Plant Archives Vol. 26, Supplement 1, 2026 pp. 590-594 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-1.081

NATURE, SURVIVAL, SYMPTOMS, EPIDEMIOLOGY AND PREVALENCE OF CHARCOAL ROT: A REVIEW

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(Date of Receiving : 11-08-2025; Date of Acceptance : 07-11-2025)

ABSTRACT

Charcoal rot caused by *Macrophomina phaseolina* (Tassi) Goidinch is an anamorphic ascomycete and infects various host plants. It is an omnipresent, soil and seed borne pathogen responsible for root and stem rot on different important economical crops. The pathogen survives in soil as saprophyte along with different soil organisms and also present in seeds. It survives as microsclerotia in soil and also acts as primary source of the inoculum. Microsclerotia are present in vascular tissues and forming a greyish-black appearance in the sub-epidermal tissues of stem. It is a vegetative propagules and show resistant against unfavorable weather conditions. It propagates in soil after decaying of the host plant. Intensity of charcoal rot disease is favoured by high temperature along with low relative humidity. The infection stages of *M. phaseolina* showed a transition state from biotrophy phase via biotrophy-to-necrotrophy switch to the necrotrophy. It leads to the cellular collapse, necrosis in epidermal, cortical cells of roots and hypocotyls regions. The charcoal rot pathogen infects basal region of stem and root in the plant. Infected plant has undergone different morphological changes having irregular lesions showing grey centres with dark brown margins, rotting of nodes and finally wilting of host plant. Charcoal rot pathogen infects different parts of the plant and ultimately causes stem, root rot and seedling blight. The main symptom of charcoal rot is sudden wilting of the plants from top portion to downwards region of during different crop growth stages. Nature of charcoal rot pathogen is non-specific in and causes disease in various important crops like pulses, soybean, maize, soybean, sesame, sunflower etc and causes heavy yield losses annually worldwide.

Keywords**:** Charcoal rot, *Macrophomina phaseolina,* pathogen, survival, soil and seed borne

Introduction

Macrophomina phaseolina (Tassi) Goidanich is a destructive, soil and seed borne pathogen. It is non-specific pathogen having wider host range. It is a pycnidial stage and known for a causative agent of an important disease commonly called "charcoal rot". The sclerotial stage of the pathogen is *Sclerotium bataticola* Taub and identified as causal organism of charcoal rot disease of sweet potato in the USA. Charcoal rot pathogen is envisaged as *Macrophomina phaseolina* due to presence of sclerotial-bearing mycelial stage and causes characteristic stem and root rot disease. In India, Butler (1925) identified a similar sclerotial-bearing fungus and compared with earlier isolates and named as *Rhizoctonia bataticola* (Taub.) and subsequently Goidanich (1947) reported as *Macrophomina phaseolina.* The charcoal rot pathogen *i.e. Macrophomina phaseolina* infects on various crops in different parts of the world. Charcoal rot pathogen is non-specific in nature having wider host range and causes charcoal rot disease in soybean, maize, sesame, sorghum and other important crops and causes huge losses annually in India (Khare *et al.,* 1973). It belongs to the phylum *Ascomycota*, class *Dothideomycetes*, order *Botryosphaeriales*, family *Botryosphaeriaceae*, genus *Macrophomina* and species *phaseolina*. Chaudhary *et al.* (2001) observed that the pathogen constantly changes nature and responsible for altering resistant varieties to susceptible. The intensity of disease is directly related to the occurrence of sclerotia in soil (Khan, 2007). Sapru and Mahajan, (2010) found that it is a facultative parasite in nature. *Macrophomina phaseolina* is also externally and internally seed borne pathogen. It is considered as a seed, soil and stubble borne in nature and can persists more than ten months under unfavourable dry soil conditions in form of sclerotia. The hyphae of pathogen are filliform and septate. The hypha of pathogen is branched at right angle having a septum just after constriction (Jakhar, 1997). Primarily hypha is hyaline subsequently changing grey to black and forming jet black oval to round shape microsclerotia having size 80-90 µm in diameter (Mahmoud and Budak, 2011). Akhtar *et al.* (2011) observed necrotrophic behaviour of pathogen and reported seed infection efficiency of *Macrophomina phaseolina* was 100 per cent with significant loss in seed index in sesame. Chowdhury *et al*. (2017) reported infection stages of charcoal rot fungus and found a transition phase from the biotrophy via BNS (biotrophy-to-necrotrophy switch) to necrotrophy phase. The charcoal rot pathogen switches the strategy of infection and host adapted its defence strategy to convene the changing situation. Low Reactive Oxygen Species (ROS) accumulation, up regulation of the signalling genes, more antioxidant enzyme activities and post BNS resulted in the resistance. There was higher accumulation of the secondary metabolites as well as up regulation of the secondary metabolite- related genes after BNS. Twenty genes functioning in the various aspects of defence in plant which monitored over a time of course during shifting infection phases showed coordinated response.

Survival

Macrophomina phaseolina (Tassi) Goidanich is a destructive, omnipresent, and non-specific fungal pathogen with wide host range (Gupta *et al*., 2023). It is a soil and seed borne pathogen and responsible for causing stem and root rot on different important crops like cereals, pulses, oilseeds, fruit and vegetables crops. It has a monocyclic disease cycle with vast host range. The occurrence of sclerotia in plant trash allows the fungus to grow in soil in absence of host plants for two or more years which depends on soil conditions. Reuveni *et al*. (1983) reported charcoal rot pathogen survives mainly in soil as microsclerotia and acts as primary source of the inoculum. Seed, soil, and plant debris are source of inoculum and disease intensity is directly related to the presence of sclerotia in soil. The microsclerotia can also survive from three months to three years under unfavorable field condition. It is formed in vascular tissues and gives a greyish-black appearance in the sub-epidermal tissues of stem of host plants. It is vegetative propagules and highly resistant to adverse climatic conditions which developed on the host tissues then spread to the soil after decaying of host plant. The charcoal rot pathogen survives in the soil in form of multicellular jet black microsclerotia which enormously produced in saprophytic phase as well as during parasitic phase (Dubey and Upadhyay, 2001).

Symptoms

The most common symptom caused by charcoal rot pathogen is sudden wilting of plants from upper part to downwards during growing period of plant. Generally irregular and deep sunken necrotic lesions are predisposed toward hypocotyls region and surfaces of the root were observed in soybean (Ammon and Wyllie, 1972). Lesions coalesce and form larger patches on stem or other parts of plant which finally leads to premature death of the host plant. Production of toxins production and sclerotia formation by the charcoal rot pathogen in xylem play significant role in the dehydration and ultimately leads to wilting of plant. Plants infected by charcoal rot pathogen dry up and decayed roots show shredded appearance. Irregular and sunken necrotic lesions in hypocotyls and surface of root were found in chickpea (Singh and Mehrotra, 1982). Colonization process of epidermal as well as cortical cells is followed by vascular cambium and phloem cells colonization occurred in chickpea (Singh *et al.*, 1990). Microsclerotia germination and production of hypha further penetrates in the epidermal cells and further grows intercellular. This infection leads to the cellular collapse, necrosis of epidermal and cortical cells of roots and hypocotyls in common bean (Mayek-Perez *et al*., 2002). Sclerotia overwinter on the weed and infect roots of plant and causes decaying of fibrous roots which lead to blackening of stem. The pathogen interrupts function of the xylem vessels ultimately causes wilting and death of the plant (Gupta and Chauhan, 2005). *M. phaseolina* is worldwide prevalent and infects different portion of plant and causes stem rot, root rot and finally seedling blight. Hypha of the fungus are septate, filliform, primarily hyaline consequently changes grey to black in colour and producing jet black oval to round shaped microsclerotia of size 80-90 µm in diameter (Akhtar *et al*., 2011). Pathogen generally infects at basal region of plant and causes deep lesions on the stem, roots, pods and seeds. The plant undergoes various morphological changes after infection of the pathogen including with irregular lesions with grey centre having dark brown borders, death of nodes and ultimately wilting of plant (Khalili *et al*., 2016).

Fig. 1 : Symptoms of charcoal rot in sesame plant

Epidemiology

Environmental factors play vital role in the development of charcoal rot disease in various plants. Environmental factors (temperature and relative humidity) imposed development of charcoal rot and it was observed that maximum disease intensity at 35^0C temperature and 76 per cent relative humidity (Gemawat and Verma, 1974). They also observed incidence of charcoal rot was favoured mainly by higher temperature and lower relative humidity. Patel and Patel (1990) also found that maximum incidence charcoal rot disease of sesame was recorded at temperature 35°C along with relative humidity 76 per cent. Incidence and progression of ashy grey stem blight disease in cowpea caused by *M. phaseolina* and showed maximum incidence at high temperature between 25°C to 40°C (Ratnoo *et al.*1993). Incidence of charcoal rot of sorghum was found maximum at temperature of 28 to 35°C and blighting symptoms increased at and above 30°C (Singh *et al*., 1998). Development of charcoal rot of sesame was maximum favoured by maximum temperature (31.6°C), minimum temperature (24.0°C) along with relative humidity (88%). The correlation between incidence of charcoal rot disease and temperature was found positive but non-significant although negative and significant between disease incidence and relative humidity (Deepthi *et al*., 2014). Different temperatures ranges appropriate for the growth of charcoal rot pathogen and which was recorded optimum temperature between 25°C and 35°C for fungal growth charcoal rot pathogen as well as sclerotial formation in the castor (Parmar *et al.,* 2018). Satpathi and Gohel (2018) found the incidence of charcoal rot was found more progressive during 37^{th} and 39^{th} standard meteorological weeks, bright sunshine varied (8.70 to 9.10 hrs), higher temperature (33.30 to 34.50°C) and lower temperature (24.20 to24.90°C).

Prevalence

Macrophomina phaseolina is one of the most destructive, economical, soil and seed borne pathogen and widely distributed globally. It is omnipresent everywhere growing of different crops. Charcoal rot disease of sesame caused by *Macrophomina phaseolina* was first reported from the Uttar Pradesh (Mehta, 1951). Charcoal rot disease was also reported from Madhya Pradesh in Jabalpur and Gwalior divisions (Jain and Kulkarni, 1965). Now it is widely prevalent in all sesame growing areas in different part of the country namely Uttar Pradesh, Haryana, Punjab, Gujarat, Maharashtra, Bihar, West Bengal, Orissa, Karnataka, Tamilnadu and Kerala. Pathogen of charcoal rot is non-specific in nature and causes disease in various crops like soybean, chickpea, lentil, maize, sorghum, sunflower, sesame and other important crops and responsible for heavy losses annually. Globally charcoal rot pathogen generally causes about 25% yield losses in United States, Soviet Union, Spain and Uruguay has been reported but under congenial weather conditions for growth and development of the pathogen, a complete crop failure have also been reported from specific areas (Tikhonov *et al*., 1976). It is also reported from Asia, Africa, North and South America and Europe but found more prevalent in tropical and subtropical countries having semi-arid climatic conditions. Murugesan *et al.* (1978) observed that 1.8kg/ha yield losses in sesame at each one per cent increase in disease intensity of charcoal rot. *M. phaseolina* causes severe loss in germination of seed and seedling stand. Charcoal rot pathogen is the most destructive among all diseases of sesame and generally incidence was observed about 50 per cent yield losses in India annually (Dinakaran and Mohammed, 2001). Deepthi *et al.* (2014) reported yield losses in sesame due to charcoal rot pathogen during capsule formation stage and also observed plant protected with fungicides had more number of capsules per plant and more test weight of healthy than infected capsule. Prevalence of sesame charcoal rot observed 10-30% and causes 10-75% yield losses in Myanmar (Min and Toyoto, 2019).

Acknowledgement

The authors gratefully acknowledge to the Director Research, BAU, Sabour and CCS HAU, Hisar for their support. This review article bears BAU Communication No. 2159/250703.

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