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Overview of Management Practices of Tomato Late Blight (*Phytoptera Infestans Mont.*) Disease

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Abstract **– The late blight disease caused by P. infestans is a serious disease in tomato crops. When the development of late blight due to the virulence of the pathogen, environmental conditions favorable for the pathogen and traditional farming systems such as the use of susceptible cultivars, monoculture cropping system, and improper fungicides application are important for the epidemiology of late blight. Growing tomatoes throughout the year have created conducive conditions for the buildup of many diseases demanding comprehensive research outputs for their effective and sustainable management. The majority of tomato production in Ethiopia is dominated by smallholders that do not have access to improved and effective pest management technologies. Efforts to transfer crop protection technologies generated through research were minimal due to poor research-extension-farmers linkage. The objective of this study was to overview research achievements of tomato late blight management, identifies gaps and suggests future research directions in the area of tomato late blight management research and development. Non-pesticide management options such as cultural and host resistance against major pests did not reach the smallholder vegetable farmers due to limited effort made by the research-extension system. Integration of resistant and moderately resistant varieties with Ridomil foliar sprays was found to be an effective treatment in reducing tomato late blight epidemics and increasing fruit yields currently. In this review use of various management options are important to reduce epidemiology of late blight. Future research should focus on developing an IDM with no or minimum input of chemical pesticides. The research-extension system and extension-farmers linkage for crop protection technologies should be strengthened.**

Keywords **– Epidemiology, IDM, Late Blight, Management, Tomato.**

I. Introduction

Tomato, *Solanum lycopersicum* Mill. (syn. *Lycopersicon esculentum* Mill or *Lycopersicon lycopersicum* Mill), is an important vegetable crop grown around the world and is second to potato (Rubatzky and Yamaguchi, 1997; Mutschler *et al*., 2006). Tomato is the most widely cultivated and lucrative vegetable in Ethiopia in particular and in the world in general.

It is one of the most important vegetable crops and is widely grown in Ethiopia, ranking 5th in the annual national production of vegetables (CSA, 2022). The importance of tomato is increasing and since it is a high-value commodity, it has been given top priority in vegetable research too in Ethiopia (Tsedeke, 2007). Tomato is an important vegetable in irrigated agriculture in the country and production is also rapidly increasing in many parts of the country (MoANR, 2016, MoA, 2012). Small-scale and commercial growers could grow the crop for its fruits in different regions of the country. It is produced both during the rainy and dry seasons under supplemental irrigation (Lemma, 2002). Tomato is an important food supplement and also serves as regular source of income for rural poor farmers (Lemma *et al*., 1994). According to CSA (2022), vegetables cover 236,772.95 ha (1.68%) and contribute 866,327.05 t/ha (2.07%) of the production of the total crops, and tomatoes took up 7,710.16 (3.3%) hectares of the land, it contributed 33,655.84 (3.9%) tons of the production. The report from CSA, 2022 shows that the national productivity of tomato is 4.37 t/ha.

However, the productivity of tomato is very low due to several biotic and abiotic factors among which diseases are the major ones (Tesfaye and Habtu, 1985; Mohammed *et al*., 2006). Tesfaye and Habtu (1985) reported that early blight (*Alternaria solani*), late blight (*Phytophthora infestans*), fruit spot (*Xanthomonas campestris pv. vesicatoria*), Septoria leaf spot (*Septoria lycopersici*), powdery mildew *(Leveillula taurica*), bacterial wilt [*Ralstonia (Pseudomonas*) *solanacearum or Clavibacter michiganense subsp. michganense*], tomato leaf curl (Tobacco virus 16 or Nicotiana virus 10) and plant-parasitic nematodes (genera: Pratylenchus, Meloidogyne, Helicotylenchus, and Longidorus) are the major and economically important tomato diseases in Ethiopia.

The major tomato disease is caused by fungi; late blight (*phytophthora infestans*) is the most common one. The occurrence of tomato late blight, if it gets suitable environmental conditions, can cause considerable yield losses; even can lead to 100% yield losses (Guenthner *et al*., 2001). The major tomato disease is caused by fungi; late blight (*phytophthora infestans*) is the most common one. The occurrence of tomato late blight, if it gets suitable environmental conditions, can cause considerable yield losses; even can lead to 100% yield losses (Guenthner *et al*., 2001). Tomato yield losses due to the disease were estimated to range between 65-70% and complete crop failures are frequently reported (Kassa and Woldegiorgis, 2000; Adissu, 2011). It is known that the decline in tomato productivity is due to different factors and tomato late blight is one such factor that impairs the quality and quantity of the yield. This leads to a reduction in the supply of tomato to the market demand and income dwindling for smallholder farmers and investors.

Generally, this study reviews research achievements of tomato late blight management, identifies gaps and suggests future research directions in the area of tomato late blight management research and development.

II. Late Blight (Phytoptera Infestans)

It is well known that the disease late blight affects tomato crops. Its impact on this crop is the devastation and reduction of both nutritional and aesthetic value. The pathogen *Phytophthora infestans* is important and destructive in tomatoes; it has been one of the most devastating diseases of tomatoes in both temperate and tropical regions (Bolkan, 1997). It has historical significance as the cause of the Irish famine during the 1840s (Lamour *et al*., 2007). The disease essentially destroyed the potato crop in Ireland between 1845 and 1846 (Chand, 2009). This famine resulted in the death of above one million people and the displacement of nearly two million more people during a short, five-year period. The Irish famine is a devastating example of the epidemic potential of late blight disease (Large, 1940). Wet, cool environmental conditions, such as those prevalent during the 1840s in Ireland, favor the development of late blight. During wet, cool weather, crop loss due to late blight can be rapid and nearly impossible to control if preventative measures are not used (Ye Guang *et al*., 2008; Stone, 2014). But on the tomato crop, the disease is not as important as the potato crop that caused the historical famine in the world, particularly in Ireland.

Late blight, caused by the Oomycete *Phytophthora infestans* (Mont.) de Bary, is economically the most important and most destructive tomato and potato disease worldwide and the disease causes annual losses of several billion dollars and it is a global threat for potato and tomato growers. The disease is capable of wiping out entire crops if the environmental/weather conditions are favorable. Not only will potato and tomato yields decrease in a given year, but also infected tubers could reside in the soil to infect future crops if not managed properly (Haverkort *et al*., 2008). The disease has a large economic impact with the loss of tomato yields, increase unemployment, as well as the cost of management. Guenthner *et al*. (2001) calculated that the disease management cost for United State growers was over US$ 287 million or US$ 507 per hectare. In addition, fungicide spray uses machinery, which increases the amount of fuel used or labor needed. From an environmental point of view, it leads to decreases in energy supplies and increases pollution of the air and water (Haverkort *et al*., 2008).

The worldwide average loss on unprotected fields in fruit yield due to late blight was 70% and with early disease outbreaks even 100%. Under favorable weather conditions, the pathogen can destroy tomato and potato foliage in 10 to 15 days and potential yield can be reduced by 50-70% (Tymcenko and Jefronova, 1987). Currently late blight is more dangerous to potato and tomato production and its management is more difficult than in the past. Genetic changes within pathogen populations represent the major challenge in efficient disease management (Hansen *et al*., 2003).

III. Management of Late Blight (Phytoptera Infestans)

3.1. *Host Plant Resistance*

The use of resistant varieties is among the most effective and environmentally safe tools for late blight management (FAO, 2008). Host plant resistance has a long-term economic benefit for farmers and it also reduces the possibility of fungicide resistance (Mukalazi *et al*. 2001; Binyam *et al*., 2014).

The resistance of host plant reduces the incidence of late blight, delays the onset of disease, and reduces the development amount of disease and the required number of sprays (Agrios, 2005; Binyam *et al*., 2014). Plant resistance for late blight started with the introduction of the resistance gene (R-gene) which has been broken rapidly by virulent strains. The breeding efforts continued identifying R-genes even though resistance durability is an issue with resistance not lasting more than five to seven years. More than 11 late blight R-genes have been identified (denoted R1 to R11) from potato wild species (Nowicki *et al*., 2012). Even though its achievement is not easy, the durability of resistance is indispensable (Vleeshouwers *et al*., 2011; Nowicki *et al*., 2012). The problem with breeding for late blight resistance is related to the ability of the pathogen to evolve quickly and to overcome resistance. Indeed, different strains of *P. infestans,* have been shown to overcome all 11 R-genes in potato (Nowicki *et al*., 2012; Thakur *et al*., 2016). Thus, researchers are looking for alternative resistance strategies more durable than R-genes which incorporate horizontal or polygenic resistance. Pyramiding resistance genes, allowing several resistance genes to be accumulated in the same genotype or cultivar, often results in stronger and more durable resistance, as has been observed in plant species, including potato and tomato (Tan *et al*., 2010).

Tomato cultivars were evaluated for their resistance/tolerance to major foliar diseases at Melkassa in Ethiopia. Among the tested tomato cultivars Floradade, Arizona, CL-5915-206-D4-2-3-0, CL-5915-553-D4-3-0, Heinz 1350 Sel. Mexico, Bl-444 (Vc294A, Solar set hybrid, Red Ball, Nova At-30) were found to be relatively tolerant to major diseases like late blight (*P. infestans*), early-blight (*A. solani*), and powdery-mildew (*L. taurica*) (MARC, 2000). Tomato cultivars introduced from the Asian Vegetable Research and Development Center (AVRDC), Tanzania (Marglobe 2009, Tengeru 97), and MARC showed lower severity (3-4 in a 1-9 scale) of late blight. Yield advantages of 96%, 60%, and 50%, respectively, were recorded over the standard variety Marglobe both on station and verification trials under farmers' conditions (Mohammed, 2002).

3.2. *Chemical Control*

There are several fungicides available for late-blight management in Ethiopia, such as Mancozeb, Mancozeb + Metalaxyl, Ridomil Gold, Agro Laxly, Mancolaxyl, Unizeb with active ingredients Mancozeb and Metalaxy-M (Haverkort, *et al*., 2012). Metalaxyl - M 4% + Mancozeb 64% (Ridomil Gold 68 WP 350g/100litre), Fungomil 250 gm/100litre, and Mancozeb + Metalaxyl (Mancolaxyl 72%) 250g/100 litre were found an effective in controlling the disease on tomato and increased the marketable yield of fruit by 40-66% (MARC, 2000). Generally, the fungicide application has been the only reliable management for late blight. Disease management strategies mostly depend on hygienic practices and well-timed fungicide applications based on favorable weather conditions, because decision support systems often are lacking in many developing countries (Fry and Godwin, 1997; Ojiewo *et al*., 2010). For late blight management, the use of fungicides in tomato production costs up to 20% (Mizubuti, *et al*., 2006).

3.3. *Biocontrol*

Bio-control of plant pathogen or diseases involves use of an organism to inhibit the growth of pathogen and reduce pathogen (Singh, 2013). Understanding the mechanisms of biological control of pathogen through the interactions between bio-control agent and pathogen may allow manipulating the soil environment to create conditions conducive for successful bio-control or to improve bio-control strategies (Vinale *et al*., 2007). Biological control reduces effects of pesticide use in the long term and makes a balance between harmful plant pathogens and their natural enemies. In this regards, antagonistic bacteria and fungi are widely used to management of plant diseases (Shahzad *et al*., 2018). Biological control of plant diseases considered as a viable alternative option to manage plant pathogen (Heydari and Pessarakli, 2010).

Among alternatives biological control is compatible with the goal of a sustainable agricultural system (Ahanger, *et al*., 2014). Biological control refers to the purposeful utilization of introduced or resident living organisms, other than disease resistant host plants, to suppress the activities and populations of one or more plant pathogens or reproduction of one organism using another organism (Pal and Gardener, 2006). This eco-friendly pest management gives greater emphasis for the usage of biological management. Bio-control approach is successful in non-chemical and eco-friendly approach in the sustainable agricultural production (Cawoy *et al*. 2013, Aboutorabi, 2018). Therefore, this management option of plant pathogens has now emerged as a broad concept, evident in the accounts and encompasses several mechanisms.

Fungal and bacterial isolates from the phyllo plane and rhizo plane of cultivated and wild tomatoes were able to reduce late blight lesion size on detached leaflets and whole tomato plants (Garita *et al*., 1998). Trichoderma spp., Fusarium spp., and Pencillium spp. such fungal species were potential biological agents to reduce late blight severity (Garita *et al*., 1999). The bacterial genera Bacillu, pseudomonas, Rahnella, and Serratia contributed to a reduction in late blight severity in potato plants in controlled condition. Two PGPR, Bacillu pumilus, and pseudomonas fluorescens, induced resistance to *P. infestans* and reduced zoospore formation and germination (Yan, *et al*., 2002).

3.4. *Cultural Practices*

Cultural management of late blight is applied all through the growing period up to storage of the tuber of potato and fruit of tomato mainly before planting safeguards. Therefore the incidence is reduced by using certified and healthy seeds and transplants (Secor *et al*., 2011). Removing volunteers is also another way to reduce disease occurrence in the next season. The presence of volunteers contributed a lot to the very early onset of infection and pathogen build-up which causes disease epidemics. Alternate hosts are other causes of infection so that removing them is essential (Flier *et al*., 2003b). Too much soil moisture are favorable conditions for the disease. Planting in shady and wet areas is not recommendable but rather well drained and sunny areas are preferred (Kirk *et al*. 2013). Another important thing to consider while planting is the timing to avoid the major disease period. For instance, in the highland tropics, farmers plant before or after rain for the plants to escape infection. Blight incidence can be reduced by high hilling, which reduces the contact between tuber and washed foliage spores, and early removal of foliage. Storage facilities are the other important factors that contribute a lot to the future tuber blight after harvest. Tubers should be stored under dry conditions which guarantee tuber health (Bohl *et al*., 2003).

3.5. *Integrated Disease Management*

The disease management approaches mainly depend on the selection of clean seed, hygienic practices, and well-timed fungicide applications. There are several integrated disease management (IDM) options for the control of late blight of tomatoes (Scot, 2008). Efforts to the management of late blight are almost totally through the usage of fungicides on varieties with low to moderate levels of resistance (Haverkort *et al*., 2008). Integrated disease management (IDM) has helped farmers drastically reduce the need for chemical plant protection while increasing production (FAO, 2008). Effective management of P. infestans requires implementing an IDM approach (Kirk *et al*., 2005). In IDM host resistance provides to reducing the number of sprays required to protect *P. infestans* below an economic threshold level. Fungicide alone could not be used for the effective management of *P. infestans* but could be used as a part in an integrated management approach. Alternative approaches can be incorporated into IDM approaches for the late blight management of tomato is needed. Integration of a low level of Ridomil spray and moderately resistant varieties of potato in late blight management is very essential eco-friendly and reduces the cost of the fungicide use, and increases in production and productivity of high-quality tuber (Kirk *et al*., 2005; Binyam *et al*., 2014). Integration of varieties and two times for resistant and moderately resistant varieties and three times for susceptible varieties with Ridomil foliar sprays were found to be effective treatments in reducing tomato late blight epidemics and increasing fruit yields (Gudero *et al*., 2018). Host plant resistance is potentially the most economically viable, technically feasible, environmentally friendly and socially acceptable disease management strategy for tomato late blight in IDM programs (Ojiewo *et al*., 2010). Integrated disease management of late blight has been adopted as a strategy in Ethiopia over the past years (1998 to 2000) (Kassa *et al*., 2002).

IV. Conclusion and Recommendations

The vast majority of vegetable production in Ethiopia is dominated by smallholders that do not have access to improved and effective pest management technologies. Efforts to transfer crop protection technologies generated through research were minimal due to poor research-extension-farmers linkage. Non-pesticide management options such as cultural and host resistance against major pests did not reach the smallholder vegetable farmers due to limited effort made by the research-extension system.

Field application of fungicides, reduced late blight infection and increased marketable yield of tomato. Screening of resistant varieties is one of best strategy for managing late blight. Late blight is most well managed with approaches applied before the disease begins to develop, or at the first sign of disease. With resistant varieties, the management practice is in place before late blight starts to develop.

In this review tomato was affected by the late blight disease caused by *P. infestans* is a serious disease. The development of Late blight due to the virulence of a pathogen, favorable environmental conditions for the pathogen and traditional farming systems such as, the use of susceptible cultivars, monoculture cropping system, and improper fungicides application are important for the epidemiology of late blight. In this review use of various management options are important to reduce the epidemiology of late blight. Chemicals are effective for late blight but the use of fungicides also has an adverse effect on the resistance to disease, ecosystem disturbance, and environmental pollution and is hazardous to human and beneficial organisms. The uses of resistant cultivars are reduced late blight infection however after a few years of production resistance gene are breakdown by late blight. Biological control method is effective but most of the bio-control agents perform well in the laboratory conditions but fail to perform to their fullest once applied to the field. The use of individual management approaches is to reduce the epidemiology of late blight but is not highly effective. From this overview it is concluded that, IDM method is best controlling late blight infection and fruit yield loss of tomato than individual control methods.

V. GAPS AND CHALLENGES

There is a need to devise safe, effective and sustainable disease management methods. The bulk of research activities conducted on tomato disease management so far dealt with pesticide chemicals. It is well known that repeated use of synthetic pesticides alone may create resistance within population of various pathogens. Moreover, since tomato are frequently treated with pesticides, there is a greater likelihood of direct human exposure and pesticide residue on fresh tomato thereby adversely affecting both domestic and export tomato market.

The majority of smallholder farmers are not able to differentiate diseases mainly due to lack of technical know-how and awareness. As a result, smallholder farmers apply pesticides haphazardly without using the appropriate rate and frequency of application and safety measures. Such misuse of pesticides could adversely affect growers, consumers and the environment in general.

The review of research in past clearly shown that there are critical research gaps to be filled for management of tomato late blight. The situation will be more serious in the future as irrigated agriculture increases. CSA reported that, every year there has been an average of 10% increase in irrigated land. It is believed that year round cultivation of tomato in the central Rift Valley created conducive environment for buildup of various diseases.

VI. FUTURE PERSPECTIVE

Vegetable production is expanding year after year in the central rift valley and in areas with similar climatic conditions throughout the country due to the use of irrigation. As the demand for vegetables both in the local market and export increases from time to time, production is expanding in area over seasons. Vegetable seed production of mainly tomato takes come to be an attractive business enterprise in many parts of the country.

Growing of tomato all through the season has created conducive conditions for the buildup of many diseases demanding comprehensive research outputs for their effective and sustainable management.

Future research should focus on developing an IDM with no or minimum input of chemical pesticides. The country being strategically linked to the European and Gulf markets, all exportable produce has to qualify with stringent criteria including EUREP GAP (Europe Good Agricultural Practice). Thus, researchers have to consider these opportunities while developing research activities.

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