7 Diseases of cardamom (fungal, bacterial and nematode diseases)

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Cardamom is affected by a number of diseases caused by various pathogenic fungi, bacteria and nematodes, in main plantations as well as in nurseries. As many as 25 fungal, bacterial and nematodal diseases have been reported till date. Based on severity, spread and extent of damage, these are grouped as major and minor diseases occurring in the main plantations and in nurseries. Among them, four major diseases in plantations and two major diseases in nurseries seriously affect the plant and cause considerable crop damage. Major diseases such as the rots, leaf blights and nematode infestation are often wide spread and lead to crop losses while minor diseases generally affect the foliage and occur in minor proportions. Diseases alone can cause up to 50 per cent crop loss if not managed properly.

1 MAJOR DISEASES

Diseases such as the Capsule rot ('Azhukal') and the Rhizome rot are comparatively severe and affect crop production while the widespread leaf blight and nematode infections, lead to weakening of plants, and subsequent reduction in productivity. The major diseases occurring in plantations are listed in Table 7.1.

1.1 Capsule rot (*Azhukal* disease)

Capsule rot, popularly known as *Azhukal* in the local (Malayalam) language means rotting, is perhaps the most serious fungal disease of cardamom. Menon *et al.* (1972) reported it for the first time from plantations of Idukki district in Kerala State.

1.1.1 History and distribution

Initially, rotting symptoms were observed on the fruits or the capsules only and accordingly it was named as capsule rot. Later the disease symptoms have been observed in several other plant parts. It is still a major problem affecting cardamom cultivation in Idukki and Wynad districts of Kerala and Anamalai hills in Tamil Nadu (Thomas *et al.*, 1989). The disease makes its appearance after the onset of southwest monsoon rains. However, capsule rot is not observed in low rainfall areas in Tamil Nadu. Cardamom plantations in Karnataka state receive a great deal of monsoon rains but this disease has not yet been found to occur in this geographical locality.

Table 7.1 Major fungal and nematode diseases of cardamom in plantations

Diseases	*Parts affected*	*Causal agents*
Capsule rot (*Azhukal*)	Capsules, leaves, panicles and young tillers	*Phytophthora meadii* *P. nicotianae* var. *nicotianae*
Rhizome rot (Clump rot)	Rhizomes, tillers and roots	*Pythium vexans, Rhizoctonia solani, Fusarium oxysporum*
'Chenthal' (Leaf blight)	Leaves	*Colletotrichum gloeosporioides*
Root knot nematode	Roots, leaves	*Meloidogyne incognita*

1.1.2 *Symptoms and damage*

Disease symptoms develop mainly on the capsules, young leaves, panicles and tender shoots. The first visible symptom appears as discoloured water-soaked lesions on young leaves or capsules. These lesions enlarge and the affected portions decay. Infection takes place on capsules or tender leaves simultaneously or first on capsules followed by foliar infection (Thomas *et al.*, 1991a). When foliage infection occurs, water-soaked lesions appear on leaf tips or leaf margins which later enlarge and adjacent lesions coalesce to form large patches. Immature unopened leaves fail to unfurl following infection. As the disease advances, the lesion areas turn necrotic, the leaves decay and shrivel and finally they give a shredded appearance (Fig. 7.1a). Infected capsules show water soaked discoloured areas; they turn brownish and later such capsules decay and drop off (Fig. 7.1b). Such rotten capsules emit a foul smell. Capsules of all ages are susceptible to infection. However, young capsules are seriously affected by the disease.

During favourable climatic conditions the disease is aggravated and infection extends to panicles and tender shoots also. In extreme cases the whole panicle or the whole psuedo-stem decays completely. In such cases the rotting extends to underground rhizomes also. The root system of such plants gets decayed and the entire plant collapses. Nair (1979) described similar symptoms and observed that the disease severity is uniform in the three major cardamom types, viz. *Mysore, Vazhukka* and *Malabar*. Nambiar and Sarma (1976), who studied the disease earlier, have reported a crop loss of 30 per cent. However later it has been shown that as high as 40 per cent crop loss can occur in severely disease-affected plantations (Anonymous, 1989a).

1.1.3 *Causal organism*

Menon *et al.* (1972) first reported *Phytophthora* sp. as the causal organism. Thankamma and Pillai (1973) identified it as *P. nicotianae* Brede de Haan var. *nicotianae* Waterhouse and as *P. palmivora* Butler (Radha and Joseph, 1974). Nambiar and Sarma (1976) reported the association of *Pythium vexans* and a *Fusarium* sp. along with *Phytophthora* sp. However later studies by Nair (1979) showed that *P. nicotianae* var. *nicotianae* is the causative organism which could be successfully isolated from all infected plant parts. *P. meadii* Mc Rae has also been widely observed as causing *Azhukal* disease (Anonymous, 1986). Host-range studies show that *P. palmivora* from coconut and rubber is infective to cardamom (Radha and Joseph, 1974), *P. palmivora* from cardamom is infective to cocoa, coconut, arecanut, black pepper and rubber (Manomohanan and Abi Cheeran,

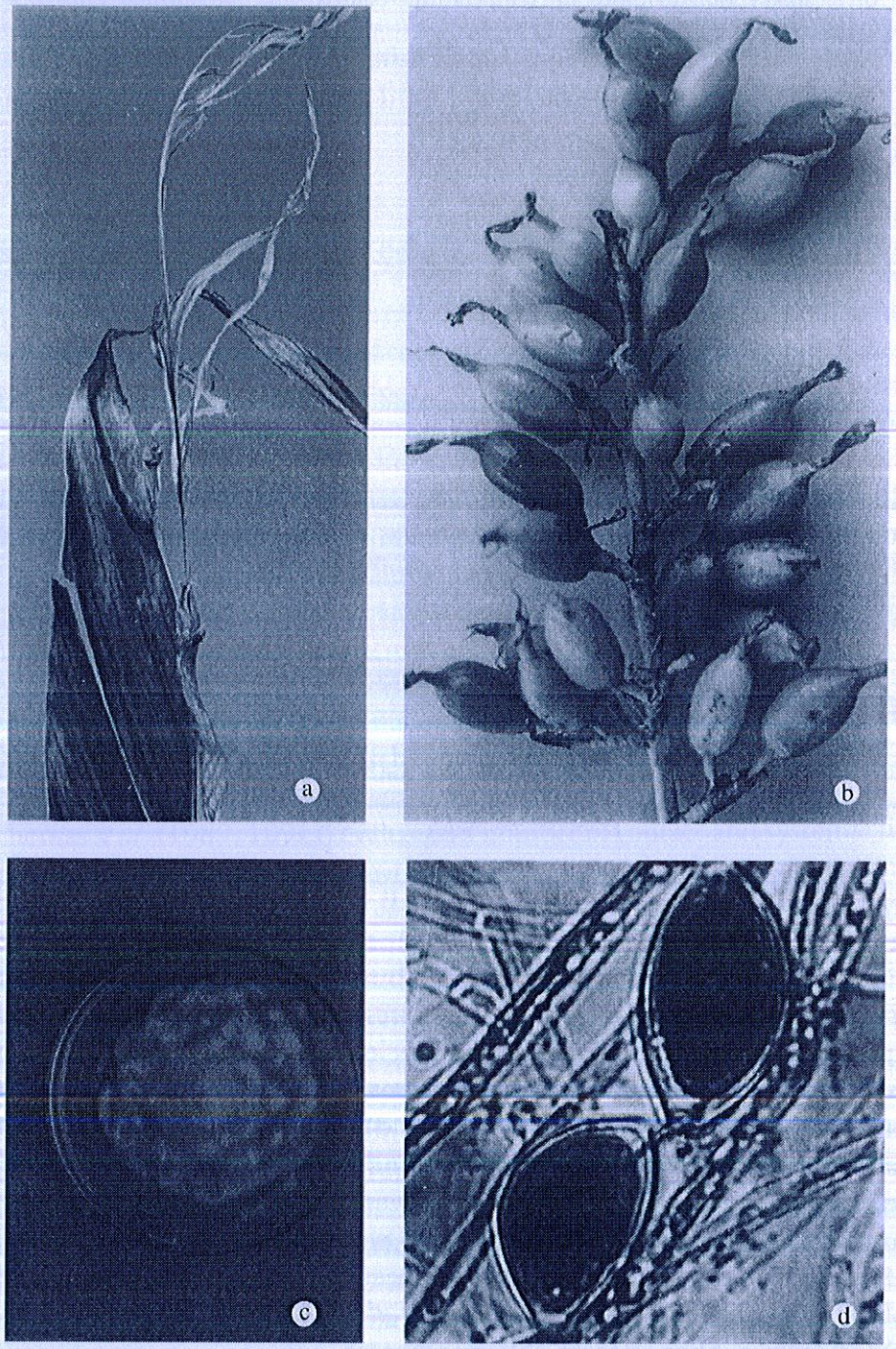

Figure 7.1 *Azhukal* disease symptoms: (a) rotting and shredding of leaves; (b) rotting of capsules; (c) *Phytophthora meadii* in carrot agar medium; (d) Sporangia of *P. meadii*.

1984), and *P. meadii* from cardamom is infective to cocoa, black pepper and citrus (Sastry and Hedge, 1987, 1989). Nair (1979) observed that wild Colocasia plants in cardamom plantations serve as collateral hosts for *P. nicotianae* var. *nicotianae*.

Seven different isolates of *P. meadii* from various localities causing infection on capsules, leafy stems, rhizomes and leaves of cardamom have been characterized based on their culture characters, sporangial morphology, sexual behaviour and pathogenic

Table 7.2 Grouping of *P. meadii* isolates based on temperature requirements for optimal growth and sporangial characters

Isolates		*Opt. temp.* °C	*Length* μm	*Breadth* μm	*L/B ratio*	*Pedicel length* μm
*I**	*II***					
	159	20	45.96 (24.8–66.9)	24.96 (19.8–29.7)	1.83 (1.1–2.4)	32.86 (19.9–26.8)
209	–	20	34.72 (19.8–42.1)	20.01 (12.4–22.3)	1.75 (1.3–2.2)	6.51 (2.4–12.4)
–	239	24–28	40.82 (32.2–47.1)	22.01 (17.3–22.3)	1.82 (1.4–2.0)	35.22 (12.4–71.4)
–	240	24–28	46.55 (27.2–62.0)	22.51 (17.3–29.7)	2.09 (1.5–2.3)	40.92 (24.8–94.4)
241	–	24–28	33.57 (24.8–49.6)	19.84 (14.8–24.8)	1.80 (11.3–2.2)	20.90 (19.9–37.2)
–	244	32	33.57 (32.2–54.5)	19.84 (17.3–32.2)	1.80 (1.3–2.2)	20.90 (0.0–2.4)
252	–	32	34.72 (29.2–39.6)	17.69 (14.8–22.3)	1.85 (1.3–2.3)	22.87 (4.9–39.6)

Notes
* Sporangial length 33.57–34.72 μm; Sporangial breadth 17.69–20.01 μm.
** Sporangial length 40.82–46.55 μm; Sporangial breadth 20.01–24.96 μm.

virulence (Anonymous, 1989a). These seven isolates fall in two groups in their requirement for optimum temperature for growth and mean sporangial dimensions (Table 7.2). In single cultures no oospores are formed but when paired with A1 mating type, five of them readily formed sex organs and oospores confirming that most of these isolates belong to the A2 mating type. The type species of *P. meadii* from cardamom readily grows on carrot agar and sporulates; the sporangia are caducous, ellipsoid, papillate and with short to medium pedicels (Fig. 7.1c,d). Although these seven isolates morphologically differ slightly, all of them were found to be pathologically virulent types. The pathogen, *P. nicotianae* var. *nicotianae*, survives in the soil and plant debris in the form of chlamydospores and in moist soil upto 48 weeks (Nair, 1979). However in the case of *P. meadii* no chlamydospore formation has been observed either in moist field soils or under laboratory conditions. Dantanarayana *et al.* (1984) also have reported the inability of *P. meadii* from rubber to form chlamydospores.

1.1.4 Epidemiology

Nair (1979) studied the epidemiology of *Azhukal* disease. He observed that high disease incidence is correlated to high and continuous rainfall during the monsoon seasons.

The number of *Phytophthora* propagules increases in soil and results in heavy disease incidence coinciding with high soil moisture levels (34.3–37.6 per cent), low temperatures (20.4–21.3 °C), high relative humidity (83–90.6 per cent) and high rain fall (320–400 mm) during the months of June to August (Nair and Menon, 1980). Presence of high level of soil inoculum, thick shade in the plantation, close spacing, high soil

moisture, water logging together with favourable weather conditions such as high relative humidity, continuous rainfall and low temperature predispose the plants to *P. meadii* infection. Nair (1979) also found that the density of *Phytophthora* population reduces with increasing distance from plant base and from soil surface.

1.1.5 Disease management

As the outbreak of disease is during the monsoon season, disease management measures have to be initiated sufficiently in advance i.e. before the primary infection starts. During earlier years various types of fungicides have been extensively used for controlling the disease. Spraying and drenching of copper fungicides such as one per cent Bordeaux mixture and 0.2 per cent Copper oxychloride (Menon *et al.*, 1973; Nambiar and Sarma, 1974; Nair, 1979; Nair *et al.*, 1982) was recommended as the control measure. Inhibition of the fungus under *in vitro* conditions was reported following treatments with organomercurials (Wilson *et al.*, 1974). Nair (1979) observed 86 per cent reduction in soil population levels of *Phytophthora* when drenched with one per cent Bordeaux mixture or 100 ppm Dexon (Bay, 5072). Alagianagalingam and Kandaswamy (1981) observed that the disease could be controlled by spraying the plants with 0.2 per cent Dexon (Bay-5072) at the rate of 4 kg/ha.

Although a number of fungicides have been reported to control the disease, often disease control in the field has been a challenging experience. The factors responsible for the constraints in achieving satisfactory disease control include lack of phytosanitation, effective and timely application schedules, high cost and unavailability of fungicides and the continuous rain that makes any fungicidal application ineffective.

Thomas *et al.* (1989, 1991a) evaluated a number of contact and systemic fungicides under field conditions and concluded that two to three rounds of sprays including one round of prophylactic spray with one per cent Bordeaux mixture or 0.3 per cent Aliette (Fosetyl-Aluminium) after proper phytosanitation effectively controlled the spread of the disease.

1.1.6 Biological control

Bio-agents play an important role in an eco-friendly system of disease management to fight against plant pathogens in a totally safe manner avoiding the use of expensive and hazardous chemical fungicides. Inhibition of *P. meadii* under laboratory conditions and disease suppression in cardamom nurseries have been studied by Thomas *et al.* (1991b) using *Trichoderma viride, T. harzianum, Laetisaria arvalis* and *Bacillus subtilis*. Suseela Bhai *et al.* (1993) achieved field control of *Azhukal* disease using *Trichoderma viride* and *T. harzianum* and have further developed a simple carrier cum multiplication medium for *Trichoderma* application in the field (Suseela Bhai *et al.*, 1994, 1997). *Trichoderma viride* and *T. harzianum* isolates harbouring native cardamom soils have been screened and effective strains for high biocontrol potential have been developed (Dhanapal and Thomas, 1996). Today, field control of *Azhukal* disease of cardamom has become effective, environmentally safe and cost effective due to the bio-control potential of *Trichoderma* sp.

1.2 Rhizome rot

Rhizome rot, also known as Clump rot, is a common disease occurring in cardamom plantations during the monsoon period. The disease was first reported by Park (1937).

Subba Rao (1938) described it as clump rot disease. The disease is widely distributed through out cardamom plantations in Kerala and Karnataka states and in heavy rain fall areas of Tamil Nadu such as the Anamalai hills.

1.2.1 Disease symptoms

The disease makes its appearance during south-west monsoon period by about middle of June. The first visible symptom is the development of pale yellow colour in the foliage and premature death of older leaves. These leaves show wilting symptoms. The collar portion of the aerial shoots becomes brittle and the tiller breaks of at slight disturbance. Symptoms of rotting develop at the collar region, which becomes soft and brown coloured. At this stage the affected aerial shoots fall off emitting a foul smell. Mayne (1942) reported the incidence of the disease in cardamom hills of Kerala. The tender shoots or the young tillers also turn brown coloured and rot completely. As the disease advances, all the affected aerial shoots fall off from the base. The panicles and young shoots attached to this also are affected by rot. The rotting extends to the rhizomes and roots also. Falling off shoots resulting from rhizome rot infection becomes severe during July–August months. In severely affected areas as much as 20 per cent disease incidence was recorded.

1.2.2 Causal organism

Subba Rao (1938) observed that cardamom rhizome rot is caused by *Rhizoctonia solani* Kuhn., and it was associated with a nematode. Ramakrishnan (1949) reported *Pythium vexans* de Barry as the causal organism. Thomas and Vijayan (1994) reported that *Fusarium oxysporum* is also occasionally found to cause rhizome and root rot infections.

1.2.3 Disease management

The disease is usually observed in areas previously affected by rhizome rot disease. Therefore phytosanitation plays a major role in disease management. Presence of inoculum in the soil and plant debris, overcrowding of plants, and thick shade are congenial conditions for disease development. Therefore, any disease management schedule has to be followed with these points in mind. Application of superphosphate at the rate of 300–400 g per plant has been recommended for controlling clump rot in plantations (Anonymous, 1955).

Soil drenching with one per cent Bordeaux mixture or 0.25 per cent Copper oxychloride or neem oil cake at the rate of 500 g per plant followed with one round pre monsoon and two rounds post monsoon soil drenching with 0.25 per cent copper oxychloride at one month interval has been reported to be very effective for controlling the disease (Thomas and Vijayan, 1994).

1.2.4 Biological control

Recent attempts in rhizome-rot control are by the use of *Trichoderma* sp. *Trichoderma viride* and *T. harzianum* were reported to reduce rhizome rot incidence in plantations (Thomas *et al.*, 1991b). A formulation of *T. harzianum* in a carrier medium consisting of farmyard manure and coffee husk mixture has been developed for field application in

the integrated disease management system for control of rot diseases of cardamom (Thomas *et al.*, 1997).

1.3 Chenthal (leaf-blight)

A leaf-blight disease popularly known as *Chenthal* has been reported in cardamom plantations (George *et al.*, 1976) from Idukki district of Kerala state. Since then, the occurrence of the disease has been observed in many plantations. The disease spread is faster in partially deforested areas and less shaded plantations. Though it was reported as a minor disease of limited spread, presently the situation is alarming as the disease is spreading to newer areas and is becoming a major problem.

1.3.1 Symptoms and damage

Chenthal makes its appearance mostly during the post-monsoon period and becomes severe during summer months. Symptoms develop on the foliage as water soaked rectangular lesions, which later elongate to form parallelly arranged streaks. The length of these streaks varies from a few millimeters up to 5 cm. The lesion areas become yellowish-brown to orange-red in colour and often the central portions become necrotic. Usually the two youngest leaves are not attacked by the disease. As the disease advances more and more lesions develop on older leaves, adjacent lesions coalesce and these areas begin to dry up. Severely infected plants show a burnt appearance. George and Jayasankar (1979) reported reduction in plant height, panicle length and crop loss due to failure in panicle formation in severely affected plants. However, Govindaraju *et al.* (1996) studied the symptomatology in detail and found that *Chenthal* infection affects only the leaves and not the plant height, panicle emergence or crop yield.

1.3.2 Causal organism

Chenthal was originally reported as a bacterial disease caused by *Corynebacterium* sp. (George and Jayasankar, 1977). They also recommended penicillin spray for controlling the disease. As later workers could neither isolate *Corynebacterium* sp. nor could control the disease with penicillin sprays, the bacterial etiology was suspected and the cause of the disease remained obscure for more than a decade. Govindaraju *et al.* (1996) conducted detailed investigations on symptomatology, etiology and management strategies of *Chenthal* and have clearly shown beyond doubt that the causal organism is the fungus *Colletotrichum gloeosporioides* (Penz.) Penz and Sacc. The fungus closely resembles *C. gloeosporioides* causing anthracnose disease of capsule reported by Suseela Bhai *et al.* (1988). Both the leaf and capsule isolates showed similar cultural and morphological characters and were cross-infective to capsules and leaves and *vice versa*. However, these two isolates exhibited considerable differences in their period of occurrence, type of symptoms, distribution and spread of the disease.

1.3.3 Disease management

As the disease was considered to be caused by *Corynebacterium* sp. penicillin spray was suggested as a control measure for the disease (George and Jayasankar, 1977). But it was not effective and was not followed by planters. Govindaraju *et al.* (1996) reported that

three sprays at monthly intervals with carbendazim (Bavistin, 0.3 per cent) or Mancozeb (0.3 per cent) or Copper oxychloride (0.25 per cent) effectively controlled *chenthal* disease spread in the field.

1.4 Nematode diseases

Nematode infestation in cardamom is a major problem often amounting to heavy crop losses. Although, as many as 20 genera of various plant parasitic nematodes have been reported from cardamom soils (Ali, 1983), only the root knot nematode *Meloidogyne incognita* causes severe damage to the crop. Root knot nematodes are widely observed in almost all cardamom plantations and nurseries (Ramana and Eapen, 1992) while the lesion nematode *Pratylenchus coffeae* and the burrowing nematode *Radopholus similis* are noticed in mixed plantations.

1.4.1 Symptoms and damage

Root knot nematode causes aerial symptoms such as stunting of plants, reduced tillering, rosetting and narrowing of leaves, yellow banding on leaf blades and drying of leaf tips or leaf margins. The flowering is normally delayed. Immature fruit dropping results in yield reduction (Anonymous, 1972, 1989b). Underground symptoms develop on the roots of infected plants in the form of pronounced root galling. Tender root tips show spherical–ovoid swellings. Severe infestation can result in crop losses up to 80 per cent (Ramana and Eapen, 1992). Nematode population is high in cardamom soils during post-monsoon period (September–January). Heavy shade in plantations, moist soil and warm humid weather are predisposing factors for nematode multiplication.

Nematode infestation is a chronic problem in cardamom nurseries where the same site is repeatedly used for raising seedlings. Nematode-infested soils affect seed germination and result in severe and heavy galling in the root system, marginal yellowing and drying of leaves, stunting and reduced tillering. The leaves become narrow and the leaf tips show upward curling.

1.4.2 Nematode control

As infected seedlings serve as the source of inoculum, transplanting of affected seedlings should be avoided. Pre-treatment of infested nursery beds with methyl bromide at the rate of 500 g/10 M^2 or soil drenching with 2 per cent formalin is usually recommended. Solarization of nursery beds is reported to reduce nematode populations in the soil.

Application of nematicides such as aldicarb, carbofuran or phorate at the rate of 5 g ai per plant twice a year was recommended for controlling nematodes in plantations (Ali, 1984). Recently, a bio-control schedule was developed with *Trichoderma* and *Paecilomyces lilacinus* for control of damping off and nematode damage in cardamom nurseries (Eapen and Venugopal, 1995).

2 MINOR DISEASES

A number of minor diseases affecting leaves, capsules and aerial stems occur sporadically in cardamom plantations. While some of these are frequently observed in all areas, others are

Table 7.3 Minor fungal and bacterial diseases in cardamom plantations

Diseases	*Parts affected*	*Casual agents*
Leaf blotch	Leaves	*Phaeodactylium alpiniae*
Phytophthora Leaf blight	Leaves	*Phytophthora meadii*
Leaf rust	Leaves	*Phakospora elettariae (Uredo elettariae)*
Leaf spots	Leaves	*Sphaceloma cardamomi, Cercospora zingiberi, Glomerella singulata Phaeotrichoconis crotalariae Ceriospora elettariae*
Sooty mould	Leaves	*Trichosporiopsis* sp.
Stem lodging	Pseudostem (Tillers)	*Fusarium oxysporum*
Anthracnose	Capsules	*Colletotrichum gloeosporioides*
Capsule tip rot	Capsules	*Rhizoctonia solani*
Fusarium capsule rot	Capsules	*Fusarium moniliformae*
Capsule canker (Vythiri spot)	Capsules	*Bacterium* (?)
Capsule ring spot	Capsules	*Marasmius* sp.
Bacterial rot	Rhizomes	*Erwinia chrysanthimi*

restricted to certain specific localities. These include various types of leaf spots and capsule spots, stem infections etc. caused predominantly by fungal pathogens (Table 7.3).

2.1 Leaf blotch

Agnihothrudu (1968) reported a foliar disease in cardamom characterized by typical blotch symptoms on leaves. The disease appears during monsoon season i.e. from June to August months, normally under heavily shaded conditions. Thick shade, continuous rainfall and high atmospheric humidity predispose plants to infection. Leaf blotch was thought to be a minor disease. However, recently it was found spreading in high proportions in certain localities.

2.1.1 Symptoms

Symptomatology of leaf blotch disease has been studied in detail (Nair, 1979). During rainy period, round, ovoid or irregular water-soaked lesions develop on middle leaves, usually near the leaf tips or at the mid rib areas. These areas enlarge in size, become dark brown with a necrotic centre. In moist weather, a thick, gray coloured fungal growth is seen on the under side of these blotched areas (Fig. 7.2a). The periphery of lesion shows a dark band of water-soaked zone as the lesions spread. The lesion areas enlarge and characteristic dark and pale brown zonations develop in the blotched areas. However, the lesion spread is limited in size following a dry period.

2.1.2 Causal organism

Leaf blotch is a fungal disease caused by *Phaeodactylium venkatesanum* (Agnihothrudu, 1969). Later this fungus was identified as *P. alpiniae* (Sawada) (Ellis, 1971).

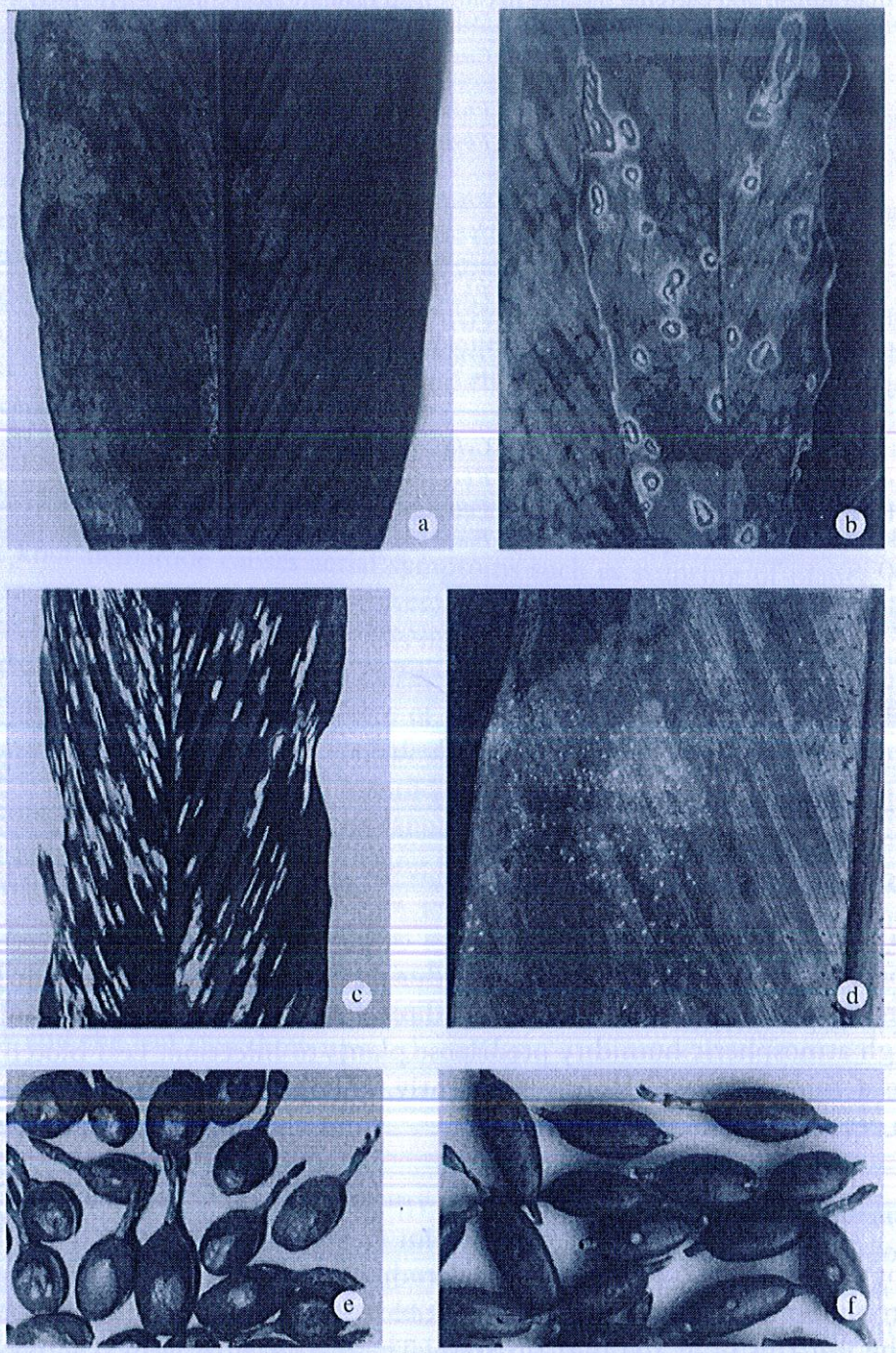

Figure 7.2 Symptoms of leaf and capsule spot diseases: (a) leaf blotch; (b) *Glomerella* leaf spot; (c) *Cercospora* leaf spot; (d) leaf rust; (e) capsule canker; (f) anthracnose.

The pathogen grows profusely on the underside of leaves and also grows abundantly on potato dextrose agar medium. Hyphae are hyaline, smooth, partially submerged, 6–10 μm thick, dichotomously or often trichotomously branched with conidia formed at their tips. Conidia are solitary, hyaline with three transverse septa, smooth, elliptical with tapered basal end and broad apices. Conidia measure 15–25 μm × 4–7 μm. The pathogen infects and produces typical symptoms on *Alpinia* sp., *Amomum* sp. and *Hedychium* sp.

2.1.3 *Disease management*

Nair (1979) has observed that the fungus was completely inhibited under *in vitro* conditions by Bordeaux mixture (1 per cent), Bavistin (0.1 per cent), or Hinosan (0.15 per cent). Fungicidal spray with copper oxychloride or Bordeaux mixture was reported to control leaf blotch infection in the field (Ali, 1982).

2.2 *Phytophthora* leaf blight

A widespread leaf blight incidence is observed in many cardamom plantations during the post-monsoon season. The infection starts on the young–middle aged leaves in the form of elongate or ovoid, large, brown coloured patches which soon become necrotic and dry off. These necrotic dry patches are seen mostly on leaf margins and in severe cases the entire leaf area on one side of the midrib is found affected. The disease appears during October–November months and may even extend up to January–February. Thick shade, low night temperature and fog prevailing in isolated pockets pre-dispose the plants to leaf blight infection. The causal organism is *Phytophthora meadii*, which can be easily isolated from infected leaf portions using water-floating technique. The infection is aerial and the infected plant debris serves as the source of primary inoculum. The pathogen grows internally and under moist or misty conditions produce abundant sporangia, which are disseminated by wind spreading the disease to other areas. Disease symptoms are seen only on the leaves. Although *Phytophthora* is a potential pathogen infecting all parts of cardamom, the leaf blight isolate is seen specific to only leaves under natural conditions. However cross inoculations of *P. meadii* leaf isolate on capsules and vice versa were found to be infective on plant parts tested under laboratory conditions.

2.2.1 *Disease management*

Leaf blight infection can rapidly spread to adjacent areas and can result in severe leaf necrosis and leaf drying unless the disease is controlled at the initial stage itself. One round of foliar spray with one per cent Bordeaux mixture, Aliette 0.3 per cent or Akomin 40 (Potassium phosphonate) at 0.3 per cent were found to be effective in limiting the spread of the disease.

2.3 Leaf rust

Thirumalachar (1943) reported the occurrence of a type of rust disease in cardamom plantations of Karnataka. This disease appears after monsoon during October–May. Disease symptoms appear on leaves in the form of numerous yellowish rusty coloured pustules distributed on leaf surface in several patches (Fig. 7.2d). These are mostly seen on the underside of leaves. As disease advances, pustules or uredosori become reddish-brown in colour and they protrude out from the leaf surface. The mature pustules break open and release uredospores. In severe cases infected leaves show several yellowish patches with numerous rusty coloured pinhead spots distributed in these yellowish areas on leaf surface. These areas later dry off as the disease advances.

The disease is caused by the rust fungus *Phakospora elettariae* (Racib.) Cummins (Syn: *Uredo elettariae* Racib.). Naidu (1978) reported a mycoparasite *Darluca filum* (Biv) Cast, hyperparasitising this rust fungus. The mycoparasite produces dark brown to black

coloured pycnidia in large numbers, and they protrude out from the uredosori. The hyperparasitised uredospores shrivel off and they do not germinate. *Darluca filum* develops only in advanced stage of rust development. However it helps to prevent further secondary spread of the rust fungus. The spread of leaf rust infection can be minimized by spraying fungicides such as Mancozeb 0.2 per cent (Dithane M45) or Indofil M-45.

2.4 Leaf spot diseases

Cardamom foliage is affected by a number of leaf spot diseases caused by a variety of pathogenic fungi. They occur both at the seedling stage and in mature plants in the plantations. The types of leaf spots occurring in main plantation are dealt here and nursery leaf spots elsewhere in this chapter. Leaf spots generally occur as minor diseases and as such do not cause considerable damage to plants.

2.4.1 *Sphaceloma leaf spot*

Muthappa (1965) reported the occurrence of this leaf spot for the first time from Coorg area of Karnataka. Symptoms of the disease appear on leaves in the form of scattered spherical blotches measuring a few millimetre in diameter. The adjacent lesions coalesce to form large necrotic patches. In Coorg it was reported as a major disease problem. Although the disease is present throughout the year, its abundance and severity are more during the post-monsoon period. This disease is caused by *Sphaceloma cardamomi* Muthappa. Naidu (1978) reported that Ceylon and Alleppey Green cultivars in Coorg area showed resistance to *Sphaceloma* leaf spots. Cultivars having erect panicles are mostly resistant to leaf spot while cultivars with creeping or prostrate panicles are susceptible.

2.4.2 *Cercospora leaf spot*

Another leaf spot occurring in Coorg area was reported by Rangaswamy *et al.* (1968). Symptoms originate on the leaf blade as water-soaked linear lesions, which are rectangular and parallelly arranged alongside the veins. On upper leaf surface, lesions turn dark brown with dirty white long patches in the centre (Fig. 7.2c). In advanced stages, lesions become grayish-brown in colour and later these areas dry off. The disease is caused by *Cercospora zingiberi* Togashi Katsaki. The fungus produces conidiophores in clusters from many-celled dark brown stroma. Conidiophores are simple or branched rarely, septate, straight or curved, geniculate and often undulate at the tip and light brown coloured. The conidiophores measure 17.5–56 μm × 5.23–3.5 μm. Conidia are formed singly, linear, indistinctly septate with 3–6 septa, mostly curved with obtuse base 37–195 μm × 1.75–2.5 μm. Naidu (1978) observed that cultivars having erect (var. *Mysore*) panicle are relatively resistant to *Cercospora* leaf spot compared to var. *Malabar* having prostrate panicles.

2.4.3 *Glomerella leaf spot*

Nair (1979) reported the occurrence of a leaf spot disease characterized by the presence of circular–ovoid dark brown, concentric spots on the middle leaves. This disease

appears during the post-monsoon period in isolated pockets. The disease is generally seen only in var. *Malabar*.

Infection starts as small pale yellow water-soaked lesions on leaves, which may be irregular in shape measuring 1–2 mm in size, later enlarge in size and form a depressed central area surrounded by a dark band of tissue. Later, alternate concentric dark and pale brown bands develop with yellow halo around the entire spot (Fig 7.2b). Large mature spots may coalesce and the lesion areas start drying. Sometimes the lesion areas measure as large as about 4 cm in diameter. The fruiting bodies of the fungus are seen as dark brown dot-like structures in the lesion areas.

The causal organism is identified as *Glomerella cingulata* Stoneum Spanding and Shronk. The fungus forms grayish white mycelial growth in potato dextrose agar medium which becomes dark gray with zonations. Acervuli are produced in cultures. Conidiophores short, hyaline, conidia cylindrical, hyaline and aseptate 12–25 μm × 3–5 μm in size. Perithecia are globose dark brown coloured, ostiolate and measure 85–135 μm in diameter.

2.4.4 *Phaeotrichoconis leaf spot*

Another type of leaf spot caused by *Phaeotrichoconis* was reported by Dhanalakshmy and Leelavathy (1976). Symptoms formed on young and old leaves are characterized by irregular papery white spots with brown margins on leaf blade. Under moist conditions the lesions enlarge and coalesce. During dry weather the central portion of lesions dries off. Causal organism is identified as *Phaeotrichoconis crotalariae* (Salam and Rao) Subram. The pathogen grows profusely in culture and produces yellowish-brown mycelium with numerous dark brown sclerotia. Conidiophores are indistinguishable from the hyphae, conidia solitary, elongate, fusoid, straight or slightly curved and 5–8 septate.

2.4.5 *Ceriospora leaf spot*

Yet another type of leaf spot seen rarely on cardamom leaves was reported by Ponnappa and Shaw (1978) from Coorg and is caused by *Ceriospora elettariae* Ponnappa and Shaw. The symptoms are appearance of numerous spots on the foliage, which are circular or oval, up to 8 mm diameter and they coalesce to form larger patches. The lesion centre is dirty white surrounded by light brown, circular necrotic areas.

2.4.6 *Management of leaf spot diseases*

Many of the leaf spot diseases described above occur sporadically in minor proportions and as such do not have much deleterious effect on crop yield. The spread of these can be prevented by one or two rounds of spraying with common fungicides such as Bordeaux mixture (1 per cent) or Mancozeb (0.25 per cent).

2.5 Sooty mould

A sooty mould infection on leaves of cardamom growing under the shade tree *Cedrella toona* Roxb. was reported by Nair (1979). The disease appears during January–February months when the shade trees are in blossom. Infection starts as minute scattered dark mycelial growth on the upper leaf surface. This spreads rapidly and covers the entire

lamina and in severe cases extends to the petioles and leafy stems, which are later, covered with black mycelial growth. In advanced stages, leaves tear off at margin along the veins and dry prematurely. The sooty mould fungus is identified as *Trichosporiopsis* sp.

2.6 Stem lodging

A relatively new disease affecting the leafy stem (tillers) of cardamom has been found to occur in several plantations in Idukki district of Kerala and in lower Pulney area in Tamil Nadu (Dhanapal and Thomas, Unpublished). The disease attacks the middle portion of tillers in the form of pale discoloured patches, which lead to a sort of dry rotting. The leafy stem is weakened at this portion and leads to partial breakage. The partially broken tillers bend downwards and hang from the point of infection. Where infection occurs at lower region of tillers, they fall off giving a lodged appearance. In such tillers leaves and leaf sheaths dry up soon. The disease is caused by *Fusarium oxysporum*, and appears usually during post-monsoon period.

2.7 Anthracnose

Anthracnose occurring on cardamom capsules was reported as a minor disease in certain localities of cardamom cultivation (Suseela Bhai and Thomas, 1988). Symptoms appear on capsules as reddish brown round or oval spots of 1–2 mm diameter, often with a soft depressed centre (Fig. 7.2f). The lesions vary in number and size and in rare cases coalesce to form large lesions. Often less than 2 per cent disease incidence is noticed. But in Anamalai areas of Tamil Nadu as high as 10–28 per cent incidence also was noticed.

2.7.1 *Causal organism*

Colletotrichum gloeosporioides (Penz) Penz and Sacc has been shown to be the causative organism of anthracnose disease (Suseela Bhai *et al.*, 1988). The fungus grows profusely in potato dextrose agar medium producing dark, gray coloured, dense mycelium. Setae are dark brown, conidia abundant, cylindrical, straight 12–24 μm × 2.5–5 μm.

A similar infection of *C. gloeosporioides* on capsules resulting in the formation of much large lesions often extending upto three-fourth area of the capsules occur in plantations of Karnataka state. This severe form of anthracnose leads to decay and loss of infected capsules. Fungicides such as Cuman-L, Foltaf or Bavistin when sprayed 3 times at 0.3 per cent concentration was found to control the disease.

2.8 Capsule tip rot

A characteristic type of rotting of the tip of capsules is of common occurrence in plantations of Karnataka. The disease makes its appearance as small water-soaked lesions at the distal end of the capsule, which later spreads downwards. The tip portions of the infected capsules and often up to the middle from the tip, exhibit decaying symptoms. In advanced stages, the rotting extends to the entire capsule. *Rhizoctonia solani* is the causal agent of capsule tip rot. Spraying capsules with Foltaf (0.2 per cent) or Bavistin (0.2 per cent) or Copper oxychloride (0.2 per cent) reduces the disease spread.

2.9 *Fusarium* capsule disease

Wilson *et al.* (1979a) reported a type of capsule disease caused by *Fusarium moniliforme* Sheld. Infection appears as small lesions on capsule rind which later decays and the lesion's periphery turns reddish-brown in colour. In severe infection, entire capsules decay during rainy period. The disease symptoms described by Wilson *et al.* (1979a) closely resemble those of anthracnose, but *Fusarium* infection, often leads to decay of capsules.

2.10 Capsule canker

Agnihothrudu (1974) reported a type of capsule spot suspected to be caused by *Xanthomonas* sp. This is locally known as *Vythiri* spot and was initially found in Wynad areas. Later, occurrence of the disease was observed in several cardamom plantations. Symptoms develop on capsule rind as raised shining blisters or eruptions, which are pale to silvery white in colour (Fig. 7.2e), sometimes extending to cover almost half the area of the capsules. The nature of the causal organism is not established beyond doubt, as no pathogenic fungi or bacterium was found associated with these spots. The disease occurs only in minor proportions and is not alarming since no crop loss is observed due to infection. However, infected capsules fetch lesser price in cardamom auctions, as these blisters are clearly visible on cured capsules.

2.11 Capsule ring spot

A rare infection of capsules is noticed in certain plantations in Karnataka. The symptoms are characteristic reddish-brown concentric rings or zonations, which develop on capsule rind. These areas turn necrotic and later dry off. This infection is suspected to be caused by *Marasmius* sp., however it requires further detailed investigations.

2.12 Erwinia rot

Tomlinson and Cox (1987) reported a serious rot disease of cardamom in Papua New Guinea. Symptoms of the disease are manifested on the foliage as yellowing of leaves of mature plants. Rotting and collapse of leafy stems at ground level often accompany this. A pale brown colour develops on rhizomes, which later leads to decay of rhizomes. Roots become blackened and necrotic in advanced stages of infection. Infection is observed in the var. *Malabar* and often leads to collapse of the entire plant.

2.12.1 Causal organism

The disease has been reported to be caused by a gram-negative bacterium, which has been identified as a strain of *Erwinia chrysanthemi* Burkholder. Tomlinson and Cox (1987) have isolated this bacterium from infected cardamom rhizomes and roots and were found to be pathogenic. The bacterium has been biochemically characterized and identified as a pectolytic bacterium readily grows on crystal violet peptone agar (cvp agar). Colonies slightly raised with fried-egg appearance having distinct orange coloured centre. Pathogenic isolates are KOH soluble gram-negative rod-shaped bacteria. The bacterium survives in infected rhizomes and roots and also in the rhizosphere.

3 DISEASES IN NURSERIES

Cardamom is propagated mainly through seeds, which are raised in nurseries. The seedlings are retained for about 10–18 months in the nursery before they attain the age of field planting. Normally the nurseries consist of two stages, the primary nursery and the secondary nursery. Major diseases occurring in seedlings are given in Table 7.4.

Table 7.4 Diseases of cardamom in nurseries

Diseases	*Parts affected*	*Causal agents*
Primary nursery		
Damping off	Young seedlings	*Rhizoctonia solani* *Pythium vexans*
Seed/seedling rot	Seeds, young seedlings	*Fusarium oxysporum*
Seedling rot	Leaf/leaf sheath, Pseudostem	*Sclerotium rolfsii*
Leaf spot	Young leaves	*Phyllosticta elettariae*
Secondary nursery		
Seedling rot (clump rot)	Rhizomes, tillers roots and leaves	*Pythium vexans* *Rhizoctonia solani*
Leaf spot	Leaves	*Colletotrichum gloeosporioides*

3.1 Damping off

Wilson *et al.* (1979b) observed the incidence of damping off in young seedlings at the age of 1–6 months. Affected seedlings become pale green and wilt suddenly in masses, as their collar portion rots. Overcrowding of seedlings and excess soil moisture are the predisposing factors of this disease. The causal organism of damping off was identified as Rhizoctonia solani (Wilson *et al.*, 1979b) and *Pythium vexans* (Nambiar *et al.*, 1975).

3.2 Seedling rot or clump rot

This disease is similar to the rhizome rot disease of plantations. Usually, the disease is observed in nurseries where the seedlings attain an age of 6–12 months and is often seen during rainy season in overcrowded nurseries. The disease symptoms are characterized by wilting and drooping of leaves. Leaves turn pale yellow, followed by rotting of the collar portion of seedlings. As infection advances the young tillers fall off and the entire seedling collapses. The causal organisms reported are *R. solani* and *P. vexans*. In some nurseries, seedlings are affected by root rot alone. In such cases only *Fusarium* sp. was found to be pathogenic. Ali and Venugopal (1993) have reported the association of root knot nematode, *Meloidogyne incognita*, along with *R. solani* and *P. vexans*.

Siddaramaiah (1988a) reported the occurrence of seed rot disease resulting in the wilting of seedlings. The disease is caused by *Fusarium oxysporum*. Another seedling disease caused by *Sclerotium rolfsii*, which results in the rotting of leaves, leaf sheath and leafy stem, was also reported by Siddaramaiah (1988b).

3.2.1 *Disease management*

Pattanshetty *et al.* (1973) reported that pre-sowing treatment of nursery beds with 2 per cent formaldhyde improved seed germination and reduced damping-off incidence. Thomas *et al.* (1988) reported fungicidal control of seedling rot and damping off by soil drenching with Emisan 0.2 per cent or Mancozeb 0.4 per cent or Brassicol 0.2 per cent. Seed dressing with *Trichoderma harzianum* followed by one or two rounds of *T. harzianum* in nursery beds at 30 days intervals has been found to reduce the incidence of seedling rot disease.

3.3 Nursery leaf spot

Incidence of leaf spot is a serious problem in nurseries amounting to severe loss of seedlings. The disease was reported by Subha Rao (1939) and later Mayne (1942) identified the causal organism as *Phyllosticta* sp. The pathogen was isolated and studied in detail by Chowdhary (1948) who identified it as *Phyllosticta elettariae* Chowdhary. The disease occurs mainly in the primary nursery on tender leaves as minute water-soaked lesions almost circular in shape with light coloured periphery and a depressed necrotic centre. This central portion later dries off and becomes papery white. In later stages, shot holes are formed at the lesion centre. As disease advances numerous such lesions of varying sizes develop and the entire leaf dries off. Several minute dark pinheads like pycnidia of the fungus can be seen in the lesion areas. The older leaves of the seedlings are less susceptible to the disease. As the seedlings grow old they develop resistance to infection. The disease can be easily controlled by spraying with fungicides such as Difolatan (0.2 per cent) or Bordeaux mixture (1 per cent) or Dithane (0.2 per cent) when sprayed at 15-day intervals (Rao and Naidu, 1974).

3.4 Leaf spot in secondary nursery

Another type of leaf spot is observed in 6–12 months old seedlings in the secondary nursery. The disease is characterized by the development of many rectangular water-soaked lesions on the foliage. These lesions enlarge longitudinally and are parallely arranged along the side of the veins. As they mature, they exhibit a muddy red colour and become necrotic. The leaves dry off as too many lesions occur side by side. The disease is caused by *Colletotricum gloeosporioides*. Spraying the foliage with Mancozeb (0.25 per cent) is effective in reducing the disease spread.

4 CONCLUSION

Fungal diseases of cardamom are relatively easier to control than the more devastating systemic infections caused by viruses. However the use of fungicides and insecticides are being discouraged due to the strong antipathy of consumers for the use of phyto-chemicals. In view of the increased importance and interest in organically grown spices, it is essential to evolve effective biocontrol strategies against the more serious fungal diseases. A protocol for the production of organic cardamom needs to be developed and popularized in order to cater to the demand in the international market.

Extensive and intensive search for natural resistance to the pathogens needs to be initiated. The Western Ghats, being the centre of diversity for cardamom, the possibility of locating resistance is fairly high. Once such resistance genes are located, they can be incorporated in to the elite cultivars by conventional breeding. Where resistant genes are absent, biotechnological approaches may have to be resorted to for developing resistant genotypes.

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