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Review Article

The impact of fusarium wilt diseases on tomatoes (*Lycopersicon esculentum* Mill.) and their management

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A high-esteem dietary component, tomato feeds rural and urban populations worldwide. Many factors contribute to decreased tomato output, including fungus, bacteria, nematodes, viruses, and dominating weeds. The most important and common tomato disease is Fusarium wilt, which is brought on by *Fusarium oxysporum* f. sp. *lycopersici*. Only tomatoes are susceptible to this soil-borne Hyphomycetes disease, which causes wilt. Young plants show vein-let clearing and petiole drooping first. Fusarium wilt causes yellowing of older leaves. Lower leaves yellow and die. To infect host plants, Fusarium species generate macroconidia, microconidia, mycelia, and chlamydospores. Dormant, parasitic, and saprophytic phases comprise the life cycle. Most saprobes are harmless; however certain parasitic species produce mycotoxins on plants.

Keywords: *chlamydospores, Fusarium oxysporum, macroconidia, parasitic species*

Introduction

The tropical vegetable crop in question has significant importance and is extensively used on a global scale. According to (Attia et al., 2022) this particular crop has significant value in the local market and serves as a crucial nutritional component, hence enhancing nutrition and livelihoods for both rural and urban populations. Organic products are often used in many culinary applications; such as being used as a garnish for mixed greens or cooked as a vegetable (Figure 1). This family is very valued for vegetable and fruit crops (FAOSTAT, 2019). The tomato is quite versatile, but thrives in warm environments with ideal temperatures ranging from 150°C to 250°C. Elevated humidity and temperatures reduce fruit set and yield. The occurrence of colour creation and ripening has been postponed due to very low temperatures, but the fruit set, lycopene generation, and taste are hindered by temperatures over 30°C. Tomatoes flourish most effectively in regions with moderate to low precipitation, supplemented by irrigation during the non-growing season. The presence of moisture exacerbates disease outbreaks and has an impact on fruit maturation. According to (López-Zapata et al., 2021) tomatoes exhibit optimal growth in various soil types characterised by high organic matter content, effective drainage, and a pH range of 5–7.5. Tomato plants prefer soil with effective drainage and extensive organic matter enrichment. It is necessary for the soil to possess a high moisture-retention capacity. Tomato growth is optimal within an elevation range of 1000 m to 2000 m above sea level (Dholu et al., 2021). Tomatoes provide several bioactive components that contribute to overall health and may be readily included into a well-rounded dietary regimen (Martú et al., 2016). In recent years, there has been an increased recognition among consumers about the potential health advantages of foods and their significance in the prevention of various chronic illnesses and dysfunctions (Pem & Jeewon, 2015). While there is a wide range of functional meals available to meet these needs, it is worth mentioning that consuming "conventional foods" such fruits and vegetables is more efficient for achieving this goal (Viuda-Martos et al., 2014). Tomatoes possess a range of health-promoting components, such as vitamins, carotenoids, and phenolic compounds, which contribute significantly to their nutritional significance (Liu et al., 2016). According to Raiola et al. (2014), the bioactive chemicals exhibit a diverse array of physiological capabilities **(Figure 1)**. According to Viuda-Martos et al. (2014), tomatoes are abundant in carotenoids, which serve as the primary dietary source of lycopene in humans (Tohge & Fernie, 2015). According to Agarwal & Rao (2000), tomatoes include inherent antioxidants Vitamins C and E, along with significant quantities of sucrose, malate, hexoses and ascorbic acid (Li et al., 2018).

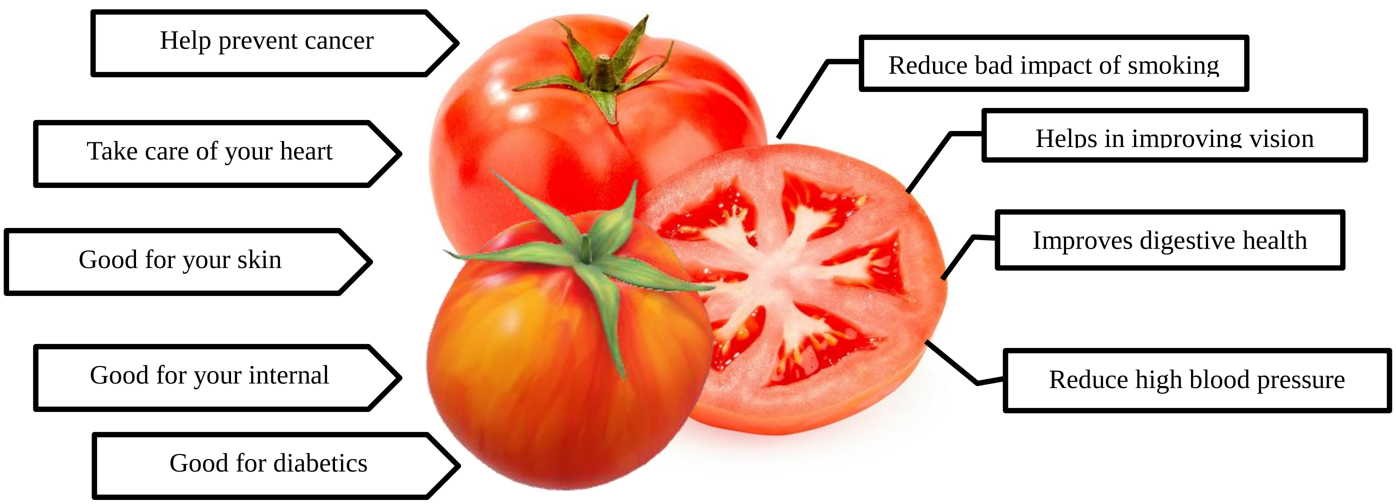

Figure 1. Health benefits of Tomato

Fusarium species

The fungus in question is a soil-dwelling organism that has a global distribution. Certain species of Fusarium have a preference for tropical regions, while others are more prevalent in temperate zones. Additionally, certain species are known to inhabit desert, alpine, and arctic environments characterized by severe climatic conditions (Balali & Iranpoor, 2006). Numerous Fusarium species have a high prevalence in rich agricultural and rangeland soils, but their occurrence in forest soils is rather limited. The various species of this organism are widely recognized as significant pathogens of plant diseases. Certain species have the ability to produce mycotoxins, which can contaminate plants and enter the food chain. This contamination poses a threat to the health of both humans and animals, as well as wildlife, agricultural products and livestock (Wang et al., 2011). According to Wang et al. (2011), the genus Fusarium now encompasses more than 20 species. Several species of Fusarium exhibit a teleomorphic condition (Aoki et al., 2014). Molecular techniques, such as the sequencing of the 28S rRNA gene, may be used to efficiently identify Fusarium strains at both the species and subspecies levels. Additional methods include PCR for detecting rDNA (Lacmanova et al., 2009) and the use of SDS-PAGE and esterase isozyme electrophoresis for detecting protein banding patterns (El-Kazzaz et al., 2008).

Fusarium wilts

Fusarium oxysporum is the primary agent responsible for Fusarium wilts, as was mentioned before. This fungus has a large number of important pathogenic species that are capable of infecting a variety of plants and giving rise to wilts in crops that are of significant economic relevance. It is routine practice to isolate strains of *F. oxysporum* from roots that are in good condition. Strains that originate from plants that seem to be in good condition are referred to as non-pathogenic strains. This species, *Fusarium oxysporum*, is very complicated. It's responsible for causing devastating vascular wilts in a broad range of crops (Joshi, 2018). According to PADIL (2011), Pathogenic strains in *F. oxysporum* demonstrated a high degree of host specificity, leading to the development of the concept of "formae specials."

Plants affected by fusarium wilt

The most vulnerable plants to this disease include tomatoes, sweet potatoes, solanaceous crops, legumes, bananas and cucurbits (Miller et al., 2011). However, it may also affect other herbaceous plants. Additional host species include

Callistephus, Dianthus, beans, hebe, and peas. Nevertheless, it is important to note that specific pathogenic strains belonging to certain species have a restricted range of hosts. Consequently, strains that possess comparable or equal host ranges are categorized under the same formae speciales (Edel-Hermann & Lecomte, 2019).

Fusarium wilt of tomato

Infestation frequently manifests on fully developed plants subsequent to the initial stages of blooming and fruit development. Severe wilting is the greatest challenge for mature tomato plants, but its severity is comparatively less pronounced in younger shoots (AVRDC, 2005). The downward drooping and curling of older leaves, the darkening of vascular tissue, and the consequent withering and death of the plant are indicative of seedling infection. After flowering, the leaves of older sick plants exhibit a yellow coloration. The stem's vascular tissue has a dark brown coloration, while the pith stays in a healthy state. Fruit infection has the potential to manifest, exhibiting a consistent brown vascular discoloration. The global significance of Fusarium wilt in tomato cultivation is evident, as it has been recorded in a minimum of 32 nations. This disease is particularly severe in regions characterized by warm climates, including the US, UK, Australia, the Netherlands, Morocco, Vietnam and Iraq. Infection by root knot nematode can be linked to the disease (Mui-Yun, 2003).

Symptoms

According to Inoue et al. (2002), the fungus has the ability to enter roots and establish itself in the vascular tissue. Fusarium wilt exhibits a spectrum of symptoms, including inhibited growth, leaf yellowing and wilting, reddish pigmentation of the xylem vessels (observable dots and lines within the stem), and the presence of orange and sometime pink or white fungal growth on the outer surface of affected stems under moist circumstances. Additionally, root or stem decay is observed **(Figure 2).**

The assault initially manifests as a mild clearing of veins on the outer surface of the young leaves, followed by the occurrence of epinasty in the older leaves (Sally et al., 2006). This particular manifestation frequently manifests unilaterally or on a single stalk of the plant. The leaves undergo consecutive yellow wilting and perish, frequently prior to the plant reaching full maturity. As the disease advances, there is a tendency for growth to be inhibited, resulting in minimal or no fruit production. When the primary stem is severed, it is possible to observe the presence of dark brown streaks that extend longitudinally along the stem (Mui-Yun, 2003).

Figure 2. Symptom of Fusarium Wilt on Tomato stem (Carmona et al., 2020)

Carmona SL, Burbano-David D, Gómez MR, Lopez W, Ceballos N, Castaño-Zapata J, Simbaqueba J, Soto-Suárez M. Characterization of Pathogenic and Nonpathogenic *Fusarium oxysporum* Isolates Associated with Commercial Tomato Crops in the Andean Region of Colombia. *Pathogens*. 2020; 9(1):70. https://doi.org/10.3390/pathogens9010070

Fusarium wilt vs Verticillium wilt symptoms

The vascular darkening resulting from *F. oxysporum* typically manifests as a darker and more consistent brown stain in stem tissue, while Verticillium induces a stain that appears as a "flecking" or "spotty" pattern. The presence of vascular discolouration is observed to be more pronounced in the lower stem of Fusarium plants compared to Verticillium. Another noteworthy distinction is in the preference of Fusarium wilt for elevated temperatures, whereas Verticillium wilt has a preference for lower temperatures. This implies that Verticillium exhibits greater damage in the aftermath of cool weather due to its heightened growth activity in cooler conditions. In numerous instances, however, not universally, there is a notable occurrence of substantial damage. Consequently, plants infected with Fusarium have a greater degree of stunting (Hutmacher et al., 2003).

Diseases transmission

The pathogen gains entry into the plant via root tips (Sally et al., 2006), and has the ability to persist in the soil for a duration of up to 30 years, as reported by Thangavelu et al. (2004). The mycelium proliferates within the xylem vessels, causing a disruption in the water supply and subsequent wilting (Stephen et al., 2003). Fusarium wilt frequently exhibits a correlation with nematode colonization, wherein the nematodes serve as a means of entry for the fungus. Enzymes can potentially aid in the infiltration of Fusarium into the plant host (Babalola, 2010). The disease has a higher degree of severity in sandy soils and is generally less prevalent in heavier clay soils (Larkin et al., 2002).

Management and control of fusarium wilt

On the other hand, the period at which symptoms show and the rate at which the disease progresses in plants might vary significantly within a field, which can give the impression that secondary spread is occurring. Several chemical fungicides suppress the illness by fostering resistance. Some of these chemicals include prochloraz and carbendazim (Song et al., 2004), Bavistin and salicylic acid (Amel et al., 2010).

Soil solarization

To do this, a sheet of transparent plastic is placed over the soil and left there for a number of weeks. This facilitates the capture of solar energy, which in turn prevents the growth of soilborne illnesses, nematodes, insects, and a wide variety of weed seeds (**Figure 3).**

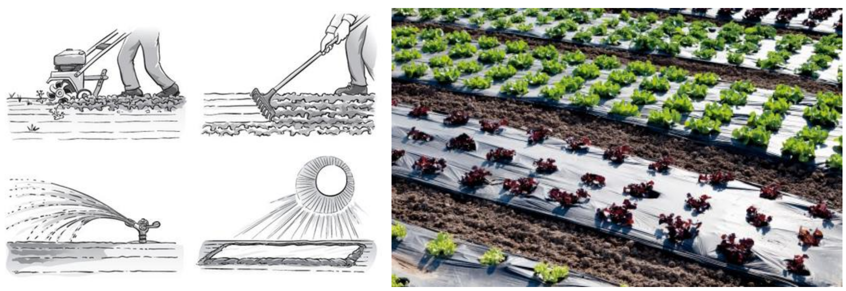

Figure 3. Soil solarization treatment in field
https://ceventura.ucanr.edu/?blogpost=9106&blogasset=19305
https://natraj.org/news/soil-solarization/

Soil disinfection

Utilization of Steam and Heating Typically, this practice is carried out as a preplanting approach. According to Bawa (2016), the use of hot water can be done, and it has the potential to sterilize the soil for a period of up to three years. Additionally, steam can be utilized, particularly in controlled environments like as greenhouses (Ajilogba & Babalola, 2013). It is possible to maintain sterility and eliminate disease-causing bacteria in the soil through the process of disinfection **(Figure 4).**

Figure 4. A Machine applying soil disinfection film in the field.
https://www.researchgate.net/figure/Soil-disinfection-machine-used-in-this-study_fig1_349317572

Use of resistance cultivar

The utilization of resistant cultivars, when accessible, is the most economically efficient and ecologically sound approach to management. Certain plant species, such as peas and China aster, have varieties that are either resistant to or tolerant to Fusarium wilt. The exploitation of tomato varieties that are impervious to the illness, as suggested by Pritesh et al. (2011), gives a viable alternative to the application of chemical substances. However, the process of breeding for resistance might pose significant challenges in cases when a dominant gene is not identified. Furthermore, it has been observed that novel strains of pathogens have the ability to overcome host resistance (Balogh et al., 2003). This strategy offers several benefits, such as cost savings in chemical usage for disease control and improved cultivation of formerly contaminated fields.

Integrated disease management (IDM)

The efficacy of Integrated Disease Management (IDM) in enhancing agricultural output and addressing environmental degradation in underdeveloped nations has been acknowledged (Waiganjo et al., 2006). Methods that can contribute to the development of fertile soils encompass crop rotation, incorporation of organic matter, or utilization of high-residue tillage equipment. Extensive study has been carried out globally on the use of compost products to control pests and illnesses. The findings indicate that composts have the potential to offer a natural biological means of managing soil-borne illnesses that impact the collar, roots, and foliage of plants (Recycled Organics Unit, 2006). Adding green manures and cover crops to a rotation is a highly effective method for promoting fertility, controlling weeds, and interrupting insect cycles (Jeff, 2009).

Conclusion

Fusarium wilts pose a significant global challenge, resulting in substantial economic losses in agricultural crops, despite the implementation of preventive and control methods. While the utilization of resistant cultivars is the most effective approach for control, it is important to note that new strains of the pathogen may emerge. Consequently, researchers are exploring alternate control tactics, including biocontrol technologies. This research is crucial for enhancing our comprehension of the organism's biology. Ultimately, it is crucial to focus on investigating and enhancing the effectiveness, efficiency, and longevity of these technologies in real-world settings, rather than solely in controlled laboratory environments. The consideration of various formulations of microbial products that yield optimal efficiency is of paramount importance in the field of biological control. The primary focus should be on providing farmers with education on the proper utilization of cultural practices and their incorporation into other techniques to improve and achieves safer outcomes.

Author contributions

All authors contributed to the study's conception and design. Author Muhammad imran jhammat was responsible for creating the study and writing the protocol. Muhammad imran jhammat and Javed Abbas handled the preparation of the materials, data collection, and analysis. Muhammad imran jhammat wrote the first draft of the manuscript, and Areej Zubair provided feedback on earlier iterations. Authors Fatima Tauqeer, Zunaira Hussain, Saima Nadir Ali the literature searches and contributed a lot to Strategies Portion. The final part of the manuscript is Hinder Hunger written by Aliza Fermaish Ali and Dr. Umair Ashraf. Saima Nadir was in charge of managing the references and citations. All authors read and approved the final manuscript.

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Conflict of interest

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Ethics approval

Not applicable

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