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POTATO YIELD GAP, LATE BLIGHT AND ITS HOST PLANT IMPORTANCE

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ABSTRACT
Potato is one of the food security and income fetching crops of the Ethiopian farmers. It plays a great role in escaping hanger during summer where other cereals are leafy and not edible. Potato is a highly productive, short season crop, easily processed and ready for consumption. Its production and productivity are affected by abiotic and biotic factors. Late blight is one of the highly devastating biotic factors that occur all over the potato growing areas of the world. This late blight is a fungal disease that has rapid multiplications and dissemination. The main sources of inoculums are infected tuber seeds, host plants, and volunteer potato plants. The inoculums are transmitted from the infected part to other potato growing areas by the wind. Potato growing farmers should strictly remove the host plants from around potato growing land and volunteer potato plants from the field of previously potato is grown land to minimize the source of inoculums and mitigate the occurrences of the late blight. Farmers in Ethiopia are giving almost no attention for volunteers and even do not know what these hosts plant looks like. But the impacts of these sources are as great as a source of inoculums for late blight and causing the highest yield losses. The research center and Wereda experts should work on awareness creation especially on the host plant growing year-round and are sources of inoculums for late blight.

KEWWORDS: Potato, late blight, Host plant, sporangia, and Fungus.

INTRODUCTION
Potato is reproduced in botanical seed (true potato seed), vegetatively using tubers, and sometimes in a controlled environment using cutting. The botanical seed of potato is the true potato seed formed from flower male and female joining and mostly used in breeding for creation of variation and selection for purposive varietal improvement. One flower of potato contains 100-200 genetically different seeds each of them can be considered as one clone different from the others. Potato is a cool-season crop or highland crop grown for food in many countries. It grows in between temperature ranges of 15-29^{0}c and altitude ranges of 1500-3200m a. s.l., respectively (Thomas et al., 2018). The annual rainfall range requirement of the potato crop is 400-1500mm while the pH requirement is 5-6.5. It can be grown below 5 up to 4.5 pH levels but micronutrient abundance which directly imposes toxicity and shortage of macronutrients like phosphorus is needed to be solved. Ethiopia has the highest natural resources gift which satisfies potato production requirements among African countries (FAO, 2008). As result, its production is rapidly expanding (Haverkort and Struik, 2015) and it is a strategic crop for increasing food security in Ethiopia (Abebe et al., 2013 and Hirpa et al., 2012). According to Thomas et al. (2018), potato production in Ethiopia is governed during the belg (February–May), kiremt (June–September), and off-season under irrigation. Among these cropping seasons, the belg is the most important season of potato production (Thomas et al., 2018) and its area coverage is 77% (Tufa, 2013). Less area coverage of irrigation production system is one of the problems of low yield of potato despite available large irrigable lands and water suitable for irrigation. The meher season is also good for the production of potatoes except for the prevalence of late blight which requires more cost and knowledge to control the disease's damage extent. The productivity of potatoes is depending on the cumulative effect of disease control, agronomic practices, variety planted, and climatic condition of the production seasons. In intensive agriculture, foreign country, a potato has found to yield up to 90 t/ha. But in Ethiopia, the national average yield is very much lower than this value (13.77 t/ha CSA, 2017). In the farmers' field, supported by research seed and agronomic techniques of production, it can yield up to 30 t/ha (Abebe et al., 2017). Farther more, in the research field, there is a Belete variety which can provide up to 47 t/ha. To reduce within-country yield variation the strategies to be followed will be increasing good quality seed delivery, facilitating high yielding variety production, improving research proved technology transfer to producers, and encouraging farmers

knowledge about various types available varieties, potato agronomic practices, and time of their implementation, the importance of disease-free planting materials, sources of quality seed tuber, care given to potato seed tubers during transporting and materials used for transporting as well as finally about potato seed tuber store.

On the other hand, to reduce the yield difference between other country and Ethiopia, strengthening research in line with new variety development, importing the technology and working on its adoption, developing varieties suiting the different agro-ecologies of the country(high land, midland, and low land), supporting different production season by research(main rainy season(June-August), Residual moisture growing season(September-November), irrigation (Dry season =December-February) and Belg season (March-May).

The main potato yield-reducing factor is potato agronomic management which is probably from economic weakness like fungicide application. Potato in Ethiopia requires application of late blight control fungicide 2-3 times when grown during the rainy season. During the rainy season, farmers lack purchasing power due to finishing their stored finance and there is no loaning aid private or government-supported organization for farmers. There is also the problem of chemical access during the rainy season as cars do not go in every part of the farmers' village due to road unsuitability. The disease damage behavior also worsens the problem as it requires one-two weak to completely devastate one field after lesion occurrence (Van der Zaag, 1996 and Agrios, 2005). Farmers are not capable to spray reluctant contact fungicides for preventing the development of the disease. There is not anything that indicates when to spray the contact fungicides in the country considering the climatic data. In other words, there is no a late blight forecasting program that estimates the disease's prevalence time and informs farmers to apply the chemicals. According to Abewoy (2018) yield losses of potato late blight was estimated to be 6.5-61.7. Even it can reach up to 100% based on variety tolerance and disease management extent (Shiferew et al., 2011). It can damage up to 100% especially when control measure is not applied (Rubio et al., 2005). The problem of storage after a late blight attacked is huge because damaged tuber rots soon after storage and can be used neither as seed tuber nor as food; it is generally unmarketable. This review simply gathers the information about late blight causal agent, mode of transmission, conducive environment and the host plants of potato late blight.

Potato Late blight

The potato late blight is a fungal disease caused by Phytophthora infestans which devastate potato crops universally. It has a wide host range including all Solanaceae family and some weeds. Late blight of potato is the most prevalent and devastating type of potato diseases which occur where ever potato grows. Under the favorable condition, it has fast multiplication rates and causes 100% crop failure where not control management is applied and susceptible varieties are allowed to be grown. The potato breeding program in Ethiopia worked for several years on variety improvement employing the two basic breeding objectives together with higher-yielding and late blight resistance. This is because producers in Ethiopia are unable to spray fungicide to potato crops in the field due to affordability and attitudinal problem. The potato tuber cost for food was low or cheap for a long time in the country. But, recently, potato for food purchase raised and become nearer to the cost of some cereals crop. Any Ethiopian farmers growing potatoes has now and then no longer a problem of economic feasibility. If they get higher-yielding variety only also, they can produce it with spraying similar to other countries as the other countries spay more than five times per season of production. In Ethiopia, the disease occurs throughout the major potato production areas and it is difficult to produce without chemical control application during the main rainy season (Shiferew et al., 2011). Due to the climatic change, the belg growing potato also face suitable environmental condition for potato production as it rarely requires the chemical application for late blight control. Previously, belg (February to May according to Thomas et al. (2018) receive short time rain which used to grow drought-tolerant cereals such as; sorghum, maize, and soon. Now, it receives almost all months a rain enough to grow potato even sometimes high rain followed by the heavy cloud which facilitates occurrences of late blight.

Dissemination of causal agent

The causal agent's spores disseminate from one location to another by the wind. One spore is enough to devastate one field when there is a favorable condition to germinate and penetrate a plant part in most cases leaves of potato where it grows and multiplies. Rain splash also wash leaves spores to the ground where it get and infect not covered young potato tubers. Long-distance transmission requires movement of infected tubers or other infected parts either by man or moving agent from one place to another.

Conducive environment

Infections frequently begin from sporangia which germinate either directly by means of a germ tube or indirectly by the use of zoospores. Zoospores swim for some minutes, after which time they encyst and germinate. A germ tube penetrates a living host and starts using it as the source of food within the first few days in a well-matched interaction. If the interaction is incompatible, host cells die quickly and disease development stops. Sporulation begins after a day or two days of infection under 10-25^{0}C temperatures and 90-100% relative humidity of leaves. The fungus grows to a vegetative string-like structure called sporangiophores on which sporangia formed within 8-12 hours in the period of favorable conditions. When the relative humidity changes sporangia separate from sporangiophores and captured in air currents where they survive for hours in an unsaturated atmosphere (Minogue and Fry, 1981). It can move by wind 100 km (Van der Zaag, 1956). After landing on the host plant, sporangia infected a host within 2 hours under favorable conditions and a single lesion produces up to 100,000 sporangia (Legard et al., 1995) which facilitates the rapid progress under cool and wet conditions.

Host plants

This pathogen attacked almost all Solanaceae family plants and some others. According to Forbes et al. (2016), Phytophthora infestans has a wide host range within the Solanacea family including cultivated potato, tomato and pear melon. 24 tuber-bearing and 4 non tuber-bearing wild species were reported as hosts of Phytophthora infestans in Peru (Lindqvist-Kreuze et al, 2020). According to Lindqvist-Kreuze et al. (2020), these host wild species are adapted to a wide range of climates. Phytophthora infestans was found infecting a broad range of hosts, including species not previously considered as hosts. Many new host, which were not identified before as host were reported in (Särkinen et al., 2013). Some of the perennial hosts' lesions formed in the woody tissues can be a source of inoculums for long periods of time (Forbes et al., 2013). Among the host ranges, many of them are economically important species (Olmstead et al., 1999 and Hawkes, 1999). Many hosts are in the genus Solanum (Adler et al. 2002, Deahl et al., 2004, Derie and Inglis, 2001, Flier et al., 2003 and Fontem et al., 2004), while other families, such as petunia (Petunia × hybrida), Calibrachoa (Calibrachoa × hybridus), and Nicotiana benthamiana was also reported as hosts (Deahl and Fravel, 2003, Inglis et al., 2001 and Rathbone et al., 2002). For easy understanding as an example, 31 of the host ranges excluding potato were indicated in figures below. Among 31, 18 are mentioned as a solanum family while 13 belonged to other families. The Solanum family represents 58% hosts members while the other families were 42%.

1. **Capsicum frutescent**

Source: Oregon State University, Dept of Nutrition and food management
Figure 1. Capsicum frutescens (chilli) fruit.

2. **Capsicum annuum fruit.**

Source:- Oregon State University, Dept of Nutrition & Food Management
Figure 2. C. annuum fruit.

3. **Lycium barbarum (Matrimonyvine)**

Source: http://climbers.lsa.umich.edu/wp-content/uploads/2013/07/Lycium-barbarum-wiki.jpg
Figure 3. Lycium barbarum (Matrimonyvine)

4. Currant Tomato, Wild Tomato (Solanum pimpinellifolium)

Source: https://pics.davesgarden.com/pics/2006/05/07/tremax/5f0b7c.jpg

Figure 4: Currant Tomato, Wild Tomato (Solanum pimpinellifolium)

5. Nicotiana glauca (tree tobacco)

Source: https://www.cabi.org/isc/portfolio/compendia/normal/29957.img

Figure 5: Nicotiana glauca (tree tobacco)

6. Datura metel (Hindu datura)

https://image.shutterstock.com/image-photo/hindu-datura-metel-period-fruiting-600w-730487656.jpg
https://www.shutterstock.com/image-photo/beautiful-datura-innoxia-green-fruit-known-1559898833

Figure 6: Datura metel (Hindu datura)

7. Datura stramonium (jimsonweed)

https://www.cabi.org/isc/portfolio/compendia/normal/15351.img

Figure 7:- Datura stramonium (jimsonweed)

8. Hyoscyamus niger (black henbane)

https://www.cabi.org/isc/portfolio/compendia/medium/31199.img

Figure 8:- Hyoscyamus niger (black henbane)

9. Ipomoea purpurea (tall morning glory)

https://www.cabi.org/isc/portfolio/compendia/normal/29218.img

Figure 9:- Ipomoea purpurea (tall morning glory)

10. Petunia

https://www.almanac.com/sites/default/files/styles/primary_image_in_article/public/images/petunias.jpg?itok=pyW560NZ

Figure 10:-Petunia.

11. Ipomoea nil or Pharbitis nil (Japanese morning glory)

https://image.shutterstock.com/z/stock-photo-ipomoea-flower-of-the-field-morning-glory-lobedleaf-pharbitis-pink-flowers-1809517405.jpg,
https://upload.wikimedia.org/wikipedia/commons/thumb/9/98/Ipomoea_nil_Akatsukinoumi1.jpg/800px-Ipomoea_nil_Akatsukinoumi1.jpg

Figure 11:- ipomoea nil or Pharbitis nil (Japanese morning glory)

12. Physalis angulata (cutleaf groundcherry)

https://www.cabi.org/isc/portfolio/compendia/normal/25957.img

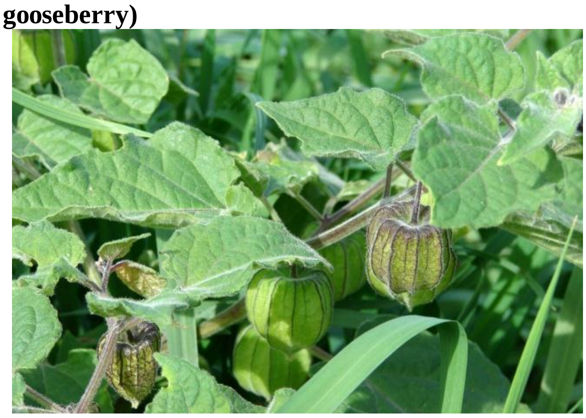
Figure 12:- Physalis angulata (cutleaf groundcherry)

13. Physalis ixocarpa

http://tropical.theferns.info/plantimages/9/b/9bf403da915fa43f4ff704f50e86e604e90e337b.jpg,
http://tropical.theferns.info/plantimages/9/b/9bf403da915fa43f4ff704f50e86e604e90e337b.jpg

Figure 13:- Physalis ixocarpa.

14. Physalis peruviana (Cape gooseberry)



https://www.cabi.org/isc/portfolio/compendia/normal/23426.img

Figure 14:- Physalis peruviana (Cape gooseberry)

15. Rumex acetosa var. hortensis (garden sorrel)

https://www.shutterstock.com/image-photo/close-on-red-seeds-curled-dock-1645694809,
https://www.shutterstock.com/image-photo/meadow-dock-rumex-obtusifolius-l-plants-399937054,
https://image.shutterstock.com/image-photo/rumex-crispus-curly-dock-curled-600w-1723520218.jpg

Figure 15:- Rumex acetosa var. hortensis (garden sorrel)

16. Solanum cardiophyllum

https://www.cultivariable.com/wp-content/uploads/2019/11/scardiophyllum-tubers-2-border-190x190.jpg

Figure 16:- Solanum cardiophyllum.

17. Solanum (nightshade)

https://www.cabi.org/isc/portfolio/compendia/normal/29384.img,
https://www.cabi.org/isc/portfolio/compendia/medium/30733.img

Figure 17:- Solanum (nightshade)

18. Solanum demissum

https://www.cultivariable.com/wp-content/uploads/2018/08/sdemissum-flower-buds.jpg

Figure 18:- Solanum demissum.

19. Solanum dulcamara

https://www.kingcounty.gov/~/media/environment/animalsAndPlants/noxious_weeds/imagesM_N/nigthshade_bittersweet_berries_kulak_ac_be.ashx?la=en

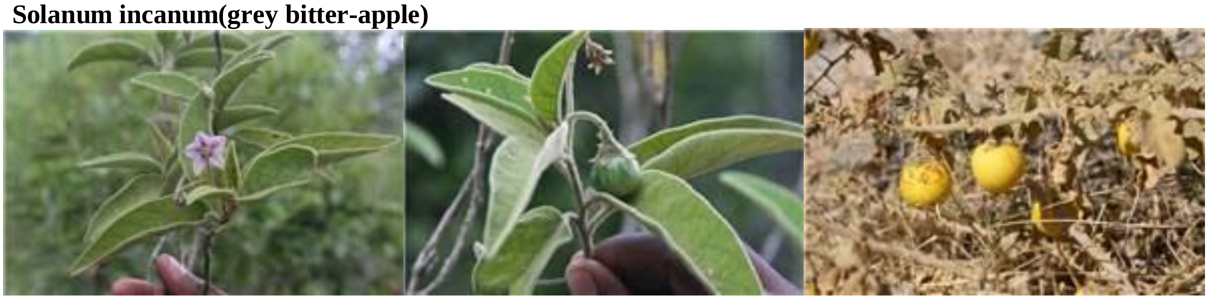
Figure 19:- Solanum dulcamara.

20. Solanum ehrenbergii

https://www.cultivariable.com/wp-content/uploads/2018/09/sehrenbergii-flower-190x190.jpg

Figure 20:- Solanum ehrenbergii

21. Solanum incanum(grey bitter-apple)



https://keys.lucidcentral.org/keys/v3/eafrinet/weeds/key/weeds/Media/Html/images/Solanum_incanum_(Sodom_Apple)/solanum_incanum_03.JPG

Figure 21:- Solanum incanum(grey bitter-apple)

22. Solanum indicum

https://www.shutterstock.com/image-photo/solanum-indicum-brinjal-colorful-bunch-orange-771293629

Figure 22:- solanum indicum.

23. Solanum laciniatum

https://image.shutterstock.com/image-photo/kangaroo-apple-shrub-native-australia-600w-1451247188.jpg

Figure 23:- Solanum laciniatum.

24. Solanum lycopersicum(tomato)

https://www.cabi.org/isc/portfolio/compendia/normal/31775.img

Figure 24:- Solanum lycopersicum(tomato)

25. Solanum marginatum (white-edged nightshade)

http://pestplants.aucklandcouncil.govt.nz/plant-search/solmar#

Figure 25:- Solanum marginatum (white-edged nightshade)

26. Solanum melongena (aubergine)

https://image.shutterstock.com/image-photo/lose-organic-long-purple-aubergine-600w-1673434237.jpg

Figure 26:- Solanum melongena (aubergine)

27. Solanum muricatum (melon pear)

https://www.jardins-du-monde.be/en/perennial-plant/711-pepino-melon-pear.html

Figure 27:- Solanum muricatum (melon pear)

28. Solanum physalifolium

https://upload.wikimedia.org/wikipedia/commons/1/16/Solanum_physalifolium_002.jpg

Figure 28:- Solanum physalifolium.

29. Solanum stoloniferum

http://tropical.theferns.info/plantimages/f/a/fafea52a3f5ce22bcb60329f1dedd832ad3be500.jpg

Figure 29: Solanum stoloniferum.

30. Solanum verrucosum

https://www.cultivariable.com/wp-content/uploads/2018/08/sverrucosum-flower-buds-190x190.jpg

Figure 30: Solanum verrucosum.

31. Solanum viarum (tropical soda apple)

https://www.cabi.org/isc/portfolio/compendia/medium/23198.img

Figure 31:- Solanum viarum (tropical soda apple)

Each of the 31 host ranges has its own number varieties from which one or two of them were mentioned above. Considerations given to these host plants are less. But these plants cause a great impact on potato production damage by late blight through bridging the two consecutive production cycles and play a vital role in the multiplication of the pathogen Phytophthora infestans. Potato producers should have planned to eliminate these plants from around the potato growing field. Even though, these plants have environmental importance, like nutrient recycling, environmental ecstatic, soil erosion control, and others, due to their high impact on potato damage by late blight and are also weeds they have to be removed from the high land areas where potatoes are predominantly produced.

Symptom and Sign

- Sign is the part of the disease causing organism
- Symptom is the color, shape and sizes of attacked part of the host plant
- There are white sporangia and sporangiospheres on lower side of infected leaves.
- On the outside or external surface of attacked tubers white mycelium presence is common.

All the parts of the potato plant attacked by late blight. The leaves, stem, pod, and tuber are parts which show the symptoms of late blight.

Attacked leaves

- Very light green young lesions on potato foliage appear as irregularly shaped, small (2-10 mm) lesions with or without a small surrounding area of collapsed but still green tissue.
- Lesions later turn brown.
- Older lesions are larger and assume a circular appearance unless delimited by the leaflet margin. Figure 32 below indicated late blight attacked leaves with different stages.

Figure 32. Late blight attacked leaves.

Attacked stem and petiole

Late blight causes light brown lesions on stem and leaf petiole which elongates and encircles the stem and petioles finally force them to break down and kills the plant/leaves. Stem and petiole infection symptom looks like figure 33 below.

Figure 33. Stem and leaf petiole infection.

Attacked potato fruit or bears

Brown black discoloration of the fruit occurs when attacked by late blight. It may or may not have spot developed like the figure 34 below because the developments of the sprongia on the fruit depend on time and conducive environment after infection.

Figure 34. Potato fruit attacked by late blight.

Attacked tuber

The symptom of late blight attack on potato tuber are presence of hard depressions with purplish drop on outer surface and Corroded brown discoloration of the flesh part(Figure 35).

Figure 35. Late blight attacked potato tuber.

CONCLUSION

Potato late blight is controlled using both preventive and curative measures. Among preventive control methods, avoiding host plants from the field used to grow potatoes throughout the years is one that decreases the inoculums source and occurrences of the diseases. Farmers have no or little knowledge about these hosts and they should know them in detail to contribute their role in the control of these disease occurrences and save their field together with their neighbors. Extension workers and trainers of farmers should include the types of these hosts in an easily understandable way.

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