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An Overview on Potato (*Solanum tuberosum*) Bacterial wilt (*Ralstonia solanacearum*) Disease Management Strategies

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Abstract: Bacterial wilt (BW) is caused by the pathogen *Ralstonia solanacearum*. It is a major threat to crop production worldwide. Latently infected potato seed tubers are known to spread the pathogen over long distances, jeopardizing crop production and facilitating the spread of the pathogen. *R. solanacearum* forms a highly variable species complex consisting of four phylotypes, five races and six biovars. Members of the *R. solanacearum* species complex (RSSC) cause bacterial wilt (BW) in numerous economically important crops and threaten sustainable crop production. Strains in RSSC are highly destructive due to their severity, persistence, wide host range and wide geographic distribution. This study aimed to critically review BW disease and find more convincing treatment strategies against this pathogen. The lack of effective chemical treatment for BW, combined with the long-term persistence of the bacterium in infected areas, is a challenge in developing effective control strategies for this devastating disease. Significant progress has been made in recent years in testing alternative control agents, particularly in the use of microorganisms (biocontrol) to combat bacterial wilt. However, because microorganisms have adapted to the environment in which they were isolated, many biological control agents are not successful in the new habitats into which they are introduced. Therefore, new biocontrol agents are needed to solve this problem. In this review, the use of different treatment options is important to reduce the epidemiology of BW. Future research should focus on developing an IDM that does not use chemical pesticides or only uses small amounts of chemical pesticides.

Key words: *Ralstonia solanacearum* Species Complex · Strains · Latent Infection · Management Strategies

INTRODUCTION

Bacterial wilt caused by *Ralstonia solanacearum* is a major threat to crop production [1]. *R. solanacearum* is very common in most African countries [2]. *R. solanacearum* is an exceptionally diverse and complex species; divided into five races based on its ability to infect different plant species and six biovars based on its ability to oxidize hexoses, alcohols and sorbitols and utilize disaccharides [3]. *R. solanacearum* forms a highly diverse species complex consisting of four phylotypes, five races and six biovars with geographically diverse distributions [4]. Recent reports indicate the separation of the *R. solanacearum* species complex into three species: *R. solanacearum*, *R. pseudosolanacearum* and *R. syzygii* [5]. This species complex infects 100 plants, including many economically important crops [1]. Bacterial wilt caused by *R. solanacearum* (Smith) is one of the most important potato diseases in the world [6]. Strains within the RSSC are highly destructive due to their severity, persistence, broad host range and wide geographic distribution [7]. In Ethiopia, bacterial wilt of potato is caused by *R. solanacearum*, race 3 [8]. Since BW cannot be controlled by chemicals and persists in the soil for a long time, it is becoming a growing threat to potato production in Ethiopia [9]. The destructive effect and exceptional survival of this pathogen in soil [1], plant debris and root hairs of host plants [10], the presence of different weeds that are symptomatic, less carriers of the pathogen [11], contaminated seed tubers and their means of propagation contribute to massive yield losses [12]. They cause annual losses of US$ 1 billion worldwide for potatoes alone [13]. Latently infected propagation materials such as potato tubers can be a source of

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pathogen transmission [14] (latent infections are plant tissue infected with phytopathogenic bacteria that do not show disease symptoms on host plants [15]. Strains in RSSC can persist in soil, water and alternative hosts for several years [16]. The pathogen has been reported to invade more than 450 plant species from 54 botanical families [17]. The lack of effective chemical treatments for BW, combined with the long-term persistence of the bacterium in infected areas, is a challenge in developing effective treatment strategies. *R. solanacearum* is currently the most intensively studied phytopathogenic bacterium. Despite the fact that various strategies have been developed to combat bacterial wilt, there is a lack of effective environmental and human health control measures [18].

Potato Bacterial Wilt (Ralstonia Solanacearum) Disease

Dispersal of the Pathogen: *R. solanacearum* spreads in several ways; because humidity and temperature significantly affect the development of the disease [19]. *R. solanacearum* can spread long distances on vegetative propagation material and remains an essential source of inoculum for approximately 2-3 years [20]. Contaminated wet soil and weeds, contaminated irrigation water, contaminated agricultural machinery and waste from the crop processing industry have a high potential risk for the development of *R. solanacearum* [21]. Crop residues in fields infected with *R. solanacearum* were also a source of disease inoculum [22].

Epidemiology and Survival of the Pathogen: *R. solanacearum* is the most destructive soil-borne pathogen and usually enters plant roots through open soil or natural wounds. Once the bacterium has entered the host, it colonizes the root cortex and vascular parenchyma, after which it reproduces rapidly and then reaches the xylem vessel [23]. The pathogen moves up through the vascular system and infected xylem and then blocks water transport [24]. The rupture of xylem vessels and adjacent tissues causes plant death. Notably, infected plants die rapidly within 3-4 days [25]. After plant death, *R. solanacearum* cells are released from infected roots into the soil and spread to neighboring plants. When the environmental conditions are more favorable, the bacterial cells multiply rapidly and together with the exopolysaccharide slime reduce the sap flow [26]. If the conditions are somewhat favorable, the disease develops slowly, characterized by a delay in the development of adventitious roots. Later, the plants fall and die due to excessive decay of the veins. The bacterium returns to the soil after the plant dies and lives as a saprophytic organism. Bacterial wilt is mainly promoted by high soil moisture and temperature [27].

Symptoms and Signs of Bacterial Wilt: Plants infected with *R. solanacearum* may show symptoms a few days after infection and are characterized by sudden wilting and yellowing of the leaves and eventual death of the plant. In most cases, the stem near the root produces many adventitious root buds, which is also a sign of infection of the vascular bundle. Significant cortical attack can cause water-soaked lesions to appear on the outer surface of the stem. When a diseased stem is cut, small drops of yellowish viscous or a dirty white or milky bacterial ooze emanate from it Karim and Hossain [25]. A plant infected with *R. solanacearum* can undergo a latency period that can cause the plant to exhibit all these symptoms [28]. Other symptoms of bacterial blight characterized by streaky light yellow to dark brown discoloration of the vascular system [29].

Economic Impact of Bacterial Wilt: The pathogen causes significant yield loss [13]. Every year, about 13 billion tons of food is wasted or lost worldwide. Reducing these losses would increase the amount of food available for human consumption, thus increasing global food security. Microbial (bacterial) spoilage is the main cause of many postharvest losses, accounting for a 14 percent decrease in crop production worldwide. Thus, reducing plant diseases increases crop production. Soil-borne diseases are estimated to cause 10-20% of annual crop losses [25]. *R. solanacearum* is the second most destructive among the 10 most deadly bacterial species [7]. The pathogen has been reported to cause severe yield loss in many solanaceous plants [30]. Bacterial wilt has been reported to affect 50-100% of potatoes in Kenya [31]. In Ethiopia, the percentage of bacterial incidence is 63% for potatoes and 55% for tomatoes [32]. In potato, since most wilted potato plants do not produce salable tubers, yield losses due to disease can be very high [33]. Damages are increasing as agriculture is now expanding into lands where sensitive crops were not previously grown. The presence of *R. solanacearum* in the field prevents the planting of many vegetables in home and family gardens, leading to a significant reduction of food sources [34]. The pathogen is known to have high survivability and damage other vegetation worldwide. Cost-effective postharvest treatments include controlled atmosphere maintenance, various pesticides and waxes used to control the disease [35]. However, most of these treatments are relatively expensive and/or pose some risks to humans and/or the environment [36]. So; there is an urgent need to critically evaluate this disease and develop more convincing control strategies against this pathogen.

MATERIALS AND METHODS

According to Kurabachew and [33], bacterial wilt is a difficult disease to control, especially when it has spread to the soil. This is due to the wide range of host organisms, the ability to survive in the soil for a long time; this is due to the broad host and genetic diversity of the pathogen, long-term survival in soil and survival in vegetation as a latent infection [37, 25]. Physical, cultural, chemical and biological control practices [38].

RESULTS AND DISCUSSIONS

Physical Control: Physical control includes soil solarization, hot water and bio-fumigation, known as biological soil disinfection [39].

Solarization of Soil: Soil solarization is done by spreading a transparent plastic sheet over the soil during long periods of time at high ambient temperature. This helps to trap the radiant energy of the sun, thereby warming the topsoil layer, which in turn eradicates insects, pathogens and weed seeds [40]. Solarization of the soil improves soil structure and increases the availability of nitrogen and other essential plant nutrients [40]. The main drawback of solarization is its negative potential impact on valuable soil microbes [41].

Disinfection of Soil Through Heating: Hot water between a temperature of 70 and 90°C can be poured into the soil before planting to increase soil temperature to levels lethal for weed seeds, pests and pathogens. It is an environmentally friendly procedure, as it does not disturb soil micro flora completely [42].

Biological Soil Disinfection: Biological soil disinfection is a process in which a farm attempts to destroy soil-borne plant pathogens before planting a crop. The process does not require higher temperatures or prolonged temperatures to stimulate the activity of indigenous microbes in the soil with the addition of organic materials [43]. The treatment consists of four steps, including: (i) flooding the soil with irrigation, (ii) covering the soil with a plastic film to degrade soil conditions, (iii) adding easily degradable organic materials to the soil and (iv) applying volatiles or chemicals removes plant residues. Bio-fumigation with wheat bran or molasses has proven effective against many soil plants [44-46].

Cultural Control: Cultural control involves cultivation techniques that help increase the quality and quantity of crops and reduce the incidence of diseases [47].

Cultivar Resistance: Growing varieties highly resistant to bacterial wilt is the most effective, economical and environmentally friendly way to fight the disease [48]. Breeding of varieties resistant to bacterial diseases has been mainly practiced with crops such as potato, eggplant, tomato, groundnut and pepper.

Crop Rotation: It is a low-cost method of controlling plant diseases and involves growing different crops on the same farm at different times of the year [47]. Continuous cultivation of similar plants can lead to populations of certain plant pathogens; for example, tomatoes planted in the same field year after year encourage the growth of disease-causing organisms in the soil. Crop rotation cultivation interrupts its harmful effects and reduces diseases caused by soil-borne pathogens [49, 50]. For crop rotation to effectively control soil-borne pathogens, the pathogen must be completely eradicated from the field by replacing the contaminated soil with fresh garden soil from another part of the farm [51].

Soil Amendment: The use of organic matter as an alternative to prevent bacterial wilt has had a beneficial effect on crop productivity by improving the chemical, biological and physical properties of the soil, which has a positive effect on plant health [52]. Decomposition of organic matter can directly affect pathogen survival by releasing inhibitory substances into the soil, limiting available nutrients. Application of silicon fertilizer and cane sugar ram (an alternative source of silicon) has also been reported to reduce bacterial wilt and bacterial wilt and increase fruit production in tomatoes [53]. Soil amendments have been found to improve tomato yield compared to un-amended soil and significantly reduce bacterial wilt in tomatoes by 81% [54]. Thus, soil amendment can be useful in controlling *R. solacearum* in the world's most important growing areas of Solanaceous plants.

Grafting: It is joining of the upper part of a plant (scion) of a desirable cultivar onto a resistant rootstock of another compatible species [55]. The grafting of vegetables globally has been to produce crops that are resistant to soil-borne pathogenic diseases [56].

Chemical Control: Various chemical methods have been used over the years to combat bacterial wilt. However, due to the complex nature of the pathogen, no single method is useful when used alone and economic considerations often influence the chemicals chosen [57]. Application of methyl bromide in combination with 1, 3-dichloropropene reduced bacterial wilt by 72-100% and at the same time significantly increased tomato yield in the field by 17-25 times [58]. Pesticides have been reported to provide a greater net benefit in bacterial wilt than other control methods [59].

Biological Control: It has emerged as a promising alternative chemical use, especially as an integral part of pest management to reduce the use of synthetic fungicides. Biological pesticides have several properties that have increased their use compared to the use of chemicals. Such characteristics include reduced input of non-renewable natural resources, their ability to self-sustain and spread after initial establishment and the ability to provide long-term disease prevention [60, 61]. Several studies have reported that biocontrol of bacterial wilt can be achieved by antagonistic rhizobacteria and epiphytic bacteria [62, 63]. Also, Biratu *et al*. [64] reported the possible use of functional bacteria as part of an integrated treatment of bacterial wilt through in vitro evaluation of functional bacterial isolates. Possible biocontrol mechanisms of these species include multifaceted interactions between host, pathogen and antagonists, involving processes such as competition for nutrients and space, mycoparasitism, plant-mediated systemic resistance, production of siderophores and production of extracellular degradation enzymes [65]. Most of the tested bacteria that have been used as biocontrol agents for bacterial wilt include rhizobacterial, endophytic and epiphytic bacterial species. Therefore, understanding the diversity and ecology of epiphytic bacteria of Solanaceae plants, especially pepper, may be important in the search for genera that can be used as biocontrol agents against bacterial wilt in crops.

CONCLUSION AND RECOMMENDATION

Bacterial wilt is a difficult disease to control, due to the great variability of the pathogen, the great ability of the pathogen to survive in complex environments, to survive as a latent infection in plant cover and to persist for a long time in the soil. Chemical pesticides have traditionally been used to combat bacterial diseases. However, pesticides lose their effectiveness over time and most of these treatments are relatively expensive and pose some risk to humans and the environment. It is clear that significant progress has been made in recent years in the testing of alternative control agents, particularly in the use of microorganisms (biocontrol) to combat bacterial wilt. However, because microorganisms have adapted to the environment in which they were isolated, many biological control agents are not successful in the new habitats into which they are introduced. Therefore, new biocontrol agents are needed to solve this problem. The use of individual treatments to reduce the epidemiology of BW, but it is not very effective. The IDM method controls BW better than individual control methods. The situation will become more serious in the future as irrigated agriculture increases. The CSA reports that growth of irrigation land has averaged a 10 percent increase each year. It is believed that year-round cultivation has created a favorable environment for the accumulation of various diseases.

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