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Important Diseases of Major Spice Crops

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INTRODUCTION

India, aptly so briquetted as "The Homeland of Spices" is one among the largest producers, consumers and exporters of spices as well as spice products. Spices comprise different plant components or parts such as floral, fruits, berries, seeds, rhizomes, roots, leaves, kernel, aril, bark and bulbs. The recorded history of use of spices dates back to 5000 years from the Egyptian or from the Indus valley civilization. International Organization for Standardization lists 109 herbs and spice plant species useful as ingredients in food and India grows over 50 spice crops. Spices are used for flavouring, seasoning and imparting aroma in various cuisines. Moreover, some spices are also known to be fungistatic, antimicrobial, antioxidative and antibiotic. Spices are also processed into numerous value added products such as spice oleoresins, essential oils and curry powder. In India, the estimated annual production of spices for the period 2016 - 17 is 7.08 MT from an area of 3.52 m ha. The major export oriented spices *viz.*, black pepper, cardamom, ginger, turmeric, chilli and vanilla are of high economic value, contributing substantially to agricultural exports at global and national levels. However, diseases incited by oomycetes, fungi, viruses, bacteria and nematodes are considered as the major production constraints in spice cultivation. Most of the diseases are both soil - borne and air - borne and appear with the onset of monsoon whereas, viral diseases occur as an all - time threat in crops like black pepper, cardamom and vanilla. In light of the above background, information on various aspects of important diseases in major spice crops including black pepper, cardamom, ginger, turmeric and vanilla, their epidemiology and management aspects are discussed.

BLACK PEPPER (*Piper nigrum* Linnaeus)

Black pepper, the King of Spices, is one among the most valued and commonly used spices in the world. The moist evergreen forest expanse of Western Ghats, South India is its centre of origin and diversity of several other *Piper* spp. The black pepper of commerce is the mature dried fruits, the berries (Ravindran, 2000).

Foot rot

Foot rot is the most dreadful disease of black pepper. All parts of vine are vulnerable to the disease and symptom expression depends on site of infection which is broadly classified into aerial and soil infections (Anandaraj, 2000).

Symptoms

In nurseries, foliar symptoms appear as black lesions with fimbriate margins which later enlarge leading to defoliation. Infections originating from contaminated soil lead to collar and root rot subsequently leading to death of plants. In field, the disease initiates as black spots on foliage with typical fimbriations along advancing margins. The tender leaves and succulent shoot tips of runner shoots trailing on the soil turn black when infected. Infection at collar region results in wilting of entire vine followed by shedding of leaves, spikes and consequently collapses within a span of short period (Fig. 1). If the damage is confined to the feeder roots, expression of symptoms are delayed till monsoon recedes during which the vine exhibits declining symptoms such as yellowing, defoliation and drying (Anandaraj, 2000).

Causal organism

Earlier, the causal organisms were identified as *Phytophthora palmivora* var. *piperis*, *P. palmivora* and *P. palmivora* MF4. *P. palmivora* MF4 was subsequently merged with *P. capsici* as most isolates from pepper resembled *P. capsici*. In India, during the International Pepper Community Workshop in Goa, it was decided to refer the disease as *Phytophthora* foot rot and the pathogen as *P. capsici* (Anandaraj, 2000).

Disease perpetuation and pre-disposing factors

High soil moisture (>25%), daily precipitation (15.8 - 23 mm), high relative humidity (81 - 99%), low temperature (22.7 - 29.6°C) and short sunshine hours (2.8 - 3.5 per day) during monsoon aggravates the disease. The disease progression in arecanut - black pepper mixed cropping system was positively correlated with rainfall, number of rainy days as well as relative humidity and negatively correlated with temperature and sunshine hours. The increase of soil temperature from 24.5 - 29.63°C reduced *P. capsici* population from 89.76 to 25.76%. In soil phase, the inoculum survives up to 19 months in the absence of host plant. The pathogen concentrates on the surface 0 - 30 cm and reduces as the distance and depth increases from foci of infection. The main survival structures of *P. capsici* in the soil are chlamydospores and thickened mycelium (Anandaraj, 2000).

Disease management

- Follow strict phytosanitation and provide adequate drainage facility, as soil moisture facilitates inoculum build - up, besides predisposing the plant to infection.
- Solarization or steam sterilization of the potting mixture and fortification with bioagents was found to be effective under nursery conditions.
- Shade regulation greatly alters the microclimate, reducing initiation of the disease. Injury to the root system due to cultural practices such as digging should be avoided. The freshly emerging runner shoots should be pruned before onset of monsoon.
- Sprays with Bordeaux mixture (1%) and drenching the basin with either Bordeaux mixture or copper oxychloride (Anandaraj, 2000) was recommended against both aerial and collar infections. However, based on epidemiological studies, the practice of pasting the collar with Bordeaux mixture was discouraged. Systemic fungicide, metalaxyl - mancozeb (0.125% @5 - 10 liters per vine) both as spray and drench after the receipt of few monsoon showers is recommended as an alternative approach.
- A combination of arbuscular mycorrhizal fungi, *T. harzianum* and *Pseudomonas fluorescens* is recommended to produce healthy robust plants. Under field conditions, with the onset of monsoon, apply commercial formulation of *T. harzianum* @50g/vine along with organic manures such as neem cake, farmyard manure, decomposed coffee pulp or coir pith during August - September which may be repeated for 2 - 3 consecutive years. The potential of endophytic bacteria (Aravind *et al.*, 2012) and actinobacteria (Bhai *et al.*, 2016; Ansuree and Bhai, 2017) was also exploited in managing the disease.

- Cultivate foot rot tolerant varieties *viz.*, IISR Shakthi and IISR Thevam in endemic regions.

Slow Decline

Slow decline was first reported by Van der Vecht (1950) (in Ramana and Eapen, 2000) as pepper yellows in the islands of Banka, Indonesia and *Radopholus similis* was reported as the causal agent. Association of *R. similis* with black pepper in India was first reported by D'Souza *et al.* (1970).

Symptoms

The symptoms initiate as mild to moderate foliar yellowing. In the later stages, the infected vine defoliates and exhibits die - back, loss of vigour leading to death of the vine. The foliar yellowing is more pronounced with the depletion of soil moisture during summer season (Fig. 2). Gradual decline and foliar yellowing are the predominant symptoms induced by root knot nematode, *Meloidogyne* sp. Such plants exhibits dense inter - veinal chlorosis with galls or knots on secondary and fibrous roots and as elongated swellings on thick primary roots. Foliar yellowing and defoliation are the main aerial symptoms induced by *R. similis*. Root penetration by *R. similis* causes necrotic lesion on feeder roots which subsequently merge and encircle the root cortex (Ramana and Eapen, 2000).

Causal organism

A synergistic effect of *Meloidogyne* sp., *R. similis* and *Fusarium* sp. reduces growth of pepper vines and increase severity of foliar yellowing. Pervez and Eapen (2015) reported *Tylenchorhynchus* sp., *Meloidogyne incognita, Pratylenchus* sp., *Radopholus similis, Hoplolaimus indicus, Helicotylenchus multicinctus, Criconemoides* sp., *Xiphinema* sp. and *Scutellonema* sp. as the most prominent plant parasitic nematode genera associated with black pepper in Kerala.

Disease perpetuation and pre-disposing factors

R. similis populations from arecanut and pepper in Kerala complete their life cycle in 25 - 30 days at temperature of 21 - 23°C.

Disease management

- Uproot and destroy infected vines along with root system that are beyond recovery.
- Avoid intercrops and standards susceptible to nematodes. Coconut and arecanut are hosts of *R. similis.* Whereas, standards less susceptible or not affected by nematodes like, *Garuga pinnata, Macaranga indica, Erythrina indica* and *Gliricidia sepium* can be used to trail the vines.
- Application of neem cake @ 2 kg per vine was found effective against *M. incognita* than *R. similis.* Addition of chopped leaves of *Glyricidia maculata* (10g per kg soil) reduced populations of *R. similis* (Jasy and Koshy, 1992).
- Nematicides like phenamiphos, aldicarb sulphone, phorate, carbofuran and aldicarb are reported to be effective in India, Malaysia, Indonesia and Brazil.

- Antagonistic microbes *viz.*, *Pasteuria penetrans, Paecilomyces lilacinus* (Ramana and Eapen, 2000; Sosamma and Koshy, 1997; Eapen *et al.*, 2005) and endophytic bacteria, *Bacillus megaterium* and *Curtobacterium luteum* (Aravind *et al.*, 2009) and *Daldinia eschscholtzii* (Sreeja *et al.*, 2016) have been reported antagonistic to nematodes infecting black pepper. *Pochonia chlamydosporia* or *Trichoderma harzianum* (10^8 cfu/g) can be applied @50g/vine during April - May and September - October) to manage slow decline.
- Pournami, a selection from Ottaplackkal was found tolerant to root knot nematode (Ravindran *et al.*, 1992) and the accessions HP 39 and C 820 (IISR collections) were found resistant to *R. similis* (Eapen, 2006).

Anthracnose/Spike shedding/Fungal pollu

Symptoms

The initial symptoms appear as small darkly shaded spots surrounded by yellow halo on the leaves. In severe cases, the expansion of lamina is affected, resulting in crinkled appearance (Fig. 3) and defoliation. Infection on spikes results in spike shedding whereas, infection on mature berries leads to formation of brownish splits due to unequal development. In later stages, the discolouration gradually increases and the berries exhibits characteristic cross splitting.

Causal organism

The disease is caused by *Colletotrichum gloeosporioides.*

Disease perpetuation and pre-disposing factors

Misty conditions and delayed emergence of spikes were found to be the major reasons for spike shedding. Biju *et al.* (2013) observed low disease incidence during February to May and a rapid increase in June which subsequently registered a peak during September. Maximum temperature had negative correlation, while minimum temperature, rainfall and number of rainy days had positive correlation with the disease incidence. Biju *et al.* (2017) reported the oversummering of pathogen as microsclerotia in the runner shoots.

Disease management

- Irrigating the vines at an interval of 5 - 7 days @ 40 to 50 litres per plant commencing from March, followed by shade regulation to provide 7500 to 10000 lux light reduces anthracnose incidence and spike shedding.
- In nurseries, pre - planting treatment of two/three node cuttings by immersing in carbendazim - mancozeb (0.1%) for 30 minutes and spraying Bordeaux mixture (1%) alternating with carbendazim (0.1%) manages the disease (Biju *et al.*, 2017).
- In field, spray Bordeaux mixture (1%) or carbendazim - mancozeb (0.2%) or mancozeb (0.2%).
- Cultivate field tolerant cultivars *viz.*, Aimpiriyan and Arakulammunda.

Stunt disease

Virus - induced symptoms referred differently like dog's ear, mosaic, little leaf, wrinkled leaf and stunted disease have been reported from Brazil, India, Indonesia, Malaysia, Philippines, Sri Lanka, Thailand and Vietnam (Lockhart *et al.*, 1997; Sarma *et al.*, 2001; de

Silva *et al.*, 2002; Bhat, 2008). In India, the disease was first noticed in Neriamangalam, Idukki, Kerala (Paily *et al.*, 1981). The yield loss due to the disease may range from negligible to 85%.

Symptoms

Mosaic, mottling, leaf deformation and stunting are the common visible symptoms. The initial symptoms include formation of chlorotic specks, vein clearing, mosaic and yellow mottling (Fig. 4). Severe symptoms develop sporadically on flushes of new growth, while mature leaves exhibits milder symptoms or remain symptomless. The infected vine produces short spikes with poor filling. In severe cases, the leaves become abnormally narrow and appear sickle shaped. The internodes of vines become abnormally short leading to stunting of plants and affected branches give a typical witches broom appearance in advanced stages (Paily *et al.*, 1981; Lockhart *et al.*, 1997; Sarma *et al.*, 2001; de Silva *et al.*, 2002; Bhat *et al.*, 2003).

Causal organism

Cucumber mosaic virus (CMV) and *Piper yellow mottle virus* (PYMoV) are associated with the disease among which, CMV is a single stranded RNA virus belonging to *Cucumovirus*, family Bromoviridae. PYMoV is a circular double stranded DNA virus representing the genus, *Badnavirus* under the family Caulimoviridae which also infects betelvine, Indian long pepper and other related species (Siju *et al.*, 2008). The complete genome sequence of four isolates of PYMoV revealed that the genome size varies from 7559 to 7584 nucleotides with four ORFs (Deeshma and Bhat, 2015).

Disease perpetuation and pre-disposing factors

The major means of spread is through infected planting materials. CMV could also be transmitted mechanically to several cucurbitaceous and solanaceous hosts (Sarma *et al.*, 2001). On contrary, PYMoV has narrow host range and transmitted semipersistently by mealybugs such as *Ferrisia virgata* and *Planococcus citri* (Lockhart *et al.*, 1997; Bhat *et al.*, 2003), by black pepper lace bug (de Silva *et al.*, 2002) and also through seeds (Deeshma and Bhat, 2015).

Disease management

- Rapid and sensitive nucleic - acid based diagnostic tools are essential for indexing the mother stocks to further produce virus - free planting materials. Several diagnostic tools like PCR for PYMoV (Bhat *et al.*, 2009), single tube multiplex RT - PCR for simultaneous detection of CMV and PYMoV (Bhat and Siju, 2007), SYBR green - based real - time PCR for PYMoV and CMV (Bhat and Siljo, 2014), loop - mediated isothermal amplification (LAMP) for PYMoV and reverse transcriptase (RT) LAMP for CMV (Bhat *et al.*, 2013) have been developed and found efficient in detecting both the viruses.
- Under field conditions, regular inspection and rouging of infected plants should be carried out promptly followed by replanting with disease - free healthy plants.
- A mother block raised with virus - free planting materials from certified high yielding source plants of known elite varieties should be established from which disease - free

planting materials collected shall be multiplied in nurseries under protected condition (insect - proof).

- In the nurseries and fields whenever insect vectors such as aphids and mealybugs are observed, recommended insecticides should be sprayed.
- Adopt proper soil and plant health management packages by providing irrigation and shade during summer season and application of balanced fertilizer based on soil test.
- In case of mild and moderate stages of infection, supplementary foliar sprays with micronutrient (0.25%) after spike emergence and setting during June and September should be undertaken. However, no planting material should be collected from such infected plants (Bhat *et al.*, 2010).

CARDAMOM (*Elettaria cardamomum* Maton)

Small cardamom, popularly acclaimed as Queen of Spices is a commercially important spice crop belonging to the rhizomatous family, Zingiberaceae. The cardamom of commerce *i.e.*, the dried fruits or capsules is highly valued for its intrinsic superior qualities like flavour and aroma (Ravindran, 2002).

Capsule rot (*Azhukal*)

Capsule rot, also referred as *Azhukal* (rotting in Malayalam) is the most devastating disease of cardamom. The disease was reported for the first time from Idukki, Kerala and is reported to be widespread cardamom cultivating regions of South India with a reported crop loss of 30%.

Symptoms

The first visible symptoms appear as discoloured water soaked lesions on young leaves and capsules which subsequently enlarge resulting in decay. As a result, immature unopened leaves fail to unfurl. As the disease advances, the lesion turn necrotic, leaves decay, shrivels and shreds. On capsules, water soaked discoloured patches develops which later turn brownish leading to rotting (Fig. 5) and dropping. From the capsules, infection may spread to panicle and whole inflorescence is affected. In severe conditions, entire pseudostem and panicle decays in which, rotting extends to rhizomes and roots resulting in collapse of the entire plant (Thomas and Bhai, 2002).

Causal organism

Earlier studies indicated that the disease is caused by *Phytophthora palmivora*. *Pythium vexans* and *Fusarium* sp. were also found associated with the disease. Later, *Phytophthora nicotianae* var. *nicotianae* was identified as the causative agent which also infects cocoa, coconut, arecanut, black pepper, rubber and wild *Colocasia* (Thomas and Bhai, 2002). Later, Bhai (1998) reported capsule rot of cardamom is caused by A2 mating type of *P. meadii.*

Disease perpetuation and pre-disposing factors

The disease appears after the onset of South - West monsoon and favoured by high soil moisture (34.3 - 37.6%), low temperature (20.4 - 21.3°C), high relative humidity (83 - 90.6 %) and high rainfall (320 - 400 mm), thick shade, closer spacing and water logging (Thomas and Bhai, 2002). *Phytophthora* survives in soil as hyphae and sporangia for 4 - 6 weeks while as chlamydospores, it survives for 48 weeks in moist soils.

Important Diseases of Major Spice Crops

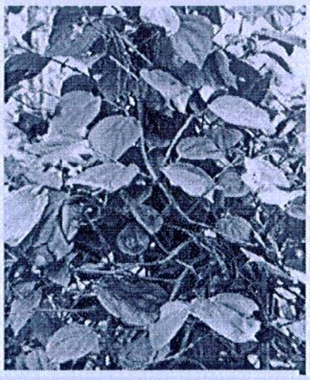
Fig. 1. Foot rot of black pepper

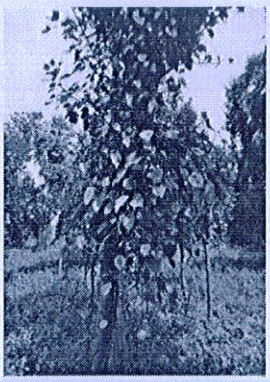
Fig. 2. Slow decline of black pepper


Fig. 3. Anthracnose of black pepper


Fig. 4. Stunt disease of black pepper

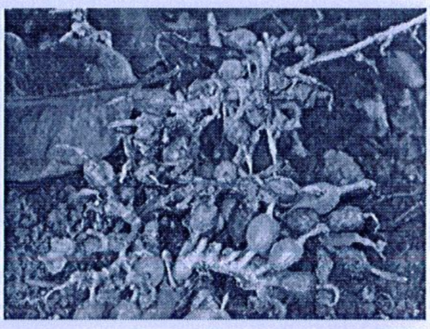
Fig. 5. Capsule rot (*Azhukal*) of cardamom


Fig. 6. Rhizome rot of cardamom

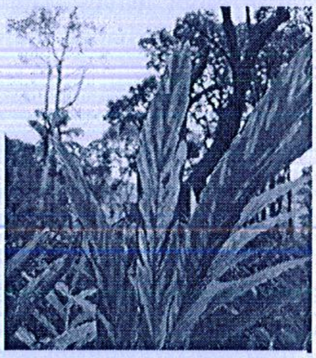
Fig. 7. Leaf blight of cardamom

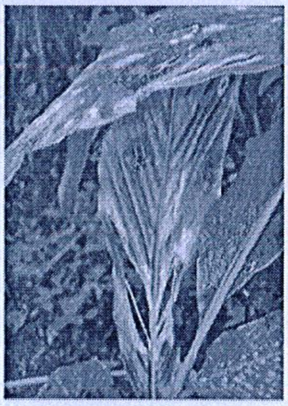
Fig. 8. *Phytophthora* leaf blight of cardamom

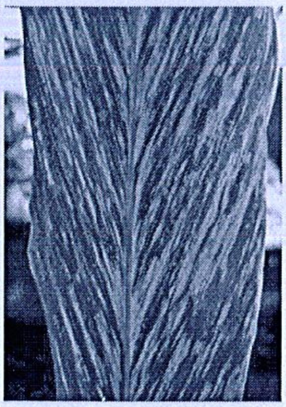
Fig. 9. *Katte*/mosaic disease of cardamom

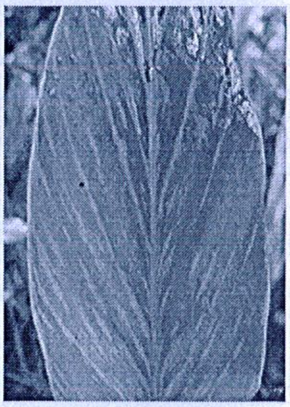
Fig. 10. Chlorotic streak of cardamom

Disease management

- Adopt strict phytosanitation and prevent water stagnation.
- Spraying and drenching with Bordeaux mixture (1%) and copper oxychloride (0.2%) or 2 - 3 rounds spraying; one round of prophylactic spray with Bordeaux mixture (1%) or Aliette (fosetyl aluminium) (0.3%) effectively manages the disease (Thomas and Bhai, 2002) under field conditions.
- Biocontrol agents like *Trichoderma viride* and *T. harzianum* applied to plant basins @1 kg during May and September - October are also recommended to manage the disease (Suseela Bhai *et al.*, 1993).
- Two cultivars each of Mysore and Malabar morphotypes *viz.*, MCC 60, 61, 12 and 40 (ICRI selections) were found moderately tolerant to *Azhukal* disease.

Rhizome rot/clump rot

Rhizome rot, also known as clump rot is a devastating soil - borne disease of cardamom. The disease was first reported by Park in 1937 and later, Subba Rao (1938) designated it as clump rot disease (in Thomas and Bhai, 2002).

Symptoms

The first visible symptom is the development of pale yellow colour on the foliage and premature death of older leaves. The collar portion of aerial shoots become brittle and the tiller breaks at slight disturbance. Symptoms of rotting develop at the collar region, which becomes soft and turns brownish. In the advanced stages, all the affected aerial shoots topple (Fig. 6). The rotting extends to the panicles, young shoots, rhizomes and roots, resulting in total destruction of the plant.

Causal organism

Subba Rao (1938) reported rhizome rot is caused by *Rhizoctonia solani* in association with a nematode. Later, Ramakrishnan (1949) reported, *Pythium vexans* as the causal agent of rhizome rot. *Fusarium oxysporum* occasionally causes rhizome and root rot (Thomas and Bhai, 2002).

Disease perpetuation and pre-disposing factors

The disease attains severity during July - August. Prolonged dampness, presence of abundant inocula in the soil and plant debris, overcrowding of plants and thick shade provides congenial conditions for disease development (Venugopal *et al.*, 2006).

Disease management

- Phytosanitation along with other cultural operations like shade regulation, adequate spacing and provisions for drainage shall be adopted.
- Drenching plant basins with Bordeaux mixture (1%) or copper oxychloride (0.25%) or neem cake followed by pre - monsoon and post - monsoon drenching with copper oxychloride (0.25%) at one month interval and application of *T. harzianum*

formulation in a carrier medium consisting of farmyard manure and coffee husk mixture have been reported effective (Thomas and Bhai, 2002) in managing the disease.

- Eapen and Venugopal (1995) and Eapen *et al.* (2005) reported the effectiveness of *T. harzianum* in reducing damping off and rhizome rot in cardamom nurseries.
- In endemic areas, the resistant variety, IISR Avinash can be cultivated.

Leaf blight (*Chenthal*)

Leaf blight popularly known as *Chenthal* has been reported in cardamom plantations 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.

Symptoms

The characteristic symptoms of leaf blight are formation of water soaked rectangular lesions on leaves which later elongates to form parallel streaks. In the later stages, the lesions become yellowish - brown to orangish - red with necrotic center (Fig. 7). In the advanced stage of disease development, more number of lesions develops on older leaves. These lesions subsequently coalesce together resulting in drying of the affected area. The flowers produced during advanced stages fail to set (Thomas and Bhai, 2002).

Causal organism

The causal agent of *Chenthal* disease was earlier reported as *Corynebacterium* sp. (George and Jayashankar, 1977). Later, detailed investigations on symptomatology, etiology and management clearly indicated that, the disease is caused by *Colletotrichum gloeosporioides* (Govindaraju *et al.*, 1996 in Thomas and Bhai, 2002).

Disease perpetuation and pre-disposing factors

The disease though prevalent throughout the year in the plantations, assumes severity during post - monsoon period. The disease spread is faster in partially deforested areas and less shaded plantations.

Disease management

- The disease can be managed by spraying carbendazim (0.3%) or mancozeb (0.3%) or copper oxychloride (0.25%) at monthly intervals (Govindaraju *et al.*, 1996 in Thomas and Bhai, 2002).

***Phytophthora* leaf blight**

Phytophthora leaf blight is prevalent in cardamom plantations during the post - monsoon season. (Thomas *et.al.*, 1994).

Symptoms

The infection starts on the young and unopened leaves as water soaked patches which soon become necrotic and dries (Fig. 8). A burned appearance is observed under conditions of severe infection in the plantations.

Causal organism

The disease is caused by *P. nicotianae var. nicotianae* (Bhai and Sarma, 2003).

Disease perpetuation and pre-disposing factors

Thick shade, low night temperature and fog prevailing during the winter period pre-dispose the plants to infection.

Disease management

- Foliar sprays with Bordeaux mixture (1%) or potassium phosphonate (0.3%) are found effective in limiting spread of the disease.

Anthracnose

Symptoms

Reddish brown sunken spots of 1 - 2 mm diameter with soft depressed center are formed on the capsules. The lesion varies in number and size and sometimes coalesces to form large lesions (Bhai *et al.*, 1988).

Causal organism

The disease is caused by *Colletotrichum gloeosporioides.*

Disease management

- Spraying fungicides such as Cuman L, Captofol or carbendazim (0.3%) thrice at 15 days interval found to be effective in managing the disease.

Mosaic or *Katte* Disease

Katte/mosaic/marble disease is the major viral disease of cardamom with a wide distribution in all cardamom growing tracts with incidence ranging from 0.01 - 99%. Crop losses of 10 - 60%, 26 - 91% and 82 - 92% were reported under cardamom-areca mixed cropping in first, second and third years of production respectively. In monocrop situations, a yield reduction of 38, 62 and 68.7% were reported for the first, second and third year of infection (Venugopal, 2002). In general total decline of plants occur within 3 - 5 years of infection.

Symptoms

Prominent, discontinuous yellowish stripes radiating from midrib to the margin are formed on young leaves (Fig. 9). The size of leaves gets reduced progressively; the plant looses vigour and becomes stunted with mottling on the leaf sheath. The disease gradually spreads to all tillers in a clump and in advanced stages, the affected plants produce shorter and slender tillers with few short panicles.

Causal organism

The disease is caused by *Cardamom mosaic virus* (CdMV). Earlier, involvement of a flexuous rod shaped virus with dimensions of 650 nm and 10 - 12 nm resembling *Potyvirus* was reported. Further, the presence of pinwheel type inclusion bodies in the cytoplasm of infected plants confirmed the association of *Potyvirus* (Gonsalves *et al.*, 1986). Based on coat protein and 3' untranslated region (UTR) sequence studies the *Katte* virus was placed as a new member of the genus, *Macluravirus* of family, Potyviridae. Based on cloning and sequencing of the coat protein and 3' UTR region the existence of different strains was reported (Jacob and Usha, 2001). RT -PCR for the detection of the virus with primers targeting conserved region of coat protein was also developed and validated (Biju *et al.*, 2010).

Disease perpetuation and pre-disposing factors

The primary sources of infection include, infected clones, nearby infected plantations and volunteers (Venugopal, 2002). In plantations, primary spread occurs at random due to the activity of viruliferous alate forms of vector, *Pentalonia caladii* (Foottit *et al.*, 2010). Incubation period for the virus within the plant vary from 20 - 114 days and expression is directly influenced by growth of plants (Venugopal, 2002).

Chlorotic streak

Chlorotic streak is a viral disease of recent origin with an incidence ranging 0 - 15% (Siljo *et al.*, 2012).

Symptoms

The disease is characterized with the formation of continuous or discontinuous spindle shaped yellow or light green intravenous streaks along the veins and midrib. The disease initially manifests as spindle shaped chlorotic streaks intravenously and on the midrib region (Fig. 10). These streaks coalesce together and imparts yellow or light green colour to the veins. Discontinuous spindle shaped mottling on the pseudostem and petioles are also noticed. In severe cases, tillering of the affected plants was suppressed. The distinguishing feature of the disease is the formation intravenous chlorotic streaks (Siljo *et al.*, 2012).

Causal organism

Leaf dip electron microscopy of infected leaves revealed the presence of flexuous virions resembling *Potyvirus*. Cloning and sequencing of coat protein gene from different geographical isolates showed an identity of >94% with *Banana bract mosaic virus* (BBrMV) indicating that the causal virus is a strain of BBrMV. Phylogenetic analyses showed high sequence conservation among BBrMV isolates irrespective of host and geographical origin. Subsequently, RT - PCR based procedure was developed using primers designed for conserved coat protein region of the virus (Siljo *et al.*, 2012).

Disease management

- Raise the primary or clonal nurseries in isolated locations to produce disease - free healthy seedlings.

- Rouging of the infected volunteers and total avoidance of volunteers in the vicinity of primary nurseries (Venugopal, 2002). Dimitman (1981) reported that, large areas are free from *Katte* infection in Guatemala. Hence, prevent movement of planting materials from endemic areas to new regions to check the introduction and spread of viruses.
- Chemical control methods are less effective owing to the non and semi - persistent modes of transmission by the vectors. Further, year round persistence of vector in the plantations makes control measures with chemicals challenging (Venugopal, 2002).
- Periodical removal of senile old parts and natural hosts like *Colocasia* and *Caladium* destroys breeding sites of the vector.
- Extracts from several plant species including, neem, aqueous extracts of *Acorus calamus*, seeds of *Annona squamosa* and leaves of *Lawsonia inermis* were found to reduce setting percentage of aphids on cardamom leaves.
- Entomogenous fungi like *Beauveria bassiana*, *Verticillium chlamydosporium* and *Paecilomyces lilacinus* were also found promising in suppressing aphid population.
- Cardamom being perennial, propagated vegetatively, detecting viruses in planting material is important to prevent disease spread through infected planting material. Detection of CdMV by Enzyme Linked Immunosorbent Assay was reported by Gonsalves *et al.*, (1986). Biju *et al.*, (2010) and Siljo *et al.* (2012) developed reverse transcription - polymerase chain reaction protocols targeting coat protein for CdMV and BBrMV, respectively. Protocols for the detection of CdMV and BBrMV were also developed using SYBR Green one step reverse transcription - quantitative PCR (Siljo *et al.*, 2014).
- The immune variety, IISR Vijetha is recommended for *Katte* endemic regions (Venugopal, 2002).

Nematodes

Symptoms

The aerial symptoms induced by root knot nematode includes, stunting, reduced tillering, rosetting and narrowing of leaves. Symptoms manifested on foliage include yellow banding on the leaf blades and drying of leaf tips and margins (Fig. 11). Flowering is normally delayed in the affected plants and immature fruits drop resulting in yield reduction. Underground symptoms develop on the roots in the form of prominent galls while the tender roots exhibit spherical or ovoid swellings.

Causal organism

Among the 20 genera of plant parasitic nematodes reported from cardamom soils, *Meloidogyne incognita* causes severe damage. Root knot nematodes are commonly found in almost all plantations and nurseries while, the root lesion nematode, *Pratylenchus coffeae* and the burrowing nematode, *Radopholus similis* are noticed in plantations where cardamom is grown along with other component crops.

Disease perpetuation and pre-disposing factors

Nematode population is high in cardamom soils during September - January (post - monsoon period). Nematode multiplication in cardamom soils are favoured by heavy shade, moisture level of the soil and warm humid weather (Ramana and Eapen, 2000).

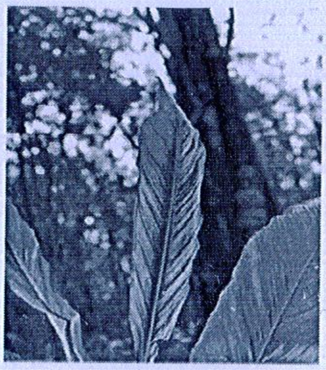

Fig. 11. Nematode-induced symptoms in cardamom

Fig. 12. Soft rot of ginger

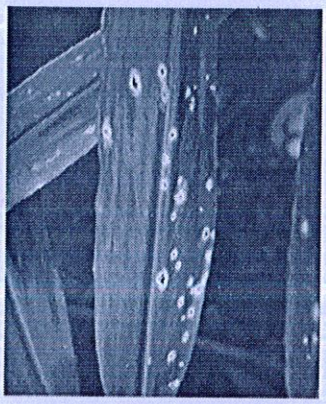

Fig. 13. *Phyllosticta* leaf spot of ginger

Fig. 14. Bacterial wilt of ginger

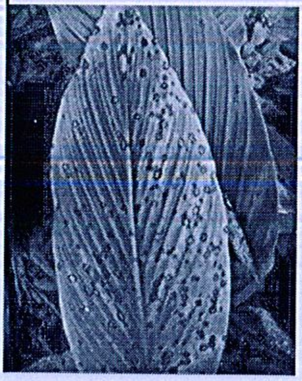

Fig. 15. Leaf blotch of turmeric

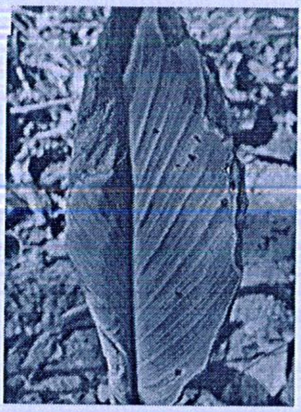

Fig. 16. Leaf spot of turmeric

Fig. 17. *Phytophthora* bean rot of vanilla

Fig. 18. Root rot of vanilla

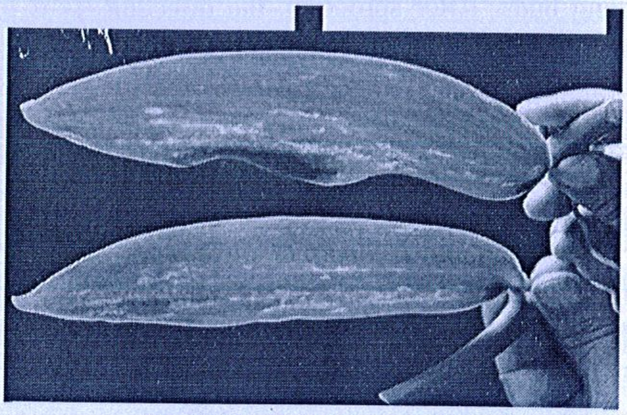

Fig. 19. Virus disease of vanilla

Disease management

- Avoid transplanting nematode infected seedlings to plantations.
- Solarization and/or pre - treatment of nursery beds with methyl bromide (@500g per $10m^2$) or soil drenching with formalin (2%) and application of nematicides such as aldicarb, carbofuran or phorate at the rate of 5g a.i. per plant twice a year were found effective in reducing nematode population.
- Application of biocontrol agents like *Trichoderma* sp. and *Paecilomyces lilacinus* (Eapen and Venugopal, 1995) can be used as an eco - friendly strategy to manage nematodes.

GINGER (*Zingiber officinale* Roscoe)

Ginger, the herbaceous rhizomatous plant is a member of Zingiberaceae family. Globally, commercial cultivation of ginger is concentrated in countries like India, China, Taiwan, Malaysia, East - West Africa and Tanzania. The ginger of commerce is the fresh or dried rhizomes of *Z. officinale*. In India, ginger is commercially cultivated in Kerala, Karnataka, Tamil Nadu, West Bengal, Bihar, Uttar Pradesh, Meghalaya, Sikkim and Odisha (Ravindran and Nirmal Babu, 2005).

Soft Rot

Soft rot, also referred as rhizome rot or *Pythium* rot was first reported by Butler (1907) from Surat (Gujarat), India (Kumar *et al.*, 2012). Among the diseases of ginger, soft rot is considered as the most destructive and reported to be prevalent in India, Japan, China, Nigeria, Fiji, Taiwan, Australia, Hawaii, Sri Lanka, and Korea (Dohroo, 2005).

Symptoms

In mature plants, collar infection leads to foliar yellowing which starts from leaf tip and spreads downward along the margins (Fig. 12) leading to death of leaves, which droop and hang until the entire shoot dries. The basal portion exhibits pale translucent discolouration which later turns water soaked and soft leading to toppling of affected shoots. The rhizomes initially turn brown, gradually decompose transforming into a watery mass of putrefying tissue enclosed within skin of the rhizome emitting foul smell. However, the fibro - vascular strands are not affected and remain isolated within the decaying mass. The roots of affected rhizome become soft and rotten. Ginger is susceptible to *Pythium* infection at all stages of growth. When the seed rhizomes are infected, they fail to sprout due to extensive rotting of young buds. After sprouting, the infection takes place through root or through collar region, finally spreading to the rhizome (Kumar *et al.*, 2012).

Causal organisms

Globally, several species of *Pythium viz.*, *P. aphanidermatum*, *P. myriotylum*, *P. vexans*, *P. ultimum*, *P. splendens* and *P. deliense* have been reported infecting ginger. About six *Pythium* species namely, *P. aphanidermatum*, *P. butleri*, *P. deliense*, *P. myriotylum*, *P. pleroticum*, *P. ultimum* and *P. vexans* have been reported to cause soft rot in different parts of India (Dohroo, 2005) of which, the predominant species is *P. myriotylum* (Kumar *et al.*, 2008).

Disease perpetuation and pre-disposing factors

High soil moisture, high relative humidity and relatively low temperature are major pre -disposing factors. The high soil moisture content and ambient temperature (25°C - 30°C) prevailing during monsoon provides conducive environment. From the primary foci of infection, disease spreads to adjacent clumps primarily through soil water by means of zoospores and/or hyphal fragments. The disease is generally low in well - drained soils while, water stagnation aggravates disease severity (Dohroo, 2005).

Disease management

- Infected rhizomes are the primary source of infection and hence, select disease - free rhizomes for planting and ensure adequate drainage facilities to prevent water stagnation.
- Soil solarization with transparent polythene film (300 microns thick) ideally during March to significantly reduces soil - borne inoculum.
- Treating seed rhizomes with mancozeb (0.3%) or carbendazim (0.3%) for 30 minutes prior to storing and planting is recommended to reduce seed - borne inoculum. Carbendazim alone or in combination with mancozeb is also used to prevent the seed - borne inocula of both *Pythium* and *Fusarium.* Drenching with mancozeb (0.3%) or Cheshunt compound or metalaxyl @ 500 ppm was reported to reduce soft rot.
- Soil amendments with oil cakes of *Azadirachta indica* or *Calophyllum inophyllum* are reported to be effective in reducing the rot incidence.
- *Trichoderma harzianum, T. hamatum, T. virens, Bacillus lentus* and *Pseudomonas fluorescens* have been reported to suppress soil - borne pathogens of ginger (Bhai *et al.*, 2005).

Fusarium yellows

Fusarium yellows was originally reported from Queensland and subsequently from Hawaii (USA) and India (Kumar *et al.*, 2012).

Symptoms

The symptoms initiates as marginal yellowing of lower leaves, which gradually spreads to entire leaf lamina. The mature leaves dry initially, followed by the younger ones. Other pronounced symptoms include, premature drooping, wilting and drying in patches. On rhizomes, creamish to brown discolouration develops accompanied with shriveling and vascular rotting. In the advanced stages, only the fibrous tissue remains within the rhizomes. Nematode infestations are generally found associated with *Fusarium* yellows.

Causal organism

The disease is caused by *Fusarium oxysporum* f. sp. *zingiberi* and predisposed by nematode infestation especially by *Pratylenchus coffeae* (Kumar *et al.*, 2012).

Disease perpetuation and pre-disposing factors

A temperature range of 15 - 30°C (optimum 23 - 29°C), accompanied with high humidity and moisture favours disease development. Maximum disease incidence occurs when the soil temperature range from 24 - 25°C and the soil moisture from 25 - 30%.

Disease management

- Collect planting materials from disease - free regions. While selecting the seed rhizomes, discard shriveled pieces with brown discolouration.
- Crop rotation for at least 2 - 5 years between ginger crops will reduce soil - borne inoculum.
- Seed treatment, consisting of a mixture of mancozeb – thiophanate methyl (0.25%) and carbendazim (0.1%) for 60 minutes was found to be effective.
- Pine needle amendment alone and in combination with a fungicidal seed treatment and combination of *Trichoderma harzianum* and *Gigaspora margarita*, resulted in better control with maximum yield. Inhibition of *Pratylenchus* spp. was best with pine needle organic amendment in combination with *T. harzianum* seed and soil application (Dohroo, 2005).

Leaf spot

In ginger, leaf spot diseases are incited by *Phyllosticta zingiberi*, *Colletotrichum gloeosporioides*, *Helminthosporium maydis* and *Pyricularia zingiberi* of which, leaf spot incited by *P. zingiberi* is the major one which was reported for the first time in Godavari and Malabar regions of India (Ramakrishnan, 1942).

Symptoms (*Phyllosticta* leaf spot)

Initially small, spindle to oval or elongated spots with white papery center and dark brown margins surrounded by yellowish halo appear on younger leaves. The spots later expands and coalesce to form large spots, which eventually decrease the effective photosynthetic area. The infected areas often dry up at the center, forming shot - holes (Fig. 13) and subsequently, the entire leaf dries. In the advanced stage, the crop develops a greyish disheveled look.

Causal organism

The phyllosphere fungus, *Phyllosticta zingiberi* causes the disease.

Disease perpetuation and pre-disposing factors

The disease appears towards end of June when the plants are at the most susceptible stage (3 - 4 leaf stage) and have received high cumulative rainfall which is conducive for disease spread. During this period, the temperature varies between 23.4 and 29.6°C and relative humidity between 80 - 90%. Later in July, when the number of rainy days and total rainfall increases, the disease aggravates and spreads at faster rate. Ginger upto the age of 6 - 7 months are susceptible to the disease and two weeks old leaves are most susceptible.

Disease management

- The seed rhizomes should be selected from disease - free areas, as the disease can be spread through rhizomes.
- Seed rhizome can be treated with carbendazim - mancozeb or carbendazim (0.25%) before planting. Prochloraz, tebuconazole, chlorothalonil, mancozeb, captan and chlorothalonil - copper are also reported to be effective and increase yield in ginger in Brazil (Nazareno and De - Nazareno, 1995).
- Providing shade is a natural method for management of leaf spot diseases.

Important Diseases of Major Spice Crops

Bacterial wilt

Bacterial wilt is one of the most important production constraints in tropical, sub - tropical and warm temperature regions of the world (Kumar and Hayward, 2005).

Symptoms

The first noticeable symptom of bacterial wilt is downward curling of leaves due to loss of turgidity. The bacteria enter the plant system and move through xylem vessels leading to interference with translocation of water and nutrients. Subsequently the leaves droop and wilt leading to death of above ground parts (Fig. 14). The affected rhizome starts rotting and putrefying due to attack of saprophytic soil microorganisms. The rotted rhizomes emit foul smell and the affected plants die within 2 - 3 weeks.

Causal organism

Bacterial wilt caused by *Ralstonia solanacearum* biovar 3, is one of the important rhizome - borne diseases of ginger. In India, biovar 3 causes rapid wilt in ginger in 5 - 7 days under artificial stem inoculation and in 7 - 10 days under soil inoculation (Kumar and Hayward, 2005).

Disease perpetuation and pre-disposing factors

Rhizome - borne inoculum is primarily responsible for disease initiation which further spreads horizontally aided by high rainfall and cool weather. The rhizomes collected from previously diseased field may disseminate the disease to new locations as well as to next season (Kumar and Hayward, 2005). The pathogen survives in soil and makes it unsuitable for ginger cultivation once introduced through infected planting material. In India, the disease is reported in all major ginger growing regions and severe in hot and humid southern states (ambient temperature is 28 - 36°C) as well as in cold high altitude regions of Sikkim (ambient temperature is 7 - 22°C).

Disease management

- Use healthy rhizome material from disease - free area with no history of bacterial wilt in the past.
- Pre - plant rhizome treatment by heat or rhizome solarization.
- Strict phytosanitation in the field including restrictions on movement of farm workers and irrigation water across the field and adopt nematode management measures.
- Crop rotation with non - host plants like cereals such as paddy and maize.
- Apoplastic bacteria of ginger have been found inhibitory to *R. solanacearum* (Prameela, 2016).

Nematodes

Symptoms

The symptoms induced by nematodes include stunting, chlorosis and failure to tiller profusely. Histopathological studies demonstrated that, nematodes enter the rhizomes and penetrate the tissues intracellularly, resulting in destruction of tissues and formation of channels or galleries within the rhizomes. Secondary organisms eventually rot the entire rhizome.

Causal organism

Several plant parasitic nematodes including *Meloidogyne* spp., *Radopholus similis* and *Pratylenchus* spp. have been reported to cause significant damage in ginger of which, *M. incognita* was found causing damage to ginger in Kerala, India. *P. coffeae* infection reduces germination as well as marketability of ginger rhizomes and further aggravates *Fusarium* yellows.

Disease mmanagement

- Hot water treatment of seed rhizomes (50°C for 10 minutes), soil solarization for 40 days and incorporating *Pochonia chlamydosporia* in ginger beds (20 g/bed with 10^6 cfu/g) at time of sowing reduces nematode population.
- Soil application of carbofuran at 3kg a.i./ha, 3 weeks after planting of ginger decreased yield losses due to *Meloidogyne.* Pre-planting application of neem cake (1 t/ha) followed by post planting application of carbofuran (1kg a.i./ha) 45 days after planting is found effective to control *M. incognita.*
- Cultivate the resistant variety, IISR Mahima in regions with high nematode population.

TURMERIC (*Curcuma longa* Linnaeus)

Turmeric is also known as the golden spice as well as the spice of life. Turmeric is cultivated extensively in India, followed by Bangladesh, China, Thailand, Cambodia, Malaysia, Indonesia and Philippines. India is the largest producer, consumer and exporter of turmeric (Ravindran, 2007).

Rhizome rot

Symptoms

The collar region of the pseudostem becomes soft and water soaked, resulting in collapse of the plant and decay of rhizomes.

Causal organism

The disease is caused by *Pythium graminicolum* and *P. aphanidermatum.* However, the predominant species associated with rhizome rot of turmeric is *P. aphanidermatum* (Anoop *et al.*, 2014).

Disease management

- Adopt strict phytosanitation.
- Practice crop rotation with maize and chilli.
- PCT - 13 and PCT - 14 and Ca 69 and cv. Shillong were found tolerant to rhizome rot disease.

- Rhizome treatment with a combination of mancozeb (0.25%) and quinalphos (@0.075%) for 15 minutes is recommended. Soil drenching with metalaxyl - mancozeb (0.2%) or mancozeb (0.2%) at 15 - 20 days interval twice with the first appearance of the symptoms is effective in managing the disease (Dohroo, 2007; Anandaraj *et al.*, 2014). *Trichoderma* species have also been found effective in managing the disease (Anoop and Bhai, 2014).

Leaf blotch

Symptoms

The disease initiates as small, oval, rectangular or irregular brown spots on either side of the leaves which soon become yellowish or dark brown. The leaves also turn yellow (Fig. 15). In severe cases the plants present a scorched appearance and rhizome yield is reduced significantly.

Causal organism

Leaf blotch is caused by *Taphrina maculans.*

Disease perpetuation and pre-disposing factors

The early appearance and severity of *T. maculans* depends on the presence of inoculum in the soil. Primary infection occurs on the lower leaves during October - November at 80% relative humidity and 22 - 23°C. The pathogen perpetuates through viable ascogenous cells borne on the infected leaf debris as well as through desiccated ascospores and blastospores during the crop season, oversummering in the soil and leaf thrash. Secondary infection is related to the availability of inoculum periodically produced under cool and humid conditions (Ahmad and Kulkarni, 1968). *Curcuma amada, C. angustifolia, Zingiber cassumnar, Z. zerumbet* and *Hedychium* sp. are reported to be the collateral hosts of *T. maculans* (Dohroo, 2007).

Disease management

- Adopt crop rotation and field sanitation to reduce the inoculum build - up in the soil.
- Foliar spray with zineb (0.2%), mancozeb (0.3%), copper oxychloride (0.2%) and carbendazim (0.1%) were found effective in controlling the disease (Srivastava and Gupta, 1977).
- Varieties such as CLL 324, Amalapuram, Mydukur, Karhadi Local, CLL 326, Ochira 24 and Alleppey among the *C. longa* group and Ca 68, Ca 67, Dahgi and Kasthuri among *C. aromatica* types are found tolerant to the disease (Nambiar *et al.*, 1977).

Leaf spot

Symptoms

The disease appears as brown spots of various sizes on the upper surface of young leaves. The spots are irregular in shape with white or grey center. Later, two or more spots may coalesce and form an irregular patch spreading entire leaf (Fig. 16). The affected leaves eventually dry up.

Causal organism

Leaf spot is caused by *Colletotrichum capsici*.

Disease management

- Adopt crop sanitation.
- The severity of the disease was found to be reduced (2%) under heavy shade of pigeon pea and partial shade (4.5%) of maize in comparison to open cultivation (Singh and Edison, 2003).
- Spray Bordeaux mixture (1%) during August, before the appearance of the disease. Two sprays of carbendazim (0.2%) at disease initiation and 15 days interval twice or six sprays of mancozeb (0.25%) at 15 days interval were found effective in managing leaf spot (Thamburaj, 1991).
- Varieties like Nallakatla, Sugandham, Duvvur and Gundikota were found resistant to leaf spot and Mannuthy Local showed high degree of field tolerance (Dohroo, 2007; Anandaraj *et al.*, 2014).

Nematodes

Root knot (*Meloidogyne* spp.) and burrowing nematode (*Radopholus similis*) are the two important nematode genera infecting turmeric. Root lesion nematodes (*Pratylenchus* spp.) are of common occurrence in Andhra Pradesh. In nematode endemic areas, use only healthy, nematode - free planting material. Increasing organic content of the soil also checks the multiplication of nematodes. *Pochonia chlamydosporia* can be applied to the beds at the time of sowing @ 20 g/bed (10^6 cfu/g) for managing nematodes (Dohroo, 2007; Anandaraj *et al.*, 2014).

VANILLA (*Vanilla planifolia* Andrews)

Vanilla, the prince of spices, is a succulent climber cultivated for vanillin which is highly priced in the international market. In India, vanilla is grown largely in Karnataka, Kerala and Tamil Nadu (Bhai and Jithya, 2008).

Phytophthora bean rot

In India, the disease is reported in several plantations of Karnataka and Kerala (Suseela Bhai and Joseph Thomas, 2000) which makes its appearance with the onset of South - West monsoon.

Symptoms

The symptoms manifest as rotting of beans which usually initiates from the tip and extends to the stalk or from pedicel region which progresses towards the tip. The affected beans becomes water soaked, soft, turn dark brown (Fig. 17) and sheds during moist weather while in dry weather, the rotten beans shrivels and remain attached to the bunch. The fully infected bunch drops, emitting a foul smell. In advanced stages of infection, the rotting extends to stem as well as leaves (Suseela Bhai and Joseph Thomas, 2000).

Causal organism

The disease is caused by *Phytophthora meadii. P. parasitica* and *P. jatrophae* are also reported to cause similar type of fruit rot disease.

Disease perpetuation and pre-disposing factors

Excess shade, continuous heavy rains, overcrowding of vines and water logged conditions are the pre - disposing factors.

Disease management

- Adopt phytosanitation measures.
- Regulate the shade during monsoon season to provide 30 - 50% shade.
- Foliar sprays with Bordeaux mixture (1%) and drenching the basins with copper oxychloride (0.25%) twice depending on the severity reduces the disease spread.

Premature yellowing and bean shedding

Yellowing and shedding of immature beans was reported from most of the vanilla plantations in lower elevations of Kerala and Karnataka (Bhai *et al.*, 2006).

Symptoms

The disease is characterized by dropping of dried corolla from the tip of immature beans. As the corolla drops, the exudates from the beans accumulate at the tip, the beans turn yellow and drop. The bean yellowing is followed by dark brown discolouration from the tip which proceeds upwards.

Causal organism

The disease is caused by *Colletotrichum vanillae.*

Disease perpetuation and pre-disposing factors

Overcrowding of beans, high temperature (32.57 - 35.57°C) and low relative humidity (45 -63.57%) during February - April aggravates the disease.

Disease management

- Provide 50% shade in the plantation followed by mist irrigation at least for 4 - 6 hours during pollination till the onset of pre - monsoon showers and maintain > 70% relative humidity.
- Restrict pollination to 15 - 18 flowers per inflorescence.
- Spraying thiophanate methyl (0.2%) or carbendazim - mancozeb (0.25%) at 15 - 20 days interval with the initiation of flowering manages the disease.

Stem rot

The disease has been reported from Java, Bali, North Sulawesi and North Sumatra. In India, stem rot disease is found as a serious threat to several vanilla plantations.

Symptoms

The symptoms appear as water soaked lesions on leaf axils extending to both sides of the stem. Later, elongated patches develop on the stem resulting in rotting and drying of tissues. In advanced stages, the leaves and stem turn yellowish and dries. The basal or middle portions of the vines shrivel and the remaining distal portions wilts.

Causal organism

Stem rot is caused by *Fusarium oxysporum* f. sp. *vanillae.* The pathogen was found to be specific to vanilla and failed to infect tomato, potato, groundnut, cucumber, ginger and cotton.

Disease management

- The disease can be managed by spraying mancozeb (0.2%) or in combination with carbendazim.
- Tombe *et al.* (1994) reported a rhizospheric bacterium of *Allium* sp. is promising. They also reported a number of mutants of *F. oxysporum* as biocontrol agents against pathogenic forms of *Fusarium* sp.

Root rot

Root rot is reported for the first time in Puerto Rico and noticed in isolated gardens where the drainage is very poor.

Symptoms

The infection appears as browning of root tips near to the soil (Fig. 18). In advanced stages, the roots decay leading to death of underground root system. The affected plants produce numerous aerial roots, but most of them wither before reaching the soil. The stem and leaves become flaccid, shrivels and the vines exhibits a wilted appearance.

Causal organism

Root rot is caused by *F. oxysporum* f. sp. *vanillae.* The disease is also reported to be caused by *Fusarium batatis* var. *vanillae. F. oxysporum* f. sp. *vanillae* invades the roots mainly through wounds caused by insects, nematodes or other agents.

Disease perpetuation and pre-disposing factors

The disease is aggravated during summer season due to excess sunlight and the vines become less capable of withstanding the infection due to lack of adequate translocation of water and minerals.

Disease management

- Providing adequate drainage, regulating shade, mulching plant basin and irrigation during drought period are recommended as management measures.
- Prophylactic sprays with carbendazim (0.2%) are found effective in reducing the disease incidence and *Paecilomyces* sp. was found effective under challenge inoculated conditions (Bhai *et al.*, 2009).
- Among various species, *V. pompona, V. phaentha* and *V. barbellata* are reported to be resistant to the pathogen.

Sclerotium bean rot

Symptoms

The symptoms appear as rotting of bean tips which proceed towards the pedicel regions. Affected beans are covered with thick white coloured mats of fungal mycelium forming a mantle around the fruit bunch. White threads of fungal hyphae run longitudinally on the leaves, stem and beans. Occasionally reddish brown sunken lesions are also formed on the affected plant parts (Joseph Thomas and Suseela Bhai, 1999).

Causal organism

The disease is caused by Sclerotium *rolfsii.*

Disease management

- The disease can be managed by drenching and foliar sprays with carbendazim (0.2%) or carbendazim - mancozeb mixture (0.25%) twice at 15 days interval (Joseph Thomas and Suseela Bhai, 1999)

Brown spot

Symptoms

The disease is characterized with the appearance of small water soaked spots on beans which later develop into characteristic brownish sunken lesions. The lesions will be either elongated, round or oval with sunken center which later coalesce to form larger lesions. Leaves of the affected plants also develop similar spots.

Causal organism

The disease is caused by *Cylindrocladium quinqueseptatum.*

Disease management

- Brown spot can be managed by spraying carbendazim or its combination with mancozeb (0.25%) (Bhai and Anandaraj, 2006).

Viral diseases

Symptoms

The symptoms of virus infected vanilla include mosaic or mild mottling with chlorotic specks or streaks on the leaves (Fig. 19) and rarely on stems followed by stunting, sterility and leaf distortions (Pearson *et al.*, 1993). The three cultivated species *viz.*, *Vanilla planifolia*, *V. pompona* and *V. tahitensis* are found susceptible to infection. In most cases spread of viruses occurs through vegetative means and to some extent through insect vectors like aphids.

Causal organism

Vanilla, being an orchid serves as reservoir of viruses. At least seven distinct types of viruses are reported) which includes, *Cucumber mosaic virus* (CMV) (Madhubala *et al.*, 2005), *Cymbidium mosaic virus* (CyMV), *Odentoglossum ring spot virus* (ORSV) (Pearson *et. al.*,1993), *Vanilla mosaic virus* (VMV), *Vanilla necrosis virus* (VNV) (Pearson *et al.*,1993), Bean common mosaic virus and *Bean yellow mosaic virus* (Bhadramurthy *et al.*, 2011). In most cases combined infection by more than one virus is seen.

Disease management

- Use of virus - free planting material invariably required to prevent virus spread. The mother plants should be indexed with sensitive nucleic acid tools to ascertain the virus - free status.
- Regular monitoring should be carried out to identify the plants with virus infection and such infected vines should be removed and destroyed in order to avoid further disease spread.
- Weed and crop hosts (especially pea, pumpkin and watermelon) which might act, as reservoir for the virus also needs to be removed. The removed plants may be burnt or buried deep in the soil.
- Physical contact of infected vines with healthy ones should be avoided to eliminate mechanical transmission of the disease.
- The insect vectors such as aphids may be controlled with insecticide spray.
- Movement of planting materials from infected regions to disease - free regions should be avoided.

FUTURE PERSPECTIVES

Spices are considered as 'India's charismatic signature", ever since our predecessors embarked on arduous explorations for herbs endowed with properties to impart flavour, aroma and taste to diverse forms of cuisines. Unlike other countries, in India, spices are grown as mixed crop in homestead gardens, coffee, tea, arecanut and coconut plantations. On contrary, ginger, turmeric, chillies and seed spices are grown in rotation with pulses and other field crops. The spice cultivating regions of India are bestowed with favourable weather conditions that support large-scale cultivation of a wide range of spices. However, unprecedented shifts in weather influence the existing synchronicity between host plant and pathogen, leading to disease outbreaks and epiphytotics. Diseases incited by a myriad of pathogens are considered as the major stumbling blocks adversely affecting production as well as productivity in spices. Further, evolution of new strains/races of pathogens and resurgence of minor pathogens with potential to create havocs still remains as threats to spice cultivation. The selection and timely adoption of mitigation strategies may help growers to cope with both abiotic and biotic stresses in the regime of climate change. In view of this scenario, multipronged approaches as exemplified with IDM modules encompassing varieties with durable resistance, cultural practices, chemicals as well as bioagents should be re - oriented amalgamating novel strategies for sustainable and economic production of spices.

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