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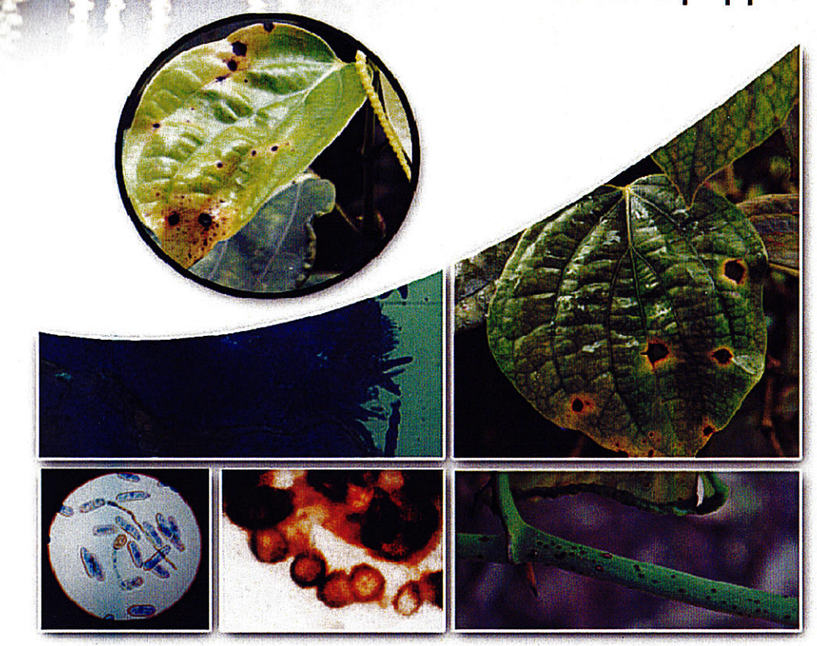
Anthracnose
of black pepper



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Introduction

Black pepper (*Piper nigrum* L.) representing the family Piperaceae, is a tropical perennial vine commercially cultivated for its pungent berries extensively used as spice, in medicine as well as in spice-based industries. Globally, India is one among the major producer, consumer and exporter of black pepper besides Brazil, Indonesia, Malaysia, Sri Lanka and Vietnam with an area and production of 299053 hectares and 117067 tonnes, respectively (Anonymous, 2025). In India, black pepper is widely cultivated in the Western Ghats region of Karnataka, Kerala and Tamil Nadu and to a limited extent in Maharashtra, North Eastern states and Andaman and Nicobar Islands among which, Karnataka occupies the top rung in cultivated area (207811 hectares) and production (80805 tonnes) followed by Kerala and Tamil Nadu (Anonymous, 2025).

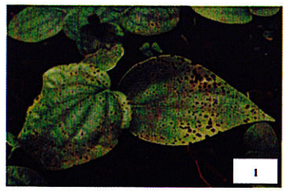
Black pepper suffers from a wide spectrum of diseases of which, anthracnose also known as spike shedding and fungal *pollu* is one among the most economically important besides foot rot and stunt diseases and occurs throughout the black pepper growing tracts. Anthracnose caused by *Colletotrichum* spp. is

gaining importance especially in black pepper plantations located at higher altitudes.

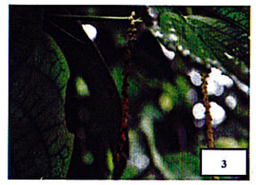
Geographical distribution and yield loss

The disease, also referred as "*pollu*" (means hollow fruits) and blackberry disease is reported from India, Malaysia and Indonesia. Although sporadic, the disease often attains epiphytotic proportions under misty conditions leading to severe defoliation and spike shedding. In India, the disease was first reported from North Malabar region of Kerala as 'berry spot' and 'berry split' (Ramakrishna Ayyar, 1921). Later, the disease was christened as 'fungal *pollu*' and the causal organism was identified as *Colletotrichum gloeosporioides* (Rao, 1926). The severity of the disease was reported to be in the range of 28-34% causing a crop loss to the magnitude of 1.9-9.5%. Maximum damage due to the disease was noticed during August-September (Unnikrishnan *et al.*, 1987). Fungal *pollu* caused 1.93-9.54 per cent spike shedding and the percentage loss due to the infection ranged between 0.69-3.74 and total loss of weight was 0.67-137.75 grams per plant (KAU, 2001). Anthracnose of the green berries causes significant yield losses of 10-20 per cent in India in shaded pepper (Radhakrishnan and Naik, 1983).

Symptomatology

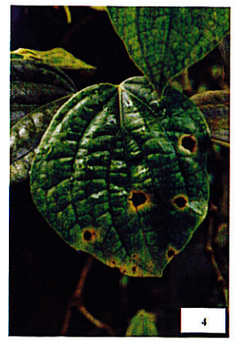


In nurseries, yellowish to dark brown circular spots with chlorotic halo are manifested on the leaves (Fig. 1). Under field conditions, the initial symptoms appear as small dark necrotic spots surrounded by yellow halo on the leaves (Fig. 2). In severe cases, expansion of the leaves is adversely affected subsequently leading to crinkling and defoliation.



Infection on spikes (Fig. 3) 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. Delayed infection on the leaves leads to the formation of randomly distributed discrete necrotic lesions either with greyish center or with shot-holes (Fig. 4) and lesions with dark brown margin on the older leaves of lateral branches (plagiotrophs). Whereas, on climbing shoots (orthotrophs) (Fig. 5) and runner shoots (Fig. 6) trailing on ground, the symptoms develop as linear necrotic lesions.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Characterization: Morphological and molecular

The *Colletotrichum* species are fundamentally characterized based on macro-morphological features like colony colour, appearance and patterns of sectoring (Fig. 7).

Further, the isolates are characterized based on micro-morphological traits such as conidial shape (Fig. 8).


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dimension as well as features of appressoria including number of lobes and dimension (Fig. 9).

Forty isolates of *Colletotrichum* collected from black cultivating regions of Karnataka, Kerala and Tamil Nadu were characterized based on morphological traits (Anonymous, 2017).

Morphological keys were employed to characterize *Colletotrichum* isolates representing major black pepper cultivating tracts of South India *viz*., Kerala, Karnataka and Tamil Nadu and derived five morphological groups (Chethana *et*

al., 2015). The morphological group I (*C. endophytica*) exhibited orangish to white with grey coloured colonies, cylindrical to slightly ovoid conidia and unlobed or slightly lobed appressoria. The colonies of morphological group II (*C. guajavae*) exhibited pale olivaceous grey, brown to green with sectoring, cylindrical to fusiform conidia and subglobose/elliptical appressoria. The colonies of morphological group III (*C. queenslandicum*) were light orange with no aerial mycelium, cylindrical straight with broadly rounded conidia and globose appressoria. The colonies of morphological group IV (*C. siamense*) exhibited greyish white, pale yellowish with black and orange sectoring, ovoid appressoria and cylindrical conidia. The colonies of morphological group V (*C. syzygicola*) were white to grey coloured, ovoid to cylindrical conidia and clavate to lobed appressoria.

Multi-loci phylogenetic analysis using partial sequences of *ITS, ACT, CHS1, GAPDH, TUB2, CYLH3, GS* and *ApMat* gene regions revealed five groups representing *C. syzygicola, C. queenslandicum, C. siamense, C. endophytica* and *C. guajavae* (Chethana *et al*., 2015).Verma *et al*. (2023) also reported the association of *Colletotrichum siamense* with black pepper

anthracnose from North-East India based on morpho-molecular analyses and pathogenicity studies. Four species of *Colletotrichum* namely, *C. siamense*, *C. fructicola*, *C. arecicola* and *C. kahawae* were identified as the pathogens causing black pepper anthracnose in Hainan, China based on multi-gene phylogenetic analysis and morphological characters (Xue *et al*., 2023).

Epidemiology

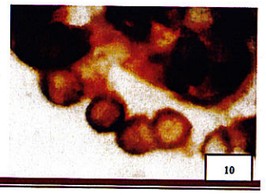
Impact of weather variables: Monsoon serves as an external stimulus triggering the disease incidence under field conditions. Moreover, the misty conditions prevailing in high altitudinal regions provide a conducive environment for the pathogen to proliferate and induce disease. The maximum temperature has unfavourable impact thereby adversely influencing disease development, while minimum temperature, rainfall, number of rainy days and atmospheric humidity favours disease initiation and subsequent spread (Biju *et al*., 2013).

Disease progression and vulnerable crop stages: In the initial phase *i.e.,* during February to April, the disease incidence was low and mainly confined to older leaves. On the leaves, the symptoms were manifested as randomly distributed necrotic

lesions surrounded by yellow halo. However, after the receipt of pre-monsoon showers, the disease was initiated as small circular necrotic lesions on the young leaves of the runner shoots from which it advanced to the leaves of plagiotrophs (laterals), orthotrophs (climbing shoots) as well as to the spikes which resulted in subsequent shedding of leaves and spikes (Biju *et al.*, 2013). Epidemiological studies to determine the impact of weather factors such as temperature, rainfall, rainy days and relative humidity on anthracnose incidence in seven different black pepper varieties revealed that, rainfall, minimum temperature, rainy days and morning relative humidity are the most significant contributors to disease occurrence (Verma *et al.*, 2023).

Survival: Colletotrichum infecting black pepper survived up to 90 days in the infected plant parts buried in soil and 150 days under *in vitro* conditions (Anoop Sankar and Santha Kumari, 2002).

Colletotrichum gloeosporioides employs microsclerotia (Fig. 10) in the trans-seasonal perpetuation which forms dark, melanized structures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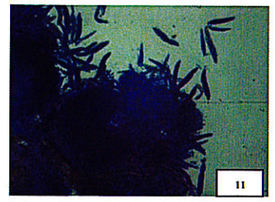
embedded in the necrotic lesions on the runner shoots. The sequential events in the formation of MS included germination of conidia, formation of conidial anastomosis tubes, aggregation of hyphae and the formation of melanized microsclerotial bodies. Three types of microsclerotial germination were observed under *in vitro* conditions *viz.*, sporogenic, myceliogenic and both (Biju *et al.*, 2017). The occurrence of perithecial (teleomorphic) phase of *C. gloeosporioides s. l.* infecting black pepper is reported (Biju *et al.*, 2020).

The pin-head structures formed on the necrotic lesions on leaves produced orangish exudation embedded with asci, ascospores and perithecia (Fig. 11) when incubated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under high humid conditions. The perithecia were also induced artificially under *in vitro* conditions, which retained fertility and infectivity for more than three months. Cross infectivity and molecular analysis showed that the isolates of *Colletotrichum* infecting black pepper and coffee are distinct (Machenahalli *et al.*, 2021).

Management

(a) Host plant resistance

Fourteen accessions of black pepper were evaluated for yield, quality and anthracnose disease resistance and found that, all the varieties were susceptible and did not differ significantly. However, the percentage of infected leaves was highest in Acc. 2426 (Kottanadan) and lowest in Subhakara (Sainamole Kurian*et al*., 2002). Eleven black pepper genotypes were assessed for resistance and biochemical defense reaction to anthracnose disease. The disease incidence under glasshouse conditions upon challenge inoculation was minimal in IISR Girimunda with a concomitant higher activity of antioxidant enzymes such as peroxidase, polyphenol oxidase, catalase, phenylalanine ammonialyase and superoxide dismutase (Faisal *et al*., 2023). Screening methodology along with disease rating scale to identify black pepper genotypes resistant to anthracnose disease is documented (Biju *et al*., 2023).

(b) Chemical

Evaluation of contact and systemic fungicides for the management of anthracnose disease of black pepper in Idukki (Kerala) indicated that the incidence of the disease on leaves and

spikes was significantly lower in vines treated with the combination fungicide, carbendazim-mancozeb (0.1%) followed by carbendazim (0.1%) (Sainamole Kurian *et al*., 2008).

The fungicides *viz*., hexaconazole and carbendazim-mancozeb were found effective against *Colletotrichum gloeosporioides* infecting black pepper under *in vitro* conditions. Validation of the efficacy of fungicides *viz*., carbendazim-mancozeb, carbendazim, Bordeaux mixture and hexaconazole as well as soil application of *Trichoderma harzianum*, singly and in combination showed that, spraying carbendazim-mancozeb was superior in reducing anthracnose incidence at 30 days spray interval under field conditions (Anonymous, 2017). The combination product, trifloxystrobin and tebuconazole was reported to be effective against black pepper anthracnose under field conditions in Malaysia (Ann and Mercer, 2017). The combination fungicide, carbendazim-mancozeb (0.1%) and the bioagent, *Trichoderma viride* were reported to be effective against *Colletotrichum gloeosporioides*, the anthracnose pathogen of black pepper under *in vitro* conditions (Behera *et al*., 2019). Pre-planting treatment of two/three node cuttings prepared from the runner shoots by immersing in carbendazim-

mancozeb (0.1%) solution for 30 minutes and spraying Bordeaux mixture (1%) alternating with carbendazim (0.1%) was found to be promising in managing the disease under nursery conditions. Under field conditions, foliar sprays with Bordeaux mixture (1%) are recommended to prevent the disease initiation as a prophylactic measure. However, once the disease initiates and subsequently aggravates under field condition, aerial sprays with carbendazim-mancozeb (0.1%) is recommended to prevent further spread as a curative measure (Biju *et al*., 2023).

(c) Biological

Thirty five plant species were evaluated under *in vitro* conditions against *C. gloeosporioides* and found that, phytoextracts of *Solanum nigrum* (5%), *S. torvum* (20%) and *Azadirachta indica* (5%) exhibited maximum inhibitory effect whereas, *Leucas aspera*, *Costus igneus*, *Datura stramonium*, *Lantana camara*, *Glycosmis pentaphylla* and *Adhatoda vasica* promoted growth of the pathogen. Microscopic observations revealed abnormal morphological and structural alterations of hyphae, including increase in size and number of vacuoles, anomalous branching and abnormal swelling of hyphal tips

(Biju and Praveena, 2018). *Trichoderma harzianum* and *Aspergillus niger* isolates applied to the soil and as foliar spray were found to be equally effective in promoting growth and suppressing development of anthracnose in black pepper under nursery conditions (Anoop Sankar, 2002). Three applications of consortium of bioagents (*Pseudomonas fluorescens*, *Bacillus subtilis* and *Trichoderma harzianum*) as foliar spray and basal drenching at 30 days interval from July to September were found to be effective in reducing the anthracnose (fungal *pollu* disease) of black pepper under field conditions (Vijayan *et al*., 2014). Foliar application of *Trichoderma viride* and *T. harzianum*, either individually or in combination, resulted in a significant reduction of disease incidence and growth promotion. Physiological and biochemical analyses revealed a notable increase in chlorophyll (Chl a, Chl b, Total chl), superoxide dismutase (SOD) and flavonoid contents, coupled with reductions in hydrogen peroxide (H_2O_2) and malondialdehyde concentrations (Verma *et al*., 2023).

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