J.Mycopathol.Res. 63(2) : 253-258, 2025, ISSN : 0971-3719 (Print), 2583-6315 (Online) 10.57023/JMycR.63.2.2025.253

REVIEW

Cashew wilt: An emerging problem in cashew cultivation in major cashew growing countries

SUSMITA PATI[1], RAKESH PATSA[1], SUBHENDU JASH[2*], ARINDAM SARKAR[2], GOLAM MOINUDDIN[2], SUBRATA DUTTA[1] AND MINI PODUVAL[3]

[1]*Department of Plant Pathology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, 741252, West Bengal*

[2]*Regional Research Station (Red & Laterite Zone), Bidhan Chandra Krishi Viswavidyalaya, Jhargram, 721507, West Bengal*

[3]*All India Coordinated Research Project on Cashew, Regional Research Station (Red & Laterite Zone), Bidhan Chandra Krishi Viswavidyalaya, Jhargram, 721507, West Bengal*

Received : 22.12.2024 Accepted : 08.05.2025 Published : 30.06.2025

Fusarium wilt of cashew is threatening to cashew cultivation in many African countries recently. The disease appears both in cashew seedlings as well as in mature cashew plants. Initial symptoms are yellowing and wilting of leaves followed by visible reddish discoloration of xylem vessels inside the stem. Three species of *Fusarium* were reported so far as causal agent of cashew wilt; *Fusarium oxysporum* from Tanzania and *F. falciforme* and *F. decemcellulare* from India. Light textured soil, high air and soil temperature, relative humidity of above 70% favor cashew wilt disease. Being soil borne in nature, integrated management strategies were adopted to manage the disease. Detailed systematic study is required for better understanding of host pathogen interaction in order to check the disease severity as well as economic loss in cashew cultivation.

Keywords : Cashew wilt, epidemiology, *Fusarium oxysporum*., *F. falciforme, F. decemcellulare,* management, symptoms

INTRODUCTION

The cashew plant (*Anacardium occidentale* L.), which belongs to the Anacardiaceae family and originated from northeastern Brazil, is an important drought tolerant tropical and sub-tropical high - valued plantation crop. Portuguese people brought cashew plant into African and Asian countries from savanna forest in central Brazil during sixteenth century (Johnson, 1973). Then it was shifted to south East Asia, followed by Australia and finally settled down to coastal part of North America (Nair, 2010). India, Vietnam, Philippines and Indonesia are the major cashew growing countries in Asia. Ivory Coast, Mozambique, Burkina Faso, Tanzania, Guinea Bissau, Nigeria and Ghana are leading cashew growing countries in Africa (FAOSTAT, 2025). The area and production of cashew has been increasing over recent years due to high market value of delicious cashew kernel. This crops cultivated globally under rainfed condition in less fertile soil (Paiva *et al*. 2003). However, productivity is very low due to several reasons. In several African countries cashew nut production is one of the major sources of income generation in small and marginal farmers.

In India, it was introduced by the Portuguese in the coastal part for soil conservation, afforestation and wasteland development programme, but later it emerged as one of the important cash crops (Saroj and Rupa, 2014). India is the second largest producer and exporter as well as the largest consumer of cashew nuts in the world, accounting for an area of 119254 ha with an estimated annual production of 781.92 MT and annual productivity of 766 kg/ha (DCCD, 2023). Despite being an important perennial cash crop,

*Correspondence: drsubhendujash@gmail.com

the low productivity of cashew in India is of major concern. Biotic and abiotic stresses are the important factors responsible for low productivity (Saroj and Rupa, 2014; Patsa *et al*. 2023a; Vidya *et al*. 2015). The quality and quantity of cashew nuts are affected by various biotic stresses like pests and diseases. The major diseases reported globally affecting yield of cashew are shoot dieback, gummosis and inflorescence blight incited by *Lasiodiplodia theobromae*, powdery mildew (*Oidium anacardii*), anthracnose (*Colletotrichum gloeosporioides*), black mold (*Pilgeriella anacardii*), angular leaf spot (*Septoria anacardii*), Pestalotiopsis leaf spot (Cardoso *et al*. 2013; Freire *et al*. 2002; Khatun *et al*. 2017; Majune *et al*. 2018a, b; Patsa *et al*. 2023a, 2024, Wonni *et al*. 2017; Zombre *et al*. 2016). In India, dieback and gummosis disease caused by *Botryodiplodia theobromae* (Khatun *et al*. 2017), leaf spot by *Pestalotia heterocornis* (Joshi, 2005), Pestalotiopsis leaf spot by *Pestalotiopsis oxyanthi* (Patsa *et al*. 2023a) and inflorescence decline due to *Candidatus Phytoplasma australasia* (Mitra *et al*. 2020) resulted in huge crop loss.

Recently, cashew wilt, a minor disease, caused by a soil-borne pathogenic fungus *Fusarium oxysporum* Schlechtend. Fr. (Mbasa, 2021) is gaining more importance and threatening to the cashew growers in the last ten years in African countries. It was first identified and reported in Tanzania in 2012 at Magawa village in Mkuranga district in the coastal region (Tibuhwa and Shomari, 2012). In India, so far two species of *Fusarium,* causing wilt in cashew, have been reported (Manjusha *et al*. 2023; Patsa *et al*. 2023b). The outbreak of cashew wilt had a devastating consequence, resulting in the wilting and decline of cashew trees, massively forcing cashew farmers to cut down dying log of cashew trees within a small span of time. The disease affects cashew production, leading to yield losses of up to 100% if not controlled (Tibuhwa and Shomari, 2016).

SYMPOMATOLOGY

The typical symptoms of Fusarium wilt is yellowing and drooping of leaves, vascular discolouration and death of plants. Similar symptoms were also observed in the infected cashew plants where a progressive colour change was noted from natural greenish colour to yellowish (chlorosis) and ultimately brown-hued (Fig 1). The disease also results in brown/yellow streaks or dark black patches on the colonized vascular vessels, reddish discoloration of xylem vessels, which spread over the course of two to three weeks and cause the plant to completely wilt and die (Tibuhwa and Shomari, 2016, Mbasa *et al*. 2021). Initial external symptoms of yellow, brown leaf symptoms and stem gummosis appear, often localized on one side of the cashew (Mbasa *et al.* 2021). The disease then spread to other surrounding cashew trees until the entire field appears wilted. Mycelium and macroconidia have been seen in xylem vessels of the infected tissues during cross-section examination. Formation of tyloses and complete blocking of xylem, was also reported (Tibuhwa and Shomari, 2016).

AETIOLOGY

The genus *Fusarium* is associated with cashew wilt globally. Tibuhwa and Shomari (2016) identified the cashew wilt pathogen in Tanzania as *Fusarium oxysporum* based on morphological parameters and DNA sequence data. In India, presently two *Fusarium sp.* have been reported against wilt diseases in cashew; *F. falciforme* from West Bengal (Patsa *et al*. 2023b) and *F. decemcellulare* from Kerala (Manjusha *et al*. 2023). This soil-borne anamorphic genus is also responsible for the outbreak of the deadly vascular wilting symptom in several plants (Matiæ *et al.* 2018). *F. oxysporum* isolated from the cashew plant produces flat cottony colonies with a slightly yellowish margin on PDA. Pathogen produces thick-walled globose chlamydospores, oval-shaped microconidia and fusiform or slightly curved, 3-septate macroconidia (Tibuhwa and Shomari, 2016). Perez-Vicente *et al*. (2014) reported that in the absence of a host plant, the pathogen can survive for a long time by reproducing asexually and remain dormant in the soil with the help of chlamydospores. The pathogen produces spores, which are found either outside or inside the plant tissues. The pathogen also produces both macro and micro conidia (Jimenez-Diaz *et al.* 2015). Microconidia are most prominent in the live tissues of the host

Fig 1 : Wilting of cashew plant infected by *Fusarium* sp.

plant and are responsible for clogging of vascular tissues in the upper parts of the plant (Pegg *et al*. 2019).

Colonies of *F. falciforme* were reported by Vega-Gutiérrez *et al*. (2019) as white to cream coloured with aerial mycelium; falciform, colourless, three-septate, macroconidia measuring 29.5 to 50.3 µm × 5.0 to 8.1 µm on carnation leaf agar media. Similar studies conducted by Patsa *et al.* (2023b) showed that *F. falciforme* forms a white to pinkish white colony with light orange pigmentation on the PDA media. The pathogen produces hyaline, falciform, and 3-6 septate macroconidia; oblong, hyaline, occasionally unicellular, and usually 1-2 septate microconidia that were carried in false heads, measuring 7.8 " 4.7 ¼m × 2.7 " 1.6 ¼m in size. Manjusha *et al*. (2023) reported that the colonies formed by the isolates of *F. decemcellulare* were white, later turning pink. But after subculturing, the mycelium becomes floccose and appears white to peach in colour, forming small, dotted cushion-like structures of sporodochia formed on the media. Morphological studies reveal that the hyphae had smooth walls, septate, branched, and measured 1.5 to 5.2 µm in width. The conidiophores measuring 65–70 × 1.18 to 2.2 µm were produced on the lateral side of the hyphae. Macroconidia measuring 23.79–70 × 4.31–7.44 µm, were fusoid , straight to falcate, and had two to six septate walls. Microconidia formed, measuring 4.78–7.77 × 2.88–2.95 µm, were hyaline, oval, and smooth-walled. Microscopically, hyphae, micro- and macro-conidia were often seen together.

EPIDEMIOLOGY

Fusarium wilt prefers warm temperatures as the pathogen is more active in warm weather. The growth and virulence of the *Fusarium* pathogen are correlated with edaphic parameters, specifically soil pH (Tibuhwa and Shomari, 2016), temperature (Peng *et al*. 1999), relative humidity (Gheorghe *et al*. 2015), and soil nutrients (Pérez-Vicente *et al*. 2014). Soil pH values below or close to 7 influences the sporulation of the pathogen and lead to high disease severity (Domínguez *et al*. 2000). Peng et al. (1999) studied the attack of Fusarium wilt disease on lettuce and bananas and found that an increase in temperature between 24-34°C and 26-28°C increased the severity of the disease. The nutrient status of soil also affects the wilt disease. High organic matter and phosphorus suppress the Fusarium wilt disease in banana (Pérez-Vicente *et al.* 2014). Application of nitrate-containing fertilizers as the source of nitrogen, soil amendments, planting of different cover crops to reduce soil temperature (<30°C) reduces the pahogen sporulation. Liming the soil to adjust its pH since Fusarium typically grows best in a pH range of 4 to 8 (Borrero *et al.* 2012).

Light soil texture (sandy and sandy loam) which harbor low microbial diversity (Pérez-Vicente *et al*. 2014; Ploetz, 2015), high air and soil temperature of about 31-35°C and relative humidity of above 70% that favor the pathogen sporulation are reported to influence incidence and severity of the cashew wilt disease (Tibuhwa and Shomari, 2016). Lilai *et al*. (2021) stated that soil pH, soil temperature, air temperature, and relative humidity positively correlated with cashew wilt disease incidence and severity, while nitrogen, phosphorus, and carbon depicted negativey correlation with the disease.

DISEASE CYCLE

The pathogen is soil-borne in nature and enters the cashew plant through natural wounds or cracks present on rootlets during lateral root formation (Tibuhwa and Shomari, 2016). Mechanical injury to roots during transplanting, other intercultural operations and wounds due tto root feeding insect or nematode also help in the entry of the pathogen. *F. oxysporum* penetrates the vascular system through the roots and root cortex and causes the disease (Agrios, 2005; Tibuhwa and Shomari, 2016). Root/stem vascular vessels are colonised by the hypha, macro-microconidia, and growth following post-cortical entrance (Groenewald, 2005; Warman *et al*. 2018).

Chilinga *et al*. (2022a) critically studied quantitatively the role of the Fusarium pathogen in the transmission of cashew wilt at the orchard through mathematical modelling in Tanzania and found that the contact rate of infected plants and chlamydospores with susceptible hosts through root contact played a significant role in disease transmission. They reported that chlamydospore contact rate increased the number of plants exposed to disease up to the first 9 months and then declined gradually. Decayed plant tissue in the field also enhances the population of pathogens in the soil, resulting in an increase in disease outbreaks and huge economic loss (Chilinga and Hugo, 2023). Increased chlamydospore and macroconidia population in soil initially increases the population of wilted plant. However, there was an inverse relationship between chlamydospore and macroconidia population in soil reported by Chilinga *et al*. (2022a).

MANAGEMENT

Cashew is an important cash crop in many African countries, including Tanzania. Most of the cashew farmers in African countries and India did not have awareness on the management of cashew wilt. Management of Fusarium wilt is a challenging task because of the long-term survival of the pathogen in the form of chlamydospores in soil and continuous evolution of races, etc (Jash *et al*. 2022). Integrated disease management strategies have been adopted to manage the vascular wilt caused by soil-borne Fusarium species. These include crop rotation, field sanitation, summer ploughing, soil solarization, intercropping, organic amendments, tillage practices, in addition to chemical and biological management, etc (Koike and Gordon, 2015, Gogh *et al.* 2015; Ploetz, 2015; Ajilogba and Babalola, 2013; Mbasa *et al*. 2021; Jash *et al*. 2018). Chilinga *et al*. (2022b) reported that the increase in awareness among the farmers shows a significant impact in decreasing disease transmission through mathematical modelling using different parameters of control strategies such as cutting and burning severely infected cashew plants, fungicides application, and through an extension programme. Cultural practices like cutting and burning infected cashew trees and quarantine of the planting materials (seed and seedlings) from infested areas, intercropping cashew with leguminous crops, soil fumigation, tillage application, crop rotation, flood fallowing and application of organic amendments can be applied. However, these methods are effective in small areas, whereas in large areas the disease can be controlled by planting resistant cultivars.

Several chemical fungicides like carbendazim, thiophanate methyl, triazoles were reported for control of Fusarium wilt disease (Mbasa *et al*. 2021, Song *et al*. 2004, Amel *et al*. 2010). However, soil application of these chemicals is harmful to soil microflora, human and the environment. Pre-formulated mixture of carbendazim + mancozeb was found as the best fungicide formulation in reducing cashew wilt severity and the highest per cent reduction of disease (Patsa et al. 2023b). Mbasa et al. (2021) reported that application of carbendazim at 10 g/L, azoxystrobin at 15 g/L and thiophanate methyl at 15 g/L was optimum, thus can effectively suppress Fusarium wilt disease of cashew.

Use of suppressive soil is very crucial for the biological control of Fusarium wilt of cashew and helps in temperature regulations, thus minimising soil overheating. There were several reports of the application of resident biocontrol agent *Trichoderma* species against *Fusarium oxysporum* (Jash *et al*. 2005). Tibuhwa and Shomari (2016) reported that the use of antagonistic microbes, especially *Bacillus sp*., which protect and promote plant growth by colonizing and multiplying in both the rhizosphere and plant system, could be the best potential alternative approach for the management of Fusarium wilt of cashew. The potential efficacy of *Azadirachta indica* has been reported from various host crops of *F. oxysporum*. These include control of *F. oxysporum* in beans (Obongoya *et al*. 2009), onion (Hussain *et al*. 2019) and tomato (Sreenu and Zacharia, 2017). Application of botanical fungicides with *A. indica* @ 0.6ml and *Lantana camara* @ 0.4ml provides effective control against disease (Mbasa, 2021). Integrated management strategies are the best options for sustainable management of fungal wilt.

DECLARATION

The authors do hereby declare that they don't have any conflict of interest.

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