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REVIEW

Scenario of fungal leaf spot and leaf blight diseases in coconut and arecanut

KEERTHANA JAYARAJAN, GREENA K.K, DALIYAMOL*, VINAYAKA HEGDE AND PRATHIBHA, V.H.
ICAR- Central Plantation Crops Research Institute, Kasaragod, Kerala

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Coconut and arecanut are two important plantation crops (palms) of the tropical region. Throughout the growth period, the palms are affected by different diseases from root to fruit. Among which Leaf spot and Leaf blight diseases are observed in all palm cultivated areas. The severity of the diseases depends on favourable conditions and nutritional status of the garden. However, the drastic change in climate caused serious impact on the distribution of the leaf spot diseases. Previously minor diseases like Leaf spot of arecanut (*Colletotrichum* species and *Phyllosticta* species) and *Lasiodiplodia* leaf blight of coconut are becoming lethal in different locations. Regular monitoring and integrated disease management approach is the key to keep the disease in check. An attempt is being made in the present review paper to summarize the different leaf blight and spot diseases affecting coconut and arecanut.

Keywords: Arecanut, coconut, Leaf blight, Leaf spot, management

INTRODUCTION

Coconut (*Cocos nucifera* L) and arecanut (*Areca catechu L)* are important plantation crops cultivated around the world. Coconut is grown mostly by small and marginal farmers and is the most useful since every part of the plant can be utilized. Globally, coconuts are grown in over 94 countries, and Asia and the Pacific region accounts for over 89.6% of coconut growing areas. In India, the plants are majorly cultivated in Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. In addition, coconuts are grown in Maharashtra, Orissa, West Bengal, Assam, Gujarat, Puducherry, Goa, as well as the islands of Lakshadweep and Andaman and Nicobar. Arecanut or betel nut is an important cash crop of India. Major arecanut growing countries include India, Bangladesh, Indonesia, Myanmar, China and Thailand. India ranks first in both area (49%) and production (50%). In spite of the fact that the production takes place in a few states, the commercial products are distributed across the country and are consumed by an array of different classes of people. Apart from using for chewing, it is also an important component of the social, religious and cultural celebrations in India.

Both plants being perennial are affected by many pests and diseases. Among the major pathogens infecting coconut, diseases caused by Phytoplasma*, Phytophthora* and *Ganoderm*a are the major threat to coconut production. Other fungal pathogens infecting coconut such as *Thielaviopis*, *Lasiodiplodia* and *Pestalotiopsis* have also emerged as serious diseases in different regions (Iyer *et al*. 2018). More than 70 fungi are associated with leaf diseases in coconut. Major ones include the leaf blight of coconut caused by *Lasiodiplodia theobromae* and Grey leaf blight caused by *Pestalotiopsis palmarum.* Among the major pathogens attacking arecanut, *Phytophthora*, Phytoplasma and *Ganoderma* are responsible for substantial loss in arecanut yield. Apart from this, various arecanut growing regions in the country have been reported to have emerging problems related to *Colletotrichum, Fusarium,* and *Xanthomonas.* Leaf spots and blights are noticed in almost all arecanut growing areas. Major ones include leaf spot caused by *Colletotrichum gloeosporioides* and Leaf blight caused by *Phyllosticta arecae*.

*****Correspondence: dmol86@gmail.com

Even though these diseases are not fatal compared with the major diseases, they do make considerable damage to the neglected plantations in advanced stage of infection by substantially decreasing the photosynthetic area and thereby decreasing the yield and general vitality of the palms. Currently with changing climatic conditions some of these pathogens are becoming emerging threats to the respective palms. Leaf blight caused by *L. theobromae* in coconut and Leaf spot caused by *C. gloeosporioides* are two of such examples of recent concern. Despite its importance, these diseases are poorly studied and understood. An attempt is being made in the present review paper to summarize the different leaf blight and spot diseases affecting coconut and arecanut.

IMPORTANCE

The Leaf spot and blight diseases have a detrimental effect on the growth and development of palm trees. It will not only reduce the yield exponentially, but also have a negative impact on the long-term yield. Even though the diseases are minor in nature there are instances when a minor disease finding a favourable environment or in combination with another disease, had caused epidemic and great financial loss. In the major coconut growing countries around the world, more than 70 different leaf diseases incited by fungi were reported (Ghose, 2014).

More than a dozen and half fungi have been identified as causing coconut leaf diseases in India.

Leaf blight is an emerging problem in all of the major coconut growing areas. It is reported that intensity of leaf disease caused by *Botryodiplodia theobromae* ranged from17 to 48 per cent in Guerrero coasts in Mexico. In recent years the disease is spreading at a faster rate in Coimbatore, Erode, Dindigul and other districts of Tamil Nadu (Jonson *et al*. 2017). The leaf blight disease is spreading rapidly in Thanjavur district, Tamil Nadu as reported by Surulirajan *et al*. (2014). It can cause yield loss ranged from 10-25% (Johnson *et al*. 2014, Ramjegathesh *et al*. 2019).

Generally, Grey leaf blight is a minor problem, but it can become severe under crowded or wet conditions, or after insects damage the leaves. In Hainan province of China, grey leaf blight caused yield loss of 2.24 million nuts in a growing area of over 23000 ha. In Paraiba province of Brazil, disease incidence of *Pestalotiopsis* leaf blight was found to be 100% (Cardoso *et al*. 2003). Karthikeyan *et al.* (2002) observed 10.0 to 23.6 per cent reduction in nut yield of coconut due to grey leaf blight disease in Veppankulam, Tamil Nadu. The imprudent management practices of coconut cultivation have led to the growth of this disease, especially in southern Kerala (Subramanyan and Santha Kumari, 2007). Rajan (2011) reported that the grey leaf blight fungus, *P. palmarum*, intensified the damage, causing rampant scorching of coconut leaves affected by coconut slug caterpillar, *Macroplectra nararia* in areas of east coastal India.

Leaf spots and blights are noticed in almost all arecanut growing areas and in all age groups of palms. However, the severity of the disease depends on favorable conditions, location and nutrient status of the arecanut gardens. Recently, the spread of leaf spot disease in arecanut plants has been worrying the farmers in several parts of Belthangady and Sullia taluks of Dakshin Kannada district of Karnataka with nearly 225 ha of plantations getting affected. Hegde (2018) reported that yield losses due to Leaf blight caused by *Phyllosticta arecae* in Uttar Kannada district is up to 60%.

STATUS AND DISTRIBUTION

Despite its cosmopolitan distribution, *L. theobromae* is most commonly found in tropical and subtropical areas. The pathogen is reported from Latin America, Africa, Asia, Florida, Hawaii and the Pacific regions (CABI/EPPO 2010). In India, the disease is widespread in major coconut growing states such as Tamil Nadu, Karnataka, Kerala, Andhra Pradesh, Orissa, Gujrat, Assam and Maharashtra. Johnson *et al*. (2014) reported that *Lasiodiplodia* has become a major problem in coconut growing districts of Tamil Nadu viz., Coimbatore, Erode, Dindigul, Tirunelveli and Kanyakumari which lead to yield reduction of 10–

25%. The disease is endemic in Sencherimaali, Thanthoni and Karapadi villages of Tirupur district and Odayakulam and Kaliapuram of Coimbatore district (Esakkimuthu *et al*. 2020). Survey conducted by Neeraja *et al*. (2020) in West Godavari and East Godavari districts of Andhra Pradesh indicated that the disease incidence was more in Jangareddygudem village of West Godavari (25.8%) and in Mamidikuduru village of East Godavari (25.5%).

Grey leaf blight caused by *P. palmarum* is widely distributed over South Asia, Brazil, Brunei, Colombia, Fiji, Guyana, Mexico, Mozambique, New Caledonia, Papua New Guinea, Nigeria, Samoa, Seychelles, Solomon Island, Tanzania. The disease was first identified in Guyana in 1931 and is now widespread throughout the tropical regions. Maximum incidence of the disease occurred during August and November in Andhra Pradesh. It is reported that at Vepangulam, Tamil Nadu disease intensity in East Coast Tall coconut was maximum in December (40.5 %) and minimum in June (23.9 %). Surveys conducted by Esakkimuthu *et al*. (2020) in Tamil Nadu showed that Avalchinnampalayam, Angalakuruchi and Kalliyapuram villages of Coimbatore district had maximum disease incidence and the severity was more in dwarf varieties compared to tall varieties. Study conducted in plantation crop based cropping system plots of Wayanad district of Kerala to assess different diseases for their incidence during different seasons revealed that in Coconut, grey leaf blight was found to be the most severe one with a disease incidence of 98.6% incidence during NE monsoon (John *et al*. 2011).

Inflorescence dieback and leaf spot caused by *C. gloeosporioides* is an emerging and serious disease that affects arecanut. In Hainan province of China, where anthracnose is prevalent, palms are subjected to 90% incidence of the disease (Zhu *et al*. 2015). In Karnataka and Kerala states of India, up to 60% of palm trees suffer from this disease according to studies conducted during 1970s. Survey conducted during 2018-2021 in 7 thaluks of Karnataka state viz., Shivamogga, Thirthahalli, Hosanagara, Shikaripura, Soraba, Bhadravathi, Sagara showed a mean disease incidence of 56.5 % with Shivamogga having the maximum incidence of 71.9% (Naik *et al*. 2021). Study undertaken in plantation crop based cropping system plots of Wayanad district of Kerala to assess different diseases for their incidence during different seasons revealed that in arecanut, leaf spot was found to be the most predominant one with a disease incidence of 97.3% incidence during NE monsoon (John *et al*. 2011).

Leaf blight caused by *Phyllosticta arecae* can cause heavy damage, especially during rainy weather. In Karnataka state, the disease was severe in the Uttar Kannada district during 1990s. In Uttar Kannada district average per cent infection per leaf due to leaf spot disease ranged from 2.13 to 29.65, 4.18 to 36.70 and 2.50 to 25.35 on arecanut. Based on surveys conducted during 2018-2021, *Phyllosticta* leaf spot was observed to be a frequent problem in almost all the talukas of Shivamogga district, with maximum incidence in Shivamogga taluk (37.6 %) (Naik *et al*. 2021).

LEAF SPOT DISEASES OF COCONUT

Grey leaf spot or grey leaf blight (Table 1) is one of the important foliar diseases of coconut (Elliott *et al*. 2004). The disease was first recorded in British Guyana. Later it was reported from other regions including Malaysia, Sri Lanka, India, Trinidad and Bangladesh (Bhuiyan *et al*., 2021). The palms at early stages (5-10 days) are shown to be more susceptible to the infection by *Pestalotiopsis*. But the pathogen is capable of causing serious damage both in seedling and adult palms (Iyer *et al*. 2018). The disease advances with the date of maturity of palm. Apart from coconut, the fungus also affects other palms such as arecanut, date palm, palmyrah and ornamental palms (Karim, 2005). Host range studies revealed that the fungus could infect other palms including oil palm and different ornamental palms, and these could act as collateral host of the pathogen. Grey leaf blight is a wide spread problem in all coconut growing areas especially in drought affected and neglected plantations. In India, the severity of the disease is more in summer months in low rainfall parts of Tamil Nadu and Karnataka. Subrahmanyan and Santha Kumari (2007) reported a positive correlation of

relative humidity, rainfall and wind speed on the incidence of the disease. Studies have also revealed that severity of grey leaf blight in coconut gardens surveyed was higher in all three seasons (summer, south-west monsoon and north-east monsoon) in Wayanad district of Kerala (John *et al*. 2011). The disease severity and the damage caused by the disease depend on the nutritional status and climatic factors and varieties. The incidence was observed throughout the year, but intensity of the disease increased with fall in temperature and increased rainfall and relative humidity (Ghose *et al*. 2006). Incidence of this disease often indicates the poor nutritional status of the garden, either potassium deficiency or excess nitrogen (Iyer and Nambiar, 2007; Ramesh *et al*. 2022). The symptom first appears on outer whorls, as small yellow spots with dark brown margin, which gradually turn in to brown with greyish centre. The spots eventually coalesce to form blighted appearance (Chinara, 2012; Rajeswari *et al*. 2020). On adaxial surface of leaves, rectangular, ovoid, globose or spherical black pycnidia are produced (Iyer *et al*. 2018). The infected palms were observed to flower lately than healthy palms. It is recorded that *P. palmarum* as the main inciter of leaf spot disease of coconut in British Solomon Islands, and observed evident difference in lesions produced by this fungus and other three *Pestalotiopsis* species. The genus *Pestalotiopsis* separated from *Pestalotia* on account of septation of conidia and number of apical appendages. *Pestalotiopsis* produces five celled conidia with three median brown cells and hyaline terminal cells. The conidia have a single hyaline basal appendage and two to four hyaline apical appendages (Maharachchikumbura *et al*. 2014). In Brazil, the symptoms on coconut leaves caused by *Pestalotiopsis guepinii* (Desm.) were evident and which was observed as dark coloured rounded elliptic spots with edges defined. As the symptom progressed the lesions became reddish brown and finally drying of the rachis part (Cardoso *et al*. 2003; Cardoso *et al*., 2020). Similar kinds of spots were observed in Brazil in dwarf variety of coconut and the causal organism was reported as *Neopestalotiopsis foedans* based on multigene analysis (Barbosa *et al*. 2023). In advanced stages, the spots coalesce and cause extensive blight on leaves with the presence of black acervuli on the upper surface. This leads to drying and shrivelling of leaves giving a burnt appearance. Premature shed of leaves leads to reduction in number of leaves and prolongation of pre-bearing age of the young palms. Infection in the juvenile stage affects the growth of the palm significantly. Significant damage can be caused by this single disease in nursery. *Pestalotiopsis* leaf blight was reported in both adult and juvenile palms of coconut in Tamil Nadu and it was observed that the palms of age 20-40 years were more susceptible to the infection by the fungus. Studies have shown that the disease incidence in the nursery stage could lead to reduction in height (10.4%), leaf production (20. 1%) and collar girth (12.5%) (Karthikeyan *et al*., 2002).

Lasiodiplodia leaf blight of coconut is one of the economically important fungal diseases in Brazil (Monteiro *et al*., 2013). Symptoms of the disease appear on the leaves of outer whorls, usually start from the tip and then the fungus systemically invades the rachis resulting in complete drying of the leaves and reduction of photosynthetic area (Neeraja *et al*. 2020; Rajeswari *et al*., 2020; Santos *et al*., 2020). As a consequence, leaves exhibit a burnt appearance and leaves of outer whorls of the palm fall off. Eventually the crown topples down causing the death of the palm (Bhaskaran *et al*. 2007a). Leaf blight affected leaves can be seen with apical necrosis with an inverted 'V' shape. Symptoms are often been confused with those of drought and other stresses (Chowdappa and Sharma, 2014). The fungus hastens the death of the palm already weakened by other abiotic stresses (Iyer *et al*. 2018). Bhaskaran *et al*. (2007b) reviewed this emerging disease as lethal leaf blight disease as the disease caused serious loss in coconut yield in certain districts of Tamil Nadu. The disease is responsible for the diminished productivity of the some coconut varieties in the coastal regions of Brazil ((Monteiro *et al*. 2013). Multigene analysis combined with morphological characters and pathogenicity studies revealed the association of *L. theobromae*, *L. pseudotheobromae* and *B. fabicerciana* with leaf blight in Brazil (Santos *et al.* 2020).

Distribution of minor leaf spots of coconut is given in Table 2. Leaf spot and blight caused by

Curvularia spp. have been reported from various parts of the coconut growing countries, where it is a problem especially in coconut seedlings and the severity is dependent on season. Different species are reported to be associated with the spot disease in coconut, such as *C. eragrostidis*, *C. lunata*, *C. oryzae* (Xu *et al*. 2020), *C. pseudobrachya* (Lekete *et al*. 2022). In China, the leaf spot caused by *C. oryzae* showed initial symptoms as water stained chlorotic spots which later progressed to form almost round, long oval, occasionally irregular with dark greyish white centre, brown edges and distinguishable yellow halo (Xu *et al*. 2020). The disease become serious in poorly drained neglected gardens and also nurseries established in heavy shade. *Colletotrichum* sp. incited brownish black lesions are generally observed on the nuts and it is reported that anthracnose symptoms on coconut leaves are also observed. Leaf spot symptoms caused by *Colletotrichum gloeosporioides* was reported from Hainan region of China. The lesions surrounded by yellowish halo later turned to grey with greyish mildew appearance at the centre, often resulted in defoliation (Sun *et al*. 2016). *Colletotrichum* leaf spot in hilly district of Kerala was reported to more severe in south west monsoon time (John *et al*., 2011). In Moju region of Brazil, epidemics of leaf spot led to reduction in production of many coconut trees. Although three fungi viz., *Cylindrocladium pteridis*, *Bipolaris incurvata* and *Pestalotiopsis* sp. were isolated, only *B. incurvata* caused the peculiar symptom upon pathogenicity test (Miranda *et al*., 2010). Based on morphological and molecular data, a different species of *Bipolaris* causing leaf spot in coconut seedlings was reported from China. Sporadic occurrence of *B. incurvata* in seedling and adult palms of Andaman and Nicobar islands was identified and the symptoms appeared as small dark spots often towards the leaf tip and the disease severity was slightly higher in the dry season. The spots appeared as brown elliptical flecks at first along with water soaked lesion. The lesions later eventually become yellow and merge together to spread to the leaf apex (Niu *et al*. 2014). Both *P. palmarum* and *B. invcurvata* were found associated with the leaf blight disease reported from Sri Lank (Anonymous, 2006). *Stemphylium* leaf spot was recorded from Oman observed as small circular spots enlarged to form olive green water soaked lesion and progressively dark brown spots. The fungus was inoculated on four different palms out of which only arecanut were infected with *Stemphylium*. In some parts of Maldives, the leaf spots caused by *P. palmarum*, *Pseudoepicoccum cocos* and *Fusicoccum* sp. were widespread in coconut plantation with little economic importance (Hunter and Shafiya, 2000). A new leaf spot caused by *Periconia* sp has been reported from India. The spots were identified as purplish brown small circular to elongated lesions. In the first record of *Drechslera* leaf spot of coconut, the disease symptom was described as dark brown sunken necrotic lesion on young leaves turning enlarged spots with pale centre and dark brown margin. Severe situation led to complete drying up of leaves. A severe incidence leaf blight disease was noticed in one to three year old seedlings of coconut in Andhra Pradesh, and the causal organism was identified as *Alternaria alternata* based on morphological characters. The spots were round to oval black which later turned to leaf blight with the advancement of summer. In introduced varieties in Cote d'Ivoire, leaf spot caused by *Helminthosporium halodes* caused severe damage. Inoculation studies have been conducted in nursery stage to investigate entry point of the pathogen, susceptibility to the disease and progression of the damage.

LEAF SPOT DISEASES OF ARECANUT

Major and minor Leaf spot and blight diseases of arecanut are enlisted in Tables 3 and 4. Even though leaf spot and blight diseases are common in arecanut growing regions, severity of the disease is dependent on favourable conditions, nutrient status and location of arecanut gardens. Leaf spots are observed in seedling and juvenile palms in different seasons. Palms of all age groups are noticed to be susceptible to leaf spots and blight diseases. Different fungi are associated with the disease in arecanut and the entry of the fungus to the host tissue is through the stomata and wounds. Severe infection of leaf spot pathogens was reported in coastal parts of Kerala and Karnataka during the monsoon (Chowdappa *et al.* 2007). *Colletotrichum gloeosporioides* and *Phyllosticta arecae* are the two major fungi causing leaf spot disease in arecanut. The

Table 1. Major Leaf spot and blight diseases of coconut

	Disease	Causal Organism	Symptoms
	Grey leaf blight	*Pestalotiopsis palmarum*	Spots appear as grey with a thin dark brown border. Sometimes, the spots join together and are surrounded by yellow haloes. Fungal fruiting structures are visible as tiny black dots within the spots.
	Leaf blight	*Lasiodiplodia theobromae*	Leaflets affected by this disease dry out from the tip downward and appear charred or burned. In general, leaves in the outer whorls are affected.

Table 2 : Other minor leaf spot and blight diseases of coconut and their distribution

Disease	Causal Organism	Distribution
Alterneria leaf spot	*Alternaria alternata*	India
Bipolaris leaf blight of coconut	*Bipolaris incurvata*	Hawaii, Florida, Jamaica, Asia, Australia, Oceania (French Polynesia, Fiji), Philippines,Seychelles,Brazil
Curvularia leaf spot of coconut	*Curvularia* spp.	Malayasia, India, China, Ghana, Sri Lanka
Drechslera leaf spot	*Drechslera incurvata*	Papua New Guinea, Jamaica, Brazil, S.E. Asia, Australasia and Oceania: British Solomon Islands, Fiji, French Polynesia, Malaysia, New Caledonia, New Hebrides, Papua -New Guinea, Philippines, Sri Lanka, Vietnam, Thailand
Algal leaf spot	*Cephaleuros virescens*	Hawaii
Anthracnose	*Colletotrichum gloeosporioides*	Brazil, India, China
Tar spot of coconut	*Catacauma* spp.	Brazil
Graphiola leaf spot	*Graphiola phoenicis*	-
Leaf blight	*Cytospora palmarum*	USA
Periconia leaf spot	*Periconia saraswathipurensis*	India
Stemphylium leaf spot	*Stemphylium* sp	Oman
Thread blight	*Pellicularia filamentosa, Corticium penicillatum*	Sri Lanka, Fiji, Papua New Guinea, Samoa and Solomon Islands in Oceania
Leaf spots	*Botryosphaeria cocogena*	Brazil
	Capitorostrum cocoes	Papua New Guinea, Indonesia
	Cercospora spp.	India, Fiji
	Cylindrocladium pteridis	Brazil
	Epicoccum spp.	Indonesia, Malaysia,

	New Caledonia, Papua
	New Guinea, Philippines, Samoa, Solomon Island,
	Tonga, US Trust Territory
Helminthosporium spp.	India, Ivory Coast, Fiji, Polynesia, Indonesia, Malaysia, New Caledonia, Papua New Guinea, Philippines, Sri Lanka, Thailand, Virgin Island, Solomon Island Lanka
Macrophoma spp.	-
Macrosporium cocos	-
Melanconium spp.	Papua New Guinea, SriLanka
Mycosphaerella spp.	India, Malaysia, Samoa, Sri Lanka, Bangladesh, Fiji, Australia,
	Indonesia, Papua New Guinea, Solomon Island
Periconiella cocoes	Australia, Papua New Guinea
Pseudoepicoccum cocos	Australia, American Samoa, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Kiribati, Marshall Islands, Niue, Palau, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis & Futuna
Phomopsis cocoes	Australia, Guam, India, Jamaica, Kenya, Malayasia, Mauritius, Nepal, Papua New Guinea, Peuto Rico, Seychelles, Solomon Islands, Sri Lanka, Trinidad and Tobago
Phyllosticta spp.	India, Brazil, Comoros

Table 3: Major Leaf spot and blight diseases of arecanut

Disease	Causal organism	Symptoms
Phyllosticta leaf spot	*Phyllosticta arecae* Hohnel	minute dark brown speck on the leaves, gradually increase in size to form irregular or oval to round spots with an ashy brown centre, with yellowing around the spot
Anthracnose	*Colletotrichum* spp	Circular to irregular brown spots with yellow halo; in advanced stage, leaf blight and shot hole symptom

symptom can be visible either individually or in combination. Severe infection was noticed when both the fungi were inoculated together (Chowdappa *et al.* 2014).

The fungus, *C.gloeosporioides* is known to have a very wide host range and it is progressively becoming important pathogen in many economically important crops worldwide. Inflorescence die back and button shedding caused by the fungus are some of the reasons

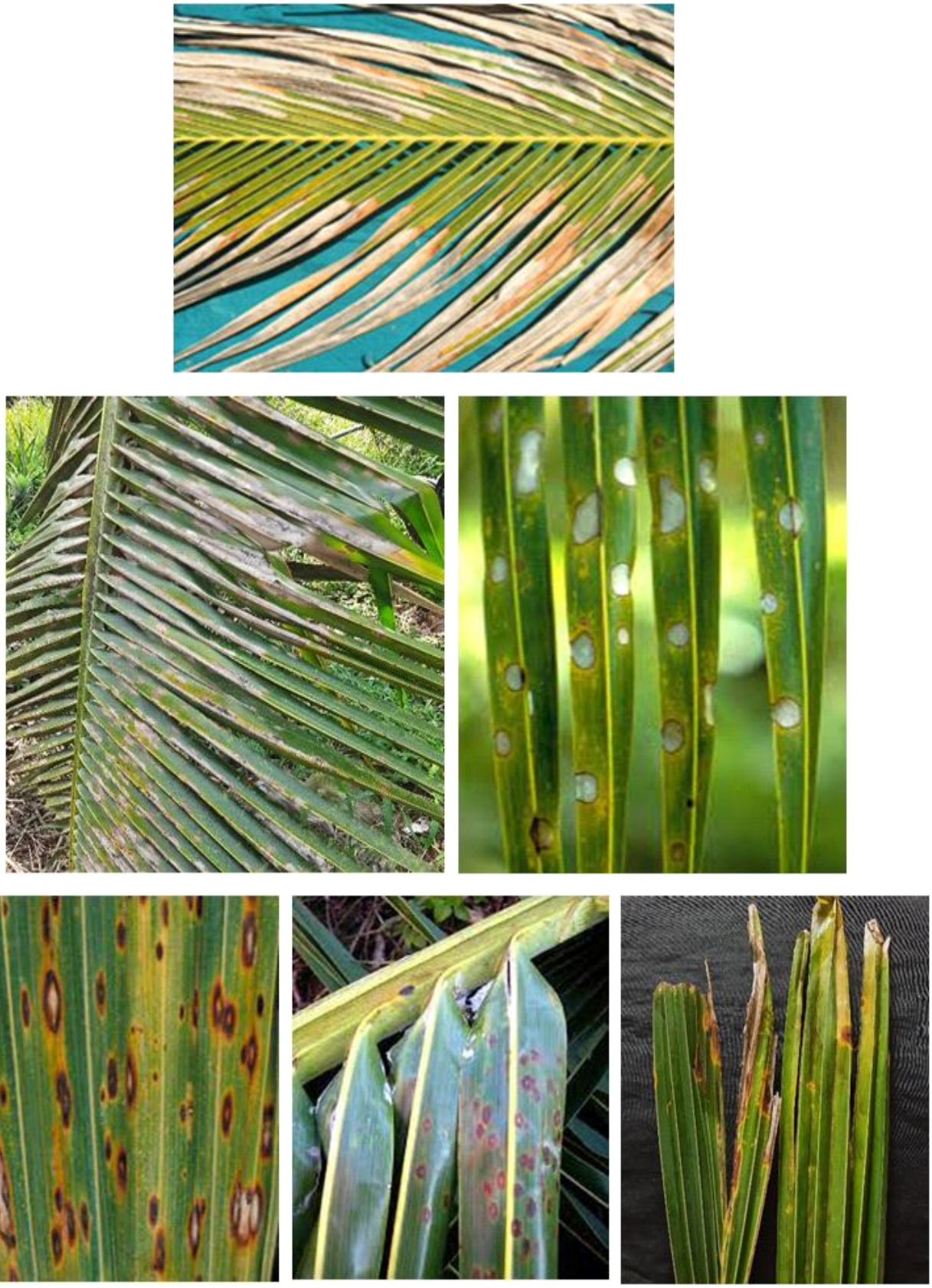

Fig. 1: leaf spot and blight disease in coconut; **a)***Lasiodiplodia* leaf blight; **b)** grey blight ; **c)** grey leaf spot by *Pestalotiopsis*; **d)***Bipolaris*leaf spot ; **e)***Pseudoepicoccum*leaf spot ; **f)** seedling blight caused by *Colletotrichum* [Picture Courtesy for (c), (d) and (e): Kohler *et al*.(1997)]

Table 4 : Other minor leaf spot diseases of arecanut

	Curvularia leaf spot	*Curvularia* sp
	Grey leaf blight	*Pestalotia palmarum*Cooke
	Phomopsis leaf blight	*Phomopsis palmicola*(Wint.) Sacc.
	Helmintnosporium leaf spot	*Helminthosporium* sp.
	Diaporthe leaf spot	*Diaporthe limonicola*
	Alternaria leaf spot	*Alternaria tenuis*

for the low productivity of the areca palms. It was also reported to cause anthracnose in the palm. Rectangular to irregular, dark brown spots develop on leaves and fronds of areca palms, later advancing to pitting and defoliation symptom due to the fungus, *C.gloeosporioides.* The conidia from infected tissue were hyaline, single celled and oblong to cylindrical with oil globules at the centre. The disease symptom starts with appearance of brown circular to irregular spots with yellow halo, which enlarge as the disease progresses. The spots are dark brown in colour with a greyish centre and dark brown margin. In severe cases, the spots later coalesce to form irregular blighted patches and shot hole symptoms and finally cover the entire lamina. The leaf veins also turn yellow from tip to base (Harahap, 2022; Raju *et al*. 2022). A multigene based phylogenetic analysis revealed association of more than one species of *Colletotrichum* with anthracnose disease. Eight species of the fungus were distinguished including previously identified five species (*C. gloeosporioides, C. fructicola, C. crodylinicola, C. tropicale* and *C. siamense*), one unidentified species, a novel species, *C. arecicola* (*gloeosporioides* species complex) and *C. karstii* (*boninense* species complex) (Cao *et al*. 2020). *Colletotrichum* leaf spot and grey blight occurrence were observed throughout the season in arecanut fields, with observance of highest incidence during NE monsoon in hilly areas of Kerala (John *et al*. 2011).

Phyllosticta leaf spot is a common problem in arecanut gardens and the incidence is independent of the age of the seedling. However, the maximum infection was noticed in older leaves and gradually reduced from lower to inner leaves. In all the age group the top leaves were observed as free from the fungal infection irrespective of the age of the palm, suggesting the infection of leaves of depleted sugar levels. The symptom initially spotted as minute dark brown speck on the leaves, which gradually increase in size to form irregular or oval to round spots with an ashy brown centre, with yellowing around the spot. Severe infection leads to blighted appearance, premature drying and shredding of the leaves. The pycnidia of the fungus was described as nearly spherical, dark, ostiolate, scattered, sub erumpent and measured 77.5 - 130 µm in diameter. The pycniospores were minute, single celled, hyaline, filiform, guttulate and subglobose to ellipsoidal with round end. Mucilaginous appendages were also noticed on the broader end of the spore.

Curvularia leaf spot in arecanut reported from China, showed symptoms as dark red oblong lesions which eventually turned brown spindle spots on older leaves. The centre portion of the spot was shallow and edges with yellow halo (Wang *et al*. 2019). Based on the multigene analysis, the *Curvularia* sp. showed higher similarity with *C. pseudobrachyspora* from *Eleusine indica*, but narrow difference from other isolates of *Curvularia* (Manamgoda *et al.* 2012). The isolate from arecanut was evidently different from *C. oryzae* causing leaf spot of oil palm. Early attack of *Curvularia* leaf spot was noticed in February-March months and increased till onset of rains in Karnataka state of India. The disease was first noticed as yellow spots, gradually turning to brown shallow centre with yellow halos. Plants raised under exposed conditions were observed as more susceptible to the disease. In Maldives, in a field study, occurrence of leaf spot incited by *Mycosphaerella* spp. was recorded, but was of minor importance in that area with respect to economic production of the palm (Hunter and

Shafiya, 2000). A new leaf spot was reported from Hainan region of China observed long oval or irregular black to brown lesions with distinct yellow halo. The morphological and molecular data revealed the identity of the fungus as *Diaporthe limonicola* (Xu *et al*. 2020). *Alternaria* leaf spot recorded from Allahabad region, showed symptoms throughout the year and which was observed as olive buff coloured circular to oval spots which later turned to blackish brown due to the fructification. Leaf veins also get infected in some cases and the spots later progressed to leaf blight. The disease was revealed to rapidly spread in the garden during rainy season and the infection slowed down at the onset of summer condition.

MANAGEMENT OF LEAF SPOT DISEASES

Cultural practices are the first step to the management of diseases in coconut and arecanut gardens. The suppression of diseases was demonstrated in studies conducted in field conditions. Practices like phytosanitation (Anonymous, 2018; Chowdappa *et al*. 2016; Pandian *et al*. 2022), wider spacing, shade management in nurseries, improving drainage, fertilizer application, organic amendments addition (Pandian *et al*., 2022). Regular application of Potassium fertilizers was reported to help in decreasing the severity of the leaf spot and leaf blight diseases (Anonymous, 2006; Iyer and Nambiar, 2007; Rabha *et al.*, 2014; Iyer *et al*., 2018).

Biological control of plant diseases is currently important strategy to control plant diseases. Among antagonistic fungi used against pathogenic fungi, *Trichoderma* spp. are most popular. Many attempts have been made to evaluate the capability of this fungus in managing the leaf spot diseases in plantation crops. Studies showed suppressive effect of different *Trichoderma* species viz., *T. viride* (Bhuiyan *et al*. 2021), *T. harzianum* (Khan and Hossain, 2013; Vijayaraj, 2013), *T. asperellum* (Sudha *et al*. 2021) against spot and blight causing fungal pathogens. Different bio-agents have been tested against *Lasiodiplodia*. A microbial consortium consisting *Pseudomonas fluorescence*, *Bacillus subtilis* and *Trichoderma viridae* isolated from coconut rhizosphere was observed as effective in field condition against *Lasiodiplodia* (Johnson *et al*. 2017). A study demonstrated the volatile and non-volatile compounds produced by three biocontrol agents viz., *T. asperellum, Streptomyces rochei* and *B. subtilis* efficiently inhibited *L. theobromae* under *invitro* (Sudha *et al*., 2021). Two *Streptomyces* species, *S. fumigatiscleroticus* and *S. seoulensis* found having higher suppressive activity against *Pestalotiopsis* leaf spot of coconut under laboratory and glasshouse condition (Azlan *et al*. 2020).The effectiveness of forty antagonistic bacteria isolated from different palms of arecaceae family, was tested against *Curvularia* sp., among which thirty three isolates showed inhibited the growth of *Curvularia* in a range of 4.4 to 86.6%. Some bacterial isolates produced volatile organic compounds which suppressed the growth of the fungal colonies with an inhibition rate of 92.27 to 97.21% (Deden *et al*. 2018).

Fungicidal treatment might be considered if the disease is spread in gardens with good management. Different fungicide formulations were tested against leaf spot pathogens of coconut. Hexaconazole, propiconazole and tebuconazole were shown to inhibit the growth of grey leaf spot and leaf blight pathogens under *in vitro* conditions (Bhaskaran *et al*. 2007b; Rahman *et al*. 2013; Chalbhagath and John, 2014; Surulirajan *et al*. 2014).The effectiveness of carbendazim, thiophanate-methyl, carbamates and copper based fungicides in controlling the pathogens both *in vitro* and *in vivo* was proved in different studies (Anonymous, 2006; Rahman *et al*. 2013; Khan and Hossain, 2013; Iyer *et al*. 2018). Root feeding of effective fungicide from *in vitro* studies, found to reduce the severity grey blight of coconut. In field trials, root feeding of tridemorph was found as efficient in managing *Lasiodiplodia* leaf blight with highest mean nut yield (Bhaskaran *et al*. 2007b). Ushamalini *et al*. (2019) tested fifteen various fungicides against *Lasiodiplodia* under both *in vitro* and *in vivo* conditions. Effectiveness of three fungicide, viz., carbendazim, propiconazole and tebuconazole+ trifloxystrobin was proved under *in vitro*, but only carbendazim treatment realised effective results in field condition. However, the reduction rate in field is less and also many fungi are showing

Fig.2: Sudden flare up of arecanut leaf spot diseases emerging as severe incidence in arecanut growing areas of southern Karnataka, the causal organism is confirmed by morphological and genetic investigations as *Colletotrichum*;(a), (b), (c), (d) different kinds of leaf spot symptoms observed; (e) spots on nuts; (f) symptoms on seedlings; (g) blighted appearance in advanced stage; (h) field view of severely affected garden

resistance to carbendazim in present scenario (Tzec-sima *et al*. 2022). In arecanut, effective control of *Colletotrichum* spots and inflorescence die back using carbendazim and mancozeb was reported (Lokesh *et al*. 2013; Chowdappa *et al*. 2016; Narayanaswamy *et al*. 2018). In field efficacy testing, triazole fungicides viz., hexaconazole, propiconazole and difenoconazole were found effective in controlling arecanut leaf spot disease (Islam *et al*. 2004; Lokesh *et al*. 2013; Hegde, 2018). Copper based fungicides, mancozeb and carbendazim were effective in suppressing the mycelial growth of *Phyllosticta* leaf spot of arecanut. Antifungal activity of plant extracts was also exploited on account of eco-friendly disease management. Extracts of *Lawsonia inermis, Cinnamomum zeylanicum, Lantana camara*, *Calotropis gigantea*and *Allium sativum* showed inhibitory effect on *Pestalotiopsis palmarum* mycelial growth and sporulation (Islam *et al*. 2004; Bhuvaneswari *et al*. 2010; Rasmi, 2015). Effect of seaweed salt on grey leaf spot of coconut was studied in Philippines and reduction in number of leaf spot formed in coconut seedlings was reported.

Attempts were also made to explore resistant sources against the leaf spot pathogens in coconut and arecanut. The preliminary studies in coconut have shown that the varieties were more resistant to *Psetalotiopsis palmarum*, than hybrids of coconut (Suriachandraselvan *et al*. 2000). It has been reported that the reaction of local coconut cultivars of Andaman region and found that Katchal variety was more tolerant to the disease with a disease index of 2 per cent. Varietal screening for leaf spot caused by *Bipolaris incurvata*, on juvenile palms of three coconut hybrids in Brazil revealed hybrid PB121 as promising source (Gomez-Navarro *et al*., 2009). PB141 hybrid from Brazil showed tolerance to *Botryodiplodia theobromae* leaf blight than PB 231 hybrid and Brazilian Tall variety. A fair level of resistance was reported in eleven cultivars of coconut including Andaman Ordinary, Dwarf, Dwarf x Tall, Tall x Dwarf, West Coast Tall, Malayan Dwarf x West Coast Tall, to grey leaf spot. It is recorded that out of eight varieties and twelve hybrids of coconut screened in Kerala, none were proven to be resistant to leaf blight disease. However, Malayan Yellow Dwarf has shown lowest disease incidence (based on percentage of leaflets infected) followed by Chowghat Green Dwarf. Evaluation of eight coconut cultivars against grey leaf spot in coastal parts of Odisha, was done to check the performance of the cultivars. Tiptur tall variety showed highest tolerance level with lowest mean annual disease incidence (Ghose *et al*. 2006). In screening studies for *Helminthosporium halodes*, coconut varieties were grouped into susceptible, intermediate and resistant. Malayan Dwarf (red and yellow forms) was more susceptible than green forms.

CONCLUSION

Leaf spot and leaf blight diseases in coconut and arecanut have a worldwide distribution. Even though they have minor importance in well managed gardens, severe incidence may have impact on long term yield of the palms. However, the minor diseases could possibly find favourable conditions or in combination with other diseases can lead to epidemics. Minor leaf spots and blight disease are emerging in many palm cultivated parts of the world and climate change might potentially accelerate the incidence and severity of the diseases. Despite its importance, these diseases are poorly studied and understood. Also, management of foliar spot diseases in crops like coconut and arecanut is a challenging task. Emphasis should be given to practice integrated disease management strategies for the effective management of the disease.

DECLARATIONS

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