

Management of Some Common Insect Pests and Diseases of Tomato (*Solanum lycopersicon* L.)

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Abstract: Several of the insect pests and diseases that cause havoc on their productivity affect Tomatoes. The most common insect pest affecting tomato yields is tomato leaf minor (TLM), also described as *Tuta absoluta* (Meyrick), while *Fusarium oxysporum*, Early blight, and Late blight are among the most widespread diseases systematically destroying tomato yields in many tomato-growing major countries. The rapid spread of *Tuta absoluta* over a wide area could be caused by a variety of factors, such as its high biotic potential and a variety of host plants. On the upper portion of immature leaves, attack symptoms such as minor vein clearing could be seen, whereas older leaves might develop epinasty. Use of Entomopathogens, Cultural Control Methods, Chemical Control, and integrated Pest Management Strategies are among the methods used to manage *Tuta absoluta*. The use of hostile microorganisms is another disease management technique that can be used to provide an environmentally friendly *Fusarium* disease control system. The most long-term solution is to implement an integrated system that includes cultural practices, fungicide spraying, and the adoption of broad-spectrum genetic resistance cultivars. Because single management practices may not be effective in the control of pests, Integrated Pest Management is the best strategy to control these diseases and insect pests.

Keywords: *Fusarium* Wilt Disease, IPM, Late Blight of Tomato, *Tuta absoluta*

1. Introduction

Tomato (*Lycopersicon esculentum* L.) are often regarded as one of the world's most significant vegetable crops. This crop is affected by numerous diseases and insect pests inflict damage on its yield. *Tuta absoluta* (Meyrick), otherwise known as tomato leaf minor (TLM), is a severe insect pest that attacks tomatoes in many tomato-producing locations across the world. It started in South America, quickly infiltrated several European countries, and quickly spread across the Mediterranean Basin, including Egypt [1]. It is regarded as a major agricultural danger to tomato production in Europe and North Africa. Gelichiidae, Order: Lepidoptera, Class: Insecta, Phylum: Arthropoda, Family: Gelichiidae, Order: Lepidoptera, Class: Insecta, Phylum: Arthropoda.

A soil-borne plant pathogen of the Hyphomycetes class called *Fusarium oxysporum* f. sp. *lycopersici* (Sacc.) W. C. Snyder and H. N. Hans is the cause of *Fusarium* wilt in tomato plants. *Fusarium* vascular wilt diseases have been

linked to more than 100 cases worldwide [2]. After the pathogen has damaged the root tissues, they colonize the external cells of roots as harmless endophytes, and others live in the soil as saprophytes [3]. Many factors influence tomato yield and quality, with illnesses playing a significant effect [4]. Early blight, anthracnose, bacterial wilt, bacterial canker, tomato spotted wilt, verticillium wilt, and fusarium wilt are the most frequent tomato illnesses [5]. The infection is caused on by fungus and bacteria (*Pseudomonas* spp (*Verticillium* and *Fusarium* spp.)). The wilt diseases are the result of this [6]. *Fusarium* wilt of the tomato is one of the most common tomato diseases globally, affecting tomatoes grown outside and under controlled environments [7-9]. Yellowed leaves, wilted plants, and little to even missing agricultural yields are all symptoms of this fungus's illness. This article aims to summarize the various aspects of fusarium wilt disease and the various management options devised to tackle this destructive tomato disease and other tomato insect pests.

One of the most frequent foliar diseases is early blight, which is caused by *Alternaria solani* (Ell. and Mart.) Jones and Grou. It causes yield losses of up to 70%. [10]. Multiple applications of chemical fungicides throughout flowering and fruiting are required to control this disease [11]. Furthermore, the use of synthetic pesticides to treat fungal plant diseases of food commodities is limited due to their probable carcinogenicity, high and acute toxicity, long degradation periods, and potential pollution of the environment. Because plant extracts are a rich source of bioactive substances such as phenols, flavonoids, quinones, tannins, alkaloids, saponins, and sterols, they may be a viable alternative to chemical fungicides for suppressing phytopathogenic fungus [12]. Since these extracts can be active against fungal phytopathogens, and are biodegradable to nontoxic.

One of the most damaging diseases to tomato and potato crops is late blight (LB), which would be brought on by the oomycete *Phytophthora infestans* de Bary. In the globe, incurring enormous economic losses each year. The pathogen is well recognized in favor of its part during the Irish potato famine, which resulted in the deaths of over a million people. If left unchecked, *P. infestans* can wipe out a tomato or potato crop in a matter of days. *P. infestans*' pathogenicity stems from its efficient asexual and sexual life cycles, as well as its extraordinary ability to overcome plant resistance genes quickly. Researchers have labeled *Phytophthora infestans* with "high evolutionary potential" because of this trait. The genome of *P. infestans* has undergone evolutionary and comparative analysis, revealing the unique structural design that enables the pathogen's rapid adaptability to host plants [13]. *P. infestans*' ability to reproduce asexually and through sexual mating leads to rapid reproduction, quick epidemics, and enhanced genetic diversity and survival. The integration of cultural methods, fungicide sprays, and the adoption of resistant cultivars is required for long-term control of the LB disease [14]. The objectives of this article is to look at how to deal with some of the most frequent insect pests and diseases that affect tomatoes in Ethiopia.

2. *Tuta absoluta*'s Origin and Regional Spread

As it has spread into new countries during the last decade, its pest status has grown in importance. After establishing resistance to routinely used plant protection agents, the species is currently migrating south on different solanaceous crops from the lower Mediterranean coastlines into Africa. It is considered to have originated in Chile and moved to South America, Europe, and eventually South East Asia [15] they looked at all countries infected with *T. absoluta* from all over the world.

T. absoluta's rapid spread across large areas could be due to a variety of factors, including its high biotic potential, a diversity of host plants (improving its ability to persist in cultivated areas and overwinter there), the ease with which human transportation facilitates intra-continental spread, and the deliberate selection of insecticide-resistant populations [15]. In addition, the lack of Co-evolved natural enemies might be the reason why the dynamics of pest populations are more rapid in recently invaded areas than in native habitats. [16].

2.1. Entry and Pathways of *T. absoluta*

Tanzania was likely introduced to the pest through bordering countries that were impacted first, such as Kenya, Ethiopia, Uganda, Mozambique, and Sudan. Porous East African boundaries and a not have quarantine standards, amongst other factors, may comprise aided the rapid spread to Tanzania. Import of tomato fruits intended for consumption from countries where the pest is present; packing materials boxes, crates, pallets, etc.. For import of tomatoes, eggplants, potatoes, tobacco, and peppers from countries where the pest is present; and planting material originating from countries where the pest is present (mainly tomatoes) are the most relevant pathways for *T. absoluta* entry [15].

2.2. Host Plants of *T. absoluta*

T. absoluta feeds, natural enemies that co-evolved with the pests may help to explain why the dynamics of the pest population are more rapid in recently invaded areas than in native habitats. Other host plants include: *Solanum lycopersicum* (tomato), *Solanum tuberosum* (potato), *Solanum melongena* (eggplant), *Capsium annuum* (pepper), *Nicotiana tabacum* (tobacco), *Solanum nigrum*, *Datura stramonium*, *Solanum eleagnifolium*, *Physalis peruviana*, *Solanum nigrum*, *Datura stramonium*, *Solanum saponaceum*, *Solanum bonariense*, *Solanum sisymbriifolium*, *Datura ferox*, *Lycium* sp., *Malva* sp., *Lycopersicon puberulum*.

If the pest is not correctly handled, a considerable infestation of *T. absoluta* can cause significant harm by feeding on all aerial sections of the tomato plant, resulting in economic losses of up to 80-100 percent [1]. The majority of the damage is seen on the leaves and fruits, but inflorescences and stems can also be impacted. *T. absoluta* eggs are laid individually or in small groups on leaves, and

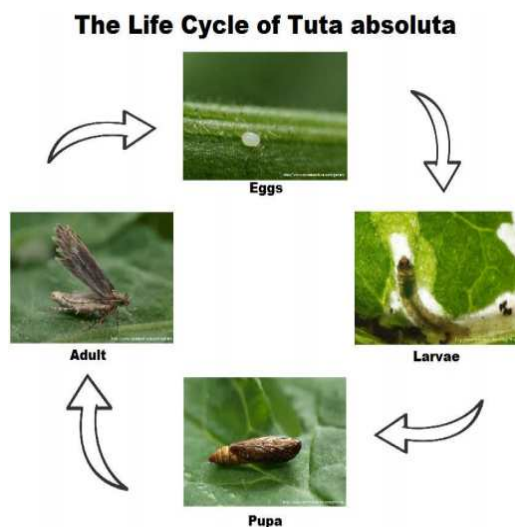


Figure 1. The life cycle of *Tuta absoluta*.

the larvae feed on leaves, stems, and fruits. *T. absoluta* larvae eat on the leaf's mesophyll, leaving just the epidermis with its feces intact, which then expands as the damaged tissue dries. The damaged leaves become yellow, wither, and senescence because of the attack; the fruits are damaged; and the plant is eventually die [17].

2.3. Management of *T. absoluta*

2.3.1. Biological Control

The use of biological control employing natural enemies and any integrated pest management (IPM) approach for managing TLM would include a concerted effort as a key component. Trichogrammatidae egg parasitoid species are regarded effective biological control agents and are commonly utilized commercially to suppress and control lepidopterous pests on a variety of crops [18]. Trichogramma species are used to treat about 32 million hectares around the world. They are easy to raise and release in vulnerable crops or open fields [19], with inundative releases being the most common method. The effectiveness of a biological control program depends on selecting the appropriate Trichogramma species for a specific insect pest [1, 19].

2.3.2. Using Predators

T. absoluta's natural enemies have been identified and reported from their source (South America). *T. absoluta*'s enemies are commercially accessible and can be utilized to manage it. Ratta *et al.* published a report that highlighted a list of commercially accessible predators that have shown to be useful [15]. These may include: because they consume the pest's eggs in large quantities, predatory insects like *Macrolophus pygmaeus* and *Nesidiocoris tenuis* have been identified as the most promising natural enemies of *T. absoluta* in Europe. The mired *Dicyphus maroccanus*, the nabid. The two phytoseid species *Amblyseius swirskii* and *Amblyseius cucumeris* (these two mites in aubergine (eggplant)) and *Nabis pseudoeuropaeus* are also present. have also been discovered as predators of *T. absoluta* [15].

2.3.3. By Parasitoids

These are one of the potential natural enemies employed to restrict *T. absoluta* population rise in both tomato fields and greenhouses. In South America, where the pest originated, they are the largest part of commonly employed biologic control of *T. absoluta*. In the Mediterranean region of Europe, parasitoids have been discovered parasitizing *T. absoluta* larvae. In Spain and Italy, at least two *Necremnus* species have been discovered. Infested tomato plots in Spain have spontaneously sprung *Stenomatus* spp. and other unidentified species (mostly Braconidae), illustrating how locally prevalent parasitoids are adjusting to the new host. Trichogramma achaeae has been identified as a possible biological control agent of *T. absoluta* eggs and is presently being deployed in commercial tomato greenhouses [15].

2.3.4. Use of Entomopathogens

Bacillus thuringiensis being the sole exception var. *kurstaki*, research by Sequeira *et al* found little data on the

usefulness of entomopathogens in controlling *T. absoluta* [20]. *Bacillus thuringiensis*, an entomopathogenic bacterium, has been used to manage tomato plant pests and has been described as a highly effective bio-insecticide by a number of writers. When biological control IPM programs are applied, it has been widely used to control the pest in crops.

2.3.5. Effect of Bio-pesticides on *T. absoluta* Larvae

The effect of bio-pesticides on *T. absoluta* larvae revealed that there were significant (P0.01) differences between the treatments in all evaluated districts. When compared to untreated control and standard check 2.09 percent and 94.74 percent, respectively, mean larval percent mortalities due to application of different bio-pesticides resulted in 0-96.19 percent mean larvae percent mortalities after 3 days. Vayego 200 SC had the highest percent mortality (96.19%) and *Nicotiana* sp. had the lowest percent mortality (39.35%), but both entomopathogenic fungi (*B. bassiana* and *M. anisopliae*) had no effect on *T. absoluta* within 3 days of treatment application, owing to the time it takes for fungi to establish in insect pest larvae.

The mortality percentage of *T. absoluta* on tomato fruit was better on the 5th day of the trial than on the 3rd day in all treatment plots and in all locations except the standard check (Coragen 200 SC) and Vayego 200 SC, which exhibited high percent mortality in all districts. After 10 days from the third day of the trial, the percent mortality of the other treatments gradually grew from 0% to 74.26 percent. Tetraniliprole (Vayego 200 SC), a chemical insecticide, had a very low toxic effect on *T. absoluta* after 10 days of treatment, and percent mortality was low in all areas when compared to other treatments, but highly significant (P0.01) when compared to the untreated control.

2.4. Detection and Identification

According to Ratta and Herhe, using pheromone traps to detect the presence of *T. absoluta* is a reliable method [15]. *T. absoluta* natural sexual attractants are used in pheromone traps, therefore the approach exclusively captures adult male moths. The sample is submitted to the bug identification facilities for investigation once it has been caught. Pheromone traps are employed not only to detect the pest, but also to reduce the infestation of *T. absoluta* by disrupting mating and mass extinction. The data from pheromone traps provides early notice of both pest invasion and low population levels sooner than they turn into severe. Water traps, sticky rolls, and Delta traps are only a few examples of pheromone trapping strategies [21].

2.4.1. Sex Pheromone-Based Control Strategies

Pheromones are substances secreted in bodily fluids that are supposed to have an effect on the behavior of the other sex, such as eliciting sexual attraction and excitement. Natural sexual attractants are pheromones. Sex pheromones are chemical signals emitted by an organism to attract an individual of the same species of the opposite sex, according to. The main component of the *T. absoluta* pheromone lure is

(3E, 8Z, 11Z) 3, 8, 11 tetradecatrienyl acetate, with (3E, 8Z) tetradecadienyl acetate as a minor component [21].

2.4.2. Trap Catches

Pheromone traps used in an experimental field in the 2014 tomato Nili plantation in the Fayoum Governorate, Egypt, catch *T. absoluta* moths. Early in September 2014, when the inquiry in the permanent field commenced, two pheromone traps were placed in the plot to track the pest population. On September 9th, the first catches were discovered. As a result, additional traps were installed in plots to act as a monitoring and mass-trapping control approach. On September 12th, the initial reports of 3.75 and 7.75 moths/trap in different two plots, were reported. The moths were seen throughout the research period, from September 2014 to January 2015. The highest mean number of moth catches/traps was recorded in October (46.8 moths), followed by November (27.6 moths), and the lowest (16 moths) in September and December. The technique of mass pheromone trapping has been widely employed to manage a variety of insect species [22]. These findings corroborate those of Ltd [23], who suggested that mass trapping could be used to decrease *T. absoluta* populations and is particularly successful while growing tomatoes in greenhouses. Water traps were also the most popular pheromone traps employed for mass catching of *T. absoluta*, according to Salas [24]. They are easier to maintain and less dust-sensitive than Delta or light traps, and they also have a bigger trapping capacity. According to Cocco et al. [25], mass trapping alone was ineffective in minimizing leaf and fruit damage in male *T. absoluta* populations.

On the 28th of September, 12th of October, 26th of October, 9/11, and 23rd of November, 2014, Fytomax N was released. Infestation rates began at (7.3 percent) in September, grew in subsequent months to (8.2 percent) in October, (16.3 percent) in November, and then decreased to (12 percent) in December. Except for the application practiced by early November, infestation rates were always lower after Biotrine application than after Fytomax application. Statistical investigation revealed a highly significant difference between the usage of Bio-rational solutions ($t = 0.00111^{**}$) and the control. of mass trapping technology and *T. bactrae* release in TLM management. According to Abbes et al. [26], 20 percent of leaves were infested in the IPM cropping system (mass trapping + release of *Nesidiocoris tenuis*) versus 98 percent in the conventional cropping system, and 18.2% of fruits were infested in the IPM cropping system versus 46.8% in the conventional cropping system. The control plot was treated seven times by the grower with three different pesticides: Nomolt 15% SC twice, Pleo 50% EC twice, and Oshin 20% SG twice (3 times). The following were the application dates: Nomolt 15% SC on 18/10 and 22/11/2014, Pleo 50% EC on 7 and 13/11/2014, and Oshin 20% SG on 22/10, 28/11, and 2/12/2014. The monthly mean rate of insect infestation jumped from 13.3 percent in September to 26.8 percent in October, 60.5 percent in November, and 29.3 percent in December. This means that utilizing Biotrine or Fytomax, or

releasing parasitoids, resulted in 70-75 percent lower infection rates than using insecticides [26].

2.5. Cultural Control Methods

2.5.1. Best Agricultural Practices

Crop alternation with non-solanaceous crops (ideally Cruciferous crops), cultivation, proper watering and fertilization, elimination of pest-infested plants, and complete removal of post-harvest fruit and plant debris are all good agricultural methods for controlling *T. absoluta* [15]. It is also recommended that wild solanaceous host plants surrounding the growing region be removed, since these can house all stages of the pest, which can subsequently infect the growing crop. *T. absoluta* can be controlled through sound agricultural methods such as plowing, adequate fertilizer, irrigation, rotation with non-solanaceous crops, eradication of diseased plants, and removal of post-harvest plant debris are examples of cultural practices. For example, if fruit stalks are injured by *T. absoluta* larvae at any point during the growing cycle, the system will be overhauled. To prevent the bug from completing its cycle and spreading further, the entire plot was withdrawn and securely destroyed.

2.5.2. Planting Matrial Management

T. absoluta can be controlled by using pest-free transplants, according to Ratta and Berhe [15]. When pest damage is minimal, remove any symptomatic leaves, stems, or fruits that have been impacted by place any larvae or pupae in plastic bags to be disposed of. Eliminate any weeds in the surrounding that might serve as the bug's hosts. Crop wastes should be destroyed as quickly as possible after harvesting.

2.6. Chemical Control

A list of insecticides to control *Tuta absoluta* is available on the market, but most of these treatments have failed in the field because the pest has developed resistance to hundreds of pesticides [21]. Since the larvae consume the interiors of leaves, fruits, and stems, chemical control is difficult. Furthermore, pests with a high reproductive capacity and brief generations, such as *T. absoluta*, are more likely to evolve resistance. As a result, it's critical to avoid using a systemic approach and instead rely on experts to apply treatments based on insect population density and crop damage. It's also critical to switch between active drugs with various mechanisms of action (chemical group) Chlorantraniliprole and flubendiamide are two diamide insecticides. In Argentina resistance to abamectin, -methrin, and methamidophos was discovered, as was resistance to organophosphates and pyrethroid pesticides.

On a population of *Tuta absoluta* that is naturally present in the experimental plot tomato, insecticide treatments are applied. With the exception of the stage nymphal, all stages of the pest are monitored and observed. The active component and the dose used for each insecticide are listed in a tabular format..

2.7. Integrated Pest Management Strategies

A number of insects can be managed using an integration of techniques that are ineffective while applied without help. *T. absoluta* is one of those insects that need more than one method of control to be effectively controlled. As a result, numerous countries are developing integrated pest management (IPM) strategies to combat *T. absoluta* infestations [20]. To properly control the pest, all available control techniques must be used, including cultural treatments, biological control agents, and the proper application of licensed pesticides. In South America, IPM techniques are being developed to combat *T. absoluta*. Various active chemicals, in combination with bio-rational control methods, can be used [15]. Imidacloprid application in irrigation water 8–10 days after planting, massive trapping before planting, soil removal of crop residues, application of spinosad or indoxacarb if sporadic *T. absoluta* individuals are seen, and elimination of the crop remnants immediately after the last fruits have been harvested are all part of the recommended integrated control method. Chemical and biological treatments must often be used in order for an integrated pest management (IPM) program for arthropod pests to be successful. For the control of *T. absoluta*, an integrated pest management strategy (shown below) can be used: (1) clearing the soil and area of crop waste, fruits, and wild host plants, (2) mass trapping before or after planting (3) If occasional individuals of *T. absoluta* are observed, use sulphur, neem oil, *Bacillus thuringiensis* in combination with either methrine, spinosad, Indoxacarb, or another recommended bio-pesticide, (4) Elimination and burning of infected plants during the growing season and of the crop remnants immediately after the last fruits have been harvested. Leaf miners can be controlled using a variety of strategies. To properly control the pest, all possible control measures must be used, including physical methods, cultural methods, biological control agents, and the proper application of licensed pesticides [15, 21].

3. Fusarium Wilt Disease of Tomato

3.1. Symptoms of Fusarium Wilt Disease on Tomato

Attack symptoms include minor vein clearing on the outer portion of young leaves, followed by epinasty on older leaves [27]. This condition usually only affects one side of the plant or one branch. Before the plant reaches maturity, successive leaves become yellow, wilt, and die. Growth is usually slowed as the disease proceeds, and little or no fruit develops. Dark brown streaks can be seen going longitudinally across the main stem if it is cut. The browning of the vascular system is a symptom of the disease and can be used to identify it in most cases [28]. White, pink, or orange fungal growth can be noticed on the outside of afflicted stems, especially under moist situations [29].

3.2. Biological Control

The employment of hostile microorganisms is an alternate

disease management technique for providing an environmentally friendly Fusarium disease control system [30]. Biological control agents may use direct, indirect, or hybrid techniques to achieve their goals. The use of bioagents to combat Fusarium wilt disease on tomatoes has been reported to be extremely effective [31]. Several isolates of nonpathogenic *Fusarium* spp. (*F. oxysporum* and *F. solani*) that efficiently controlled Fusarium wilt in greenhouse tests have been found, according to Momol et al. [32]. CS-20, CS-1, CS-24, and Fo 47 were among the isolates that were consistently effective when used at a high rate. After spraying with *Phytophthora cryptogea* zoospores followed by *Fusarium oxysporum* discovered that *f. sp. lycopersici* inoculation, tomato plants show no wilt disease.

Arbuscular mycorrhizal fungi (AMF) *G. intraradices*, along with some Gram-negative and fluorescent rhizobacteria (RB), *P. fluorescens*, *P. putida*, and *Enterobacter cloacae*, were reported to be effective against *Fusarium oxysporum* f. sp. ly by Akkopru and Demir [33]. Bacterial biocontrol agents having promising results against *Fusarium oxysporum* f. sp. lycopersici include *Pseudomonas fluorescens*, *P. putida*, *P. chlororaphis*, *Bacillus subtilis*, *Streptomyces pulcher*, *S. corchorusii*, and *S. mutabilis*, according to Monda [34]. Rhizobacteria can operate as biofertilizers and biostimulants by producing plant growth hormones such as indole acetic acid, gibberellin, cytokinin, ethylene, and dissolved minerals, as well as indirectly preventing harmful microbes by producing siderophores and antibiotics [35, 36].

3.2.1. Use of Natural Products

Despite numerous research attempts to find alternative and environmentally friendly strategies to control plant diseases [37]. Plant products are only occasionally used to prevent Fusarium wilt in crops Hanaa et al. [38] investigated the effect of 10 percent aqueous extracts of *Fusarium wilt* disease in tomatoes was studied using *Azadirachta indica* (Neem) and *Salix babylonica* (Willow), and it was discovered that after 6 weeks of infection, the percentage of disease incidence was reduced to 25.5 percent and 27.8 percent, respectively.

3.2.2. Use of Resistance

Where resistant cultivars are available, using them is the most economical and environmentally responsible method of management. The use of resistant cultivars is the best disease control method [9], also one of the best alternative methods for wilt disease control. According to Pritesh et al. [4], identifying and using disease-resistant tomato plant cultivars is a viable alternative to the usage of chemicals.

3.3. Chemical Control of Tomato Wilt Disease

In tomato, seed treatment with synthetic fungicides significantly reduces the occurrence of wilt. However, their use is both costly and harmful to the environment [39]. Prochloraz, propiconazole, thiabendazole, carbendazim, benomyl, thiophante, fuberidazole, and all benzimidazoles are examples of these compounds. Using the root dip treatment approach, Nel et al. [40] found that benomyl was only partially effective

against *F. oxysporum* f.sp. *cubense*. When carbendazimal was used on tomato seedlings affected with Fusarium wilt, this approach resulted in a 24 percent increase in yield [41]. Prochloraz and carbendazim were chosen to investigate their greenhouse control effects on tomato Fusarium wilt in a hydroponic production system based on the results above.

3.4. Cultural Control

Cultural control refers to procedures and farming strategies that help to improve crop quality and quantity while also reducing pest and disease impact. It entails non-mechanical manipulation of the environment to control plant pests and diseases. It entails changing farming practices to make the environment unsuitable for disease viruses and pests to thrive in [12]. It can also refer to the intentional manipulation of a garden or farm's growing, planting, and nurturing of plants in order to reduce plant disease, insect damage, and pest numbers. It has been demonstrated that proper application of cultural approaches to reduce soilborne pathogens results in enhanced soil structure and, as a result, lower occurrence [42].

3.5. Integrated Disease Management of Fusarium

In poor nations, Integrated Disease Management (IDM) is acknowledged as an efficient strategy for enhancing agricultural output and combating environmental degradation [43]. Crop rotation, organic matter additions, and the use of high-residue tillage equipment are all practices that can help to build healthy soils. Pest and disease reduction through the use of compost products has been the subject of extensive research around the world. Composts can provide natural biological management of soil-borne illnesses that harm collars, roots, and plant foliage, according to the findings Recycled Organics Unit. Incorporating green manures and cover crops into a rotation is a great method to boost fertility, control weeds, and break up insect cycles. [44].

Including a variety of crop species in a cycle, as well as manures and/or compost, ensures a diverse source of organic matter. This diversity results in a more minerally balanced soil and a pool of nutrients that slowly become available over time, decreasing leaching, waste, and toxicity that can occur when inorganic fertilizer applications are made instantly available [44]. Crop rotation with non-similar crops such as cabbage and cauliflower for at least 4-5 years, disease resistant cultivars, natural antagonistic organisms, particularly bacillus-based biological control agents (BCAs), farm hygiene, and the use of chemicals such as prochloraz and methyl bromide are some of the integrated control strategies for fusarium wilt of tomato [29]. Finally, good soil fertility management is critical because the soil and surrounding air environments are almost intertwined, and the formation of a functional and stable system in one environment can have far-reaching consequences in the other [45].

4. Late Blight of Tomato

Tomato pathogens have been identified as more than 200

pests and illnesses that impede output. Among these are fungus, oomycetes, bacteria, viruses, and nematodes, which cause a variety of diseases.

4.1. Historical Relevance of Late Blight of Tomatao

Late blight (LB) is a serious tomato and potato disease that has been regarded as one of the most devastating plant diseases ever. Because of LB infection, an unprotected tomato field can lose up to 100 percent of its output [14]. *Phytophthora infestans* – literally "plant destroyer" in Greek is believed to have come from the same Andean region as tomatoes and potatoes [13]. Isozyme and DNA studies, as well as pathogenicity similarities among Peruvian, US, and European isolates of *P. infestans*, have recently confirmed a common origin for both the host and pathogen populations. Which was first suggested at the period of the Irish potato famine in the nineteenth century of *P. infestans* [13, 14]. In 1843, the disease caused the first documented case of potato LB in Philadelphia and New York City, both in the United States. Winds dispersed the dehiscent pathogen sporangia to neighboring states because of weather patterns, extending the region impacted by LB. By 1845, LB had spread from Illinois to Nova Scotia and from Virginia to Ontario, wreaking havoc on crops. In 1845, a cargo of contaminated seed potatoes crossed the Atlantic Ocean from the United States to Europe, spreading the illness. When *P. infestans* arrived in Ireland, a society that relied heavily on potatoes as a primary source of food and was susceptible to negative political, social, and economic circumstances, widespread potato LB nearly wiped out the crop. One million people died as a result of this, and another million were displaced, many of them immigrated to the United States. Following the pathogen's continued expansion in future years, LB had spread worldwide by the turn of the twentieth century, wreaking havoc on potato and tomato crops all over the world. Recent observations support the pathogen's aggressiveness against potato, as well as tomato: When *P. infestans* infects an unprotected crop (in a field, greenhouse, or culture under plastic cover) can be completely destroyed in seven to ten days [46].

4.2. Disease Development and Cycle

The pathogen's severe economic and social consequences piqued scientists' interest in LB research. Understanding of tomato LB has benefited by discoveries in disease biology made because of potato-driven research. Particularly harmful effects of *P. infestans* can be seen in areas where both tomatoes and potatoes are grown year-round, such as in Africa's highland tropics, the Americas, Asia, and Europe [14]. *P. infestans*' unhindered success as a pathogen stems from its efficient asexual and sexual replication. During the season, the asexual form is responsible for most incidents involving driving a car. On sporangiophores, *P. infestans* produces thousands of sporangia per lesion. Sporangiophores are undefined structures that aid in sporangia air dissemination via wind, rain, or wind-blown rain. When

sporangia settle on host plant tissue, which needs to be covered in a thin layer of water, the disease cycle begins to allow motile, germinated spores to migrate towards a penetration site [47]. Germination of Sporangia happens either by direct expansion of germ tubes or through zoosporogenesis. Cool and damp circumstances boost the latter, which is essential since it broadens the variety of meteorological conditions that might lead to infections. The sporangium seeds germinate immediately on the host tissue between 8 and 48 hours at temperatures over 21 C (optimally at 25 C). At temperatures over 15 C, the sporangium germinates immediately and quickly begins mycelia development. The sporangia release up to eight biflagellate zoo spores at temperatures below 21 C, with optimal zoospore production occurring at 12 C. Motile zoospores break through the aqueous film, detach their flagella, and encyst until germ tubes form. This happens after around two hours at the ideal temperature (12 to 15 C). Appressoria form from germ tubes and infiltrate the host through the leaf cuticle or, less frequently, the stomata. The ideal temperature for germ tube development is between 21 and 24 degrees Celsius. Intercellular hyphae generate biotrophic feeding interactions in the mesophyll by developing and traveling within the host between cells utilizing haustoria. Between 22 and 24 C, rapid colonization begins. Hyphae spreads, and sporangiophores emerge from stomata at some point. Following five to 10 days after immunization, LB symptoms appear. Sporulation results in the formation of 2N sporangia, which then release zoospores, which aid in the spread of LB through the air and keep the disease cycle going. When temperatures rise beyond 35 degrees Celsius, illness growth stops, but *P. infestans* can persist in living host tissue and the disease can progress when conditions improve [48]. Large peripheral vesicles, encystment vesicles, kinetosomes, and flagella are among the organelles seen in Sporangia that are missing in hyphae. The multinucleate sporangial cytoplasm is cleaved by nucleus-enveloping membranes during zoosporogenesis. Following that, flagella are assembled, the sporangial papilla is dissolved, and uninucleate zoospores are expelled. The vesicle-movement players produced by a variety of the early-induced genes may help to generate these structures. The early-induced genes that code for parts of spore-specific vesicles or organelles provide more than 70 flagella-associated genes and a protein that resembling thrombospondin.

4.3. Disease Development and Symptoms

Tomato and potato crops are susceptible to *P. infestans* damage at any developmental stage. In five to ten days, the entire plant might collapse. (<http://www.nysipm.cornell.edu/publications/blight/>) LB can infect any plant parts that are above ground, leading to fruit rot, leaf and stem necrosis, and eventual plant death. Tomato seed and potato tubers can also be infected by the disease [14]. Initial infection symptoms, such as tiny lesions on leaf tips and plant stems, appear after three to four days and can be as small as 1 to 2 mm in diameter in certain cases. Water-soaked lesions that

frequently have a soft yellowish-green border that blends in with healthy tissue and are purple, dark brown, or black. On the lower (abaxial) leaflet surface, fluffy white sporangia may emerge during periods of precipitation. Plant leaflets shrink and die as the disease proceeds, and the remainder of the foliage contracts the disease, resulting in severe defoliation. Late Blight of Tomato Dark brown LB lesions occur at the top of the stem or at a node and may spread down the stem. Tomato fruit lesions that are firm, dark, and greasy are common at the stem end and sides of green fruit, rendering it unmarketable. Secondary pathogens can infect infected tomato fruit, causing soft-rot disease.

4.4. Late Blight Disease Control

4.4.1. Host Plant Defense

Pathogen detection is precisely tuned in plants. They are able to detect infections' chemical and physical signals and respond quickly to infection attempts [14, 47]. Plant responses to oomycetes range from invading cells that don't show any symptoms of reaction to more concentrated reactions that prevent pathogen intracellular structures from forming, to hypersensitive response (HR) and only when pathogen growth has progressed to the establishment of an easily recognizable haustorium does programmed cell death occur [47]. Induced defense against *P. infestans* in tomato plants begins with resistance against penetration at the leaf surface. This is a highly effective defense technique that host plants deploy quickly in response to attempted penetrations. Recent research has shown that plasma membrane-bound receptor proteins play a direct role in the identification of apoplastic pathogen elicitors and the activation of host defenses. Furthermore, the invading penetration peg's physical pressure may operate as a signal to plant surface detecting systems.

Tomato and potato LB have a large financial impact on growers and consumers around the world, costing an estimated \$5 billion each year in disease control and crop losses [46]. In 2009, total yield losses in the freshmarket and processed tomato industries in the United States were \$46 million and \$66 million, respectively. Up to half of these costs could be ascribed to LB-related crop losses. In unprotected fields, fruit infection can vary from 41 to 100 percent, while in plots treated with systemic fungicides; fruit infection can range from 12 to 65 percent. Over the last few years, Poland's tomato production has been severely harmed by LB outbreaks, which have often resulted in crop failure of up to 100% [14].

4.4.2. Cultural Practices

Cultural practices are a crucial part of a grower's disease management approach, and they can have an impact on disease development and control. The goals of LB cultural control are to reduce inoculum buildup, prevent inoculum from nearby potato cull heaps or tomato transplants from entering the system, reduce infection rates, and create unfavorable conditions for disease development and transmission. Crop rotation, fallow periods, the removal of

stray tomato and potato plants, the planting of uninfected seedlings and tubers, and the lowering of LB sources such as potato cull piles are all typical cultural practices employed to lessen LB. The latter is particularly significant since *P. infestans* mycelia can survive and develop enormous amounts of airborne spores at the beginning of a fresh field season on cull heaps over the winter. If this happens, the following year's crop could be ruined by LB [46]. The pathogen may be especially devastating in regions where both tomatoes and potatoes are grown year-round, such as the highland tropics of Africa, South America, Asia, and Europe. This is because of the pathogen's recent reemergence and improved ability to create more virulent isolates through sexual recombination [14].

4.4.3. Fungicide Application

Chemical control techniques, especially when led by disease forecasting systems, can be useful in managing LB and have been used more frequently in recent years. Fungicides (e.g., chlorothalonil, dithiocarbamates and, use a solution of triphenyl tin hydroxide prior or after disease onset. Therapeutic fungicides, often known as systemic fungicides, includes phenylamides like metalaxyl/mefenoxam and aliphatic nitrogen fungicides like cymoxanil. A combination of fungicides meant to delay the disease's progression is currently used to control LB. Metalaxyl fungicides, a type of systemic fungicide, have been widely used to combat LB; they work by inhibiting the incorporation of uridine into ribosomal RNA (rRNA) polymerases in fungi [14]. On the other hand, these treatments may be ineffective, particularly if the environment promotes the growth of the condition. Furthermore, the pathogen has been under selective pressure due to improper phenyl amide administration, which has led to the spread of fungicide resistance.

4.4.4. Resistance to LB due to Genetics in Tomatoes

The host resistance gene product, also known as the R-gene product, interacts with the pathogen's pathogenicity gene product, also referred to as the Avr-gene product. Typically, Complete resistance to one or a few disease races is given by single gene resistance. Vertical resistance to the pathogen may eventually fail due to rapid evolution of pathogen effectors and sexual reproduction of *P. infestans*, which leads to more aggressive lineages. For example, in potato, the persistence of main LB-resistance genes has been found to be variable [13]. *P. infestans* isolates have been discovered that are essentially LB resistant. overcome all 11 R-genes found in *S. demissum*, a wild potato species. Although this has not been verified, a similar condition may exist for important LB resistance genes in tomato [14]. Race-nonspecific resistance, in contrast to vertical resistance, which is typically influenced by a large number of genes or quantitative trait loci (QTLs), may also be more enduring. Horizontal resistance usually offers partial resistance to a variety of pathogen isolates/races. This sort of resistance slows, but does not stop, disease progression.

5. Conclusions

Pests are threatening tomato crop all around the world. *Tuta absoluta*, Fusarium, early blight, and late blight are just a few of the most common tomato pests and illnesses. The most long-term solution is toward implement an integrated system that includes cultural techniques, fungicide spraying, and the adoption of cultivars with wide ranging genetic resistance. Some insects can be managed using a combination of techniques that are ineffective when applied alone. *T. absoluta* is one of those insects that requires more than one method of control to be effectively controlled. To properly control the pest, all available control techniques must be used, including cultural treatments, biological control agents, and the proper application of licensed pesticides. The recommended integrated control method includes Massive trapping before planting, soil clearing of crop residues, application of imidacloprid in irrigation water 8–10 days after planting, application of either spinosad or Indoxacarb if sporadic individuals of *T. absoluta* are observed, and elimination of crop remnants as soon as the last fruits have been harvested. Chemical and biological treatments must often be used in order for an integrated pest management (IPM) program for arthropod pests to be successful. In general, IPM is a smart technique of controlling illness and pests by combining chemical, biological, cultural, trapping, pheromones, and other methods when a single method is ineffective or harmful to the environment.

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