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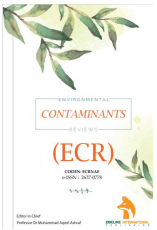

REVIEW ARTICLE

FUSARIUM AND VERTICELLUM WILT IN COTTON: A REVIEW

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ABSTRACT

Cotton (Gossypium hirsutum) is an important cash crop which is cultivated in more than 80 countries worldwide producing worth of 121.30 million bales in MY 2019/2020. However, it is attacked by many insect pests that causes high economic loss. Vertcillium wilt (VW) and Fusarium wilt (FW),a soil borne fungus caused by Verticillium dahlia kleb and *Fusarium oxysporum f.sp. vasinfectum*, is one of the most destructive diseases in cotton *(Gossypium hirsutum* L.) production deleteriously affecting the yield and quality in ,India and worldwide. The wilt is becoming serious problem for cotton growing farmer and key subject of research in cotton resistance genetics and pathology. This aim of this paper is to call for attention and concentrated action by describing potentially damage of the pest, morphology, symptoms, Epidemiology, behavior, entry pathways and control method. The key pest of cotton accounts for its production loss up to70% in the absence of compatible control measures. Its effective control strongly relies on integrated management strategies includes Bio control agents, Physical, cultural a virulent strains, resistant varieties are the best practices for pest management.

KEYWORDS

Stratiges, Destructive, Production

1. INTRODUCTION

Cotton is derived from the Arabic word "quotn" (Lee and Fang ,2015). It belongs to the Genus Gossypieae and family Malvaceae. Over 50 species of cotton are recognized so far (Fryxell 1992). The new molecular data confirmation and taxonomy recorded the two new tetraploid species of cotton which includes Gossypium ekmanianum (AD6) and Gossypium stephensii (AD7), in addition to 5 tetraploid (2n=4x=52) and 46 diploid (Gallagher, 2017; Grover, 2015.Among these, there are 4 most widely domesticated species : two of them i.e *Gossypium arboreum and Gossypium Herbaceum* are diploids domesticated from Africa and Asia and other two includes G. hirsutum and G. barbadense are allopolyploid domesticated from America (Wendel and Grover, 2015). The two allotetraploid species Gossypium hirsutum and Gossypium barbadense makes up the comprehensive production of the cotton in the world (Wendel, 1992, 2013; Wang, 2015). 90% of global cotton production with a premium quality of cotton is dominated by Gossypium hirsutum (Brown 2002; Liu *et al.* 2013).

Cotton(Gossypium) is perennial shrub or a tree which is mainly grown in subtropical and tropical climate enrolling an area of 33-37 million ha over 100 countries between the latitude of 37 ◦N - 32◦S (Noreen *et al*, 2020). The characterstics of cotton plant includes an upright branched stems, alternate dark green leaves with 5 petals, large flowers, capsulated fruit having ovoid seeds covered by thread or fibers, with the taproot system which can penetrate up to the depth of 60 cm if favorable soil and moisture is present (Ali *et al,* 2020).

Cotton is known as one of the essential crop that provide ecologically sustainable fiber to the growing global population (Cusser *et al.,* 2016). The highest Cotton producing country in the world is India with the production estimating of 28.5 million 480 lb. bales in the year 2020/21 But the highest exporter is USA estimating the export of 15 million 480 lb. bales. (USDA 2020/21). Nepal produces about 92 mt of Cotton cropped in an area of 90 ha (Krishi diary., 2019/20). Currently, Cotton in Nepal are produced in Dang, Banke, Bardiya district of Nepal in an area of 106, 27, 10 ha producing 74, 41, 12 mt of cotton respectively (MOAD, 2016/17)

There are different biotic and abiotic factors responsible for the loss of yield, viability of cotton fiber production. During the growth the two soil-borne diseases, Vertcillium wilt (VW, caused by Verticillium dahliae Kleb.) and Fusarium wilt (FW, caused by Fusarium oxysporum f.sp. vasinfectum Atk. Sny & Hans, FOV), represent two major disease problems in world cotton production (Pegg and Brady, 2002 ; Halpren *et al.,*2018). FOV is composed of eight nominal races worldwide but only six of the races with different genetic sequences are recognized (Chianchetta., 2014). Recently, FOV4 has become increasingly prevalent in Upper Rio Grande Valley of Texas in El Paso and Hudspeth Counties (Halpern *et al.*,2017), similarly in New mexico(Zhu *et al.*,2019) with severe damage on cotton seedlings. Though Fusarium wilt has a specific host range but the verticillium dahilae has the widest host range of more than 200 species among the 10 species of genus verticillium (Inderbitzin *et al.*, 2011; Inderbitzin and Subbarao, 2014).Based on the defoliating and non defoliating symptoms of cotton, Verticillium dahilae is divided into two races (Hu *et al.*,2015).

FOV is an anamorphic fungus.The morphology of F. oxysporum f. sp. Vasinfectum includes white to grayish white or bluish purple mycelium with two type of conidia present : small, one or two celled microconidia(5–20 2.2–3.5) and 3-5 septate, fusiform , sickle shaped, multinucleated macroconidia(27–48 2.5–4.5 µm) having a

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chlamydospores with short conidiophores as a distinguishing character than other species of Fusarium (Chohan et al.,2020). Similarly, the author describes Verticillium dahliae (2.0–3.5 mm at 20–25 C) having dark brown to black microsclerotia existing in the soil and crop debris having short cylindrical to ellipsoidal conidia with erect conidiophores present on it.
Both of the pathogens are soil borne (Abdelraheem *et al*., 2019), surviving saprophytically on crops and other debris (Li et al., 2017). Both of these pathogen damages the plants by producing similar symptoms like chlorosis, wilting and defoliation of the leaves that gradually damage the vascular tissue and eventually leads to death of the plant and Hence called as the 'cancer' of cotton crops (Zhang *et al.,* 2018). The symptoms of Fusarium wilt is seen from the seedling stage and is highest as the squaring stage where as in case of Verticillium wilt the symptoms are observed before the squaring stage reach highest at the boll-setting stage.(Hu *et* al., 2015).

2. Result and Discussion

2.1 Etiology

2.1.1 Fusarium Wilt

Casual Organism: Fusarium Oxysporium f.sp. vasinfectum

2.1.2 Verticillium Wilt

Casual Organism: Verticillium dahliae Kleb, Verticillium alboatrum

2.2 Symptoms

At every stage of Growth of the plant the symptoms of Fusarium wilt is seen (Davis *et al*., 2006). The different symptoms of FOV include:

2.3 Seedling stage

The disease symptoms starts from the seedling stage and is highest at the squaring stage **(**Hu *et al.,* 2015)

The initial symptoms of is seen on the cotyledon that includes:
Vein darkening, Chlorosis, withering of the young cotyledons and eventually the cotyledons droop, and die. (Chohan *et al*., 2020)

2.4 Older Plants

According to, (Synder and Hansen,2020)

Symptoms begins with the yellowing of the lower leaves margin of the older plants and then spreads towards the main veins.

It ultimately leads to drooping of the plants as the xylem vessels are blocked, leading to brownish black vascular discoloration when vertical section of the stems are cut.

Finally, necrosis of the leaves and the entire plants death is seen.

The symptom like browning of vascular system of the hypocotyl differentiate the fusarium wilt to that of damping-off caused by Pythium spp., Rhizoctonia solani Kuhn, and Fusarium spp **(**Davis *et al*.,2006).Sometimes, it is not obvious to see those apparent symptoms that are usually seen in the field if the density of inoculum is low (Synder and Hansen,2020**)**. The severity of the Fusarium wilt depends on many other environmental and soil prolificity, increased moisture and rainfall condition (Cox jr *et al*.,2019). Similarly, in a study of Greenhouse the disease symptoms of FOV were not seen below 103 conidia/gm of inoculums in Green house (Hao et al., 2009).

Though there are some typical symptoms of FOV and VW like yellowing, shrinking, shedding of the leaves, dwarfing and vascular discoloration (Deketelaere *et al*., 2017) , the verticillium wilt can be distinguished : As, VW has less vascular discoloration and leaves become red , however the disease isolation is the foremost to distinguish it**(**Davis *et a*l., 2006).The defoliating and non defoliating symptoms are also seen on the cotton infected with VW (Hu *et a*l.,2015**)**. The disease are seldom observed in non irrigated cotton than that of irrigated cotton which shows an increased incidence of Verticillium wilt by 50%**(**Land *et al*.,2017).Due to the resistant germplasm FW are however under controlled but VW control however difficult and is currently on it's way of research and study (Shaban *et al*., 2018)

Figure 1: Wilt, chlorosis of foliage of cotton seedlings affected by Fusarium wilt

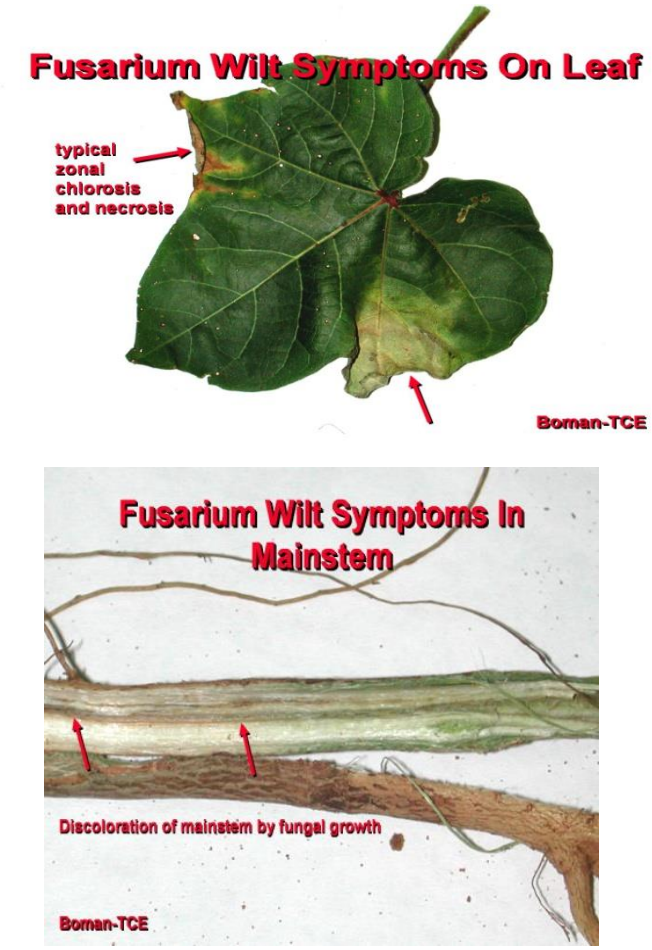

Figure 2: Chlorosis, Necrosis and vascular discoloration of Cotton by FOV

Figure 3: Wilting, Chlorosis, Vascular discoloration of cotton by Verticillium wilt

2.5 Disease cycle and Epidemiology

FW is a soil borne pathogen. The Chlamydospores produced by it persists in the soil for a several years. The infection begins from the primary source Chlamydospores and begins to produce conidia **(**Sanogo *et al*.,2015). These conidia inoculates on the root surface for about 6 hours and they form a mat of mycelium concealing the surface followed by the formation of hyphae (Chohan et al.,2020). These hypha penetrates the xylem vessels . As a result, conidia proceeds upward to the plants blocking the xylem vessels which eventually leads to wilting of the plant around 5-6 week period of time (Chohan et al.,2020).

Similarly, The survival of VW in soil is done by microsclerotia for a longer period of time at a depth below 40cm (Chohan et al.,2020) .If the favorable environment is achieved by the microsclerotia, these germinates around the plant roots and colonize over it (Deketelaere et al., 2017). The formation of hyphae take place and these hyphae penetrate the xylem vessels within only 2-4 days and colonize (Heniz *et al*.,1998; Chen *et a*l., 2004; Fradin and Thomma, 2006) and as a result xylem vessels are blocked and restricts the translocation of water and nutrients. (Liu *et al.,* 2020).

The disease symptoms of FOV are seen at the soil temperature of 26 to 28°C (Tripathy *et al*.,2020) at 80–90% moisture content (Chohan *et a*l., 2020) . According to the study by (Li et al., 2017), in China, verticillium wilt is seen at a temperature of 25°c to 30°C and is also aggravated by the rainfall with the precipitation of more than 250mm but show less pathogen occurrence in <155 mm precipitation. The VW is more serious on heavier soils and high clay and slit content 50 (Land *et al*., 2017).

2.6 Management

The management of FOV and VW of cotton can be done by different methods. These include:

2.7 Crop rotation

It is regarded as one of the most oldest and effective means of reducing the pathogen in case of FW and VW (Sanogo and Zhang,2016).Crop rotation with Barley, wheat, Sorghum, Ryegrass, Fescuse, different legumes, Peas, Soyabean, Alfaalfa, Lespedeza, mustard and rapeseeds are known to reduce the innoculum rate in VW (Raper et al.,2017) . However, these practice are difficult to be used in large scale production (Zhang etal., 2019).

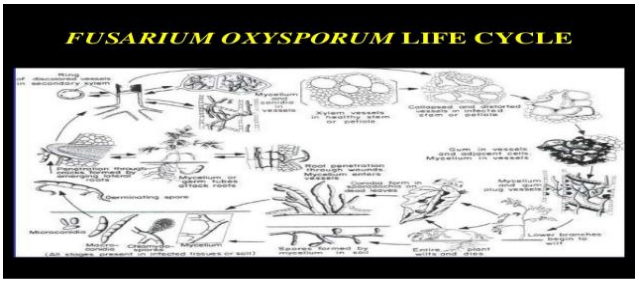

Figure 4: Life cycle of FOV

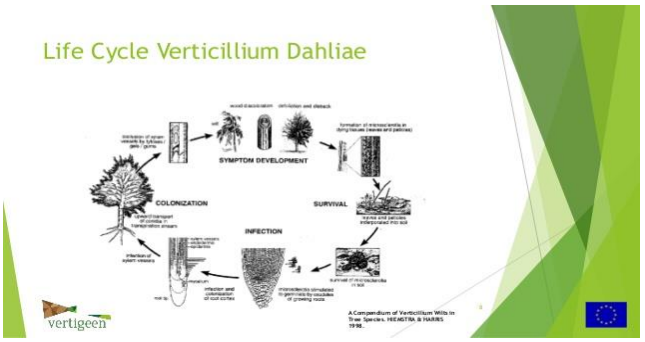

Figure 5: Life cycle of Verticillium dahlilae

2.8 Soil solarization and fumigation

Soil solarization is found to be effective as this process increases the temperature of soil to a level that becomes lethal for soil borne microorganism to survive (Kumar *et al.,*2017). The chemical soil treatment by methyl-bromide + chloropicrin, solarization, and chloropicrin and 1,3-dichloropropene showed reduced infestation of FW in race 4 of cotton (Bennet et al.,2011).Though it is the most efficient method, may not be economically feasible in cotton (Bennett et al. 2011; Doan et al. 2014)

2.9 Hot water treatment

Hot water treatment at 90°C for about 105 s showed decrease in the attack of FOV pathogens and even not affecting the viability of cotton. (Bennett and Colyer ,2010)

2.10 Irrigation

Increased Irrigation practices highly affects the disease incidence and yield in cotton (Raper et al., 2017). To reduce the infestation of VW, appropriate irrigation practices when needed, reduction in the overuse of irrigation practice should be followed. (Raper et al., 2017).

2.11 Bio control Agent

2.11.1 Endophyte as Biocontrol Agents

An endophytic fungus Chaetomium globosumCEF-082 is effective in controlling Verticillium wilt in cotton (Zhang *et al*.,2020). Similarly, endophytic fungus isolated from roots of cotton viz: CEF-818 (*Penicillium simplicissimum*), CEF-714 (*Leptosphaeria* sp.), CEF-642 (*Talaromyces flavus*.) and CEF-193 (*Acremonium* sp.) were effective to reduce the VW of cotton. (Yuan et al.,2017)

2.12 Biocontrol Agents

Biocontrol agents like Bacillus velezensis Strain AL7, Pseudomonas, Bacillus, Streptomyces is found effective in reducing incidence of verticillium wilt disease of cotton (Liu *et al*.,2020; Li *et al*., 2013; Xue *et al*.,2016; Gómez.l *et al.,*2018) Similarly, Trichoderma virens is seen to be effective on FW and VW of cotton LE (2000): Zhanng et al.,1995)

2.13 Use of Avirulent Strains

Recent study on non-pathogenic *Fusarium oxysporum* strain FO12 is found to be effective against VW as it contains volatile organic compounds and

other soluble substances that inhibited the growth of microsclerotia (Mulero.Aparicio et al., 2019)

2.14 Use of Resistant Varieties

The use of resistant varieties are the major way for reducing FW and VW. In Shaanxi Huanghuai China , Shaan 1155 variety was the first resistant variety against FW and VW that were produced on large scale (Cai *et al*.,2009) Similarly, vareties like Zhongzhimian 2, Shaimian 2177, Chuanmian 65, Chuanmianyou 2, Shaan 2365 and BD 18 are the resistant varieties against VW (Ma *et al.,* 2002).Recently, NuMex COT 17 GLS, Glandless cotton showed resistant to FW and VW on race 4 (Zhang et *al*.,2020)

2.15 Chemical Control

Chemicals like Carbendazim, ethylene thiosulphate is found to be effective for controlling seedlings pathogen (Shen 1985). The systemic fungicide Benzimidazole are used to control verticillium in cotton at different doses in the greenhouse and can be used in the field For eg : 100 ppm of Benlate in water drenchers and 10–20 kg of Benlate in field (Chohan et al.,2020)

2.16 Genetic engineering approaches

Different Genetic approaches has been described to reduce Fusarium and Verticillium wilt of cotton. According to **(**Wang *et al.,* 2016) as the verticillium wilt has varying pathogenicity and survivability.A broad spectrum Gastrodia anti-fungal protein (GAFP) when incorporated to the cotton provides resistance to many fungal pathogens and GAFP4 is the most excellent for controlling VW of cotton. Similarly, the use of Agrobacterium mediated transformation by the use of shoot apex of Upland cotton varieties as explants with SNC1 gene showed resistant to Fusarium wilt of cotton (Lei *et al.,* 2011).(Pie *et a*l.,2020)described Germin like protein (GLPs), GLP2 provides a defense function against Fusarium and Verticillium wilt of Cotton.

3. Conclusion

Cotton, the major industrial crop are threatened by Fusarium and Verticillium Wilt leading to reduce in the quality and quantity and eventually death of the plant. The persistency of Chlamydospore and microsclerotia makes Fusarium and Verticillium wilt as a limiting factor. In absence of crop host and environment these pathogen survive in the soil for many years and infects the plants showing wilting, chlorosis and necrosis symptom. In this regard, there is an utmost need to adopt the ecologically sustainable management practices in the field so that it would promote global increase in the production of Cotton. As this pathogens are soil borne, and the disease severity depends upon the soil environment. It is better to prevent the occurrence of pathogen by maintaining the good soil health and applying phyto sanitation, integrated pest management and use of resistant varieties.

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A data sheet of Cotton Market Fundamentals & Price Outlook. August 2020 Cotton Incorporated. All rights reserved; America's Cotton Producers and Importers

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