World Journal of Agricultural Research, 2015, Vol. 3, No. 1, 34-42
Available online at http://pubs.sciepub.com/wjar/3/1/8

DOI:10.12691/wjar-3-1-8

Disease Management Practice on Potato (*Solanum tuberosum* L.) in Ethiopia

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Received January 31, 2015; Revised February 12, 2015; Accepted February 26, 2015

Abstract Potato (Solanum tuberosum L.) is the fourth major crop of the world after rice, wheat and maize. In Ethiopia, the yield per unit area of potato is very low compared to those of other countries. There are many factors that reduce the yield of the crop among which the diseases like late blight (Phytophthora infestans) and bacterial wilt (Ralstonia (Pseudomonas) solanacearum) which play an important role. Management of these diseases is therefore very essential. In Ethiopia, however, much research has not been done for the management of bacterial wilt disease except identification of bacteria and screening of biological control agents and use of resistant varieties. Late blight of potato can be managed using the following management (control) strategies: use of biological control agents, use of resistant varieties, intercropping, use of certified disease-free seed, use of selective fungicides and cultural practices such as destruction of cull piles by freezing or deep burying, destruction of volunteer potato plants in nearby fields throughout the season, destruction (desiccate, disc or flail and desiccate) of infected plants to avoid spread, reduction of periods of leaf wetness and high humidity within the crop canopy by appropriately timing irrigation, application of a recommended fungicide spray program (the program should start prior to the arrival of the pathogen) and desiccation of vines prior to harvest.

Keywords: *bacterial wilt, disease control, Late Blight, management, potato*

Cite This Article: Ephrem Guchi, "Disease Management Practice on Potato (*Solanum tuberosum* L.) in Ethiopia." *World Journal of Agricultural Research*, vol. 3, no. 1 (2015): 34-42. doi: 10.12691/wjar-3-1-8.

1. Introduction

Potato (*Solanum tuberosum* L.) is the fourth major crop of the world (CIP, 1984) after rice, wheat and maize. Some inherent qualities give potato a competitive edge over the leading food crops. In fact, it is able to produce more protein and carbohydrates per unit area than cereals and some leguminous crops like soybeans (Crowell *et al.*, 2008). In addition to energy and quality protein, it also provides a substantial amount of vitamins and minerals. According to Horton (1987) and Scott *et al.* (2000), potato is the most important crop in developing countries and its production is expanding more rapidly than that of most other crops. As a result of this, it is becoming an increasingly important source of rural employment, income and food for growing populations.

Originating in the Andes, Latin America, potato was introduced to Ethiopia in the 19th century by a German Botanist Schimper (Pankhrust, 1964; Horton, 1987). It is grown by approximately 1 million farmers (CSA, 2008/2009). Potato is regarded a high-potential food security crop because of its ability to provide a high yield of high-quality product per unit input with a shorter crop cycle (mostly < 120 days) than major cereal crops like maize. Recently the price of cereals strongly increased worldwide and in Ethiopia the price subsequently stabilized at a high level, whereas the price of roots and tubers remained relatively low during the entire food crisis. This shows that there is room for added value in the chain of tuber crops. Though it has been under cultivation for almost 200 years in the country, its production was not wide spread and it contributed little to food security in the country. According to Yilma (1991) about 70% of cultivated agricultural land in Ethiopia? is suitable for potato production. However, currently only 80,000 hectares is under potato cultivation. The main reason associated to this under utilization of potato is the narrow genetic base of the early introductions and the traditional view towards potato as poor man's food and also most of the people use cereals as staple food. In addition to this, lack of high yielding and disease resistant improved potato varieties, problems of pests and disease (Gebremedhin *et al.*, 2008, are also the causes of under utilization of potato in Ethiopia. There are improved varieties that yield 19–38 Mg ha−1 on farmers' fields (Gebremedhin *et al.*, 2008).

2. Major Diseases of Potato

The potato plant is attacked by many pathogens causing significant losses to potato producers throughout the world. Bacteria, fungi, viruses, nematodes and phytoplasmas cause serious production constraints.

2.1. Bacterial Diseases of Potato

Bacterial diseases of potato have had a decisive role in the cultivation of this crop. Several bacterial species can infect the potato plant and cause diseases; however, not all of these have a significant economical impact. Bacterial diseases are encountered more often in moist soils. The pathogens enter the plant via natural openings or wounds. The most damaging bacterial pathogens of potato which are also listed as quarantine pathogens are Bacterial ring rot, caused by *Clavibacter michiganensis* subsp. *sepedonicus*, and bacterial wilt (or Brown rot) caused by *Ralstonia solanacearum*. Both are very destructive diseases and difficult to control. Because they are not present in all areas where the potato is grown, strict quarantine measures should be applied to prevent their spread. Despite all efforts, brown rot continues to gain new territories. Nowadays, *R. solanacearum* can be found in various parts of Africa, Central and South America and Asia (Wilson *et al.*, 2001).

Erwinia spp. is a large group of pectolytic bacteria that are of worldwide distribution and cause soft rots of many important crops. Typically, these pathogens cause the maceration of the tissues of their host plants causing soft rot symptoms. *Erwinia carotovora* subsp *carotovora*, *Erwinia carotovora* subsp. *atrospectica* and *Erwinia chrysanthemi* cause bacterial soft rot, aerial stem rot and blackleg diseases of potatoes respectively. Blackleg and soft rot can cause significant losses especially during storage. Scab could become problematic whenever plants are over-irrigated especially as tubers are close to maturity (Wilson *et al.*, 2001).

2.2. Fungal Diseases of Potato

Of the fungal diseases, late blight, caused by *Phytophthora infestans*, stands out from the rest. This disease is the nightmare of potato producers especially in the coastal wet regions. Late blight management programs of 15 sprays per season are not uncommon in wet and cool regions. Other significant fungal diseases include *Verticillim* and *Fusarium* wilts. Both pathogens are soil borne and cause vascular wilt. *Rhizoctonia* canker and early blight are sometimes problematic (Choueiri *et al*., 2004).

2.3. Viral and Nematode Diseases of Potato

Several viruses infect the potato such as the Potato Virus Y, A, and X. These pathogens reduce plant vigor and yield. The potato cyst nematode, a quarantine organism, can cause serious reduction to yield (Choueiri *et al*., 2004).

3. Major Diseases of Potato in Ethiopia

In Ethiopia, the yield per unit area of potato is very low compared to those of other countries like Rwanda, Egypt and Kenya. There are many factors that reduce the yield of the crop among which the diseases like late blight (*Phytophthora infestans*), bacterial wilt (*Ralstonia (Pseudomonas) solanacearum)* and viruses play an important role (Yaynu, 1989). Stewart (1956) reported bacterial wilt in areas around Jimma in the western part of the country. The following are major disease of potato in Ethiopia:

3.1. Bacterial Wilt (Ralstonia (Pseudomonas) Solanacearum E.F Smith)

Bacterial wilt also known as brown rot is caused by *Ralstonia (Pseudomonas) solanacearum* E. F Smith, a soil-borne bacterial species. It is one of the most destructive plant diseases which is predominantly distributed in the tropical, subtropical and warm temperate regions of the world (Hayward, 1994). It affects as many as 200 plant species representing more than 50 families of particularly members of solanaeceous plants such as potato, tomato, eggplant, pepper and tobacco. In Ethiopia, *R. solanacearum* is one of the most important pathogens (Yaynu, 1989), threatening the production of potato and tomato in different parts of the country.

3.1.1. Factors Favoring the Disease

The pathogen can survive for various periods of time in the soil, depending on the conditions to which it is subjected. *Ralstonia solanacearum* can survive in the soil for a few months to a few years (Elsas *et al*., 2000). Wet soil conditions and moderate temperatures usually favor the survival of the bacteria. Moreover, plant debris and rotting tubers help the pathogen to survive from season to season in the absence of host crops (Elsas *et al*., 2000).

R. solanacearum race 3 biovar 2 is more adapted to cooler climates but its virulence and density will decline when temperatures drop below 15°C and drastically below 4°C (Stansbury *et al*., 2001). Therefore, long-term survival ability of the brown rot pathogen in soils of temperate countries is significantly reduced.

R. solanacearum can spread in waterways, and is known to survive for long periods of time in water. Contaminated irrigation waters help in the spread of the pathogen from field to field (Hay, 2001). Some weeds can act as reservoir plants allowing the pathogen to survive, multiply and spread to contaminate new lands. *Solanum dulcamara* has been identified as a host for *R. solanacearum* race 3 (Elphinstone, 2001). Like almost all bacterial phytopathgens, *R. solanacearum* enters into plants via wounds made by tools during post emergence cultivation, and by nematodes and insects in the soil or natural openings. Once inside the plant, the bacteria will move preferentially towards the vascular bundles to finally colonize the xylem (Poussier *et al*., 2003). The presence of the bacteria inside the xylem coupled with the production of exopolysaccharides will block the vascular vessels inducing a water shortage throughout the plant. This causes the plant to wilt and eventually die (Poussier *et al*., 2003).

3.1.2. Economic Significance of the Disease

The economic implications of *R. solanacearum* are yet to be fully understood. This is further complicated by the fact that yield losses are influenced by many factors like host, cultivar, climate, soil type, cultural practices and the bacteria itself with some strains being more virulent than others. It is the second most important constraint to potato production in tropical, subtropical and warm temperate regions of the world. It may also occur in cooler climates such as at relatively high elevation in the tropics or higher latitudes. In India, a study conducted on one cultivar of tomato demonstrated that the pathogen killed from 10 to

100% of the plants and induced a yield loss ranging from 0 to 91% (Elphinstone, 2005).

In the case of Potato, losses are more significant since this crop is a staple food for millions of farming communities around the world. It is currently estimated that bacterial wilt of potato affects 1.5 million Ha of lands in 80 countries and induces a global cost of $ 950 millions annually (Walker and Collion, 1998). In some countries losses are outstanding; in Bolivia many reports stated that yield was reduced from 30-90% and almost all tubers (98%) were lost during storage (Walker and Collion, 1998).

In Ethiopia, bacterial wilt has been recorded on potato, tomato and eggplant in many regions (Yaynu, 1989). Stewart (1956) first recorded the disease in 1956 on potato and eggplant in Keffa region (South West Ethiopia). Stewart and Dagnachew (1967), in their index of plant disease in Ethiopia, listed bacterial wilt on potato, tomato and eggplant in Keffa (South Ethiopia) and on potato in Arsi and Shewa (Central Ethiopia). Other workers observed bacterial wilt on potato in Ethiopia. Moreover, Yaynu (1989) indicated that bacterial wilt is an important disease of potato and tomato in many parts of Ethiopia and sometimes in the past the disease caused heavy losses at some commercial farms including at the potato seed tuber multiplication farm, Tseday Farm in Central Ethiopia, as a result of which potato seed tuber multiplication in the farm has been abandoned. Moreover, pepper plants infected by *R. solanacerum* have been observed in Ethiopia recently. Its importance is increasing from time to time because of latently infected seed potatoes and decreasing land holdings that limit crop rotation (Berga *et al*, 2000).

3.1.3. Management Methods

Bacterial wilt is caused by a pathogen that isn't easily managed. There is need for more research on the epidemiology and the host-pathogen interaction in order to devise the most appropriate management strategy. Currently, several control options can be investigated and an integrated management strategy may be set-up based on local needs. The common control measures employed in other countries include the use of resistant variety, crop sanitation, crop rotation, selection of disease free planting material and other cultural practices as single or integrated disease management have met, if at all, with only limited success. However, control through the use of resistant varieties alone has yielded little success. This is because such kind of resistance is strain specific and liable to break down by virulent and highly polymorphic strains of *R. solanacearum* at ambient temperature and in nematode infested soil (Prior *et al*., 1994). Successful control of the pathogen through crop rotation is also not always effective since rotation practices recommended for one area may not perform well at other locations in addition to differences in the strains involved (Prior *et al*., 1994). However, much research has not been done on this disease in Ethiopia except identification of bacteria and screening of biological control agents and use of resistance varieties (Henok, *et al*, 2007). The following Biological control methods have been researched in Ethiopia:

3.1.3.1. Biological Control

The use of rhizosphere resident microbial antagonist specifically the fluorescent *pseudomonas* is noted as a promising control method. The rhizosphere is a habitat in which several biologically important processes and interactions takes place which is primarily due to the influx of mineral nutrients from accumulation of plant roots exudates through mass flow and diffusion (Sorensen, 1997; Bias, 2004). Among the rhizosphere organisms, fluorescent *pseudomonas* strains are often selected for biological control strategies because of their ability to utilize varied substrates under different conditions, short generation time and motility that assist colonization of roots. Moreover, they produce active extracellular compounds such as siderophores responsible for the biological suppression of several soil borne plant pathogens (Bagnasco *et al.,* 1998).

Henok *et al.,* (2007) evaluate Ethiopian isolates of *Pseudomonas fluorescens* as biocontrol agent against potato bacterial wilt caused by *Ralstonia (Pseudomonas) solanacearum.* According to Henok *et al*., (2007) three isolates of *Pseudomonas fluorescens* i.e., PfS2, PfWt3 and PfW1 showed inhibition against the growth of the pathogen. Bacterization of tubers with isolates Pf S2, Pf Wt3, and PfW1, significantly reduced by 59.83% the incidence of bacterial wilt compared to the pathogen-inoculated control and increased plant growth (plant height and dry weight) by 59.83%, 76.89% and 28.44%, respectively. This suggests the importance of the studied isolates as plant growth-promoting rhizobacteria. Therefore, the evidence presented here is suggestive of the potential of the Ethiopian isolates as biological control agents against bacterial wilt of potato by exploiting the interaction between rhizosphere microorganisms.

Lemessa (2006) working on biochemical, pathological and genetic characterization of strains of *Ralstonia solanacearum (Smith)* from Ethiopia and biocontrol with bacterial antagonists found that the most effective strains *(Pseudomonas fluorescent* APF1 and *Bacillus subtlis* B2G) consistently reduced wilt diseases and increased plant weight significantly. The Pseudomonas APF1 strain showed the greatest plant growth promotion effect, increasing plant dry weight up to 63% compared to the untreated control. Generally, plant protection rendered this way can be maximized by combining different methods in an integrated disease management approach such as resistant variety and biocontrol.

3.1.3.2. Management Options (IDM) of Bacterial Wilt in Ethiopia and Sub-Saharan Africa

Considerable research has been undertaken on bacterial wilt management both in PRAPACE member countries and elsewhere (e.g. in Cameroon and by CIP worldwide). Unfortunately no source of resistance appears to be available so far, but efforts are being undertaken to explore other promising methodologies in search for resistance against bacterial wilt. In particular, marker-assisted breeding and genetic engineering to produce transgenic varieties are now being viewed as plausible options in the search for resistant varieties. Other aspects of IDM of bacterial wilt have also been studied including effect of soil fertility and crop rotation on occurrence and severity of the disease (Berga Lemaga *et al*., 2001a; Berga Lemaga, *et al*., 2001b).

Intensive seed production on small plots under bacterial wilt conditions has also been studied in Kenya (Kinyua *et al*., 2001) and is on-going in Uganda (Alacho *et al*., 2000). Various integrated management options for controlling bacterial wilt have been developed in Ethiopia, Kenya and Uganda and are currently being disseminated on-farm in several other PRAPACE member countries (Kinyua *et al*., 2001). Though the results show positive trends in the management of the disease, bacterial wilt remains a major challenge to potato production in all ASARECA countries. As new varieties for ware and other purposes become available, their integration in bacterial wilt IDM will be key. Clearly, management of bacterial wilt requires a multi-disciplinary approach (Tusiime *et al*., 2000) and can only be effective if backed by systematic and continuous community awareness efforts.

3.2. Late Blight of Potato (*Phytophthora Infestans* (Mont.) de Bary)

Among all the crops grown worldwide, potato (*Solanum tuberosum* L.), is known to suffer the greatest losses from disease attack. Late blight of potato, caused by *Phytophthora infestans* (Mont. De Bary), is among its most important diseases, being especially devastating in the major potato growing areas. Serious economic consequences often result from complete or partial devastation of infected fields (PRAPACE/CIP, 1996; Sengooba and Hakiza, 1999). It is the most widespread throughout the world and causes serious tuber losses globally (Erwin and Ribeiro, 1996; Fry and Goodwin, 1997; Garrett *et al*., 2001). Worldwide losses due to late blight are estimated to exceed $5 billion annually and thus the pathogen is regarded as a threat to global food security (Latijnhouwers *et al.,* 2004). In the past few decades, the frequency and severity of the disease have increased in many parts of the world including Ethiopia and have been a serious threat to potato production (Bakonyi *et al.,* 2002).

In Ethiopia, the disease has been reported as the most destructive and economical disease on potato (Kassa and Hiskias, 1996). Though the effort made by researchers to reduce the effect of the disease on tuber yield is encouraging, still the loss is very tremendous (Tarekegne and Kassa, 1997).

The emergence of A1 fungal strains with deviant sexuality and the detection of fungicide resistance in some fungal isolates in potato growing regions of tropical Africa (Erselius et al., 1999) have raised concern for effective disease management. Because of the rapid development of late blight, infections occurring during various stages of crop development represent enormous economic threat. With the exception of optimum or scheduled fungicide applications based on the favourable weather conditions or decision support system, which is still under development in tropical Africa, the most economically viable disease management options is for the use of host-plant resistance.

Occurrence of *P. infestans* has been closely linked to the introduction of potato varieties in many countries of Sub-Saharan Africa (Natrass, 1951; Sengooba and Hakiza, 1999). The introductions of the fungus and its subsequent spread have been accomplished primarily through the movement of potato seed. The major factors affecting potato production such as: use of susceptible varieties, diversity of pathogen virulence and races, lack of adequate disease management tactics and favorable environmental conditions have incidentally and consequently led to perpetuation and increase in late blight disease. Although reports of disease occurrence have been thoroughly documented, to date, paucity of information exists concerning the epidemiology and characteristics of late blight fungal isolates in many countries of Sub-Saharan Africa. Moreover, the impact of environmental factors on disease development has not been adequately addressed. Studies on the epidemiology and fungal population dynamics are important for designing adequate late blight management tactics. Because of the differences in environmental conditions, and the diversity of the geographical areas in which potato varieties / clones are grown in tropical Africa, it is important to have a sound understanding of the fungal population dynamics and utilize this to design site specific management options.

3.2.1. Factors Favoring the Diseases

In Ethiopia, throughout the country the potato crop suffers from the late blight. The climate is conducive to the growth and development of the pathogen. The main sources of the disease are cull piles, volunteer plants, seed tuber and alternate hosts. Even soil contributes to the initial inoculums. Farmers do not cut the foliage and in most cases, after the crop reaches senescence, farmers do not harvest the entire field. They use the piecemeal approach of leaving the tubers in the field for extended periods of time and harvesting as needed. These practices favor the pathogen remaining in the ground and serving as an inoculum source for the next season. Also, farmers in most areas cultivate potato as mono-crop without rotation. These practices and the presence of alternate hosts significantly contribute to maintaining sources of innoculum in the system (Ethiopia Late Blight Profile, 2004). Ideal conditions for late blight are cool nights (50 to 60°F) and warm days (60 to 70°F) accompanied by fog, rain, or long periods of leaf wetness. Conditions must remain moist for 7 to 10 hours for spore production to occur.

Variation in the incidence and severity of late blight on potato has been recorded in many locations and countries. Variability in disease incidence and severity has been reported in Kenya, Ethiopia and elsewhere in Sub-Saharan Africa countries. The variation of disease incidence and severity may be accounted for by the differences in rainfall patterns between seasons (bi-modal) and years. Variation have also been attributed to susceptibility and resistance of various varieties grown in many areas, different planting dates (disease escape), and various late blight management practices (PRAPACE/CIP, 1996). In Uganda, studies conducted by Mukalazi *et al*. (2000) showed that late blight incidence in various countries range from 5 to 85.4%, while severity was in the range of 27.9 to 81.6% during a two year study.

3.2.1.1. Relationship of Environmental Factors to Late Blight Development

The impact of environmental parameters on late blight development has mainly been obtained through on station experiments of variety or clonal reactions to late blight. Most of the results have been derivative data since key environmental indicators for late blight epidemics have only been quantified in few central locations in some countries. These parameters often include: temperature, relative humidity, rainfall and hours of solar radiation recorded from the established weather stations located at research stations. In some cases, supplemental weather equipment has been deployed on station for record of additional environmental data.

In tropical Africa, the impact of environmental parameters on late blight development has not been adequately quantified. The geographical diversity of the region and the lack of modern equipment imply that there is need to quantify the driving variables for late blight epidemics. Key climatic variables most often associated with severe epidemic development include relative humidity, rainfall and temperature (Campbell and Madden, 1990; Zadoks and Schein, 1979). Derivative data on cumulative climatic variables from Uganda, Kenya and Ethiopia reveal that late blight development is positively correlated with rainfall amount and relative humidity (Bekele and Gebremedhin, 2000). However, there is very limited data on the use of micro-climate or environmental monitoring for forecasting the development of late blight epidemics at the regional or local levels.

3.2.2. Economic Significance of the Disease

In the 1940s' an outbreak of late blight ravaged potatoes. ... “The ensuing 'potato famine' (in Ireland) was the worst European disaster since the Black Death 500 years before. One million people died and 1.5 million emigrated, out of a total population of around 8 million”.

Horton, 1987:11

Late blight of potato, caused by *Phytophthora infestans* (Mont) de Bary, is the single most destructive disease of potato the world over (CIP, 1989). During the last two decades, this disease has increased globally (Fry and Goodwin, 1997). The average global crop losses of all diseases combined was approximately 12.8% of the potential production but potato alone was subjected to 21.8% loss (James, 1981). In Ethiopia the disease caused 100% crop loss on unimproved local cultivar, and 67.1% on a susceptible variety, Al-624 (Bekele and Yaynu, 1996). On station results have documented potato yield loss attributed to late blight in the range of 2.7 to 47% at Holetta Research Station (Bekele and Yaynu, 1996). Generally, potato yield loss attributed primarily to late blight is dependent on variety susceptibility or tolerance / resistant and disease management practices.

Late blight has an impact on the industry, consumers and country (Ethiopia Late Blight Profile, 2004). It is the most devastating disease of potato in countries like Ethiopia where subsistence farmers are not in a position to properly know and control the disease.

In Ethiopia, it occurs throughout the major potato production areas. The area under potato is estimated more than100, 000 ha**.** There are five major potato production regions in Ethiopia such as Central Ethiopia, Eastern Harerge, Northwest Ethiopia, South Ethiopia and Western Ethiopia.

In the central (Ginchi, Jeldu, Galessa and other districts, which are located in an altitude greater than 2800 masl) highlands there is narrow diversification of crop species in rotation to cereals and pulses (such as barley, wheat and to some extent faba bean). In this part of the country, most of the farmers grow potato as a garden crop without rotation, but in areas like Shashemene (the major supplier of fresh ware potato to the capital city) potato is grown as a field crop under short rain with supplementary irrigation and /or under irrigation. In the eastern part of the country, it may be planted as relay cropping. During the long rains (June – September) and the short rains (March – May), potato is often intercropped with cabbages, sorghum, beans, maize, eggplant, or tomato. In other parts of Ethiopia, particularly in the eastern part of the country, strip cropping with cabbage may be done under irrigation conditions. In the northwest part of the country potato is the major field crop and has a significant role in the food system of the farmers in the region. In the western part of Ethiopia, although the crop used to be important in the cropping system, due to late blight disease farmers have almost stopped cultivating potato (Ethiopia Late Blight Profile, 2004).

In Ethiopia potato production is mainly dependent on natural rainfall and smaller proportions of areas the crop is supported by irrigation. Due to the unfortunate shortage of rain in both main and short rain season's potato production was highly reduced throughout the country in 2002. As to the previous years the potato yield has been seriously affected by late blight but during 2003 the disease coupled with the shortage of rain shower that was occurred throughout the country, the yield per unit area and total production was significantly reduced. As a result there was a serious shortage of fresh potato in the local markets and about 50% higher comparing to year 2002 raised the price. Small industries were also seriously affected because of scares in supply. Farmers in marginal potato growing areas whom were partly or fully dependent on potato to feed their family and for market use were critically affected (Ethiopia Late Blight Profile, 2004).

3.2.3. Management Methods Used/Researched

Worldwide losses due to late blight are estimated to exceed $5 billion annually and thus the pathogen is regarded as a threat to global food security (Latijnhouwers *et al.*, 2004). In the past few decades, the frequency and severity of the disease have increased in many parts of the world including Ethiopia and have been a serious threat to potato production (Bakonyi *et al.*, 2002). Despite the fact that much of the success in controlling the disease has been due to the application of large quantities of chemical fungicides, their extensive use is causing a serious pollution problem in the environment (Ragunathan and Divakar, 1996). Further, the chemical control of late blight is becoming more difficult due to the appearance of new and more aggressive *P. infestans* strains (Fernandez-Northcote *et al.*, 2000). Integrated management of late blight through the use of resistant potato clones, fungicides, and cultural measures appear to offer the best option for disease management in the tropical highlands of Africa.

In Ethiopia, the following management methods (control strategies) were research results used to manage potato late blight:

3.2.3.1. Integrated Disease Management (IDM)

In Ethiopia, over the past 10 years integrated disease management of late blight (IDM-LB) has been adopted as a strategy. IDM-LB includes host resistance in combination with cultural practices such as early planting dates and reduced fungicide use. Experimental plots with IDM-LB yielded 50% and 75% more than late planting

(planting during the month recommended for potato-growing) alone. These control technologies developed in the research centers are found effective under the farmers field conditions. The improved technologies were tested under farmer's conditions with their full involvement in pilot sites through Farmer Field Schools (FFS). The only problem with the late blight control is that farmers do not have access to improved resistant varieties and fungicides as required (Ethiopia Late Blight Profile, 2004).

3.2.3.2. Fungicide Use

The first spray with Ridomil MZ 63.5% wp at a rate of 2 kg/ha and followed by 2-3 sprays (need base application) of Dithane M 45 at a rate of 3 kg /ha were found to be effective in controlling late blight (Ethiopia Late Blight Profile, 2004).

Bekele K. and Hailu B. (2001) had done a research on the efficacy and economics of fungicide spray in the control of late blight of potato in Ethiopia. The result showed that, Ridomil MZ - 63.5% WP which is both systemic and protectant in action gave the best control (78.8%). On the other hand Chlorothalonil, Mancozeb and Brestan 10 did not differ significantly in respect to disease control, and gave 59.3, 43.0 and 46.8% control, respectively. However, the three fungicides significantly ($P< 0.05$) controlled late blight when compared to the control plot. They conclude that, the fungicides Chlorothalonil 50% EC and Brestan 10 can be used to control late blight. Overall, Ridomil MZ 63.5% WP gave effective control of late blight and the best return. Therefore, those potato growers who can afford to buy it can use it as an alternative fungicide in late blight control. Although the use of fungicides at government control prices level was economic, lack of experience in use of fungicides and availability of sprayers are obstacles that hinder the use of the technology.

Studies conducted in Uganda, Kenya and Ethiopia on Fungicide and variety reaction suggests that significant late blight control can be achieved when the protectant fungicide, Dithane (a.i mancozeb) is applied on a scheduled basis. On-farm research also indicates that three timely applications of a protectant or a protectant fungicide alternated with systemic fungicide can be effective for late blight management (PRAPACE/CIP, 1996).

3.2.3.3. Resistant Cultivars

Table 1. Late blight–resistant varieties from CIP population A, which were released in 2002

CIP Number	Proposed Name	Adaptation
387792.5	Degemegne	Wide adaptation
384321.9	Guasa	Regionally released for North Western Ethiopia from Adet Research Centre
382173.12	Gorebela	Regionally released for North Shewa from Sheno Research Center
384321.19	Jalenea	Wide adaptation

Source: Ethiopia Late Blight Profile, 2004

The released improved variety Menagesha has lost resistance to late blight, but still is one of the best varieties in the high altitude areas (>2800 masl) if supported by reduced fungicide application and early planting (Integrated Disease Management, IDM). The remaining improved varieties such as Tolcha and Wechecha better express their yield potential when accompanied with IDM (Ethiopia Late Blight Profile, 2004).

3.2.3.4. Intercropping

In the central highland of Ethiopia, potato is a garden crop and intercropping with brassica at a lower population being an ordinary practice but crop like garlic is also grown as a sole crop in the same garden. Of the various options available in the high altitudes, cropping systems, other than so many advantages related to intercropping mentioned elsewhere, disease problems is low in an intercropping production systems compared to sole cropping production system (Okigbo, 1979). For pathogens like P*hytophthora* which mostly disperse by wind and rain, interrupting with none host crop for a disease may physically interfere and be able to entrap the spores, thereby reduce the available inoculum (Garret and Munndit, 2000). Skelsey *et al*. (2005) in his report also showed the influence of host diversity on the development of epidemic.

Mixture of potato with garlic could also reduce the spread of late blight through inoculums dilution and /or inhibitory effects of volatile compounds (Cizcova *et al*., 2002) that possibly could create an environment hostile to the development of late blight in potato. Hence, primarily, garlic is widely grown in the highland production system as a garden crop mainly for market; secondly, intercropping can help reduce the disease effect and probably the volatile oil which the crop emits can change the micro climate to be hostile to the pathogen.

Bekele Kassa and Tharmmasak Sommartya (2006) had done a research on the effect of intercropping on potato late blight, *Phytophthora infestans* (Mont.) de Bary development and potato tuber yield in Ethiopia. The result prevailed that, all potato-garlic ratios exhibited superior performance when compared to the fungicide unsprayed treatment. Among the proportions, 75% garlic with 25% potato (3:1) intercropped plots showed significantly ($p< 0.05$) low disease development and high tuber yield. Moreover, at 3:1 combination of garlic to potato the land equivalent ratio (LER) was greater than 1 and the monetary values were high at both testing sites. Significant ($p< 0.05$) differences were also observed among potato varieties with regards to the disease development and tuber yield. The study also demonstrated that fungicide treatment provided significant low ($p<0.05$) disease development and higher potato tuber yield when compared to the untreated monoculture control treatment. The findings of this study suggested garlic as a potential intercropping plant for the management of potato late blight disease under Ethiopian condition.

3.2.3.5. Biological Control

Ephrem Debebe *et al*. (2011) had done a research on biocontrol activity of *Trichoderma viride* and *Pseudomonas fluorescens* against *Phytophthora infestans* under greenhouse conditions in Ethiopia. The result, in In *vitro* antagonism test carried out between *T. viride* and *P. infestans*, showed a radial growth inhibition of the pathogen by 36.7% and a complete overgrowth of *T. viride* on *P. infestans* later, whereas *P. fluorescens* inhibited the radial growth of the pathogen by 88%. In Foliar spray of the suspensions, *T. viride* was found to be more efficient than *P. fluorescens* and mixed culture. This study revealed that the foliar application of *T. viride*-ES1 has good potential in controlling the late blight disease of potato.

3.2.4. Late Blight Management Options in Sub-Saharan Africa Including Ethiopia

The use of protectant as well as systemic fungicides for management of late blight have perhaps been the most studied aspects of disease management (Lunga'aho, 1998). In tropical Africa, fungicide application intervals, frequency of application and timing, fungicide dose response relationships have been experimented routinuely. Fungicide application intervals that have been used include calendar based or scheduled application intervals of 0, 7, 14 and 21 days. Farmer's practices or on-farm fungicide use scenarios often include at least three applications per cropping season. The timing of fungicide application have often frequently been based at the onset of symptom expression.

The use of host plant resistance for management of late blight has received considerable attention in many countries of Sub-Saharan Africa. This has primarily involved the introduction of potato clones from various sources and their evaluation for late blight resistance. This has often involved replicated, randomised experiments conducted under natural late blight epidemics of potato under field conditions.

The use of cultural measures for potato late blight management has been investigated in a number of instances. Management practices include manipulation of planting date for potato varieties in order to avoid period of heavy late blight infection have been investigated. Cultural management tactics also include the use of inter-cropping of non-host crops or low planting density to reduce the spread of fungal inocula.

4. The Drawbacks and Challenges of Potato Diseases Management

4.1. Fungicide Resistance

Recent studies of Ethiopian isolates found all those tested to date to be A1 mating type and the Ia mt-DNA-haplotype (Population A, high levels of resistance) (Ethiopia Late Blight Profile, 2004). Eighty percent of these isolates were metalaxyl-sensitive, 7% resistant and 13% intermediate and the majority of them were collected from unsprayed fields. It should be noted, however, that, as it was not possible to perform the tests on metalaxyl resistance on freshly collected field material, the isolates could have changed their level of sensitivity during sub-culturing. The results indicate that the isolates tested could belong to the “new” population of *P.infestans.* Moreover, the frequency of oospore production through self-fertilization in the tested isolates was as high as 97% (Ethiopia Late Blight Profile, 2004). Therefore, the major needs is that understanding the population structure of *P. infestans* in the country and developing IDM strategies that are more effective, environmentally friendly and economical. There is a great need for healthy seed. This calls researchers to examine and understand the efficiency of the isolates to initiate disease and its role in the disease cycle.

4.2. Fungicidal Use Problems

In Ethiopia, although the use of fungicides at government control prices level was economic, lack of experience in use of fungicides and availability of sprayers are obstacles that hinder the use of the technology. In general, there are still very limited advances in fungicide application methodology and technology. There is limited information on the use of environmental monitoring to aid in proper or adequate fungicide use and application technology. Data on decision support system to optimize fungicide use in conjunction with resistant varieties is still lacking.

4.3. Miscellaneous

Inadequate laboratory and growth chamber facilities especially in molecular characterization are often a limiting factor in pathogen population studies. Any environmental monitoring has been a limiting factor in the development and use of decision support systems for the optimization of fungicide spray or utilization in late blight management. However, advances in fungicide application, cultural management in addition to the use of resistant varieties has facilitated late blight management by the small-scale potato farmers. As improvements in host-plant resistance continue and the quantification and utility of general resistance (stability and durability) receives considerable attention, we are optimistic that optimum potato diseases (late blight and bacterial wilt) management and increased potato production will continue in Ethiopia.

5. Summary and Conclusion

- In Ethiopia, potato is grown in four major areas: the central, the eastern, the northwestern and the southern.
- There are many factors that reduce the yield of the potato crop production such as diseases like late blight, bacterial wilt and viruses.
- It is difficult to control the bacterial wilt diseases, because it is a quarantine pathogen, strict quarantine measures should be followed, but potato late blight can be controlled by using the following **Control Strategies**:
- Use certified disease-free seed,
- Destroy cull piles by freezing or deep burying,
- Destroy volunteer potato plants in nearby fields throughout the season,
- Destroy infected plants to avoid spread,
- Reduce periods of leaf wetness and high humidity within the crop canopy by appropriately timing irrigation,
- Start fungicide spray prior to the arrival of the pathogen,
- Desiccate vines prior to harvest,
- Use of resistant varieties,
- Intercropping and use of selective fungicides are the most important ones.

Acknowledgments

My great pleasure goes to Mr. Negash Hailu for his critical evaluations of this review article.

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