Karki, 2004; Singh *et al.*, 2016). Till date only little attention has been paid to the diseases affecting MAPs. With changes in climate, cultural practices and other control practices, the global production of crops, including MAPs, is under serious challenge (Elad and Pertot, 2014). Now, the need of the scenario is to consider the least known aromatic and medicinal plants and to nominate them as succeeding crops for well being of humankind.

Aromatic grasses belong to *Cymbopogon* species. They are known to suffer from a number of diseases caused by fungi, bacteria, viruses and nematodes. Though many of the diseases have only academic importance, several diseases cause extensive damage to these grasses. Many diseases beside reducing the oil yield affect the quality of the oil as they interfere with the biosynthetic pathway of the oils. The successful cultivation of *Cymbopogon* spp. can only be achieved when the crop remains free from the attack of different pathogens.

The main objective of this chapter is to discuss the current status of MAPs, their need, encountering disease and management of aromatic grasses with examples of four popular grasses and how these measures can be integrated to make profitable and eco-friendly crop cultivation. Integrated pest management (IPM) in medicinal plants aid in developing suitable package of practices for an easy adoption even by small and marginal farmers in India. In future, this strategy which is replicable in other medicinal plants may have perspective by the way of market demand in India and export potential.

1. LEMONGRASS [*Cymbopogon* sp.]

Lemongrass is a widely cultivated tropical perennial herb crop of the family Poaceae. The vernacular name lemongrass is given due to its specific typical lemon like odour from leaves and its essential oil. There are two natives of lemongrass found, in which west Indian native (*Cymbopogon citratus*) belongs to South Asia and while, east Indian native (*C. flexuosus*) associated with northeast and southern part of India, Sri Lanka is known as "Malabar or Cochin grass". The genus *Cymbopogon* is comprises three different species, *C. citratus* (DC.) Stapf., *C. flexuosus* (Nees ex. Stued.) Wats. and *C. pendulus* (Nees ex. Stued.) Wats., a genus of Asian, African, Australian and tropical island. *Cymbopogon citratus* is commonly cultivated for culinary and medicinal purposes because of its scent, resembles with lemons (*Citrus limon*).

Lemongrass is widely used as a culinary herb in Asian cuisines

and also as medicinal herb in India. It has a subtle citrus flavor and can be dried and powdered, or used as fresh. Most economical product of lemongrass is "Lemongrass oil", which is derived from the leaves and have a typical lemon like odour. It is an essential aromatic oil, which is commercially worldwide known as "Cochin oil" due to its most shipment from Cochin port. In India, Kerala has leadership, in terms of production and export of lemongrass oil. Globally, the annual production of lemongrass oil is approximately 1000 metric tons, which come from 16,000 ha land area. In India annual production is approximately 300 to 350 metric tons and is cultivated on 3000 ha land area (<http://nhb.gov.in>). It also has pesticidal and preservative properties. It is also used as an additive to tea, and in preparations such as *kadha*, which is a traditional herbal brew used in Ayurvedic medicine. Lemongrass leaves contain essential oil, which have an active compound known as citral. This citral compound used for the preparation of cosmetic, perfumes, flavours (alpha-Ionone) and synthetic vitamin A (beta-Ionone).

Lemongrass is attacked by various diseases, among which, following are of major importance (Table 1).

Table 1. Major diseases of Lemongrass

Disease	Causal agent
Long smut	<i>Tolyposporium christensenii</i> , <i>Ustilago andropogonis</i>
Red leaf spot	<i>Colletotrichum graminicola</i>
Leaf blight	<i>Curvularia andropogonis</i> , <i>Rhizoctonia solani</i>
Rust	<i>Puccinia nakarishikii</i>
Grassy shoot	<i>Balansia sclerotica</i>
Eye spot (Leaf spot)	<i>Drechslera sacchari</i> , <i>H. leucostylum</i> , <i>D. victoria</i> and <i>D. helm</i>
Leaf blotch	<i>C. verruciformis</i>
Root rot	<i>Botrydiplodia theobromae</i>
Leaf spot and clump rot	<i>Fusarium equiseti</i> , <i>F. verticillium</i>

1.1 Long smut

The disease is caused by both *Tolyposporium christensenii* and *Ustilago andropogoni*. The flowers in the inflorescence are transformed into, slender, tubular to conical cream-coloured sori. These sori flake off at maturity, starting from the tip and hang in shreds.

Disease management: Spraying of Dithane Z-78 (@ 0.2%) just before flower initiation and treating the seeds with Cersan (0.2%) or Emisan-6@ 1g/kg of seed before sowing, effectively manage the disease.

1.2 Red leaf spot

The main causal agent of the disease is *Colletotrichum graminicola*. The typical symptom of the disease is formation of brown spot with concentric rings in the centre, which usually appear on the lower surface of leaves. The spots may also be formed on midrib and leaf sheath and later merge to form bigger patches.

Disease management : The disease can effectively be managed by application of carbendazim (0.1%) just after the emergence of the disease at an interval of 20 days. However, 3 sprays of Dithane M-45 (0.2%) at an interval of 10-12 days is also recommended for disease management.

1.3 Leaf blight

The disease is caused by both *Curvularia andropogonis* and *Rhizoctonia solani*. The disease appears in the form of minute, circular, reddish brown spots mostly 1-2 x 0.5-1 mm in size on leaf tip and margins. The spots later coalesce to form elongated reddish brown necrotic lesions, which results in premature drying of leaves (Fig. 3). Infection usually occur on older leaves (Thakur and Hussain, 1975, Chauhan and Singh, 1981).

Disease management: The diseases can effectively be managed by spraying Dithane Z-78 (0.2%) with an interval of 10-12 days or Copper oxychloride (0.3%).



Fig. 3. Healthy (A) and (B) blighted leaf symptoms of lemongrass

1.4 Rust

The disease was first reported by Bandara (1981) from Sri Lanka. Later disease was also reported from California (Koike, 1999) and USA (Gardner, 1985).

The disease is caused by *Puccinia nakarishikii*. The pathogen appears as golden brown pustules on the leaf laminae and occasionally on sheaths. The symptoms are in the form of discrete, linear brown uredinia appear on the lower surface of the leaves associated with chlorotic streaks. The lesions are circular to elongate, sparsely scattered and 1-30 mm in length and 1-3 mm in width (Koike and Molinar, 1999). The lesions become pustular later and generally confined to lower surface (Fig. 4). The main negative effects of lemongrass rust on the plant are, defoliation, poor leaf and low oil yield (Gardner, 1985). The rust disease is normally not fatal to lemongrass plants, even though defoliation may be severe.

Disease management: The disease can effectively be managed by spraying of Dithane Z-78 (0.2%) or Copper oxychloride (0.3%) or Plantavax (0.1%) at intervals of 10-12 days. Identification of resistant and susceptible alleles for reaction to the rust pathogen have been reported by Singh *et al.* (1999), which facilitate in management of pathogen.



Fig. 4. A) Rust infection on lemongrass, B) Close up of rust pustules on lemongrass leaf

1.5 Little leaf or grassy shoot

The disease is caused by *Balansia sclerotica*. The characteristic symptoms are in the form of stunting and little leaf formation in place of normal inflorescence. It is one of the most severe diseases of lemongrass and was first observed on var. Kerala during 1983 (Gupta *et al.*, 2000). The infection leads to stunting, little leaf formation and bushy appearance

of infected plants (Janardhanan *et al.*, 1991). The conidial stage of the pathogen, EP hells has also been observed on leaves of infected plants.

Disease management: The disease can be managed by spraying Dithane Z-78 (0.3%) prior to flowering at an interval of 10-12 days. Fresh seedlings should be used for plantation.

1.6 Leaf spot

This disease is caused by various fungi viz., *Drechslera sacchari* (Butler), *H. leucostylum*, *D. victoria* and *D. helm* and have been reported from various lemongrass cultivating regions of India. The characteristic symptom of this disease is production of brown colour spots with dark purple borders and pale centres in oval shapes. In severe condition these spots turn in large necrotic spots.

Disease management: Spraying of systemic fungicides *i.e.* Mancozeb (@ 0.2 to 0.3%) at 15 days interval is found effective for disease management.

1.7 Leaf blotch

Leaf blotch disease in lemongrass was reported by Barua and Bordoloi (1983). The causal agent of this disease is *C. verruciformis*. In Indian context, *Curvularia andropogonis* causes severe disease during rainy season (Alam *et al.*, 1997). The pathogen produces characteristic symptom on leaves as circular, minute, reddish-brown spots on the leaf tips and margins. During favourable environmental conditions the spots increase in the size and space with necrotic appearance which leads to premature dying of leaves. The older leaves of plants have more susceptibility as compared to young leaves. Spraying of systemic fungicides *i.e.* Mancozeb (@ 0.2 to 0.3%) between 15 days interval is found effective for managing the disease.

2. PALMAROSA [*Cymbopogon martini*]

Cymbopogon martini is a species of grass in the genus *Cymbopogon* (lemongrasses) native to India and Indochina, but widely cultivated in many places for its aromatic oil. It is best known by the common name palmarosa (*palm rose*) as it produces rose like fragrance. In other regions, some vernacular names also used for it *i.e.* moshia, tikhadi, gingergrass, rosha and rosha grass and Indian geranium. The plant contains high value of essential oil, which has geraniol (75-90%) as active compound. This compound is used in the perfumery, cosmetics, traditional medicines and household industries. Palmarosa oil has been found as an effective and ecofriendly insect repellent for store grain pests, mosquito, etc. It also

shows an antihelminthic and antifungal properties. It grows as wild plant species in India. In some regions, it is found more prominent *i.e.* Maharashtra, Madhya Pradesh and Andhra Pradesh. It produces approximately 15 metric tonnes of essential oil annually. Major diseases are listed in table 2.

Table 2. Major diseases of Palmarosa

Disease	Causal agent
Red leaf spot	<i>Colletotrichum graminicola</i>
Leaf blight	<i>Curvularia andropogonis</i> , <i>Ellisiella caudata</i>
Grassy shoot	<i>Balansia sclerotica</i>
Long smut	<i>Tolyposporium christensenii</i>
Curvularia blotch	<i>C. andrographis</i> , <i>C. trifolli</i>

2.1 Red leaf spot

The disease is caused by *Colletotrichum graminicola* and prevalent in all the Palmarosa growing regions and appears during rainy season. Under warm and humid conditions, the disease spreads rapidly and may cause up to 35 per cent reduction in the oil production. The disease perpetuates on the left-out stumps and stubbles in the field. The symptoms can be seen as small brownish spots, scattered all over the ventral surface of the leaves. The disease also colonizes the leaf sheaths and midrib (Thakur and Hussain, 1975). Later they enlarge and get turned into brown patches. On the necrotic lesions of the leaf, black fruiting bodies of the pathogen can be seen.

Disease management: The disease can effectively be managed by applying two sprays of Bavistin (0.1%) just after the first appearance of the disease at an interval of 20 days. In addition to it, spraying of Dithane M-45 (0.3%) at an interval of 10-20 days has also been found to manage the disease effectively.

2.2 Leaf blight

It is a very serious disease of Palmarosa, which may lead to epiphytotic in palmarosa growing zones. The disease leads to an average loss of 32 per cent in oil content and 17.8 per cent geraniol in the oil. The typical symptoms of the disease are formation of circular and reddish brown spots on leaf margin and tips (Janardhanan *et al.*, 1980). In addition to *Colletotrichum graminicola*, *Curvularia andropogonis* and *E. caudata* have also been found to be associated with the disease. The disease is usually

prominent during rainy season and appears in the form of small greenish brown spots scattered on the leaf lamina (Fig 5). Later, the spots enlarge and coalesce, resulting in severe blight symptoms and causes sever losses in essential oil production and geraninol content. In the mature necrotic lesions, profuse spore mass of brownish colour are produced by the pathogen. The leaf sheath also gets affected. The disease usualluy perpetuates through plant debris or self sown plants.

Disease management: The disease can effectively be managed by application the foliar spary of broad spectrum fungicide *i.e.* chlorothalonil or Captafol (@ 0.3%) or Dithane Z-78 (0.2%) at 15 days interval.



Fig. 5. Leaf blight of Palmarosa

2.3 Little leaf or grassy shoot

The causal agent of the disease is *Balansia sclerotica* (Pat.) Hohnel (Janardhanan *et al.*, 1991). The disease attacks the floral parts and consequently the oil yield and seed production is adversely affected. The characteristic symptoms are, stunting and formation of little leaf on the plants in place of normal inflorescence. The conidial stage of the pathogen is also usually seen on leaves and infloroscense of the infected leaves, but it's pathogenicity on the crop has not been established.

Disease management: For effective management of the disease, Dithane Z-78 (0.3%) should be applied before flowering stage at an interval of 10-12 days.

2.4 Smut

This is an inflorescence borne disease, adversely affects the oil yield and seed production. The disease is caused by *Tolyposporium christensenii*. The symptoms are characterized by the transformation of seed into the smut sori, which are slightly long covered by dull yellow membrane (Fig 6).

Disease management: The disease can be managed by treating seeds with organomercurial fungicides before sowing in the nursery. Spraying of Dithane Z-78 (0.3%) just at the time of flower initiation has also proved to be effective in managing the disease.



Fig. 6. Healthy (left) and smut affected (right) inflorescence of palmarosa

2.5 Curvularia blotch

This disease is prevalent in palmarosa growing areas of U.P., M.P., Bihar, Karnataka and J&K and is caused by *Curvularia andrographis* and *C. trifolii*. Disease occurs in epiphytotic form during August and October. Small eye shaped, orange/brick red necrotic lesions appear and coalesce together resulting in premature drying of leaves.

Disease management: Foliar application of Mancozeb (@ 0.3%) at 15 days interval at initial stages of infection, effectively manage the disease.

Leaf spot, grey blight and clump rot caused by *C. verruciformis*, *Pestalotiopsis mangiferae* and *Drechslera colocasia* respectively are also diseases of palmarosa but are of minor importance.

3. JAVA CITRONELLA [*Cymbopogon winterianus*]

Java citronella is originally from Sri Lanka and is also widely grown in India, Guatemala, Honduras, Malaysia and several other countries. *Cymbopogon winterianus* is the source of the high quality java citronella essential oil, whereas, the other variety of citronella, *C. nardus* is the source of the Ceylon essential oil, but it is considered inferior in quality to the java citronella oil.

Java citronella has the higher alcohol content among the citronella oils. With its clear lemon type scent, it is used for preparing perfumes. This plant is used for a multitude for various purposes as in food flavoring, mosquito repellents, perfumery, deodorants, soaps and cosmetics industries. Chemicals like the geraniol, hydroxycitronellol and citroneliol are some components of the java citronella used in the perfumery industry. Geraniol and citronellol function as antiseptics and are used in disinfectants. The java citronella with its lemony scent makes the oil highly useful in the aromatherapy. It's aromatic and medicinal properties have rendered the java citronella a highly useful plant. The java citronella oil is obtained from the leaves and stem of the plant. The oil contains the citronellal, geraniol and hydroxy citronellol, which are highly useful in perfume making. With regard to its medicinal properties, it is useful in treating fevers, rheumatism, minor infections, stomach related and menstrual problems. The java citronella oil is used for making insect repellents. The oil is also regarded as a great stimulant, with its fresh and invigorating scent. Having astringent properties, it can be used to improve upon an oily complexion skin. It is useful in treating insomnia. Aromatherapy recognizes its utility and benefits with regard to the immune system, nervous system as well as for skin.

Many diseases affect the commercial cultivation of Java citronella (Table 3), including leaf blight caused by *Curvularia andropogonis* (Alam and Husain, 1976; Alam *et al.*, 1983), *Drechslera australiensis* (Ramaiah and Chandrashekar, 1981), purple leaf spot caused by *Colletotrichum graminicola* (Sarwar *et al.*, 1980), lethal yellowing caused by *Pythium aphanidematum* (Alam *et al.*, 1992), collar rot and wilt caused by *Fusarium monilifome* (Alam *et al.*, 1994).

Table 3. Major diseases of Java citronella

Disease	Causal agent
Leaf blight	<i>Curvularia andropogonis</i> , <i>Drechslera australiensis</i>
Sheath rot and banded leaf spot	<i>Rhizoctonia solani</i>

Collar rot and wilt	<i>Fusarium moniliforme</i>
Leaf blotch	<i>Curvularia andropogonis</i>
Lethal yellowing	<i>Pythium aphanidermatum</i> , <i>Fusarium moniliforme</i>
Leaf crinkling	Unknown etiology
Rust	<i>Puccinia cymbopogonis</i>
Mosaic	Sugarcane mosaic virus
Leaf spot	<i>Phyllosticta cymbopogonis</i> , <i>Melliola cymbopogonis</i>

3.1 Leaf blight

The disease is caused by both *Curvularia andropogonis* and *Drechslera australiensis*. Two different types of symptoms viz., leaf blight and leaf spot appear on the leaves. Initially, leaf blight symptoms appear as small, circular to ovoid reddish brown lesions on the leaf lamina, which extend and coalesce resulting into fairly big size longitudinal necrotic lesions. In the later stage, these longitudinal necrotic lesions coalesce and leaves gradually dry up. In case of leaf spot, initial symptom appear as minute, yellowish brown spots, which enlarge and spots coalesce, but lesions produced are not as elongated as leaf blight symptom. The disease drastically reduces both the quantity and quality of oil.

Disease management: The disease can be managed effectively by spraying of Mancozeb (0.1%) at an interval of 15 days.

3.2 Sheath rot and banded leaf spot

The disease was first reported by Singh *et al.* (1997) from Tarai region of Uttar Pradesh and the causal agent was reported as *Rhizoctonia solani*. The symptoms which develop on leaves and sheaths are characteristic concentric spots that cover large areas of sheaths and leaves. Discoloured lesions first appear on the leaf sheaths near the soil surface and gradually spread around the sheath and inward into the sheath tissues. Rotting remain restricted to the lower side of the plant and in advanced cases a weft of greyish fungal mycelium develop within the sheath. Numerous small, round to irregular, dark-brown sclerotia develop over the mycelial mat and inside the leaf sheath (Fig 7). Early infection result in complete killing of the plant. The disease is very severe in some fields (5-35% plants affected), where stagnant water prevail for a long period.



Fig. 7. A) Typical sheath rot symptom by *R. solani* (arrow indicating sclerotia formed on leaf sheath); B) Banded leaf spot and blight symptoms on leaves

Disease management: The disease can successfully be managed by application of Hexaconazole 75% WG @ 100 mg/ lit. First spray at the time of disease appearance and 2nd spray 15 days later. In addition to it, soil and seed treatment with *T. harzianum* is also effective in reduction of the disease.

3.3 Collar rot and wilt

Alam *et al.* (1994) reported the collar rot and wilt disease of Java citronella by *Fusarium moniliforme*. In the initial stages of infection, the plants produce crinkled, curled and chlorotic leaves. At advanced stages, the plants develop collar rot resulting in drying and death of infected plants. *Rhizoctonia solani* has also been reported to cause collar rot of citronella (Singh *et al.*, 1997).

Disease management: Foliar application of Mancozeb (@0.3%) at 15 days interval at initial stages of infection effectively manage the disease.

3.4 Leaf blotch

Leaf blotch is caused by *Curvularia andropogonis*. The symptoms of the disease appear as small pink coloured spots of 1-2 x 8.5-1 mm size, which are scattered on halli blade in initial stages (Alam and Husain, 1976). Later, the spots coalesce resulting in blotch symptoms. A loss of more than 31 per cent oil and 11.8 per cent geraniol content has been reported due to leaf blotch disease. This may be due to the production of a toxin by the pathogen (Alam *et al.*, 1997). *C. andropogonis* infected leaves of Java citronella show discoloration due to changes in phenol metabolism of host. At later stages typical browning symptoms are observed on leaves. The young seedlings may be attacked before emergence at any point, from which the infection spreads rapidly and the seedling is over run by the fungus

and dies (pre-emergence damping-off). Emerged seedlings, usually get attacked at the roots or stem at just below the soil line. The infected areas become water soaked and discolored and they soon collapse from basal part of the seedling, stem becoming softer and much thinner than the unaffected parts of the plant. In older plants, the pathogens may kill rootlets or induce lesions on the roots and stems. The lesions result in plants becoming stunted and ultimately wither and die.

Disease management: The disease can be managed effectively by spraying of Mancozeb (0.1%) and Benlate (0.1%) at an interval of 15 days. Also, drenching of 0.1% Dithane M-45 is recommended for managing damping off.

3.5 Lethal yellowing

The casual organism of lethal yellowing is *Pythium aphanidermatum*. The roots of infected plants show marked discoloration and the cortical region is completely disintegrated and is cut off from the vascular tissues. In addition to *Pythium*, *Fusarium moniliforme* has also been found to be associated with the disease (Alam *et al.*, 1994; Carrea, 1969). The main characteristic difference between the two pathogens is that in case of latter, symptoms usually appear in form of patches.

Disease management: Use of healthy slips and treatment with Ridomil (0.1%) or Thiram (0.3%) prior to planting helps in reducing the disease incidence. In addition to it, application of biocontrol agents such as *Trichoderma* and *Gliocladium* has been found to be effective in disease suppression.

3.6 Leaf crinkling

In this disease the young leaves get twisted and crinkled. The etiology of the disease is not been clear till date. This disease is more prevalent in summer season.

Disease management: For proper management of the disease, the affected plants are sprayed with monocrotophos (0.1%) at weekly interval. Application of manure also facilitates in managing the disease. Monocrotophos may be sprayed from February onwards at 15-20 days intervals. In addition to it, application of Thimet @ 7 kg per hectare is also recommended for successful management of the disease.

3.7 Rust

The rust of Java citronella has been reported from various regions viz., New Guinea (Cummins, 1971), India (Goswami and Singh, 1973;

Singh *et al.*, 1999), Hawaii (Gardener, 1985) and New Zealand (Mckenzie and Dingley, 1996). The causal agent of the disease is *Puccinia cymbopogonis*. The pathogen forms golden brown pustules on leaf sheath with circular and elongate lesions. On rupture of epidermis, dense golden mass of brown spores are released. The pustules are generally confined to the lower surface. The lesions later coalesce to cover large areas, which results in premature death of young leaves.

Disease management: The disease can effectively be managed by spraying of Dithane Z-78 (0.2%) or Plantvax (0.1%) or Copper oxychloride (0.3%) at an interval of 10-12 days.

3.8 Other minor diseases

In addition to the above mention diseases, there are several other pathogens, which cause leaf spots of minor occurrence. They are *Colletotrichum graminicola*, *Periconia byssoides*, *Alternaria alternata*, *Cladosporium herbarum*, *Spegazzinia lessarthra*, *Arthrobotryum cymbopogonis* etc.

Disease management: Treatment of terminal cuttings with Carbendazim solution (1 g/l) before plantation is an effective protection against fungal pathogens.

4. KHUS [*Vetiveria zizanioides*]

Khus is a widely distributed plant in South Asia such as Burma, Ceylon and also found in South Africa. It (Vetiver) is a widely known aromatic grass native to Indian sub continent. The plant has been harvested for 3000 years for its medicinal and economical use. The plant is also native to India, and it is mostly found in North India. The western name of the plant is derived from the Tamil word *Vettiver* meaning "hatched up". The plant grows well in riverside, rich marshy soil in plains and lower hills. In North India, it is cultivated in Rajasthan, Punjab, and Uttar Pradesh, whereas, in South India, it is grown in Kerala, Tamil Nadu, Andhra Pradesh and Karnataka. Bharatpur is the biggest khus oil industry in India.

The most important chemical constituents present in the plant are benzoic acid, vetiverol, furfurole and vetivone. The spongy and aromatic roots are being used for preparing goods *viz.*, mats, fans, door-screens *etc.* The extreme purity of the oil makes it fit for consumption and also to enhance flavor in summer sharbats, ice creams and digestives. The roots are rich source of fragrant volatile oil, which has got a high demand in both national and international market for its use in cosmetics, perfume, toiletries and allied industries.

Khus is mainly known to be affected by leaf spots and blight disease (Table 4), which remarkably limits its yield both on quantity and quality basis.

Table 4. Major diseases of Khus

Disease	Causal agent
Curvularia leaf spot and blight	<i>Curvularia trifoli</i>
Leaf spot and blight	<i>Phoma herbarum</i>
Leaf spot	<i>Gloeospora sorghi</i> , <i>Helminthosporium</i> sp.
Cyst	<i>Heterodera zae</i>

4.1 Curvularia leaf spot and blight

Leaf spot and blight caused by *Curvularia trifoli* is one of the major diseases of khus (Sarwar, 1969). The infected leaves show tan to dark spots, which later turn black in colour. The infected plants become yellow and ultimately dry out.

Disease management: The disease can effectively be managed by 2-3 spraying of Copper based fungicide (0.3%) having 50% metallic Copper @ 120-160 gallon/ha or drenching with copper oxychloride or Bordeaux mixture (0.1%).

4.2 Leaf spot and blight

The disease was first time reported by Zhang *et al.* (2017) from China. The causal agent of the disease is *Phoma herbarum*. The initial symptoms were round or irregular dark brown spots that become fusiform or irregular with reddish-brown margins. When ample moisture is present, lesions coalesce resulting in blight. Disease resulted in a reduction in the number of leaves and branches and at its peak, entire plants gets blighted.

4.3 Leaf spot

This disease is caused by both *Gleosporium sorghi* and *Helminthosporium* sp. The first report of the causal agent as *G. sorghi* was by Puranik and Suryanarayanan (1966). The main characteristic symptoms of the disease is appearance of small, diffused spots on leaf margins or may be scattered throughout the leaf and sheath (Jain 1995). The spots are oblong, oval and brown in colour.

Disease management: Application of Copper based fungicides @ 0.3% effectively controls the disease.

4.4 Nematode infestation

Lal and Mathur (1982) reported the nematode infestation of roots of khus plant by *Heterodera zaeae*. The symptoms involve development of cyst on the roots.

Disease management: The disease can be managed through application of leaf extract of botanicals such as *Tagetes erecta*.

The four above mentioned aromatic grasses are well known for their aromatic oil which has got multifarious action. Aromatic plants not only provides raw material for drugs, but also play a key role in manufacturing of cosmetics, dietary supplements, functional foods and aromatic oils. So, the biotic invasion of such plants in the form of disease is a major constraint in deriving superior plant products. It has also been estimated that with the fast climate changing scenario, resurgence of both pest diseases is likely to get elevated. Plant disease management strategies are usually designed for cereals, pulses, oilseeds and vegetables while a very modest attention is being paid in management of MAPs. Thus, management of diseases of MAPs is of utmost importance after evaluating their enormous benefits and the incurring losses due to disease. An integrated disease management strategy should be developed emphasizing the eco-friendly management practices for leading MAPs disease free, which itself are remedy of very serious ailments.

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