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Management of Late Blight of Potato caused by *Phytophthora infestans*

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A B S T R A C T

The potato (*Solanum tuberosum* L.) remains an essential crop in addressing the world's food problems. Due to advancements in agricultural machinery, the use of fertilisers, and irrigation techniques, the crop's output has seen a tremendous increase globally in recent decades. However, every year, a sizeable amount of this essential crop suffers heavy loss because of various fungal, viral, bacterial, and nematode infestations affecting it. One such infection, Late blight, caused by *Phytophthora infestans*, is among the most dreaded diseases of potato globally which causes substantial production losses. In 19th century, the Irish Famine in the middle was caused by late blight. The pathogen has a wide range of variation and may adjust to newly developed varieties and fungicides. The pathogen infects all plant growth stages that show symptoms of late blight, tuber and stem rot and can lead to 100 percent yield loss. Humans are affected by late blight because the leafy stage restricts tuber production, infections on tubers eliminate a potential food supply. Numerous management strategies for late blight have been developed and are in use globally. Implementing an integrated disease management strategy is necessary for the disease's effective control. This review focused on prevalence, life cycle of Late blight caused by *Phytophthora infestans* and also emphasized on its management including various strategies, such as integrated disease management, chemical control, and cultural control.

Introduction

The *Solanum tuberosum* L. (potato) is a significant tuberous yield grown for use in food and processed goods. Since potatoes are essentially a moderate crop, they grow best in areas where the temperature stays consistently low (15–30 °C). For the purposes of potato cultivation, tiny or big tubers with eyes are often utilized as propagation parts. More than 80% of the world's potato production is concentrated in Europe and Asia (Axel *et al.,* 2012; FAOSTAT, 2016). Followed by Russia and India, China is the world's top potato producer (Table 1). Over 24 million ha of field in Pakistan produces multiple crops, among which an average of 1.3 million hectare is used for the potato cultivation, which produces around 20 MT/ha (FAOSTAT, 2016; Sajid, 2012).

The proportion of potato produced, and the area harvested globally have increased because of excellent climatic conditions and the crop's acceptability for domestic usage (FAOSTAT, 2016; Sajid, 2012). Figure 1 shows top 5 countries with maximum production of potato crop.

Apart from the high production, majority of the crop suffers severe damage and harvest loss due to some diseases caused by pathogens. A fungus in the class Oomycetes called *Phytophthora infestans* causes late blight of potatoes. It is largest obstacle in the production of potatoes in Ethiopia (Kassa and Hiskias, 1996) and other nations of the globe (Fry and Goodwin, 1997). Among all potato diseases, it is the most well-known, well studied, and still the most harmful (Jones, 1998). The most important disease affecting potatoes and tomatoes globally is probably the late blight. According to the estimation, approx. $5 billion in losses occur yearly from late blight disease and the fungus is seen as a threat to world food security (Latijnhouwers *et al.*, 2004). One of them is the “Irish potato famine” of the 1840s, which was brought on by late blight (Mercure, 1998). Depending on the cultivar utilised, the disease reduced Ethiopian yields by 31–100% (HARC, 2007).

Humans are affected by late blight because the foliar phase restricts tuber production, infections on tubers reduce a potential food supply, and so much effort and resources are used to stop both stages. The severe epidemics in the 1840s caused great human suffering, which was made even worse by the potato scarcity. Early 19th-century Ireland had established a "potato economy," where a sizable, impoverished population relied nearly entirely on potatoes for survival for most of the year (Bourke, 1993). The great production of potatoes allowed for a population expansion, and the famine brought on by the food shortages brought on by the blight epidemic caused an estimated three million people to die and to migrate.

During the years 1916 and 1917, Germany endured a severe famine brought on by the late blight of potatoes. Because the defense production is so demanding and copper a key component of Bordeaux mixture is in limited supply. The supply of potatoes for soldier families was limited due to improper late blight management. The morale of the German troops was impacted by the deaths of many. Some observers speculate this could have led to the defeat of the Germans in World War I (Horsfall and Cowling, 1978).

Late blight's geographic prevalence

In distinct parts of the world, the late blight is one of the most common, researched, and dangerous potato diseases (Erwin and Ribeiro, 1996). This illness has become more widespread during the last 20 years (Fry and Goodwin, 1997). It is generally always found in potatoes fields (Paul, 1992). This is one of the rare plant diseases which can severely damage a crop and cause massive crop loss. During rainy and winter season, late blight may result in the destruction of every plant in a field within a week or two (Paul, 1992; Hooker, 1981; Fry *et al.*, 1993; Van der Zaag *et al.*, 1996). Tomatoes and many other Solanaceae family members are also severely hindered by the illness. Late blight can lead to the destruction of tomato and potato plant leaves and stems at any point during the growing season. Furthermore, it targets tomato fruits and potato tubers in the field, causing them to rot there or during storage (Paul, 1992). It destroys potato plants' leaves, stems, and tubers (Mercure, 1998).

Late blight has potentially expanded its association with global trade of potato seed (Van der Zaag *et al.*, 1996). In regions like Ethiopia where peasant farmers are aware of the disease's origin, epidemiology, and management, it is the most devastating potato disease. All of Ethiopia's primary potato-producing areas are affected by the disease (GILB and CIP, 2004a).

Even though late blight has a clearly destructive potential, measuring losses caused by this disease is particularly challenging since other variables concurrently impact the tuber yield (Madden, 1983). In India, losses are higher in mountainous areas than in the plains where crops are cultivated in rainfed environments. However, the disease has emerged as a significant biological component that is reducing potato output nationwide, especially in the plains and plateau.

According to estimates, potato late blight cost the US economy 210 million dollars nationwide (Guenthner *et al.*, 2001). The CIP has calculated the total cost of late blight damage in developing nations using a 15% average output loss. The above results in an overall output loss of around 2.75 billion US dollars in developing nations. Fungicide consumption is an important indicator of potato late blight's economically impact since it is simpler to calculate the cost of fungicides than crop loss. Using this information, CIP calculated that fungicide usage in developing nations costs 750 million US dollars. According to these figures, the US, Europe, and developing nations spend roughly $1 billion USD year on fungicides to fight late blight (GILB and CIP, 2004b).

The average worldwide crop loss due to all illnesses combined was around 12.8% of the amount that might have been produced, while the potato alone faces a loss of 21.8% (James, 1990). Both a susceptible variety and an unimproved local cultivar in Ethiopia had 100% crop loss because of the disease (Kassa and Hiskias, 1996). In high humid altitudes, late blight significantly reduces potato yields, with typical yield losses on susceptible types estimated to be between 30 and 75 percent (Olanya *et al.*, 2001). According to the vulnerability of the varieties, research institutions have estimated losses ranging from 6.5 to 61.7% in many different nations in recent years, as per data in table 2.

According to research from Fekede *et al.*, (Girma *et al.*, 2013; Tsedaley *et al.*, 2014), late blight of the potato causes loss of tuber production in Ethiopia. Although it is true that late blight may appear at any time throughout the growing season, it is most prevalent in the late summer and early autumn (Bevacqua, 2000). Due to the loss or destruction of potato crops, potato late blight in North America's temperate zones has had a significant negative economic effect for many years (Guenthner *et al.*, 2001). The weather in India's north-eastern hills is better suited for the advent of late blight and lasts for a longer time as a consequence; as a result, it is frequent and severe there.

Life cycle and Epidemiology of late blight

The first symptom of late blight in a field is the presence of small, irregularly shaped, light- to dark-green lesions that are streaming with water (Kirk *et al.*, 2013). These often start to show up upward on lower leaves since they are in a more humid environment (Martin *et al.*, 1994). However, they start appearing on the top leaves on favorable conditions where the pathogen has been brought into the field by air flow (Mutegi; Girma *et al.*, 2013). In humid environments, the lesions rapidly spread to form brown, deteriorated areas with shoddy borders. On the inner surface of the leaves, a zone of white, downy mildewy growth that is 3-5 mm broad develops around the margin of the lesions. The infection spreads quickly, killing and injuring whole leaves (Paul, 1992). Mycelium grows profusely between host cells, causing cellular injury that emerges as greenish brown or yellowish blotches and eventually become black as the condition progresses (Fig.2). When the environment is favorable for *P. infestans* development, other potato sections suffer significant damage that causes whole plants to wilt (Fig 3).

Phytophthora infestans may persist on other solanaceous plants, in the soil, and in live host tissue including tubers seed (Shinners *et al.*, 2003), heaps of cull, and potatoes volunteer that overwinter in the region. It typically persists from year to year in heaps of cull potatoes, infected tubers stored in storage, or in infected tubers undetected during harvest that do not freeze during the winter (volunteer potatoes).

The bottom surface of the leaf may develop a white, mildew-like growth around the lesion's margin because of the fungus. Late blight is distinguished from a variety of other foliage potato diseases by its white bloom. *P. infestans* sporangia may be spread by wind, precipitation, mechanical methods of transportation, and animals from healthy plants within one area to infected plants in other fields. During the various phases of the fungus' life cycle, the humidity and temperature that prevail have a significant impact on the development of late blight infections. When the fungus becomes established in a field, it may go through several reproductive cycles in a season, which promotes the disease's transmission.

In a couple of days or weeks, single potato plant or the entire potato field may become blighted and perish. In dry environments, the pathogen's activities are reduced or stopped. No oomycete can be seen on the beneath of the leaves, and the lesions that exist already cease developing before turning into black, curled, and withered areas. The oomycete begins to function when the climate becomes damp once again, and the illness spreads swiftly.

At the temperature between 7-13°C, sporangia may germinate and generate 8–12 motile zoospores per sporangium based on quantity of water present on the leaves. Plants may get infected by encysted zoospores either directly through a germ tube on the leaf surface or indirectly through stomata. The mycelium continues to replicate into new cells, eradicating older infected ones. However, when the infection spreads, existing lesions grow and form new ones, often causing damage to the foliage and lowering potato tuber production.

When sporangia are washed off the leaves and dispersed into the soil by rain, the second stage of infection starts in the field. Through lenticels or lesions, growing zoospores infect the tubers and continue to develop there. The mycelium in the tuber mostly develops in the spaces between the cells and disperses haustoria internally. The infection may also spread to tubers that were contaminated with active sporangia during harvest from the soil or through sick foliage. However, most of the blighted tubers decompose underground, or while being preserved. The fungus may grow and produce spores best in environments with relative humidity levels close to 100% and temperatures between 15 and 25 °C.

Phytophthora infestans - Disease Symptoms, Mode of Infection, and Propagation

P. infestans is a diploid, mycelial plant pathogen that belongs to the Kingdom Fungi due to several traits common to fungi. The pathogen produces sporangia with a lemon form on branching mycelium. When these sporangia separate from the parent mycelium, they act as asexual propagation organs that spread the pathogen's mycelia on host tissues by mechanical, wind, and rainfall mechanisms. While zoospores are formed when moisture is available and the temperature is low, between 10-15°C, lemon-shaped sporangia germinate instantly when the environment is dry and above than 20°C in temperature (Fry, 2008).

Mostly occurrences of the asexual cycle indicate the existence of a host and an appropriate environment. Sporangia and zoospores are incapable of long-term survival in soil, air, or water in the absence of a host. Despite asexual reproduction, the presence of matable hyphae (A1 and A2) may promote sexual mating, resulting in the development of antheridia and oogonia that are brought together by hormonal signals to produce oospores (Chern *et al.,* 1996).

Asexual reproduction may occur more rapidly in moderate, moist environments than sexual reproduction does, but generally, it seems that temperature and humidity have little impact on whether efficiently sexual reproduction occurs. Oospores have an advantage over sporangia and zoospores in that they may survive in soil for up to four years and are resistant to dryness and higher temperatures (Yuen and Andersson, 2013). *P. infestans* may thus reproduce asexually to produce sporangia and zoospores for the current cropping season and sexually to produce oospores for the next cropping season. Both types of inoculums—sporangia, zoospores, or oospores—can infect new plants when they encounter them and are found in tubers, soil, leaves, and other plant waste. Usually, sporangia, zoospores, or oospores access the host through the stomata of leaves and stems; however, the peel of a tuber or injured regions may indeed offer as an inviting surface for infection. When the pathogen puts the host tissues under stress, its mycelium begins to expand. To rupture the host cell wall and allow for nutrition absorption, specialized circular structures called haustoria are created (Whisson *et al.,* 2016).

The mycelia on the lower leaves become apparent due to sporangia development on sporangiophores, which starts sporulation, in moist environments (Schumann *et al.,* 2005). The sporangia are subsequently transported by air over a great distance from the infection sites to healthy tomatoes and potatoes. When sporangial spores come in contact with the host's leaves, they either instantly produce a germ tube or, if moisture is present, produce flagellated sporozoites that produce signs of disease within two or three days. A complicated process that requires interaction between the host and the virus while taking the environment's influencing aspects into account is the successful infection and establishment of the late blight disease. This interaction is controlled by several variables, including the amount of moisture present, the current temperature, the pathogen's virulence, and the level of host plants' resistance. Increased disease damage is induced by optimal pathogen growth circumstances, resulting in greater agricultural losses.

Potato genes for Long-Term Resistance to *Phytophthora infestans*

More than 150 years ago, the outbreak of late blight in Europe caused a rise in potato breeding. Conventional breeding involved fertilising a variety with a desirable characteristic, such as resistance to blight, with pollen from a high producing potato variety. When the *Solanum demissum* resistance gene from a wild species was introduced into the new variety, breeders appear to have presumed that late blight resistance had been achieved a number of times during the previous decades. When the new type was grown for a long time and on a large scale, however, the resistance was continued to lose. There was eventually enough inoculum (spores) built up to successfully infect the crop shortly after emergence, whether from appropriate spores from another source or from a mutation of the oomycete.

The inclusion of a single gene from the wild potato species *Solanum demissum* was done after 100 years of domestication had no effect. After transferring genes from other wild species, it may take up to 50 years to generate a variation, and even then, it might be difficult to improve the current ones. Due to its exceptional quality and the availability of chemical blight control, a variety of Russet Burbank from the USA and Bintje from the Netherlands are still commonly grown. Creating resistant cultivars by introgression breeding with genes other than those from *S. demissum* is an alternative strategy.

Recently, two resistant cultivars were developed and are currently used in the organic potato production in the Netherlands. Due to the potential advantages of a late blight-free potato cultivar for the environment, human health, food security, and economic profit, the Netherlands government funded Wageningen University and Research Center's efforts to develop a potato with Durable Resistance against Phytophthora (the DuRPh project) in 2006 with funding of up to $ 1 million per year for 10 years (Haverkort *et al.*, 2008).

Management of late blight

Farmers that use integrated pest management have significantly decreased their demand on chemical pesticides while improving crop output. For the purpose of controlling late blight, an integrated disease management plan must be created. Controlling late blight requires integrating many management strategies, including resistant cultivars, fungicides, and cultural techniques (excellent crop husbandry). Potato late blight may be effectively managed by combining hygienic practices, resistant cultivars, and timed or coordinated chemical treatments. Many management strategies for late blight have been created and set to practice. Implementing an integrated disease management strategy is essential for the illness's effective control. The adoption of resistant cultivars, cultural practices, and chemical controls are the most crucial strategies.

Cultural methods

For the control of late blight, many cultural strategies could be used. The primary line of protection against late blight is cultural practices (Kirk, 2009; Kirk *et al.,* 2013). By lowering the pathogen's survival, reproduction, dissemination, and penetration, cultural practices may be used to lower the population of the disease. Although it is feasible to lessen *P. infestans* ability to spread infection by using only unaffected seed tubers, preferably certified seed, eliminating any crops and volunteer potatoes, avoiding frequent or excessive watering, making sure there is appropriate soil covering (Draper *et al.,* 1994), using appropriate reaping, and storing techniques, and using fungicides as required, late blight may be prevented (Davis *et al.,* 2009). The best method for controlling late blight is to stay away from inoculum sources. Infected cull pile potatoes, infected seed tubers, and contaminated volunteer potato plants that made it through the winter, are likely to be the first sources of inoculum.

Therefore, it's essential to keep the process sterile by getting rid of all cull and volunteer potatoes. To prevent the spread of late blight on seed, particularly novel strains of the illness, seed suppliers should be carefully chosen (Kirk, 2009). At the time of harvest, if the partly blighted leaves and stems are still alive, it is imperative to destroy them with tools or chemical sprays (pesticides) or to remove the terrestrial sections of potato plants. Utilizing disease-free, healthy seed, removing rogue potato plants, hilling with enough soil, and managing plant nutrition are examples of cultural methods (Garrett and Dendy, 2001). For effective management of the disease, it is essential to avoid the factors that encourage late blight growth. The weather has a significant impact on the frequency and severity of late blight. Even though there aren't many methods to change the weather, field selection and well considered irrigation techniques may greatly shorten the periods when disease development is favourable. In fields with proper drainage and water infiltration, potatoes should be grown. Potato pieces from seed cutting procedures and Cull potatoes that were left over after loading or unloading at storage facilities should be removed as soon as possible after planting and during the growing season because they could encourage the formation of inoculum whether the pieces are sprouting or not. Controlling weeds and alternative late blight hosts, like the Solanaceae family of hairy nightshades, which may sometimes help the disease spread, is also beneficial.

Sprinkler watering must be carefully thought out or minimized since wet conditions are favorable to infection, particularly late in the growing season when the closed potato canopy promotes the development of late blight. To promote improved air circulation and faster drying of the leaves, rows should ideally be positioned parallel to the direction of the prevailing winds. Studies carried out in Israel discovered that the frequency of late blight infection was greater on potatoes watered in the morning as opposed to noon or evening (Carlson, 1994).

Applying too much fertilizer or irrigation during the late season should be avoided. Spraying foliage with labelled fungicides after vine killing may also be helpful to eliminate spores of late blight that are still alive on the foliage. Tuber damage should be kept to a minimum during harvest (Kuepper and Sullivan, 2004). When tubers are kept after being harvested, the humidity and temperature of the storage area should be kept under control, and the tubers should be dry when placed in storage. Separately store tubers harvested from healthy fields and those from farms with an infection. Potatoes should be kept dry and as cold as possible to avoid disease growth and spread. To stop the spread of illness, it is advisable to regularly inspect all stored potatoes and remove any sick tubers (Ston, 2009).

Chemical methods

The primary strategy used to stop the spread of late blight on a worldwide scale has been the use of fungicides (CIP, 1989). Fungicides are often used to guard healthy plants against infection by plant diseases, as opposed to pesticides and certain weed killers that kill established pests or weeds. Fungicides only provide temporary protection since they may weather and degrade over time.

When a disease threatens, they must also be administered at certain intervals to preserve new growth (Lyr, 1987). Fungicides used to treat late blight fall into one of two major mobility categories: penetrant or protectant. If used promptly, fungicides may reduce or halt the emergence of new symptoms but cannot reverse existing signs of late blight (McGrath, 2004).

Because of this, most fungicides must be used either before illness develops or as soon as symptoms start to show. Also, late blight damage to plants often endures long after the infection has been treated. Only young, healthy growth is immune to the fungus by fungicides. When a plant has already been affected by a disease, many fungicides are often useless (Nsemwa *et al.,* 1992).

To stop the potato late blight, several systemic and broad-spectrum fungicides are used. The two mating types (A1 and A2) produce new strains of oomycete that are ineffectual against them because they are resistant to several systemic fungicides, including metalaxyl.

Protective foliage spraying often leads to a significant decrease in tuber disease. In leaves with Systemic Acquired Resistance (SAR) induced resistance to *P. infectants*, haustoria development and hyphal growth look inhibited, altered, and damaged. Only the oomycete pathogen's cell walls and plant wall papillae in the leaves of treated plants contain specific proteins relevant to pathogenesis. In Ethiopia, it was discovered that using fungicides to suppress late blight increased potato output (Rees *et al.,* 1992; Mesfin and Giorgis, 2007; MAFRI, 2002).

The foliage must be completely covered with fungicide from top to bottom of the canopy, regardless of the method of treatment (ground or air, traditional or more modern sprays) (Shtienberg *et al.,* 1994).

Fungicides are often used in developing nations, even though it also raises production costs and has detrimental effects on the public health and environment. This is because resource-poor farmers consider fungicides to be effective.

Fungicides must be used often for effective control, maybe every five days for certain diseases. Frequent treatments are crucial to restore fungicides lost from the plant because of chemical breakdown, wind erosion, UV radiation degradation, and rainfall wash in addition to protecting new growth. Modern chemical management strategies concentrate a substantial emphasis on decreasing fungicide applications and use potato cultivars with acceptable levels of non-race specific late blight resistance.

Fungicide application to plants and the use of cultivars resistant to the disease are the main management strategies. However, attempts to cut down on the quantity of fungicide used in treating late blight have been made in response to worries about the public health, environment, and fungicide resistance. Since it offers the highest marginal rate of return, this has improved control of potato late blight (FAO, 2008).

IDM (Integrated Disease Management)

Farmers that use integrated pest management have significantly decreased their use on chemical pesticides while improving production (Kankwatsa *et al.*, 2002). Host resistance reduces the quantity of pesticides required to maintain feasible level of late blight, assisting with integrated disease management. Initial planting, improved variety, modification in treatment frequency based on host resistance of potato varieties are just a few of them (Tsedaley *et al.,* 2014).

Table.1 Nation wise crop loss due to Late Blight of Potato

Crop loss %	Country	Reference
10-75	West Bengal-India	[25]
20	Nepal	[26]
50-70	Pakistan	[27]
72	Ethiopia	[28]
75	England	[29]
80	Kenya	[30]

Table.2 Recent advances in management of potato late blight

S. No.	Treatment	Result
1.	Root treatment with benthiavalicarb, oxathiapiprolin or their mixture Zorvec-Endavia [ZE (3+7, w/w)]	Throughout the whole season, provide sustained systemic protection in a dose-dependent way against foliar oomycete.
2.	Nanostructures of silver oxide-titanium dioxide and silver oxide composite	Under laboratory circumstances, the composites greatly reduced *Phytophthora infestans'* radial growth in comparison to the untreated control.
3.	In-situ spectroscopy on potato leaves and non-destructive characterization of distinct disease physiology	Shortwave infrared wavelengths clearly differentiated between healthy and diseased plant
4.	4 B. subtilis isolates tested against late blight disease	When compared to the control, bacterial treatments considerably reduced the disease incidence of late blight.
5.	A star polymer (SPc) was developed to deliver plant elicitors/botanical fungicides at a reasonable cost.	The chitosan/SPc complexes, which were nanoscale in size, had improved control effects against potato late blight.
6.	Application of chitosan	Chitosan exhibited a synergistic impact with pesticides and dramatically reduced the mycelial development and spore germination of *Phytophthora infestans* in vitro. It also decreased the resilience of *Phytophthora infestans* to different harmful circumstances.

Fig.1 Top 5 highest potato producing nations in 2020

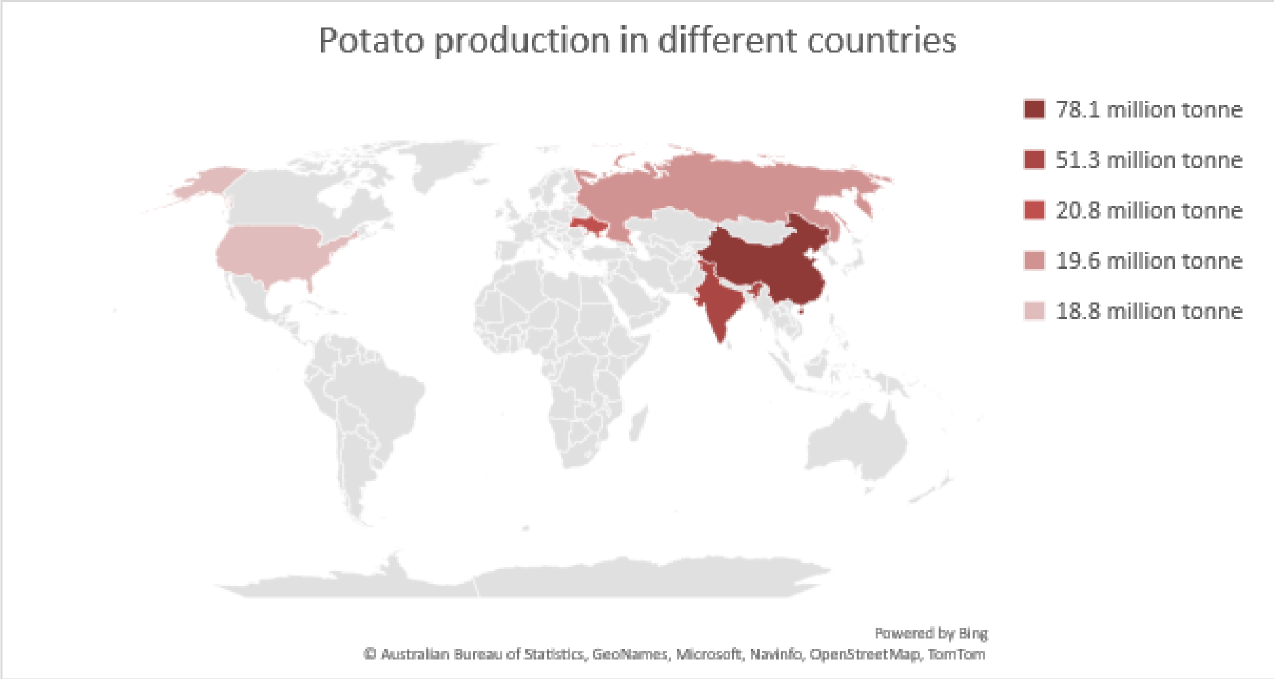
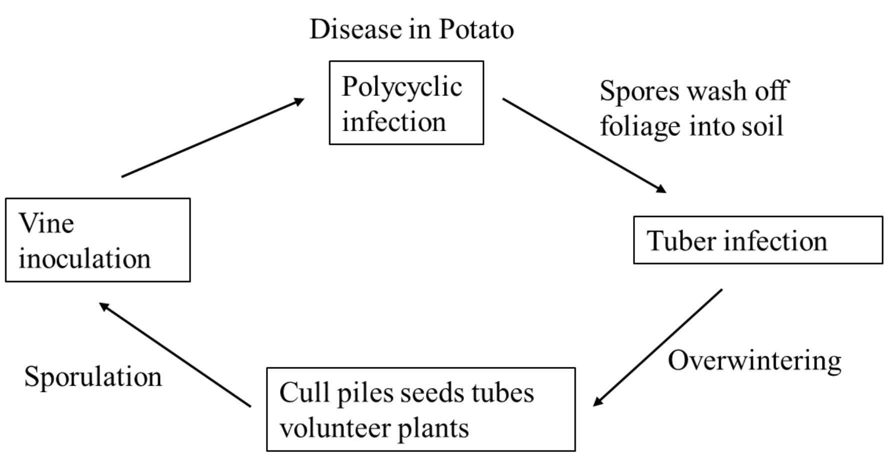


Fig.2 Late blight disease signs on potato leaves

Fig.3 Damage from late blight has caused completely wilted plants.

Fig.4 The *Phytophthora infestans* life cycle, which causes late blight.



The current management techniques for potatoes consist of the use of disease-free seed, the removal of cull heaps, the planting of resistant cultivars, and the killing of potato leaves 10 to 14 days before to harvest. It is essential to combine a lower rate of Ridomil treatment with moderately resistant potato varieties to reduce pollution and fungicide production costs while enhancing profitability and production of high-quality potato tuber yield (GILB and CIP, 2004a). To effectively combat late blight, all producers, large and small farms alike, must employ integrated management. The integration of moderately resistant cultivars and a reduced rate of Ridomil treatment reduced the frequency of late blight of potato at 59 days after planting of the disease evaluation. In comparison to premature planting (planting beyond the optimal month for potato growth), experimental plots with IDM-LB produced 50% and 75% greater yields (El-Hasan *et al.,* 2022).

Herbal approach

Over the last several years, there has been a rise in the search for plant extracts with anti-oomycete action, and effectiveness of plant extracts against *P.*

infestans has also been shown. Some of them have a great deal of promise for usage as natural fungicide substitutes. Another intriguing fact is that these substances, in several controlled tests, were just as effective as synthetic fungicides in preventing *P. infestans* from growing in vitro or at lessening the severity of late blight on host plants.

In order to determine if 357 root fungal endophytes from four solanaceous plant species collected in Kenya had any antagonistic activity against the pathogen that causes potato late blight in vitro, El-Hasan *et al.*, 2022 also tested the endophytes' performance in plants. 46 of these isolates showed potential efficacy against the pathogen in preliminary in vitro studies, which were conducted. Leaflets pre-treated with a 5% extract from these endophytes totally reduced the mycelial development of *P. infestans* and the signs of late blight (Turóczi *et al.*, 2020). In a similar vein, Turozi *et al.*, under laboratory and field circumstances evaluated the impact of a black poplar (*Populus nigra*) populin extract on seven different late blight strains. After applications of 3 and 4 v/v% populin, it was shown that the growth rate of hyphae was dramatically reduced in vitro (Lal *et al.*, 2021).

In research by Lal *et al.*, (2021), neem oil was also shown to lessen the prevalence of late blight (Khan *et al.*, 2019). The anti-P. infestans effectiveness of extracts from *Moringa oleifera* (Sohanjna), *Azadirachta indica* (Neem), *E. camaldulensis* (Safeda), and *Acacia nilotica* (Keekar) was investigated. When compared to controls, the results showed that all plant extracts dramatically reduced the pathogen's ability to develop mycelia. However, *A. indica* (59.77%) outperformed all other treatments substantially, followed by *M. oleifera*, among all plant extracts (Hakiza *et al.*, 1999).

Host Plant Resistance

The resistant showed by the host plant against the pathogen may be attributed to the long-term financial benefits for farmers. Moreover, it reduces *P. infestans* population structure alterations, which reduces the potential of fungicide resistance (Mukalazi *et al.*, 2001; Njualem *et al.*, 2001). One of the most efficient and sustainable ways to manage the infection is to utilise resistant types. Thus, *P. infestans* resistance breeding began in the 19th century and has proceeded slowly ever since. Many studies have shown that various potato types vary in their susceptibility to late blight (Njualem *et al.*, 2001). Late blight resistance is also being sought for through biotechnology. However, organic farming cannot use genetically modified plants (Shapiro and Hager, 1998). A single gene controls blight resistance, therefore new fungus strains may entirely wipe away potato cultivars with strong blight resistance. Some types have low resistance levels, which might provide some protection during dry seasons but are not very advantageous.

In partially resistant types regulated by inconsequential genes in conjunction with a low dose of fungicide, blight may be managed. Even during the annual rainfall growing seasons, cultivars with high degrees of resistance may be cultivated without chemical protection. Many resistant types are prepared for main crop. Early maturing kinds, apart from a few cultivars, are often prone to the illness. While some types have good leaf resistance, they are susceptible to tuber blight. Others, however, exhibit weak foliage-blight resistance but strong resistance to tuber blight. A cultivar should ideally exhibit strong resistance against both foliar and tuber blight (Anonymous, 2007). When the terms "durable" or "polygenic" are used, they are often taken to mean cultivars with intermediate degrees of resistance, but they may also refer to cultivars with extremely high levels of resistance. Reduced fungicide use has been made possible by polygenic resistance. As compared to susceptible cultivars, cultivars with polygenic resistance exhibit much lower values for the region under the disease progress curve (AUDPC). The introduction of field-resistant plants may assist in reducing the development rates of pathogens. The degree of late blight resistance shown by commercial potato cultivars varies, and a management strategy may be developed taking this variety into consideration. The best types for tolerating late blight are still those that are supported by lower fungicide dosages and treatment rates, even if several recently released, superior varieties have lost their resistance to the disease. Utilizing resistant cultivars, which thrive in tropical climates, is one of the primary management techniques for late blight.

Late blight may be decreased using generally resistant potato genotypes and enhanced cultural techniques. Because late blight may seriously harm these types during favorable climatic conditions unless plants are treated with an effective protective fungicide, relying just on genetic resistance to manage late blight is inadequate. To reduce the risk of being unexpectedly attacked by fungal races to which they are not resistant, even resistant cultivars should be treated with fungicides on a regular basis. Even though fungicide spraying is the primary method of disease management, it is always desirable to use resistant varieties since they delay the appearance of the disease or slow its progression, enabling fewer treatments on resistant types to achieve a tolerable level of disease control.

Recent advances in management of potato late blight

As *P. infestans* has become a major concern for the food security, it is important to continue advancements to stop or limit the spread of this infection.

Finding the main production barrier for potatoes is crucial since they are a valuable crop that may protect low-income nations from the hazards presented by increasing food costs. Late blight is the most severe of its production restrictions and may result in a complete crop loss. With its very high rate of multiplication and ability to infect and damage host tissue, *P. infestans* poses significant obstacles to the use of alternative chemicals to treat late blight. Therefore, choosing and putting into practice an effective management plan for it requires a thorough knowledge of its genesis, epidemiology, and life cycle. The impact of potato late blight may be reduced by a variety of management techniques. However, because to the introduction of new strains, there is no one management method for potato late blight that is successful worldwide. Therefore, it is crucial to create new methods of treating this illness and overcoming the issue of resistance.

References

Anonymous. Knowing Your Enemy-Blight 2007. Available on: http://sarvari-trust.org/late blight.html /05/07/2014.

Axel C, Zannini E, Coffey A, Guo J, Waters D M, Arendt E K. 2012. Ecofriendly control of potato late blight causative agent and the potential role of lactic acid bacteria: a review. Applied microbiology and biotechnology. 96(1):37-48. https://doi.org/10.1007/s00253-012-4282-y

Bevacqua K J. Late Blight of Potato and Tomato. Yard and Garden. Mannesota University Extension Service. 2000.

Bourke A. 'The visitation of god? 'The potato and the great Irish famine. Lilliput Press Ltd; 1993.

Carlson H. Potato pest management guidelines. University of California Statewide IPM Project. Available on www. ipm. ucdavis. edu/PMG/r607101211. html. 1994.

Chern L L, Ko W H, Tang C S. Factors affecting yields of α hormones of *Phytophthora parasitica* obtained by adsorption. Canadian journal of microbiology. 1996 Feb 1;42(2):172-6. https://doi.org/10.1139/m96-025

CIP (International Potato Center). Fungal diseases of potato. Report of planning conference on fungal diseases of the potato. (1989). CIP, Lima, Peru, September 21-25, 216pp.

Davis, R. M., Nunez, J. & Aegerter, B. J. Potato Late Blight. Statewide IPM Program, Agriculture and Natural Resources, (2009). University of California.

Draper M A, Secor G A, Gudmestad N C, Lamey H A, Preston D. Leaf blight diseases of potato.

NDSU Extension Service: (publication) (USA). 1994.

El-Hasan A, Ngatia G, Link T I, Voegele R T. Isolation, Identification, and Biocontrol Potential of Root Fungal Endophytes Associated with Solanaceous Plants against Potato Late Blight (*Phytophthora infestans*). Plants. 2022 Jun 18;11(12):1605. https://doi.org/10.3390/plants11121605

Erwin D C, Ribeiro O K. Phytophthora diseases worldwide. American Phytopathological Society (APS Press); 1996.

FAO (Food and Agriculture Organization). (2008). Potato World: Africa-International Year of the Potato. http://www.potato2008.org/en/world/africa.html.

FAOSTAT. 2016. Food and Agricultural Organization Statistical database, Crop production. http://faostat3.fao.org/download/Q/QC/E (accessed on 1st January 2016)

Fry W E, Goodwin S B. Re-emergence of potato and tomato late blight in the United States. Plant disease. 1997 Dec;81(12):1349-57. https://doi.org/10.1094/PDIS.1997.81.12.1349

Fry W E, Goodwin S B. Resurgence of the Irish potato famine fungus. Bioscience. 1997 Jun 1;47(6):363-71.

Fry W. *Phytophthora infestans*: the plant (and R gene) destroyer. Molecular plant pathology. 2008 May;9(3):385-402. https://doi.org/10.1111/j.1364-3703.2007.00465.x

Fry, W. E., Goodwin, S. B., Dyer, A. T., Matuszak, J. M., Drenth, A., Tooley, P. W., Sujkowski, L. S., Koh, Y. J., Cohen, B. A., Spielman, L. J., Deahl, K. L., Inglis, D. A. & Sandlan, K. P. (1993). Historical and recent migrations of *Phytophthora infestans*: Chronology, pathways, and implications. Plant Disease, 77: 653- 661. https://doi.org/10.1094/PD-77-0653

Garrett K A, Dendy S P. Cultural practices in potato late blight management. Complementing resistance to late blight in the Andes. 2001 Feb:13-6.

GILB (Global Initiative on Late Blight) and CIP (International Potato Center). (2004a). Ethiopia: Potato Production Areas and Average Yields. Available on: http://gilb.cip.cgiar.org/countryprofiles/africa/ethiopia/ Accessed at 29/3/2014.

GILB (Global Initiative on Late Blight) and CIP (International Potato Center). (2004b). Social Impact and Economic Importance of Late Blight. Available on: http://gilb.cip.cgiar.org what is late blight/ economic impact/social impact and economic importance of late blight/ Accessed at 29/3/2014.

GILB (Global Initiative on Late Blight) and CIP (International Potato Center). (2004a). Ethiopia: Potato Production Areas and Average Yields. Available on: http://gilb.cip.cgiar.org/countryprofiles/africa/ethiopia/ Accessed at 29/3/2014.

Girma F, Ayalew A, Dechassa N. 2013. Management of late blight (*Phytophthora infestans*) of potato (*Solanum tuberosum*) through potato cultivars and fungicides in Hararghe Highlands, Ethiopia. International Journal of Life Sciences. 2(3):130-8.

Guenthner J F, Michael K C, Nolte P. The economic impact of potato late blight on US growers. Potato Research. 2001 Jun;44(2):121-5. https://doi.org/10.1007/BF02410098

Hakiza J J. The importance of resistance to late blight in potato breeding in Africa. In Proceedings of the global initiative on late blight conference 1999 Mar 16 (pp. 47-48). https://doi.org/10.12691/wjar-5-3-7

HARC (Holetta Agricultural Report Center). In: "Impact of farmers' selected IDM options on potato late blight control and yield". (Mesfin Tesserra & Gebremedhin W/giorgis. 2007). Printed in El-Minia- Egypt. African Crop Science Conference Proceedings, 8: 2091-2094.

Haverkort A J, Boonekamp P M, Hutten R, Jacobsen E, Lotz L A, Kessel G J, Visser R G, Van der Vossen E A. Societal costs of late blight in potato and prospects of durable resistance through cisgenic modification. Potato research. 2008 Mar;51(1):47-57. https://doi.org/10.1007/s11540-008-9089-y

Hooker W J. Compendium of potato diseases, American Phytopathological Society, St. Paul, M N. 1981.

Horsfall J G, Cowling E B. Pathometry: the measurement of plant disease. New York: Academic Press; 1978.

James W C. Estimated losses of crops from plant pathogens. CRC handbook of pest management. 1990;1:5-0.

Jones, G. D. (1998). The Epidemiology of Plant Diseases. 3rd Edition. Kluwer Academic Publishes London. 371- 388pp.

Kankwatsa P, Adipala E, Hakiza J J, Olanya M, Kidanemariam H M. Effect of integrating planting time, fungicide application and host resistance on potato late blight development in south-western uganda. Journal of Phytopathology. 2002 May;150(4-5):248-57. https://doi.org/10.1046/j.1439-0434.2002.00750.x

Kassa B, Hiskias Y. Tuber yield loss assessment of some potato cultivars with different levels of resistance to late blight. In Proceedings of the 3rd Annual Conference of Crop Protection Society of Ethiopia (Eshetu Bekele, Abdurahman Abdulahi and Aynekulu Yamane, eds), CPSE, Addis Abeba, Ethiopia 1996.

Khan R A, Ghazanfar M U, Raza W. Eco-friendly management of *Phytophthora infestans* causing late blight of potato. International Journal of Botany Studies. 2019;4(2):144-7.

Kirk W, Wharton P, Hammerschmidt R, Abu-elSamen F, Douches D. Late blight. Michigan state university extension bulletin E-2945. East Lansing, MI. Available on: http://www. Potato diseases. org/lateblight. html. 2013.

Kirk W. Potato late blight alert for the Midwest. Field Crop Advisory Team Alert Curent News Articles. 2009.

Kuepper G, Sullivan P. Organic alternatives for late blight control in potatoes. Organic alternatives for late blight control in potatoes. 2004(IP131).

Lal M, Chaudhary S, Rawal S, Sharma S, Kumar M, Chakrabarti S K. Evaluation of bio-agents and neem based products against late blight disease (*Phytophthora infestans*) of potato. Indian Phytopathology. 2021 Mar;74(1):181-7. https://doi.org/10.1007/s42360-021-00330-6

Latijnhouwers M, Ligterink W, Vleeshouwers V G, van West P, Govers F. A. 2004. Gα subunit controls zoospore motility and virulence in the potato late blight pathogen *Phytophthora infestans*. Molecular Microbiology. 51(4):925-36. https://doi.org/10.1046/j.1365-2958.2003.03893.x

Madden L V. Measuring and modeling crop losses at the field level. Phytopathology. 1983 Jan 1;73(11):1591-6.

MAFRI (Manitoba Agriculture, Food and Rural Initiatives). Integrated Management of Late Blight in Potatoes. (2002) Published by the Pest Management Regulatory Agency.

Martin A D, Gary A S, Neil C G, Arthur H L, Duane P. Leaf blight diseases of potato. North Dakota State University Agriculture and University Extension. 1994.

McGrath M T. APSnet Education Center-Introductory Topics-What are Fungicides. Cornell University. 2004.

Mercure P. Early blight and late blight of potato. University of Connecticut. Integrated Pest Management. 1998.

Mesfin T, Giorgis G W. Impact of farmers' selected idm options on potato late blight control and yield. In8th African Crop Science Society Conference, El-Minia, Egypt, 27-31 October 2007 (pp. 2091-2094). African Crop Science Society.

Mukalazi J, Adipala E, Sengooba T, Hakiza J J, Olanya M, Kidanemariam H M. 2001. Metalaxyl resistance, mating type and pathogenicity of *Phytophthora infestans* in Uganda. Crop Protection. 1;20(5):379-88.

Mutegi R K. Influence of Farmer Field Days in Communicating Agricultural Research

Information at the Mwea Irrigation Agricultural Development (Miad) Centre: a Case of Topshot Herbicide (Doctoral dissertation, university of Nairobi).

Njualem D K, Demo P, Mendoza H A, Koi J T, Nana S F. Reactions of some potato genotypes to late blight in Cameroon. African Crop Science Journal. 2001 Mar;9(1):209-13. https://doi.org/10.4314/acsj.v9i1.27641

Nsemwa L T, Mwalyego F M, Kabungo D A. A review of past crop protection research in the Southern Highlands of Tanzania and prospects for the future. In Proceedings of an international conference on agricultural research, training and technology transfer in the southern highlands of Tanzania: past achievements and future prospects 1992 Oct (pp. 5-9).

Olanya O M, Adipala E, Hakiza J J, Kedera J C, Ojiambo P, Mukalazi J M, Forbes G, Nelson R. 2001. Epidemiology and population dynamics of *Phytophthora infestans* in Sub-Saharan Africa: progress and constraints. African Crop Science Journal. 9(1):185-93. https://doi.org/10.4314/acsj.v9i1.27638

Paul H. The potato crops. The scientific basis for improvement. 2nd Eds. London. 403pp. 1992.

Rees D J, Ekpere J A, Kamasho J A, Gillings S I, Mussei A N, Temu A E. Adapting research to farmers' circumstances in the southern highlands of Tanzania. In Proceedings of an international conference on agricultural research, training and technology transfer in the southern highlands of Tanzania: past achievements and future prospects 1992 Oct (pp. 5-9).

Sajid Z A. Biochemical characterization of in vitro salt tolerant cell lines and regenerated plants of potato (*Solanum tuberosum* L.) 2012. PhD Thesis University of the Punjab.

Schumann G L, Arcy C J, Cai G H. Late blight of potato and tomato. Late blight of potato and tomato. 2005. https://doi.org/10.1094/PHI-I-2000-0724-01

Shapiro L, Hager M. Is organic better? Newsweek. 1998;131(22):54-7.

Shinners, C. T., Bains, P., McLaren, D. & Thomson, J. Commercial Potato Production - Disease Management. Guide to commercial potato production prairies (2003). Western Potato Council. Available on: http://www.gov.mb.ca/agriculture//crops/potatoes/bda04s07.

Shtienberg D, Raposo R, Bergeron S N, Legard D E, Dyer A T, Fry W E. Incorporation of cultivar resistance in a reduced-sprays strategy to suppress early and late blights on potato. Plant Disease. 1994;78(1):23-6. https://doi.org/1094/PD-78-0023.

Ston, A. Organic Management of Late Blight of Potato and Tomato (*Phytophthora infestans*). Sustainable Agriculture Research and Education 2009. Oregon State University. Available on: http://www.extension.org/pages/18361/ Accessed on 22/03/2014.

Tsedaley B, Hussen T, Tsegaw T. Efficacy of reduced dose of fungicide sprays in the management of late blight (*Phytophthora infestans*) disease on selected potato (*Solanum tuberosum* L.) varieties, Haramaya, Eastern Ethiopia. Journal of Biology, Agriculture and Health Care. 2014;4(20):46-52.

Tsedaley B, Hussen T, Tsegaw T. Tuber yield loss assessment of potato (*Solanum tuberosum* L.) varieties due to late blight (*Phytophthora infestans*) and its management Haramaya, Eastern Ethiopia. Journal of Biology, Agriculture and Healthcare. 2014b. 2014;4(23):45-54.

Turóczi B, Bakonyi J, Szabó K A, Bálint J, Máthé I, Lányi S, Balog A. In vitro and in vivo effect of poplar bud extracts on *Phytophthora infestans*: A new effective biological method in potato late blight control. Plants. 2020 Feb 8;9(2):217.

Van der Zaag D E, Asscheman E, Bokx J A, Brinkman H, Bus C B, Hotsma P H, Meijers C P, Mulder A, Scholte K, Turkensteen L J, Wustman R. Potato Diseases, Disease, Pest and Defects. NIVAA. The Netherlands. 1996.

Whisson S C, Boevink P C, Wang S, Birch P R. 2016. The cell biology of late blight disease. Current Opinion in Microbiology. 1;34:127-35. https://doi.org/10.1016/j.mib.2016.09.002

Yuen J E, Andersson B. What is the evidence for sexual reproduction of P hytophthora infestans in Europe?. Plant Pathology. 2013 Jun;62(3):485-91. https://doi.org/10.11118/actaun201866051191

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