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Powdery mildew of tomato and its management: A review

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Abstract
Tomato (*Solanum lycopersicum* L.) is a widely farmed crop around the world. A plethora of diseases have infected this crop. Powdery mildew disease is a key yield and quality limiting issue. The goal of this paper is to review the symptoms of tomato powdery mildew illness, the pathogens that cause it, the ideal conditions for disease development, and how to manage it.

Keywords: Powdery mildew, tomato, yield losses

1. Introduction
Tomato (*Lycopersicon esculentum* Mill.) is one of the world's major vegetables with a total area and production of 4.4 million ha and 115 million metric tons, respectively [1]. The crop has been produced for the last eight decades in Ethiopia [2]. Powdery mildew, a serious disease that causes 10 to 90 percent yield losses in tomato, is one of the numerous factors leading to Ethiopia's low tomato yield [3; 4; 5]. Different *Erysiphaceae* species, such as *Golovinomyces orontii*, *Leveillula taurica*, *Oidium lycopersici*, and *Oidium neolycopersici*, may be responsible for the disease [6; 7; 8; 9]. For many years, *Leveillula taurica* has been recognized as a tomato pathogen [10]. A second, related disease, *Oidium lycopersicum*, was reported in tomato crops [11; 12]. In many regions of the world, powdery mildew infections caused by *Oidium neolycopersici* have been an issue in tomato (*Solanum lycopersicum L.*) production since the late 1980s [13]. Because all commercial tomato cultivars were vulnerable to *O. neolycopersici* at the time breeding programs were started soon after the disease's debut and rapid spread in Europe and North America [13; 14]. Wild tomato relatives were used as valuable sources of resistance [13], and the cytological and molecular basis of powdery mildew resistance in *Solanum spp.* was also deciphered [14]. The severity of the disease decreased as RH increased to a minimum level of 95 percent RH [15]. Furthermore, the disease develops at RH levels above 50%, and the optimum RH for disease development is above 90% with no free water [16]. The temperature range for disease development is 10 to 35°C, with maximum disease development occurring at temperatures below 30°C [16]. Tomato powdery mildew affects the majority of tomato varieties [17]. Tomato varieties that are resistant to tomato powdery mildew include *L. peruvianum* LA 2172, *L. hirsutum* G1.1560, Punjab Chuhara, RCMT- 2 and Pant T-8 [17]. Biocontrol agent such as *Pseudomonas fluorescence, Trichoderma koningii, Trichoderma harzianum , Trichoderma viride and Bacillus subtilis* are good bio-control agents in reducing powdery mildew severity of tomato [18;19;20]. Fungicides Score (difenoconazole), Tilt (propiconazole), Contaf (hexaconazole) and Folicur (tebuconazole) are found effective and can be used in the powdery mildew disease management [20].

2. Economic importance of tomato powdery mildew
For many years, *Leveillula taurica* has been recognized as a tomato pathogen [10]. Powdery mildew infections caused by *Oidium neolycopersici* have been a problem in tomato (*Solanum lycopersicum L.*) production in many parts of the world since the late 1980s [13]. Breeding programs were initiated soon after the disease's appearance and rapid spread, because all commercial tomato cultivars were susceptible to *O. neolycopersici* at the time [13]. A new powdery mildew disease was first identified on tomatoes in Japan, Australia, and then many regions of Europe and North America in the late 1970s, and it has since spread fast throughout the world [21]. The disease has spread throughout temperate regions of the world and can cause yield losses of 10% to 90% in tomato plant [4; 5]. Despite the lack of a reproductive stage, a global investigation of *Oidium* species that cause economic damage to tomatoes identified two taxa. One taxon found in various locations around the world (except Australia) was named

O. neolycopersici, and another, first described in Australia, was named *O. lycopersici* [21; 22].

3. Host range

Golovinomyces orontii is found on a wide variety of host plants in both temperate and tropical climates, and it is the only ectophytotic fungus on tomato that produces conidia in long chains [21; 23]. *Leveillula taurica* from tomato samples was found to be pathogenic to eggplant, pepper, and cucumber, while potato, alfalfa, sunflower, clover, and sainfoin were not infected by the pathogen [24]. In warm arid to semiarid climates, tomato is a major host of *L. taurica* [25; 26]. *Oidium lycopersicum* has also infected Eastern black nightshade, eggplant, tobacco, and potato in the greenhouse [27].

4. Disease symptoms

The first symptoms of *O. neolycopersici* infection on tomato leaves appeared as bright yellow spots on the leaves. The spots grew in size and eventually turned brown. Infection symptoms were only observed on the leaves of adult tomato plants. Fruits, stems, and petioles exhibited no symptoms. There was no sign of a severe infection; instead, the infection appeared as sparse, white circular pustules that occasionally coalesced. Pustules were only found on the upper leaf surface [28]. The symptoms include powdery white lesions on leaf blades and, in severe epidemics, similar lesions on other organs such as petioles, stems, and sepals, but not on fruit (Fig. 1). In contrast, *L. taurica* is a hemiendophytic powdery mildew pathogen that only affects leaves. In severe outbreaks, the lesions clump together and the disease becomes incapacitating [29]. Severe infections cause leaf chlorosis, premature senescence, and a significant decrease in fruit size and quality [11].

Fig 1: Powdery white lesions of O. neolycopersici on tomato leaves but the fruit are uninfected [29].

5. The causal pathogens

Erysiphaceae species such as *Golovinomyces orontii*, *Leveillula taurica*, *Oidium lycopersici* and *Oidium neolycopersici* have been linked to the disease (6; 7; 8; 9). *Golovinomyces orontii* is found on a wide variety of host plants in both temperate and tropical climates, and it is the only ectophytotic fungus on tomato that produces conidia in long chains [21; 23]. A global study of *Oidium* species identified two taxa, one of which was identified *as O. neolycopersici*. This taxon has superficial hyaline hyphae, unbranched conidiophores, and doliform conidia that form singly or in pseudo-chains of 2-6 conidia in high relative humidity [30]. The other taxon, which always produced conidia in chains, was given the name *O. lycopersici*. (29; 31; 22*). Leveillula taurica*, the other cause of tomato powdery mildew, had lanceolate, ellipsoid-lanceolate to subcylindric primary conidia and cylindrical to subcylindric secondary conidia (Fig. 2).

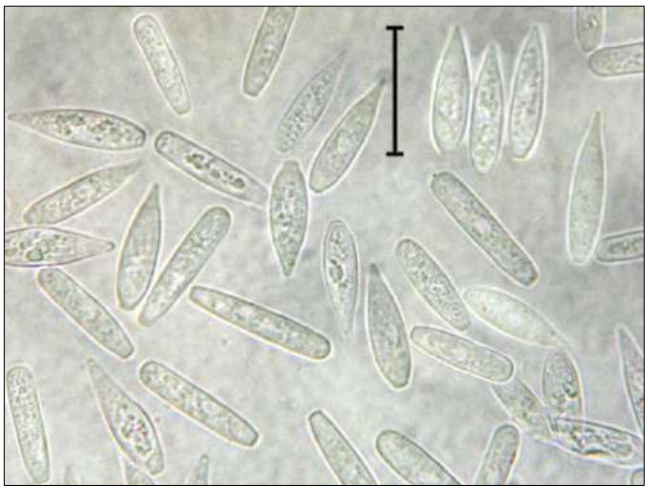

Fig 2: *Leveillula taurica* conidia from *Lycopersicon esculentum* [24]

6. Favorable conditions for disease development

Conidia of the pathogen *O. neolycopersici* can germinate in 3 to 5 hours, form appressoria in 6 to 8 hours, and penetrate the host in 11 hours [30]. The disease severity was greatest at 80 percent relative humidity in a study of the effects of relative humidity (80 to 95 percent at a constant 19°C for 8 weeks) on the development of tomato powdery mildew (RH). As RH increased to a minimum level of 95 percent RH, disease decreased [15]. Furthermore, a Connecticut report claims that the disease develops at RH levels above 50% and that the optimum RH for disease development is above 90% with no free water [16]. This same research showed that the optimal temperature range for development is 10 to 35°C, with disease development occurring at temperatures below 30°C [16]. Temperatures above 30°C were detrimental to the germination and disease development of another tomato powdery mildew pathogen, *L. taurica* conidia. Low RH levels (20 to 40%) inhibited conidial germination and disease progression. Intermediate RH levels (50 to 70%) improved conidial germination and disease development [32].

7. Powdery mildew disease management

Studies showed that, *L. esculentum* cultivars are susceptible to powdery mildew while *L. peruvianum* LA 2172 and *L. hirsutum* G1.1560 are resistant [17]. While, other studies showed that , none of the evaluated 14 tomato hybrid/cultivar was found resistant against the powdery mildew disease [20]. Formulated and unformulated prototype of *Trichoderma koningii* reduced tomato powdery mildew incidence and disease severity by 25- 28 per cent and 28- 66 per cent, respectively [18]. *Trichoderma harzianum* and *Bacillus*

subtilis showed significant reduction in tomato powdery mildew disease incidence [33]. C4 strain of *T. harzianum* among tested isolates gave better results when the formulation was sprayed on foliage in combination with drench to stem base against powdery mildew of tomato [19]. Three sprays of *Trichoderma harzianum* , *Trichoderma viride* and *Pseudomonas fluorescence* at 10 days of interval in 10 g/l found effective against powdery mildew of tomato[20]. Different fungicides were evaluated, among them Score (difenoconazole), Tilt (propiconazole), Contaf (hexaconazole) and Folicur (tebuconazole) were found effective and can be used in the management of powdery mildew disease [20].

8. Conclusion

Tomato crop suffers from various fungal pathogens which cause severe yield and quality losses by causing different diseases. This review concludes that Powdery mildew diseases of tomato can be managed by using different Biological control, resistance variety and fungicides. Using resistance variety and biological control measures are not only environment friendly but are also cost effective. There is need of the time for more research on the evaluation of tomato varieties and biological control measures against tomato powdery mildew pathogens.

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