OPEN ACCESS

Global Journal of Research in Agriculture & Life Sciences
ISSN: 2583-4576 (Online)
Volume 05 | Issue 03 | May-June | 2025
Journal homepage: https://gjrpublication.com/gjrals/

Review Article

Review on the role of healthy seed tubers in the management of potato diseases in Ethiopia

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DOI: 10.5281/zenodo.15779561 **Submission Date: 16 May 2025 | Published Date: 30 June 2025**

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Abstract

Potato (Solanum tuberosum L.) is one of the most economically important and stable food crops in Ethiopia. However, currently, the country has been facing a major challenge in potato production due to the prevalence of various seed tuber diseases. Using disease-free potato seed tuber is an important first step to assuring a successful potato crop. One of the main benefits of using disease-free planting material is the prevention of the spread of diseases from one place to another. Potato diseases can survive in the seed tuber, and infected seed tubers can act as a source of inoculums for future crops. By using such disease-free planting material, farmers can significantly reduce the risk of introducing diseases into their potato fields, and need for pesticides, leading to a more sustainable and environmentally-friendly approach to disease management. However, there are several challenges affecting the health of seed tubers for planting materials leading the increased prevalence of various diseases of potato in the future crop in Ethiopia. These are: the using of poor quality seed tubers from informal seed system, seed degeneration, poor on-farm management practices and lack of knowledge and skill on farm management practices. To overcome these problems farmers should give emphasis on the using of disease-free seed tuber from certified formal seed production and properly on-farm managed practices as well as creating awareness for farmers as priority issues. Thus, review paper will give highlight on the use of health seed tubers in the management of potato diseases in Ethiopia.

Keywords: *Disease-free, Pathogen, Season, Spread, Symptoms.*

1. Introduction

Potato (*Solanum tuberosum* L.) is one of the most important and stable crops in Ethiopia, in terms of both a food source and income for smallholder farmers (Gebru *et al*., 2017). It is the leading root and tuber crop in the country by land coverage and total output. According to the crop production survey done in the 2020/21 period, of the 307,295.80 ha of root and tuber crops (RTCs) grown, approximately 28% or 85,988.43 ha was prepared for potato cultivation, resulting in over 5,621,682 million tons of RTCs being produced. This accounted for 20.30% of the total RTC production, with potato alone yielding over 1,141,872 million tons and the average national yield for potato seed tubers was 13.28 t ha^{-1} (CSA, 2021).

The production of seed tubers in Ethiopia is facing many challenges such as lack of access to quality seed, inadequate storage and marketing facilities, and transportation, limited availability of improved varieties, and lack of knowledge and skills among farmers, high cost of seed tubers, lack of well adapted cultivars to the major agro-ecological zones, sub-optimal agronomic practices; the prevalence of diseases and insect pests (Hirpa *et al.*, 2010). A number of high yielding, wider adaptation and late blight disease resistant/tolerant potato variety has been released and under production by large number of farmers in Ethiopia (Abebe *et al.,* 2014).

Selecting and planting clean, disease-free potato seed tuber is an essential first step to assuring a successful potato crop. However, one of the main production bottle neck that contribute to low yield of potato production in Ethiopia is the lack of healthy and quality seed tubers in the required quantity and quality. Beside to the lack of healthy and quality seed tubers in the country, is challenged by various diseases and pests, which can cause significant yield losses if left unmanaged. In order to combat these diseases and pests, the use of seed healthy tubers as planting materials plays an essential role in the management of potato diseases in Ethiopia. Thus, this review paper aims to provide an overview on the roles of planting seed healthy tubers in the management of potato diseases in Ethiopia.

2. The status of potato production seed tubers in Ethiopia

Potato seed tuber is a key determinant factor in the productivity of the potato crop globally (Quere, 2018). Productivity of seed tuber of this crop is strongly influenced highly by the quality of the seed tubers such as their genetic and physical nature (Haverkort and Struik, 2015). Even though sexual propagation via botanical seed (true potato seed) is possible, potatoes are mainly propagated vegetative via tubers. In addition, pathogens and pests pass more readily to asexual than to sexual propagated methods, thus; seed tubers are much more likely to harbor a wide range of pathogens and pests compared with true potato seed. Potatoes grow below ground and are exposed to many soil borne pathogens, presenting additional challenges to maintain the phyto-sanitary quality of seed tubers.

Potato seed tubers are the initial planting material for potato production which service as a source of seeds and their quality has a significant impact on the yield and quality of the final crop. In Ethiopia, potato seed tubers are produced both by farmers and seed producers. In addition, there are also community-based seed supply systems which are undertaken by the community with technical and financial assistance of NGOs and breeding centers (Hirpa *et al.*, 2010). The majority of seed tubers produced by farmers are used for their own consumption or sold in the local market. On the other hand, seed producers produce certified seed tubers that are used for commercial potato production. However, only a small portion of the production in the country is from certified seed tubers as the majority of potato production in Ethiopia is from farmer-saved seed tubers, which are often of poor quality and result in low yields.

3. Challenges facing potato seed tubers' production in Ethiopia

The potato seed tubers production in Ethiopia is hindered by several challenges, which include:

Low availability of quality seed tubers: Potato seed quality is an important determinant of the final yield and quality. Low quality seed availability is believed to be one of the major yield reducing factors in potato production in Sub-Saharan Africa including Ethiopia (Struik and Wiersema, 1999; Fuglie, 2007). This is due to the low adoption of certified seed tubers and the majority of farmers continue to use farmer-saved seed tubers, which are often of poor quality and prone to diseases.

Limitation of accessibility to improved varieties: The limited access to improved varieties is a major constraint to the production of quality seed tubers (Chindi, 2017). The majority of potato varieties grown in Ethiopia are traditional varieties that have low yields and are susceptible to diseases. The cultivation of potatoes in numerous developing countries, including Ethiopia, is severely hindered by the scarcity of quality and disease-free seed tubers and the excessive expenses associated with their purchase (Gildemacher *et al.,* 2009). A common practice among farmers involves the use of substandard seeds that have been passed down over several generations (relies on reusing potatoes or recycling of seed tubers from previous harvests as seed potatoes), resulting in poor crop yields (lower yields or a decrease in quality) and high diseases prevalence due to the accumulation of disease (Hirpa *et al*., 2010).

Poor seed tubers handling and storage: Conditions experienced by seed tubers during their production, handling and storage can have an important effect on subsequent crop performance (Rubatzky *et al*., 1997). Potato tubers in Ethiopia are gathered, stored, packaged, and moved with insufficient caution to prevent any physical harm (cuts, bruises, and holes to the tubers) which may facilitate favourable conditions for the pathogens development. As a result, the quality of seed tubers deteriorates, leading to low yields and high disease infestations. This is most likely due to a lack of understanding about the potential consequences of physical damage among all individuals involved in the handling and storage (Guluma, 2020). Similarly, most farmers in Ethiopia have limited knowledge and resources to handle and store seed tubers properly (Kuyu, 2019). Thus, seed tubers are highly perishable thus; require proper handling and storage to maintain their quality and healthy.

Lack of quality control: The lack of effective quality control mechanisms has resulted in the production and distribution of substandard seed tubers. Ethiopia does not have an official organization tasked with overseeing the quality control and certification of seed potatoes. Nevertheless, both the International Potato Center (CIP) and the Ministry of Agriculture (MoA) have collaborated to establish a system for monitoring the quality of seed potatoes, which is currently in the process of being officially implemented (Hirpa *et al*., 2016). Moreover, the seed tubers supplied by the chains in the alternative seed system are not of a standard quality mainly because of absence of quality control system.

4. Major diseases of potato seed tuber in Ethiopia

One of the major diseases of potato seed tubers in Ethiopia is bacterial wilt, caused by the bacterium *Ralstonia solanacearum*. (Fig. 1). This disease is highly destructive and can lead to yield losses of up to 90% (Karim, 2023). The bacteria enter the plant through wounds and multiply rapidly, causing wilting, yellowing, and eventually death of the plant (Joshi, 2020). Bacterial wilt is difficult to control and can persist in the soil for several years, making it a major threat to potato production.

Another common disease of potato seed tubers in Ethiopia is late blight, caused by the fungus *Phytophthora infestans* (Kassaw *et al*., 2021) (Fig. 2). Late blight affects both the foliage and tubers of the potato plant, causing dark lesions and rotting of the tubers (Tsedaley, 2014). It spreads rapidly in cool and wet conditions, making it a significant threat to potato production in Ethiopia, where the climate is favorable for its development.

Viral diseases, such as potato leaf roll virus and potato virus Y, are also major concerns for potato seed tubers in Ethiopia (Abraham *et al*., 2014). These viruses are transmitted by aphids and can cause stunted growth, reduced yield, and poor quality tubers (Abraham, 2019). Once infected, there is no cure for these diseases, and affected plants must be removed to prevent further spread. The initial means of spreading these virus from plant to plant during the season is by aphid feeding. Overwintering and infection from one season to the next is mainly achieved in live plant tissue such as infected potato tubers. They can controlled by a combination of planting free seed tubers from these viruses, removing volunteer potatoes, weeds, and refuse tubers and managing insect vectors like aphids.

In addition, there are several other fungal, bacterial and viral diseases, such as early blight, black scurf, common scab, powdery scab and bacterial soft rot also pose a threat to potato seed tubers in Ethiopia (Fig. 3 and 4). Early blight, caused by the fungus *Alternaria solani,* affects the leaves and stems of the potato plant, leading to reduced photosynthesis and a decrease in tuber size and quality (Demissie, 2019). Black scurf, caused by the fungus *Rhizoctonia solani*, affects the tubers and can cause significant losses during storage and transportation (Arora and Sagar, 2014). These diseases can be controlled through proper crop rotation, sanitation, disease-free seed tubers and the use of disease-resistant varieties. The prevalence and severity of these diseases are influenced by various factors, such as climate, soil conditions, and farming practices (Luck *et al*., 2011).

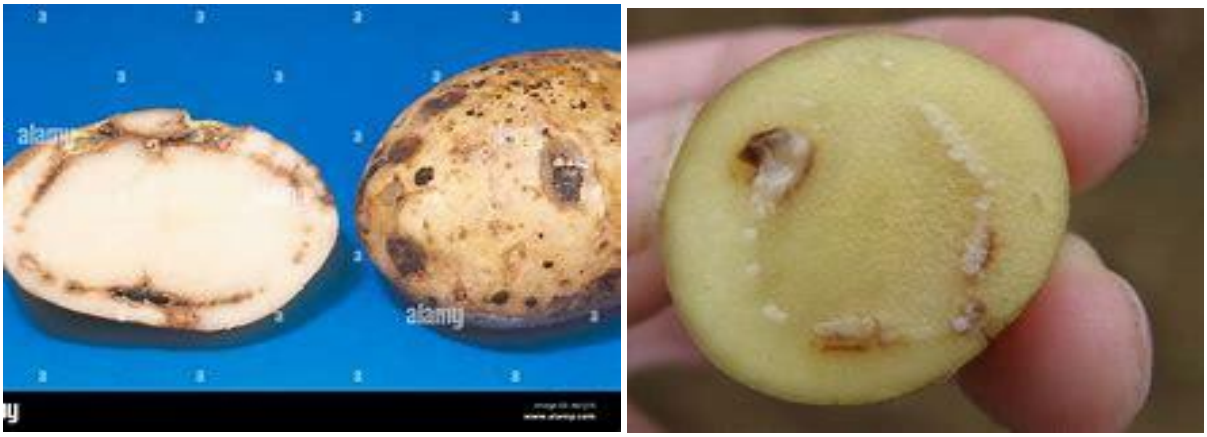

Fig. 1: Symptoms of potato bacterial wilt disease in the potato tubers (Source: potato seed tuber damaged by bacterial wilts pictures - Search images, bing.com).

Fig. 2: Infected potato tubers with late (left) and early (right) blight (source: diseases to watch for on seed potato tubers - spud smart and detection of potato tuber diseases and defects | cornell vegetables).

Fig. 3: Infected seed tuber with black scurf (left) and bacterial soft rot (right) (source: (nigel cattlin/science photo library and detection of potato tuber diseases and defects | cornell Vegetables).

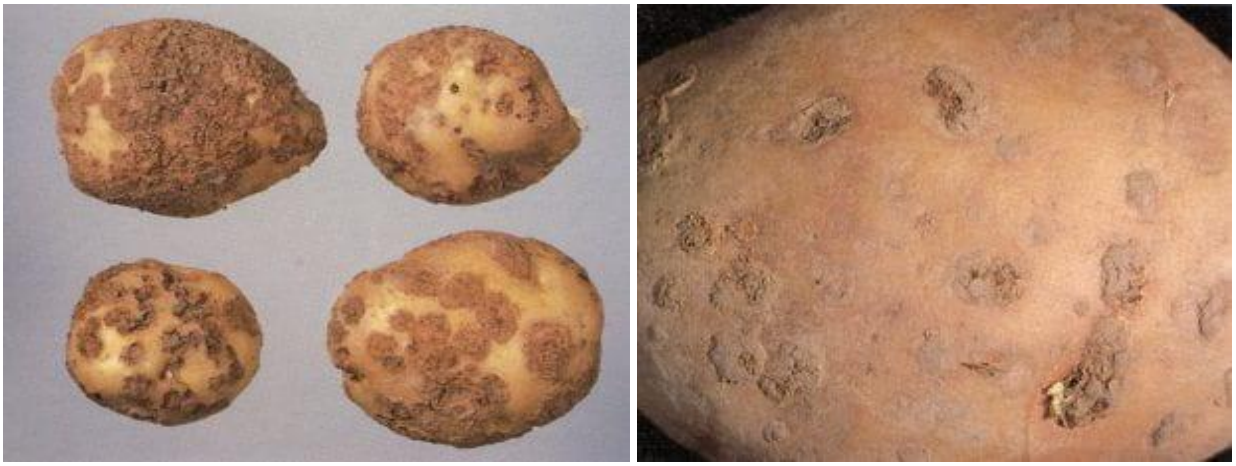

Fig. 4: Infected seed tuber with common scab (left) and powdery scab (right) (source: (detection of potato tuber diseases and defects | cornell vegetables).

At present, integrated disease management strategies can be examined and a comprehensive management approach can be established according to specific requirements. Common control tactics utilized in other country consist of employing resistant varieties, practicing crop sanitation, implementing crop rotation, choosing disease-free planting materials (healthy seed tubers), and applying cultural practices either individually or in combination. However, the effectiveness of these techniques in disease management has been limited, if not successful at all (Guchi, 2015). This includes the use of disease-resistant varieties, proper seed tuber selection and handling, crop rotation, and the adoption of good cultural practices. By effectively managing these diseases, Ethiopian farmers can improve the quality and quantity of their potato harvests, ensuring food security and economic stability for their families and communities.

4.1. Symptoms of potato seed tuber diseases

There are various symptoms of potato seed tubers disease that can be observed in Ethiopia, affecting both the quality and quantity of potato production. One of the most common symptoms of potato seed tubers disease is the presence of black scurf on the surface of the tubers (Tegg *et al*., 2014) and can result in significant yield losses (Kiptoo *et al*., 2021). The symptoms of black scurf consist of the death of sprouts before they emerge, the formation of cankers on the lower stem and stolon of the potato plant, and the use of potato progeny tubers by sclerotia for growth, all of which are indicative of this disease (Singh and Singh, 2018).

Another symptom of potato seed tubers disease is the presence of powdery scab. This is caused by the fungus *Spongospora subterranea* and can result in reduced tuber quality and quantity (Merz and Falloon, 2009). Upon infection, tubers show signs of powdery scab through the emergence of minuscule brown spots on their surface. These spots then progress in size and take on a dark, sunken appearance with a rough texture, eventually developing into white, pink, or blue pustules. This can cause the tubers to become misshapen, reducing their market value and making them difficult to peel and process.

In addition to the physical symptoms, potato seed tubers disease can also have an impact on the health of the plants and economy of the farmers. One of the common symptoms on health of the plants is stunted growth, where the plants fail to reach their full potential due to the disease (Pérombelon, 2002). This can result in reduced yields and poor quality tubers. The disease can also cause yellowing of the leaves, which can affect the photosynthesis process and further reduce the plant's ability to produce healthy tubers. Another symptom that is often observed in potato seed tubers disease is the presence of necrotic lesions on the stems and leaves of the plant. These lesions are caused by various fungal and bacterial pathogens and can weaken the plant, making it more susceptible to other diseases and reducing its ability to produce tubers (Mohan *et al*., 1994). In severe cases, the plant may die, resulting in a complete loss of the crop. The disease can cause significant yield losses, leading to reduced income for farmers who heavily rely on potato production. It can also increase the cost of production as farmers may need to invest in disease management strategies such as fungicides and resistant varieties (Kromann *et al*., 2014).

4.2. Factors favoring potato seed tuber diseases

A basic condition for adequate crop production is the use of disease-free seed tuber, which eliminates the source of primary infection from the field. The production of potato in the country is severely affected by various diseases, with seed tuber diseases being one of the major threats or contributing great role. Factors such as climate, soil conditions, cultural practices, cultivar, seed generation, and the others all contribute to the spread and prevalence of potato seed tuber diseases (Guchi, 2015; Nasir, 2016; Tafesse *et al*., 2018). One of the main factors favoring potato seed tuber diseases in Ethiopia is the country's diverse and harsh climatic conditions. Ethiopia has a wide range of agro-climatic zones, including highlands, lowlands, and midlands, which provide suitable conditions for the growth and development of various pathogens that, cause diseases in potato seed tubers (Kolech *et al*., 2015). In highland areas, where potato is predominantly grown, the cool and humid climate creates favorable conditions for the growth of various diseases such as late blight and early blight (Runno, 2013). These diseases can spread rapidly in moist environments, causing significant damage to seed tubers and reducing their quality and yield.

Moreover, the soil conditions in Ethiopia also play a crucial role in the prevalence of potato seed tuber diseases (Workayehu *et al.,* 2021). The majority of smallholder farmers in the country practice traditional farming methods, which often involve mono cropping and limited use of inputs such as fertilizers and pesticides (Gelaye *et al*., 2022). This results in poor soil health and the accumulation of pathogens in the soil, making it more susceptible to diseases. Additionally, the lack of crop rotation practices and the use of infected seed tubers also contribute to the build-up of diseases in the soil, making it difficult for farmers to manage them (Umaerus *et al*,. 1980). Poor field sanitation practices, such as the failure to remove diseased plant debris (volunteer plants or alternative weed plants) and the use of contaminated equipment, also contribute to the spread of diseases among potato plants and seed tubers (Workayehu *et al*., 2021). Smallholder farmers in the country have limited access to certified seed tubers and quality inputs such as fungicides and fertilizers as well as inadequate knowledge and skills on proper disease management such as crop rotation, use of resistant varieties and healthy seed tubers, and timely application of inputs (Hirpa *et al*., 2010; Milkias and Keba, 2021), which are essential for potato diseases control, contribute to the high prevalence of potato seed tuber diseases in Ethiopia. The use of informal seed systems in Ethiopia, which involve the use of saved seed tubers from the previous harvest, often result in the introduction (accumulation) and spread of diseases in new planting areas (Gildemacher *et al.*, 2009; Tafesse *et al.,* 2020). Gildemacher *et al.* (2009) stated that the high (89.00%) percentage contribution of produced seed tubers is from informal potato seed systems in Ethiopia. These make challenging for farmers to effectively manage potato diseases (Tafesse *et al.*, 2018).

Seed recycling for an unlimited number of generations embeds pathogens in the seed and retards the potential yield of the crop. Smallholder farmers are able to renew their potato seed depending on the number of cycles used, visual observation of infestation, crop decline in yield and other indicators, and availability of clean seed at hand for several production seasons (Kwambai *et al*., 2023; Navarrete *et al*., 2023). Even though considerable efforts made by various stakeholders across potato development in Ethiopia the formal seed system in the country had little penetration into the seed system (Hirpa *et al*., 2010; Thomas-Sharma *et al*., 2016). According to Tessema *et al*. (2023), the shortage of reliable seed sources and heavy reliance on uncertified seed tubers as planting material resulted in frequent re-infection of healthy fields in Ethiopia. Then after, such infected fields re-infect the crops whether they have planted healthy or infected plants, especially for soil-borne pathogens (Abdurahman *et al*., 2017).

Finally, seed degeneration has great role on the occurrence and distribution of potato diseases in Ethiopia, which involves in the reduction of seed quality and yield due to the accumulation of pathogens in/on the seed tubers occurring when seed is recycled (Struik and Wiersema, 1999). Seed generation favored through various factors such soil, air, vector, and seed-borne pathogens (Thomas-Sharma *et al*., 2017; Navarrete *et al*., 2022). Many plant pathogens that cause disease incidence and severity in potato crop are responsible for seed degeneration (Charkowski *et al*., 2020). Thus, degeneration due to various diseases and poor seed management practices have been the causes of considerable yield losses each year in Ethiopia and elsewhere (Tessema *et al*., 2023).

4.3. Economic impact of potato seed tuber diseases in Ethiopia

Potato is a staple crop in Ethiopia, providing both food security and income for millions of smallholder farmers (CSA, 2021). However, in recent years, the country has been facing a major challenge in potato production due to the prevalence of seed tuber diseases (Tafesse *et al*., 2020). These diseases, caused by various pathogens such as viruses, bacteria, and fungi, have a significant economic impact on the country's economic sector (Guchi, 2015). One of the main economic impacts of potato seed tuber diseases in Ethiopia is the decrease in crop yield and quality. Infected seed tubers result in stunted plant growth, reduced tuber size, and poor quality potatoes (Guluma, 2020). This not only affects the income of farmers but also leads to food insecurity and impacts the overall economy of the country. With a decrease in potato production, there is less food available for consumption and sale in the market, leading to a rise in prices and a decrease in consumer purchasing power (Adgo, 2008).

Moreover, the high cost of disease management also takes a toll on the economy. Farmers are forced to invest in expensive chemical pesticides to control the spread of diseases, which adds to their production costs (Tufa, 2015). This, in turn, reduces their profits and makes potato farming less lucrative. The cost of treating infected seed tubers is also high, as farmers have to purchase disease-free seed tubers from certified sources, which are often expensive and not easily accessible in rural areas (Chindi *et al*., 2017). Infected seed tubers not only affect the production of potatoes but also reduce the quality and quantity of seed tubers for the next planting season. This results in a domino effect, leading to a decrease in overall potato production and exports, which ultimately impacts the country's economy (Wubet *et al*., 2022). The presence of seed tuber diseases in Ethiopia has also hindered the country's ability to meet the increasing demand for potatoes in the global market (Guluma, 2020). As a result, Ethiopia has to import potatoes from other countries, leading to a drain on foreign exchange reserves and further impacting the economy. Furthermore, the spread of potato seed tuber diseases has also hindered the adoption of new and improved potato varieties, which have higher yields and better resistance to diseases (Tesfaye *et al.*, 2013). This limits the potential for growth and innovation in the potato industry, which could have a positive impact on the economy with increased productivity and profitability.

4.4. Role of healthy seed tubers in potato disease management

Healthy seed is a key factor in growing a quality potato crop. Several diseases affect seed tubers and they have the potential to reduce plant stand early in the season. Therefore, it is extremely important to examine all seed lots carefully immediately after receiving the seed. Starting the next potato growing season with disease-free potato seed tuber is the initial step in commencing a good stand that will maximize yield potential and reduce diseases infestations. All of the above mentioned diseases are mainly carried from one growing season to the next in potato tubers. Planting disease-free seed potatoes tuber is an important step in breaking the disease cycle and preventing the disease from becoming established (Fred and Monica, 2017). A healthy seed tuber (disease-free planting material) refers to potato tubers that are certified to be free of any diseases or pests, which are carefully selected and grown under strict conditions to ensure their health and quality. By using such disease-free planting material, farmers can significantly reduce the risk of introducing diseases into their potato fields.

One of the main advantages of using disease-free planting material is the prevention of the spread of diseases from one place to another (Dereje and Gebremedhin, 2012). Potato diseases can survive in the seed tuber, and infected seed tubers can act as a source of inoculums for future crops (Daami-Remadi *et al*., 2008). By using disease-free planting material, farmers can break these mines of disease transmission and reduce the overall disease burden in their fields. The use of healthy seed tuber with adequate crop rotation (cereals, legumes/pulses and non-solanaceous crops) contribute great role in the controlling of potato tuber borne diseases.

Disease-free planting material also plays a crucial role in disease management by reducing the use of pesticides. When farmers use infected seed tubers, they often have to resort to heavy pesticide use to control the diseases (Kumar, 2014). This not only increases the production cost but also poses health risks to consumers. By using disease-free planting material, farmers can reduce the need for pesticides, leading to a more sustainable and environmentally-friendly approach to disease management. The use of disease-free planting material also improves the quality and yield of potato crops since infected seed tubers can result in stunted growth, poor quality, and low yields (Mengesha, 2017). On the other hand, disease-free planting material ensures healthy and vigorous plants, leading to higher yields and better marketable produce (Struik and Wiersema, 1999; Fuglie, 2007). This, in turn, can improve the income and livelihoods of potato farmers in Ethiopia.

4.5 Challenges in the use of and approaches to overcome healthy seed tubers problems

Most small scale farmers in Ethiopia have very limited access to quality seeds and inputs resulting in poor quality and prone to various diseases (Hirpa *et al*., 2010; Tessema *et al*., 2023). The use of poor-quality seed in many Sub-Saharan Africa countries including Ethiopia was noted as the top-listed yield problem provider in the potato production system (Harahagazwe *et al*., 2018). This might be due to the seed quality supply continued as a key problem yet (Harahagazwe *et al*., 2018; Tessema *et al*., 2018). In Ethiopia, the main source of seed is informal, which comes from poor health status,

and farmers' seed quality is often poor (Hirpa *et al*., 2010; Tessema *et al*., 2023). These, poor seed tuber low in yield and prone to various diseases. Thus, in order to get available good quality seeds, accessible, and affordable, concerned bodies (researchers and international development practitioners) have started to find out the extent to which seed systems are resilient and function efficiently (Tessema *et al*., 2023).

Lack of managing seed tuber health in the management of potato diseases is a key problem in Ethiopia. This might be due to the limited knowledge and skill of farmers on farm seed management practice. Community-based farmer capacity building programs for on-farm seed management are likely to create cost-efficient solutions. On-farm seed management practices aim to reduce inoculum density and sources of inoculum. Examples of such practices are positive selection (i.e., selecting the best plants for seed mother plants; Gildemacher *et al*., 2011; Priegnitz *et al*., 2020), rogueing and early-season crop hygiene (field sanitation) (i.e., removing diseased or alternate weed hosts and volunteer plants), choice of field sites and selection of planting date, and the seed plot technique (i.e., small plot dedicated only to seed production; Bryan, 1983), tuber-uniting, varietal mixtures, crop rotations, vector management, maintaining the value of high quality seed and making the option to buy certified seed every few years more attractive (Bryan, 1983; Gildemacher *et al*., 2011). However, because these methods rely on symptom recognition, effective farmer training is critical for the success of these strategies (Sisterson and Stenger, 2013).

5. Conclusions

Potato seed tuber is a key essential element in the productivity of the potato crop over the world. Understanding and having sufficient information on the role of healthy seed tubers in the management of potato diseases as well as managing seed tubers from various diseases in Ethiopia is paramount importance in making appropriate management options. This piece of a review paper will give further insights compiled together from previous studies in various circumstances across the various countries on role of healthy seed tubers in the management of potato diseases in Ethiopia for the purpose of emphasizing the impact of healthy seed tubers productivity on food security and livelihoods under smallholder farmers. This paper will also provide directions on the challenges of using healthy seed tubers along the potato production system. It is vital to consider the health of seed tubers and it's facing challenges for sustainable management of potato diseases in Ethiopia. Planting health seed tuber is an important step in breaking the disease cycle and preventing the disease from becoming established. Disease-free planting material plays a crucial role in disease management by reducing the use of pesticides; in turn reduce the risks health to consumers, leading to a more sustainable and environmentally-friendly approach to disease management. The use of disease-free planting material also improves the quality and yield of potato crops since infected seed tubers can result in stunted growth, poor quality, and low yields that ensures the healthy and vigorous plants, leading to higher yields and better marketable produce. This, in turn, can improve the income and livelihoods of potato farmers in Ethiopia reducing potato diseases via using health seed tubers. However, various bottlenecks that tie the healthy seed tubers development pathway in smallholder farmers' settings hamper the success of the target production. These are: poor seed quality and lack of inputs, lack of managing on farm seed management practices, seed degeneration and limited knowledge and skills of farmers on the management of seeds in both in the field and storage. Thus, farmers should give high attention on the using of health seed tubers for planting purposes and training should be given for farmers on how to use and maintain their seed tubers from various diseases as priority issues.

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CITATION

Ano W.N., & Weratuw S. Y. (2025). Review on the role of healthy seed tubers in the management of potato diseases in Ethiopia. In Global Journal of Research in Agriculture & Life Sciences (Vol. 5, Number 3, pp. 97–106). https://doi.org/10.5281/zenodo.15779561