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Fusarium dieback: An emerging issue in the tea industry

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ABSTRACT

Tea is one of the important cash crops of India. It is a non-alcoholic beverage with numerous health benefits. Tea cultivation can be affected by several biotic and abiotic stresses. Both types of stresses are directly associated with productivity. Among different biotic stresses, dieback disease of tea plants caused by *Fusarium* sp. is emerging in different tea-growing regions. Earlier, this dieback disease was considered as minor one of tea cultivation but recently, tea production has been significantly hampered by dieback disease. Previously, *Fusarium solani* was considered as the sole pathogen of this disease but very recent study has shown that different other species of *Fusarium* like *Fusarium oxysporum*, *Fusarium concentricum* and *Fusarium fujikuroi* can also function as causal organism. To mitigate a particular disease, it is important to understand the host pathogen interaction. In the present review, an approach has taken to understand different aspects of this disease along with possible control measures based on Fusarium diseases. This review will help future workers to understand this disease in a lucid way along with setting up of disease protection strategies.

Keywords: Symptoms, Yield, *Camellia sinensis*, Disease cycle

INTRODUCTION

Tea is most consumed and one of the oldest known beverages in the world. It is also known as "the queen of beverages". Tea is perennial crop. By using different procedures, tea and tea products are produced from bud, tender stems and leaves. Southeast China is considered as origin of tea plants and nowadays, more than fifty countries are associated with tea cultivation. Annual global tea production reaches 3 billion kg and tea consumption is showing a notable increase worldwide. Various reports have highlighted the rising global demand for tea. The widespread popularity of tea as a readily accessible beverage can be attributed to its numerous health benefits and affordable cost. Tea plants belong to the Camelliaceae family and consist of 82 species within the *Camellia* genus. The diverse origins of modern tea plants are traced by taxonomists to three main types: *Camellia sinensis* (L.) O. Kuntze, known as the 'China' variety; *C. assamica* (Masters) Wight, the 'Assam' variety; and *C. assamica* ssp. Lasiocalyx (Planex *ex* Watt) Wight, referred to as the 'Cambod' variety (Sen *et al.,* 2020). Findings from several studies have indicated that tea and its bioactive phenolic compounds provide a range of health benefits including in prevention of different diseases like diabetes, cancer, cardiovascular issues, obesity and stroke. One of the oldest organized sectors is Tea industry. In India, tea production plays vital role in both agricultural output and national gross domestic product. According to the International Tea Committee, India ranks as the second-largest producer of tea, after China, which accounts for 25% of global production. In the past five years, India's tea production has seen a significant increase.

Both biotic and abiotic stresses are considered as major problems in tea cultivation. The cultivation methodology and suitable climate required for proper growth of tea plants encourage several phytopathogens that cause disease (Lehmann-Danzinger, 2000; Anita *et al.,* 2012; Ali *et al.,* 2014). Among these phytopathogens fungi are important. All parts of tea plants can be infected by fungal pathogens. Broadly, diseases of tea plants can be classified into three types namely foliar disease, stem disease and root rot disease (Bora and Bora, 2021). The survival of tea plants is directly associated with stem disease and root disease. On the other hand, foliar diseases have direct correlation with crop harvest (Dong *et al.,* 2024). During last few decades, tea planters are challenged by different diseases of tea plants like blister blight, black rot, charcoal stump rot, red rust, brown root rot, black root rot, grey blight, brown blight, *Fusarium* die back, red leaf spot, twig die black, branch canker, leaf blight, root rot, bacterial canker, horse hair blight etc. The different types of tea diseases is shown in figure 1. The alterations in environmental conditions, climate and topography are associated with outbreak and magnitude of crop loss (Sarmah *et al.,* 2020). Among the several pathogenic microbes, recently dieback disease of tea caused by *Fusarium* species is emerging in different tea growing regions. *Fusarium* dieback disease is considered as one of the destructive disease in West Bengal as well as North East India (Pandey *et al.,* 2023; Hazra *et al.,* 2024). Due to attack of this pathogen the tender shoots of tea plants show wilting. The pathogen infected shoots are not able to regenerate and ultimately die off. Due to attack of this pathogen, severe economic loss as well as crop loss occurs (Sarmah *et al.,* 2017). A study of 2019 showed that, 19.75% of examined tea plants in Southwest Ethiopia are infected with *Fusarium* wilt disease (Dechassa *et al.,* 2021). Annually, dieback disease is associated with 20-60% yield loss in Indian tea industry. The yield loss scenario is 30% in Sri Lanka and Taiwan due to twig dieback. If favorable condition is available, the disease can destroy entire crop (Pandey *et al.,* 2024).

Recently it has been reported that different other species of *Fusarium* can cause dieback. Considering the importance of *Fusarium* diseases of tea plants, the present review will highlight the different aspects of this particular disease along with different possible disease control strategies.

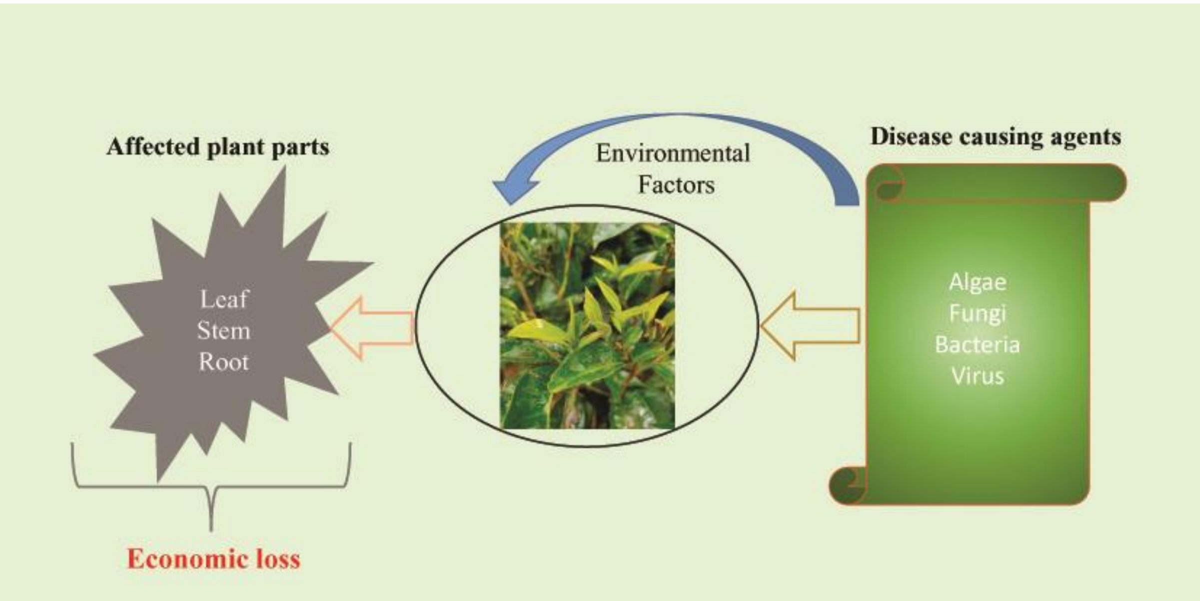

Figure 1: Different diseases of tea plants along with affected plant parts

THE PATHOGEN

One of the most concerned plant pathogenic fungi is *Fusarium*. This notorious pathogen is associated with devastating disease in different agricultural crops. In molecular plant pathology, two species of *Fusarium* were included in top ten plant pathogens based on economic importance. Apart from plant diseases, *Fusarium* can also produce wide range of mycotoxins which are associated with human and animal health issues (Summerell, 2019). Different species of *Fusarium* can also cause human disease (O'Donnell *et al.,* 2013). Different species of *Fusaria* are associated with root rot and vascular wilt disease in economically important plants (Coleman, 2016; James *et al.,* 2022). The global distribution of *Fusarium* has shown its existence in water, soil, human habitats and plants. Almost 300 phylogenetically different species of *Fusarium* have been discovered via molecular taxonomy but formal descriptions of these species are lacking. Based on ecological aspects, Fusaria may be parasitic, endophytic or pathogenic on different host plants (Aoki *et al.,* 2013). Link first diagnosed the generic concept of *Fusarium* by using the primary character as morphology of banana shaped conidia (Link, 1809).

Genetically, *Fusarium* is a complex genus belong to order Hypocreales in class Sordariomycetes (James *et al.,* 2022). Prior until 2012, the sexual (perfect or teleomorph) and asexual (imperfect or anamorph) life cycle stages of *Fusarium*, were known by various names. However, it was determined that a fungal species should only have one scientific name after the International Code of Nomenclature for Algae, Fungi, and Plants (ICN) was implemented during the 2011 International Botanical Congress in Melbourne. As a result, dual terminology for pleomorphic fungi such as *Fusarium* was abolished. For a genus such as *Fusarium*, there are a number of possible names that could be used to determine the correct name. The earliest name that has been legally published usually has precedence under the laws. Different criteria were proposed by Hawksworth to finalize a particular name (Hawksworth *et al.,* 2011).

Fusarium can grow on many fungal growth media. It shows well defined growth on Sabouraud Dextrose Agar medium at 25˚C. On culture medium, the fungus produces flat or spreading, woolly and cottony colonies (figure 2).

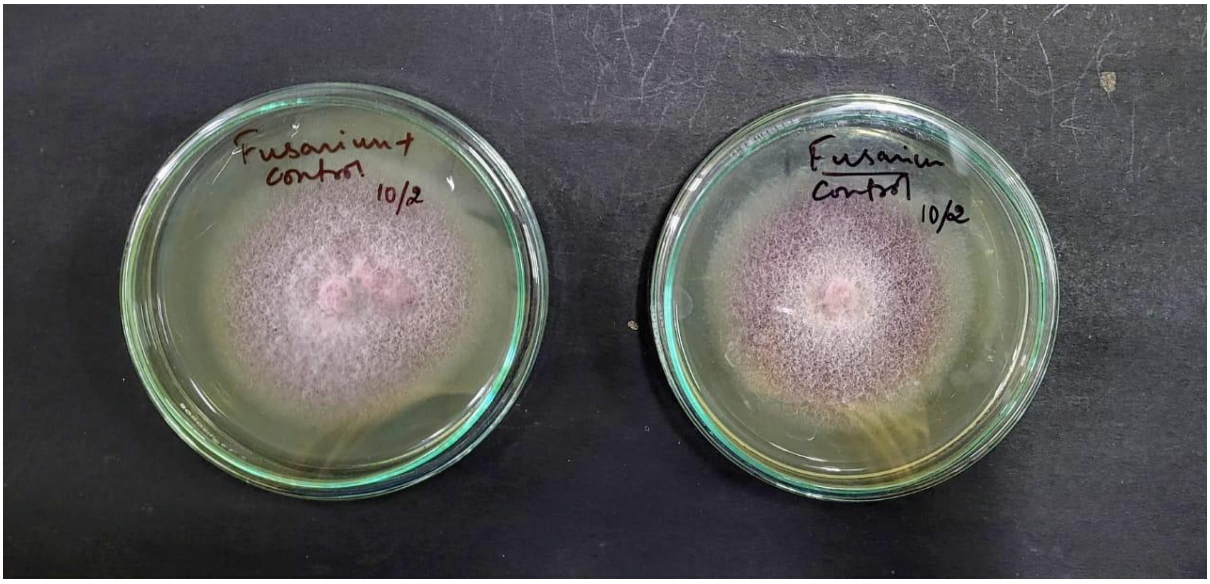

Figure 2: Morphology of culture grown on medium in laboratory

The colour of colonies may be white, tan, cream, cinnamon, yellow, pink etc. On the underside, the colour may vary (Okungbowa and Shittu, 2012). When condition is not favourable, sclerotia (mass of hyphae) are produced by the fungi which remains dormant during entire unfavourable condition and germinate during favourable conditions and function as source of infection (Nelson *et al.,* 1994; Okungbowa and Shittu, 2012). Both macroconidia and microconidia are produced by *Fusarium* species. The macroconidia are fusiform to sickle shaped, hyaline, two to several cell with apical and basal cell. Usually microconidia are hyaline, fusiform to ovoid, 1 to 2 celled and straight or curved in nature (Okungbowa and Shittu, 2012). Both sexual and asexual life cycles are followed by *Fusarium*. Haploid mycelial structures are established during both asexual and sexual stages.

In a closure look, it has been observed that the genome of some *Fusarium* species have been sequenced. The comparative genome analysis has confirmed the existence of mobile pathogenicity chromosomes in the fungus. Large number of pathogenicity related proteins are present in pathogenic *Fusarium* species in comparison to non-pathogenic one (Ma *et al.,* 2010). The hydrolytic enzymes, transcription factors and transporters encoded by this region are involved in pathogenicity of the pathogen (Cuomo *et al.,* 2007). Recently, several other genes of the pathogen have also been characterized which are involved in spore germination to pathogenicity. There are also 46 secondary metabolite biosynthesis gene clusters are present in the pathogen among which some are mycotoxin specific (Desjardins and Proctor, 2007; Ma *et al.,* 2010).

For proper identification of this pathogen, apart from morphological and microscopic characteristics different molecular techniques like polymerase chain reaction (PCR), Random Amplified Polymorphic DNA (RAPD), DNA sequencing are widely used. Among these techniques, PCR is rapid and reliable. Widely used primers for PCR are ITS1, ITS4, ITS-Fu-f, ITS-Fu-r and many more (Kachuei *et al.,*2015).

This soil borne pathogen uses various cell signalling pathways like G-protein, MAPKs, cAMP, Ras proteins and different enzymes, cell wall degrading enzymes mycotoxins to enter inside host for successful infection. The pathogenicity factors produced by *Fusarium* species are host specific or the factors may be generally produced (Poppenberger *et al.,* 2003).

SYMPTOMS, EPIDEMIOLOGY AND DISEASE CYCLE

Earlier *Fusarium* dieback disease was considered as minor one. Though earlier dieback disease affected only plucking shoots and nearby leaves of tea plants in rainy season from June to September but nowadays, severe climate change is associated with prevalence of this disease throughout the year in Indian tea gardens (Kumhar and Babu, 2019; Pandey *et al.,* 2023; Pandey *et al.,* 2024). The genus *Fusarium* is also associated with several other diseases of tea plants including leaf spot, wilt, collar canker (Tang *et al.,* 2024). *Fusarium* is necrotrophic in nature and shows worldwide distribution. The spores of *Fusarium* can persist in soil for long time and the chlamydospores overwinter on different plant parts including seeds. Rain splash can spread the pathogen (Pandey *et al.,* 2021). A disease cycle is shown in **figure 3.**

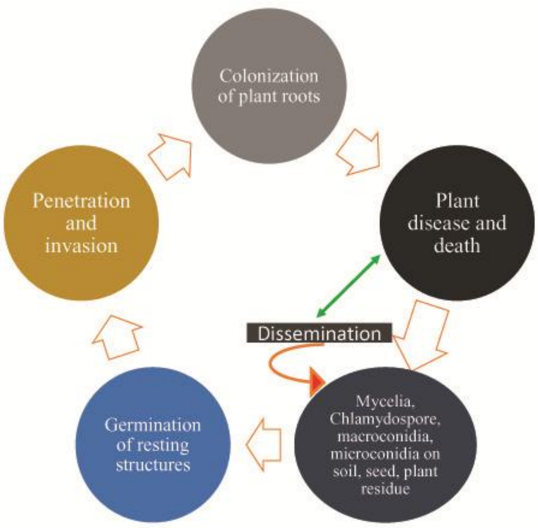

Figure 3: Disease cycle

For successful invasion of this fungal pathogen, humid and temperate climate required. During the infection process, leaf petioles become blackish and primary branches of tea plants are wilted due to progression of infection to nodes and internodes. Complete necrosis is seen in harvestable shoots. The white cottony fungal mycelial growth can be seen on dead tissues. In the advance stage, the mycelia turn brown. The pathogen infected seeds show light pink coloration along with powdery fungal mass on the surface (Kumhar *et al.,* 2022).

DEFENSE PROFILE IN PLANTS DURING *FUSARIUM* INVASION

A recent study has reported different *Fusarium* species can cause disease symptoms in tea plants. These four species namely *F. oxysporum*, *F. solani*, *F. fujikuroi* and *F. concentricum* were identified using pathogenicity and phylogenetic analyses (Tang *et al.,* 2024). Plants have its own immune system to protect themselves from foreign invading phytopathogens. Different structural, biochemical and molecular defense systems help plants to combat with different types of stresses. In a time course study of tomato-*Fusarium* interaction it was seen that that, different defense enzymes like glucanase, phenylalanine ammonia-lyase, peroxidase, polyphenol oxidase, total phenol, flavonoid, signaling molecule nitric oxide were altered. During initial period of pathogen invasion, plant defense components showed higher activities and accumulation. But at the later stage the defense profile of plant was compromised and the pathogen was able to establish itself inside the plant and caused the disease (Chakraborty *et al.,* 2023).

CONTROL MEASURES

The disease of any economically important plant can be controlled by adopting different practices like cultural, biological and chemical. As dieback disease of tea plant is emerging issue so very few studies have shown control measure for this disease using beneficial microbes, plant extracts etc. From tea rhizosphere isolated *Trichoderma reesei* induces defense responses, maintain seedling growth (Pandey *et al.,* 2023).

Extracts from different plants like *Azadirachta*, *Acorus*, *Xanthium*, *Clerodendron* were used against the disease. In field condition, *Xanthium* and *Clerodendron* reduced more than 80% disease. Extracts from *Azadirachta* and *Acorus* reduced more than 70% disease. *Bacillus subtilis* and *Trichoderma viridae* were also used against this disease. *Trichoderma viridae* showed 86.9% disease reduction (Sarmah *et al.,* 2017). *Streptomyces bungoensis* and *Kitasatospora putterlickiae* were shown to have dieback disease protection ability in a conecentration of 20%. The same group of authors also used copper oxychloride as synthetic fungicide and this fungicide showed 75.46 % disease reduction (Babu *et* *al.,* 2022). In another study, 2% aqueous suspension of *Trichoderma asperellum* (1000 and 1200 ml/ha) showed better disease controlling capability. *Azospirillum*, *Azotobacter*, *Trichoderma*, *Streptomyces*, *Bacillus*, *Pseudomonas* and extracts from different plants like *Polygonum*, *Ipomea*, *Cleome*, *Amphineuron* were shown to reduce the disease (Sarmah *et al.,* 2020). A pictorial representation of different control measures of *Fusarium* disease is shown in **Figure 4.**

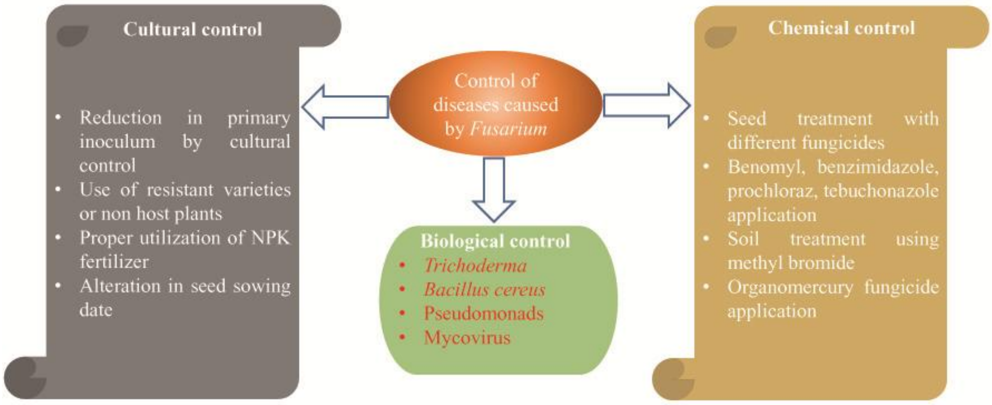

Figure 4: Different control measures of *Fusarium* disease

CONCLUSION

Fusarium dieback disease of tea plants is nowadays emerging. So, it should be taken into great interest of plant pathologists. It is essential to control this disease to prevent huge economic losses along with different health issues. To protect a plant from a particular disease, understanding the underlying pathogenesis mechanisms is very important. To accept disease controlling strategies, it is utmost important to understand various environmental factors associated with this disease. Different approaches like using resistant cultivars, application of low-cost biotic and abiotic elicitors, and application of beneficial microbes can be taken into consideration for controlling this disease. It is also very important to assess the physiological parameters of plants during plant-pathogen interaction. Transcriptomic, proteomic and metabolomic approaches can also explain the host-pathogen interaction in more elaborate manner. Finally, this emerging disease of the tea plant can open new research areas at different levels like structural, biochemical and molecular levels.

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