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Overview of Epidemiology and Management of Late Blight (*Phytophtra Infestans (Mont.)* on Potato and Tomato Crops

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Abstract – **Late blight is the main constraints affecting the production and productivity of tomato and potato crops both in terms of quality and quantity. Late blight management is major concern in tropical region which Overview of Epidemiology and management of late blight (Phytophtra infestans (Mont.) on potato and tomato crops needs to tackle yield loss and low quality of tomato and potato production is main constraints. Similarly, traditional way of controlling late blight was increases severity of disease, low production and cause yield losses. Consequently, some pest management researchers have focused their effort on developing alternative inputs synthetic chemicals for controlling pest and diseases. These different alternatives control methods are Fungicides, integrated pest management, biological control and résistance variety. Those control methods are reducing the late blight infestation and promote production. These different alternatives control methods can achieve the objective of management of late blight infestation and yield loss. These controls of late blight require further a greater understanding the epidemiology, interactions among plants, and the environment.**

Keywords – **Epidemiology, Management Methods, Late Blight**.

I. Introduction

Late blight caused by *Phytophthora infestans* is one of the most significant constraints to tomato and potato productions, caused up to 90% of crop losses in cool and wet weather conditions in Antarctica (Denitsa and Naidenova, 2005). Yield losses due to the disease are attributed to premature death of foliage, stems and fruits of tomato. The disease is more severe in humid and high rainfall areas and it occurs at a low intensity in dry areas (Srivastava and Handa, 2010). It causes serious loss in yield and quality as well as reduces its marketability values (Getachew, 2017). Nonetheless, tomato yield losses due to the disease was estimated to range between 65-70% and complete crop failures are frequently reported (Kassa and Woldegiorgis, 2000; Adissu, 2011). The estimated potato yield losses reported in Ethiopia due to late blight is 2.7%-70% (Bekele and Yaynu, 1996) and 22-46% (Girma *et al*., 2013). The management of tomato against late blight is important to maximize the productivity and the production of the crop. The disease occurs throughout the major tomato and potato production areas in Ethiopia. Yield loss due to the disease was estimated to range between 65-70% and complete crop failures are frequently reported and it is difficult to produce the crop during the main rainy season without chemical protection (Mesfin, 2009; Amin *et al.,* 2013). On this review focused late blight disease cause high yield loss in terms of both quality and quantity of tomato and potatoes production. This disease is very destructive agent that can affect potato leaves, stems and tubers and also in tomatoes leave, stem and fruits. Another reason the distribution and expansion of late blight and resistance of fungicides due to excessive use, improper timing of spray and monoculture farming system. In Ethiopia, it has been reported that late blight is a major limitation to potato production in high humid elevations; with estimate average yield losses of about 30-75% on susceptible varieties (Olanya *et al*., 2001). Fekede *et al*. (2013) reported 21.71- 45.8% and Binyam *et al.* (2014) indicated 29-57% tu-

-ber yield losses caused by late blight in Ethiopia.

II. Epidemiology of Late Blight

2.1. *History of the Pathogen*

Late blight, caused by the Oomycete *Phytophthora infestans (Mont.) de Bary*, is a devastating disease of tomato *(Lycopersiconesculentum Mill*.) and potato (*Solanum tuber sum L*.). It is best known as the disease responsible for the Irish potato famine during the 1840s (Lamour *et al*., 2007). The disease essentially destroyed the potato crop in Ireland during1845 and 1846 (Chand and Sudeep, 2009). The resulting famine was responsible for over one million deaths and the emigration of at least 1.5 million Irish citizens (Large, 1940). The Irish potato famine led to intense investigation into the nature of plant disease and resulted in de Bay's confirmation of germ theory (Reader and John, 2008).

2.2. *Taxonomy of the Pathogen*

The genus *phytophthora* is not a true fungus and belongs to the Oomycete (water molds) in the kingdom *Chromista*, phylum *Oomycota* and order *Peronsporales* (Birch and Whisson, 2001). The Oomycete are characterized by producing sporangia. Zoospores within the sporangia have two unequal flagella and often have a single nucleus. The responsible pathogen is heterothallic and forms oospores with A1 and A2 mating types, which have been found in different parts of the world, in Ethiopia the mating type is believed to be A1 (Gotoh*et al*.,2005 ; Haverkort, *et al.,* 2012). Phytophthora is a member of the Kingdom Stramenopila, phylum Oomycota, order *Peronsporales*, and family *Pythiaceae* (Volk, 2001; Lamour *et al*., 2007). There are 60 described species within Phytophthora, including: *P. cactorum,* an important pathogen of apple, *P. capsicum* which affects pepper, the citrus pathogen *P. citrophthora*, and *P. cinnamomi*, which affects many woody plants including conifers (Erwin and Ribeiro, 1996; Hawks worth *et al*., 1995). Hence, members of Phytophthora can be distinguished from the fungi since they have the following characteristics: cell walls composed of glucans and cellulose instead of chitin, motile zoospores with tinsel and whiplash flagella, and several sporangia produced on each sporangiophore, and diploid vegetative cells (Zentmyer, 1983; Arora1 *et al*., 2014).

2.3. *Pathogen Life Cycle and Development*

The life cycle of *Infestans* rapidly by asexual reproduction conducive to disease development as well as sexual reproduction, which can lead to the generation of new pathogen races. The success of *P. infestans* as a pathogen originates from its effective asexual and sexual life cycles. Cool, humid, rainy or foggy conditions favor late blight infection (Majid *et al*., 2008). *P. infestans* is an obligate parasite and survives the winter on living host tissue such as infected potato tubers or field debris in warmer areas. The primary inoculums for tomato late blight is airborne sporangia from infected plants, mycelium and sporangia on infected tubers left in fields or gardens, infected volunteer potato plants and infected transplants (Agrios, 2005; Fry, 2008). In addition to overwintering in infected potato tubers, *P. infestans* can also survive on seeds from infected tomato fruits (Akida*et. al.,* 2015).

The sporangia can be transported over a large distance by wind in the season when cool moist conditions prevail. In regions where *P. infestans* reproduces sexually, oospores in the soil or on debris also serve as a source of primary inoculums. While soil-borne sporangia remain viable for a maximum of 77 days, oospores have been shown to remain viable for eight months even in extreme temperatures (Pittis and Shattock, 1994; Arora1 *et al.,* 2014). The asexual life cycle of *Phytophthora infestans* is characterized by alternating phases of hyphal growth, sporulation, sporangia germination (either through zoospore release or direct germination, i.e. germ tube emergence from the sporangium), and the re-establishment of hyphal growth (Nowicki *et al.,* 2013). There is also a sexual cycle, which occurs when isolates of opposite mating type (A1 and A2) meet. Hormonal communication triggers the formation of the sexual spores, called oospores (Judelson and Blanco, 2005). The different types of spores play major roles in the dissemination and survival of *P. infestans*. Sporangia are spread by wind or water and enable the movement of *P. infestans* between different host plants. The zoospores released from sporangia are biflagellate and chemo tactic, allowing further movement of *P. infestans* on water films found on leaves or soils. Both sporangia and zoospores are short-lived, in contrast to oospores which can persist in a viable form for many years.

2.4. *Disease Symptoms*

The symptoms of late blight first appear as pale-green lesions often at the tip and margin of leaves. The lesion starts to develop rapidly into bigger brown lesion (Tewodros, 2017; Tsedaley, 2014). The late blight symptoms are appear usually on the upper leaf surface of tomato and water-soaked spots that enlarge rapidly into brown to black lesions that cover large areas of the petioles and stems (Scot, 2008). The symptoms which appear on the stem are brown in color (Bohl*et al*., 2003). The symptoms on fruits are golden to chocolate brown in color and sporulation is possible on the fruits as well (Secor*et al*., 2011).

2.5. *Host Range*

P. infestans generally considered to have limited host range and in agriculture, the two most important primary hosts are tomato (*Lycopersiconesculentum Mill*.) and potato (Solanum tuber sum). The main secondary hosts include red pepper (*Capsicum annuum L*.). There are also a number of wild hosts like Datura, jimson weed, Eggplants, black nightshade and Petunia (Scot, 2008; Oliva*et al*., 2002). Wild species related to potato and tomato is also part of the host rage of *P. infestans*. Plants like nightshades, *S. dulcamara, S. sarrachoides* (Vartanian and Endo, 1985*), S. nigrum, and S. sarrachodes* have been reported to be infected (Flier *et al*., 2003a).

2.6. *Environmental Factors that Favor Late Blight*

The significance of environment on disease progression is characterized by the disease triangle, which integrates host, pathogen, and environment (Van der Plank, 1968). It has been noted that a key component to the Irish potato famine, aside from the reliance on potato as a staple and the migration of the pathogen into that region of the world, was a period of weather characterized by abnormally low temperatures and increased humidity in 1845 facilitating pathogen establishment (Schumann, 1991). Late blight is highly responsive to weekly or even daily environmental changes (Duniway, 1983). Several components affect the survival, germination, penetration, and sporulation of late blight. Temperatures between 15 and 20 °C and high relative humidity are optimal for late blight initiation (Watterson, 1986 and Arora *et al*., 2014). The temperature is also an important factor for infection, even though the exact effects are dependent on the genotype (Mizubuti *et al*., 2000). 15-25°C is known to be the optimal for infection. Studies have also shown its potential to reproduce at a temperature of 30°C high. The temperature above 30°C is not appropriate for reproduction but survival might be possible but not in all phases (Agrios, 2005). Cloudy days are most suitable for late blight since high light intensity, UV radiation, can reduce sporangia viability by 95% within an hour (Mizubuti *et al*., 2000).

III. Management Options of Late Blight on Potato and Tomato Crops

3.1. *Cultural Practices*

Cultural late blight control is implemented throughout the growing season up to storage including the major before planting precautions (Secor *et al.,* 2011). Therefore subsequent Incidence could be reduced by using certified healthy potato seeds and tomato transplants (Secor *et al*., 2011). Getting rid of volunteer plants is another way to reduce disease occurrence in the next season. The presence of volunteers, contributed a lot for very early onset of infection and pathogen build-up which causes disease epidemic in the main potato crop. Alternate hosts are also other sources of infection, so removing them is necessary (Flier *et al.,* 2003b). Areas with excessive soil moisture are favorable flash points for the disease. Planting in shady and wet areas is not recommendable but rather well drained and sunny areas are more preferred (Kirk *et al.* 2013). Another important thing to consider while planting is the timing to avoid the major disease period. For example, in highland tropics, farmers plant before or after rain in order the plants to escape infection. Tuber blight incidence can be reduced by high hilling, which reduce the contact between tuber and washed foliage spores, and early removal of foliage. Storage facilities are the other important factors that contribute a lot for the future tuber blight after harvest. Tubers should be stored under dry conditions which guarantee tuber health (Bohl*et al.,* 2003).

3.2. *Host Plant Resistance*

Resistance is considered to be one of the basic control strategies for many pathogens because of health related and other side-effects of fungicide residual. After the devastating potato famine in Ireland in the 1840s breeding for resistant cultivars was an important interest (Dowley, 1995 and Widmark, 2010). The use of resistant varieties is among the most effective and environmentally safe tools of late blight management (FAO, 2008). In the late 1800s, numerous cultivars with resistance to late blight were available (Umaerus*et al.,* 1983). Host plant resistance has a long-term economic benefit for farmers and it also reduces the possibility of fungicides resistance (Mukalazi*et al.* 2001; Tsedaley, 2014). Host plant resistance reduces late blight incidence, delay the onset of disease, reduces rate of disease development and the number of sprays required (Agrios, 2005; Tsedaley, 2014).

Host plant resistance against late blight started with introduction of 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 has been identified (denoted R1 to R11) from potato wild species (Nowicki *et al.,* 2012). Even though its achievement is not easy, durability of resistance is indispensable (Halter man, 2012; Malcolm son and Black, 1966; Flier *et al.,* 2003a; Vleeshouwers *et al.,* 2011; Nowicki *et al*., 2012). The problem with breeding against late blight is related to the ability of the pathogen to evolve quickly and overcome resistance. Indeed, different strains of *P. infestans* have been shown overcome all 11 R-genes in potato (Halter man, 2012; 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 many plant species, including potato and tomato (Tan *et al*., 2010). Potato cultivars resistance against foliage late blight is quite different with their resistance against tuber blight. Cultivars which are resistant to foliage blight might be susceptible for tuber blight (Flier *et al*., 2003a; Nowicki *et al*., 2012).

In other cases, low incidence of tuber blight has been reported after high levels of foliar blight (Nyankanga*et al.,* 2007).

Selection of resistant varieties is the best strategy for managing late blight. Late blight is most effectively managed with practices implemented before the disease starts to develop, or at the first sign. With resistant varieties, the management practice is in place before late blight starts to develop. This is important, since late blight is nearly impossible to manage with fungicides under very favorable conditions for the pathogen (Margaret, 2015).

3.3. *Chemical Control of Late Blight*

Effective chemicals use in late blight control dates back to the 1880s. The copper sulphate and Lime based chemical, Bordeaux mixture, discovered in 1882 by the French Professor Pierre Millardet was used effectively against late blight (Fishel, 2013). After successive use for five Decades it was replaced by copper oxychloride in 1930s, which was shown to be more effective but they are also toxic to young plants. In contrast the fungicide chlorothalonil had low phytotoxicity. Even though, resistance development has reduced its use, Metalaxy has been the most effective systemic fungicide from the phenyl amides group, which also includes ofurace, oxadyxil, and benalaxyl (Schwann and Margot, 1991). These fungicides are characterized by possessing a curative effect; the pathogen can be killed inside the plant. Regarding tuber activity of chemicals, it is mostly by reducing sporulation, reducing viability of spores on leaves and when repeated applications cause residues to form in the soil that can inhibit formation or motility of zoospores. It is assumed that foliage protection results in tuber safety by reducing sporulation and spore viability in the leaves. In addition chemical residues in the soil inhibit formation and mobility of zoospores (Schemers and van Soesbergen, 1995). Global production cost including fungicides and losses due to late blight is estimated to be € 5.2 billion per annum (Haverkort *et al*., 2009). In Ethiopia there are a number of fungicides available for late blight control. The most common are Mancozeb, Mancozeb + Metalaxy, Ridomil Gold, Agro Laxly, Mancolaxyl, Unizeb with active ingredients Mancozeb and Metalaxy-M (Haverkort, *et al.,* 2012). In Ethiopia fungicides were screened for the control of late blight of tomato in the central Rift valley area. Potential fungicides were also verified on the farmers' fields around Melkassa, Ziway and WondoGenet. Three fungicides (Metalaxyl-M4% + Mancozeb 64% (Ridomil MZ 68%WP Gold 68WP) 350g/100 liter water, Fungomil 250g/100liter and Mancozeb + Metalaxy (Mancolaxyl 72%) 250g/100 liter were found effective in controlling the disease on tomato and consequently increased marketable fruit yield by 40-66% (MARC, 2000, Adissu, 2011 and Amin *et al*., 2013). Generally, application of fungicides has been the only reliable management for late blight. Disease management strategies primarily depend on sanitary 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). Use of chemicals to manage late blight in tomato increases production costs up to 20% (Mizubuti, 2006).

3.4. *Biological Control*

Bio-control of plant diseases involves the use of an organism to inhibit the pathogen and reduce disease (Singh, 2013). Consequently, understanding the mechanisms of biological control of plant diseases through the interactions between bio-control agent and pathogen may allow us to manipulate the soil environment to create conditions conducive for successful bio-control or to improve bio-control strategies (Vinale *et al*., 2007).

Biological control reduces the effects of pesticide use in the long term and makes a balance between harmful plant pathogens and their natural enemies. In this regard, antagonistic bacteria and fungi are widely used to control plant diseases (Shahzad *et al.,* 2018). Biological control of plant diseases has been considered a viable alternative method to manage plant diseases (Heydari and Pessarakli, 2010).

Among these alternatives are those referred to as 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 control. Bio-control methods are successful in non-chemical and eco-friendly approach in the sustainable agricultural production **(**Cawoy*et al*. 2013, Aboutorabi, 2018). Therefore, biological control of plant pathogens has now emerged as a broad concept, evident in the accounts and encompasses several mechanisms. An overview on concepts in biological control of plant pathogens. Biological control

Fungal and bacterial isolates from the phyllo plane and rhizoplane of cultivated and wild tomatoes were able to reduce late blight lesion size on detached leaflets and in whole tomato plants (Garita*et al*., 1998). Trichoderma spp., Fusarium spp., and Pencillium spp. Such Fungal spp. Were potential biological agent to reducing late blight severity in the field (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, Bacillupumilus, and pseudomonas fluorescens, induced resistance to *P. infetans* and there was reduced zoospore formation and germination (Yan *et al*., 2002).

The in vitro and in vivo tests have shown that species of Bacillu, pseudomonas, Rahnella, and Serratia can lessen late blight symptoms by a combination of antibiosis and induced resistance against *infestans* (Daayf *et al*., 2003). Cao and Forrer (2001) classified different antagonist/compounds for their efficacy in controlling late blight. Two organisms were classified as the most effective: a Pseudomonas strain used in a product identified as Immunofit M. biomonas (Filippov and Kuznetsova 1994) and Fusarium equisetii (Jindal *et al*. 1988).

3.5. *Integrated Disease Management*

Disease management strategies primarily depend on selection of clean planting materials, sanitary practices and well-timed fungicide applications. There are several integrated pest management (IPM) options for the control of late blight of tomato (Scot, 2008). Attempts to manage late blight are almost entirely through use 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 the host resistance contributes to reducing the number of sprays required to keep *P. infestans* below an economic threshold level. The integration of reduced rate of Ridomil application and moderately resistant potato varieties in the management of potato late blight, alternate host, is very important in reducing environmental pollution and input cost of the fungicide, and increase in production and profitability of high quality potato tuber yield (Kirk *et al.,* 2005; Binyam *et al.,* 2014). Fungicides cannot be used alone for effective management of *P. infestans*, but must be used as a component in an integrated management strategy. Alternative approaches that can be incorporated into IDM strategies for management of tomato late blight disease are needed. 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 many years (Kassa *et al*., 2002). Improved crop varieties, use of chemicals both fertilizers and pesticides, mechanization, urbanization and monoculture have led to agricultural simplification and biodiversity loss (Boudreau, 2013). Biodiversity reduction could cause ecosystem disservice in the agricultural ecosystem (von Döhren and Haase, 2015). Therefore, to achieve sustainable agriculture reestablishing on-farm biodiversity could be a vital strategy (Ekram *et al*., 2010)

IV. Discussion

Based on this review the Tomato and potato crop was affected by the late blight disease caused by *P. infestans* is a serious disease in major tomato and potato crop. When development of Late blight due to virulence of pathogen, environmental condition favorable for pathogen and traditional farming system such as, use of susceptible caltivars, monoculture cropping system and improper fungicides application are important for epidemiology of late blight. On this discussion of review use of management various option are important to reduce epidemiology of late blight. Chemical methods are effective control late blight but use of fungicide also adverse effect on resistance of disease, ecosystem disturbance, environmental pollution and hazardous to human and beneficial organisms. Uses of resistance cultivar are reduce late blight infestation but after few years resistance gene are breakdown by late blight. biological control method are 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. Use individual control methods are to reduce epidemiology of late blight but not more effective. Integrate disease management method is best controlling late blight than individual control methods. Do not integrated biological control agent with fungicides.

V. Conclusions

On these review concerned about epidemiology of Late blight and use of different management option. To understanding the epidemiology of late blight is important for controlling of late blight through use of different management methods such as cultural, chemical, use resistance varieties, biological control and integrated disease management (IDM) to reduced yield loss and increase productions of tomato and potato. To understanding interaction of environmental factors with the epidemiology of late blight, the activities of biological control agent and effectiveness of fungicides is important for controlling the disease. Therefore, knowing epidemiology of disease and use of integrated disease management methods is reduced severity of late blight disease.

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