

Empirical Review on Determinants of Improved Potato Technology Adoption in Ethiopia

Mamaru Tesfaye*, Lemma Tessema

Ethiopian Institute of Agricultural Research, Holetta Agricultural Research Centre, Addis Ababa, Ethiopia

Email address:

tesfayemamaru@yahoo.com (Mamaru Tesfaye)

*Corresponding author

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Abstract: Adoption of improved potato technology is essential for intensifying its productivity thereby improve the income of smallholder farmers in Ethiopia. Adoption of improved Potato also plays a great role for food security and improving the daily livelihood of farmers as well. However, there are few area-specific studies on its technology adoption to encourage farmers to substitute their production methods with modern production techniques and maximize their return from the sector. The objective of this review paper is to gain insight into the determinants of improved potato technology adoption in Ethiopia by using findings from various empirical studies. According to the review's results, adoption of improved potato technologies in Ethiopia is limited by several of biotic and abiotic factors in general, as well as demographic, socioeconomic, institutional, and technological constraints in particular. Similarly, many empirical studies were analyzed as to the determinants of potato technology adoption in this review paper, including improved seed types, fertilizers, quality seed, crops protection measures, and a storage facility. As a result of the production technology adoption factors, the sub sector's expected outcome is still low. Therefore, the pinpointing major constraints of improved potato production in Ethiopia would help to significantly improve the adoption rate and intensity of the technology by smallholder farmers and thereby sustainably improved potato production in Ethiopia.

Keywords: Adoption, Determinants, Ethiopia, Factors, Potato

1. Introduction

One in every seven persons in the world is fed and nourished by potatoes, and millions rely on them for a living. According to [1]. It is the third most significant food crop in the world, after rice and wheat. Since its introduction into Ethiopia by Schimper, a German botanist, the crop has gone through several stages and has been cultivated as a garden crop near Ethiopian smallholder potato growers' homes. After six decades, potatoes have become one of Ethiopia's most important horticulture crops, with area coverage of more than 179,000 hectares [2]. The crop is a significant food and economic crop with numerous benefits for SSA nations such as Ethiopia [3].

The crop is a food security and cash crop in highly populated highlands of Ethiopia, where land is scarce. Moreover, the crop is ready for harvest fills the food gap during August to October when most cereals are not mature

and ready for harvest. For instance, in most potato domain highlands of *Gurage* and *Silte* areas, potato cultivation is undertaken mainly between January and early July, when cereals are harvested in December and the land is fallow until the main cropping season of mid-July except when the field is used for grazing. This practice has provided another advantage to potato farmers in cereal-potato production systems to uphold their soil fertility from the residues of the preceding cereal harvest. Early maturing potatoes allow the crop to be grown during fallow periods of cereal-based systems [1] which enhances efficient utilization of scarce land resources that is under pressure from the ever-growing population and urbanization [4].

Among several other food sources, the potato is one that can help match all these constraints worldwide due to its highly diverse distribution pattern, consumption by more than a billion people, its current cultivation and demand, its bright future on expansion, particularly in developing countries with high levels of poverty, hunger, and

malnutrition [5]. Yet, potato has long been regarded as a food security crop for most developing countries, its potential is unexploited, and this is because of low adoption of production technologies among smallholder potato farmers in the country [6]. Adoption of potato technologies is constrained by various factors in the community most likely related with limited technology dissemination, weak extension linkage, financial and other socio-economic dimensions are to mention some. Therefore, the objective of this paper is to review and document the empirical results of potato production technology adoption in Ethiopia.

2. Methodology

This paper is designed using empirical research outputs published in different reputable journals suitable for this topic and national released reports mainly from CSA (central Statistical Agency) to review and support the background, justification of potato technology adoption determinants in Ethiopia.

The secondary data were used from different sources like Google scholars, Research Gate, and other reliable data sources including different University websites. The articles used were thoroughly selected depending on the suitability. To review determinants of potato production technology adoption, the peer-reviewed empirical articles which are properly reviewed, and articles composed of different factors like demographic, socioeconomic, and institutional factors of potato production technology adoption were selected over others. Finally, the statistical results of each model of articles were compared with others for similarities and differences and the results were discussed for more justification of factors of potato production technology adoption in the country.

Most empirical studies that have taken potato production technology adoption as a focus in various places and time periods have been examined and summarized based on the types of variables, models used for analysis, and technology adoption decisions. [7] Examined factors that influence farmers' adoption of potato technology using duration models. For factors impacting potato variety adoption, [8] employed binary logistic regression. Using the Two-limit Tobit model identified and studied factors of potato production technology package acceptance [9]. Similarly, used several regression models to figure out how technology adoption affects potato yield. Probit was used to investigate the factors that influence the adoption of improved potato varieties [10, 11] employed a multivariate probit model to show what factors drive farmers to adopt potato technology packages. To discuss aspects of adopting certified potato seeds, employed various models such as probit, Poisson, and Tobit models [12]. The Probit model is used to analyze the factors that affect the adoption of current potato varieties [13]. For evaluating the decision to adopt potato improved varieties, utilized a three-stage probit regression model [7].

3. Results and Discussion

3.1. Technological Factors

The overall function of technological variables in the adoption of potato production technologies is to explore how such technological factors are used in production. Technological factors are packages of technologies that help farmers to increase potato production by introducing new technologies such as improved varieties, fertilizers, quality seed, irrigation, cropping methods, crop protection, harvesting, and storage. The central factors of potato production technology adoption, according to various empirical research conducted by various researchers are technological factors that are used in a single or a combination of several technologies. Various studies were conducted to examine how those technologies are applied, used, and accessed by farmers to improve the productivity, while others focused on how to adopt and what factors influence the adoption pathway along the value chain. The technological components of potato production were mostly determined by conducting several tests to determine how different technologies can be used in potato production. The studies of numerous scholars, [8, 7, 14, 9]. Justified those different types of technological factors positively affected potato technology adoption.

3.2. Adoption of Modern Varieties

In Ethiopia, the history of modern potato variety release begun in 1987, releasing the first modern potato variety Alemaya-624 (AL-624) at Alemaya University the then Haramaya University. Most of the potato genotypes used for breeding purposes was sourced from three main pools (the international potato center, European, and North American). Until the 1990s, most modern varieties in Ethiopia were of European and American origin [15]. Afterwards, various research centers and higher learning institutes released more than 39 potato varieties suitable for different agro-ecologies [15]. Some of the varieties can adopt nationwide agro-ecologies, while others are bounded to certain parts of the country's environment, as the result limited adaptability of many potato varieties affected the adoption rate of the released potato cultivars across the country.

Another study by [16]. illustrated that there is ample breeding scope to use such released potato varieties with various merits as a parental line for future breeding strategy in Ethiopian potato variety improvement. The study also signified the existence of diverse genetic variability estimates among potato varieties studied in Central Ethiopia. Breeding strategies in most countries have focused on major improvement pillars of productivity, nutritional quality, and disease resistance [17].

In current climate challenge scenario, breeding strategies are shifted to develop potato varieties which are early-maturing, stress-tolerant, and disease-resistant in addition to the other merits desired by consumers and processors [6]. In Ethiopia, the rate of adoption of modern potato varieties

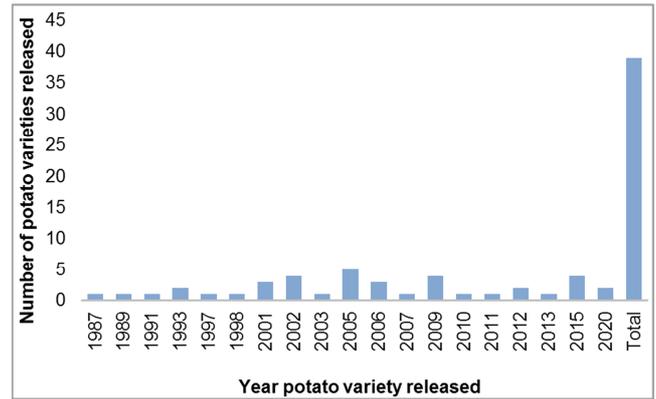
varied by agro-ecological zones and production. For instance, adoption rates of Shashemene were reported less than that of Gurage highlands Gumer and Geta districts, districts, due to the former being a mid-altitude area while potato is mainly cultivated in areas with better access to market. Whereas Gumer and Geta districts are in moist high land that provides an opportunity to access seed market leading to high rate of adoption for modern varieties [15]. Hence, the wide variation in agro-ecology, altitude, precipitation, and other biotic factors contributed to low adoption of modern potato varieties with different adoption levels across regions in Ethiopia [18]. On the other hand, Shashemene areas is among the most bacterial wilt hotspot area, leading to re-planting local potato cultivars suitable for the locality rather than adopting improved potato varieties [19]. Potato farmers in some cases prefer cultivating only a limited number of potato cultivars rather than adopting various potato cultivars with multiple backgrounds. One reason for this problem could be lack of understanding the farmers' preference along the value chain of potato breeding among potato breeders in the country [15]. The study by [20] showed 82.5% of Nepalese potato farmers preferred cultivating only one variety, whereas 12.9% of the famers preferred two varieties and the remaining 4.6% were cultivating more than two potato varieties.

In the study conducted in four districts of West and Kelem Wellega zones in Ethiopia, the adoption rate of released potato varieties was 22.7%, whereas 47.3% of the farmers were cultivating local potato varieties [6]. On the other hand, recognized seed multipliers, who are commercially oriented and well trained has positively contributed to the rapid adoption of newly released potato variety [21].

The major bottlenecks aligned with low varietal adoption in Ethiopia are in relation to:

- 1) Weak extension linkage constrained by various financial and other resource limitations to promote and disseminate released potato varieties to the farmer's level.
- 2) Private companies play a key role in multiplying and making varieties available for formers; nevertheless, there is no private company that multiply and disseminate seed for subsistence crops.
- 3) Private seed companies are not interested to multiply seed of various important crops that caused the financial burden on the breeding program.
- 4) Public investment in the variety uptake is neglected and needs improvement with well-organized as well as demarcated mandate on variety promotion.

The breeding (autotetraploid) nature of the crop [17], its narrow genetic base in Ethiopia, weak extension system on roots and tuber crops, unstructured seed production and distribution system, are major contributors for weak adoption of potato in the country [15]. On the other hand, breeding centers are focusing on their varieties adaptable to their localities rather than releasing varieties adaptable to wide agro-ecologies across the country [15].



Source: Ministry of Agriculture, 2020.

Figure 1. Trends of potato variety release and adoption in Ethiopia.

3.3. Agronomic Practices and Access to Quality Seed

Sound agronomic practices are an important aspect of any crop production and sustainable food security. In Ethiopia, potato has an immense contribution for food security and cash income for more than 5 million smallholder farmers. However, the productivity of the crop is below its yield potential due to poor agronomic practices and use of poor-quality seed potato by most smallholder potato farmers [14]. As the FAO identified factors constraining the potato sub-sector, lack of efficient seed systems was put in the second rank next to the potato's biological characters. Compared to other food crops, production of potato is capital intensive, requiring the purchase of large quantities of bulky seed and the application of high-cost inputs such as fertilizers and pesticides [23, 24].

Limited seed potato supply across the value chain could be one potential factor that hampers adoption of potato technologies. Unavailability of quality seed in in Yunnan province, China, led to dis-adoption of well-known and adopted potato variety C88 [21]. Seed security is central to crop production for smallholder farmers mainly in developing countries where quality seed supply remains as the major production constraint [25]. In central Ethiopia, the survey study result in two districts notified that farmer are still depending on informal seed sources, although they are using a range of seed sources [22]. Limited access to improved seed sources was the main factors that farmers hinder to practice better varieties of good quality seeds for cereals [25].

Among many potato adoption determinants, insufficient supply of quality seed is crucial for smallholder potato growers in many developing countries including Ethiopia. However, farmers' decision to use certified seed potato is determined by multiple factors that hinder their potential yield. In Kenya for example, distance to the market (a proxy for transaction costs), household food security, and endowment were identified as major factors affecting the decision to use certified seed potato [12].

In potato, Potato bacterial wilt (*Ralstonia solanacearum*) and major potato viruses are major production constraints for

the re-use of tubers and threaten potato farmers as they are critical seed borne pathogens [18, 19]. To mitigate these production bottlenecks, access to quality seed for smallholder farmers has crucial advantages and adopting effective quality assurance mechanisms through time in local seed system should be implemented.

3.4. Pest and Disease

Diseases are the major production constraints for potato mostly in developing countries where certified seed is in scarce [16]. Nevertheless, out of 261 potato farmers surveyed in Ethiopia 48% of potato growers commonly practiced a one season interval for crop rotation [26] causing disease spread from season to season through infected seed or infected field. The use of pesticides on crop fields has negative impact on human health [27]. In most developing countries smallholder farmers are applying pesticides which might be totally banned in developed nations due to various constraints like knowledge gaps, cheap price of the expired/banned chemicals, weak regulatory rules on human health, food sources, unaffordability of pesticides, etc. [28]. Considering gender in research on pest and disease management activities has an immense importance because it facilitates an efficient approach towards adoption of crops protection technologies and practices by women and men farmers based on their perspectives and skills [29]. In most potato breeding programs, pest and disease resistance varieties are breeder's focus areas of improvement in addition to improving productivity and nutritional quality of the crop. These production constraints are addressed by genetic modification or gene editing using genetic engineering tools [17]. Socioeconomic and Institutional Determinants of Adoption of Potato Technology.

Different authors of empirical research on potato production technology adoption identify the variables of technology adoption and interpret the significance of each element in different places. These characteristics are categorized as follows: i. demographic factors (age, gender, family size, and so on), ii. Socio-economic factors (education level, farm size, and so on), and iii. Institutional factors (extension services, credit services, access to technology information, and so on). IV. Technologically linked aspects, such as increased innovation, enhanced seed, and technology adoption.

3.5. Demographic Factors

Age: The empirical study of [7, 30] found that when farmers' ages increase, they adopt more improved potato varieties and irrigation, respectively. This might be due through time as their age increased household become experienced about the existing or new technologies. Age teaches farmers about what types of agricultural technologies exist, how they are applicable, their advantages and disadvantages and learn more through creating social network when to decide to adopt technologies. But, the research result of [30, 31] revealed that as age of household

increased their adoption improved potato varieties reduced. This contradicting result might occur due to differences in area of study as accessibility of different technologies, attributes related with it and different alternatives technologies supplemented with others where farmers have probability of selecting one over other and dropping other/s as his/her age increased. Other findings from [32] revealed that there is no significant association between age and adoption of this technology.

Sex: As various empirical research authors highlighted, being male or female had a substantial impact on family adoption of potato technology. According to the findings of [14, 10] male households are more likely to adopt improved fertilizer used for potato production than female households because females are primarily constrained by fixed costs, and [30] found that males adopt more improved potato varieties than females do because males spend more time in farming than female counterparts. Females are discouraged from participating in potato farming, purchasing different, not accessing different sources of credit, and female farmers are not restricting themselves but they are restricted to at home in developing countries due to the force of culture behind them.

Family size: Starting with land preparation and ending with harvesting, potato production is a labor-intensive activity. The existence of a large number of labors contributes to how to adopt various types of potato technology packages by generating various ideas, advice, and participating as labor force to prepare land, manage weed, share experiences from others, and hold a collective conversation. According to the findings of various empirical studies, large family size and potato technology adoption follow the same path. [33, 8, 7]. Highlighted how a larger family size might improve technology handling. To the contrary, [7, 34] revealed that larger family members are less likely to adopt improved potato varieties. This is due to the inability of low-income families to obtain improved varieties. This is because low-income family members unable to purchase improved varieties of potato unless the concerned bodies subsidize them.

3.6. Socio-Economic Factors

Education: Empirical research on potato production technology adoption indicated that the level of education received by households has a significant impact on farmers' willingness to adopt technology packages. Farmers easily aware of what types of technology to adopt, expect outcome and a bundle of benefits of adopting it. [7, 8, 10] found that farmers with a higher degree of education are more likely to use various potato production technologies in Ethiopia. Similarly, [32] found that education has a good and significant impact on potato technology adoption because it allows people to internalize what agricultural professionals say and properly apply technology packages. Conversely, [30] stated that farmers' technology adoption of improved varieties and irrigation usage are reduced when compared with intercropping strategies as their level of education increased. This is due to since intercropping is provided as

one of technology adoption, farmers in developing countries want fight fluctuation of climate by planting different plants and cropping potato which might enable then to achieve goal.

Land allocated: Land is perhaps the most essential resource because it serves as the base for all economic activities, particularly in the rural and agricultural communities. Most empirical research literature stated that land size allocated for potato production increase the probability of farmers to adopt different technology packages. Farmers with large landholdings size could boost their productivity and, as a result, are more likely to have access to technology packages than those with small landholdings size. The research findings of [34, 2, 26, 12] Revealed that the land size allocated for potato production increase the probability of adopting potato technology packages. But, [9] found that land size has negative effect on adopting potato technology adoption. These contradicting results might occur between empirical research studies due to type of crops largely produced in the area which could shift from potato to others, labors who manage the production of potato, climate, income of farmers, and the existing market for different agricultural products which might favor or disfavor potato technology adoption.

3.7. Institutional Factors

Extension services: The relationship between farmers and extension services makes it easier for potato production technology to be adopted. Access to Extension: Many research findings throughout time and location agree on the promising relationship between access to extension and technology adoption. Similarly, [32] demonstrates that access to extension was positively influenced by adoption of improved potato technology package by respondent farmers, and it is statistically significant. However, other studies have found that extension has a detrimental impact on the adoption of potato technology. Extension services were found to have a negative impact on the adoption of potato irrigation and other technologies [7, 9]. These results might occur that as frequent contact by extension agent increased, farmers might become less likely to adopt potato technology since most of the time extension agents go to farmers to collect information about quantity; they produced to prepare their own reports than providing advisory service.

Credit services: Credit encourages farmers to purchase and adopt various potato production technology packages, which is frequently and positively linked with technology adoption in several literatures. [8, 10] found that farmers that have access to finance services are more likely to adopt potato technology. Farmers can use loans to buy improved varieties, insecticides, fertilizers, and quality seed, as well as rent land, buy pumps, and store materials. In contrast to these findings, [7] exhibited that credit had a negative impact on the adoption of potato irrigation technology. These controversies arise because, in most developing countries, farmers have typically created sufficient irrigation services from local water bodies without incurring fees, while using credit to buy and use other potato production methods.

Information: The findings of many empirical studies, such as [30, 7, 10] exhibited that information from various sources assists farmers in facilitating the adoption of potato technology packages. Farmers use radios, television, friends, non-governmental organizations, and the market to learn how and when to adopt technologies.

4. Other Barriers to the Adoption of Improved Potato Technology

Potato's importance continues to rise because of increased urbanization and demand, serving as a source of nutrition, contributing significant amounts to the national economy, and improving food security and income for smallholder farmers through value-added goods [35, 36, 9]. The potato crop is vulnerable to a variety of abiotic (mostly temperature and precipitation-related) and biotic threats that threaten its long-term viability.

Lack of farmland, low crop prices at harvest but high seed tuber prices at planting, natural disasters, seeding rate, problems with using improved seeds, diseases, storage issues, a lack of money to purchase agrochemicals, and insufficient seed tubers during planting are all factors that affect potato production in Ethiopia [35].

5. Conclusion and Policy Implication

Potato is one of the most widely grown horticultural crops in Ethiopia, although its productivity and technology adoption are limited by several factors, including lack of improved potato seed/varieties, lack of knowledge and skill, lack of clean storage facilities, and backward production system. Smallholder farmers, who access the technologies from public institutions, are likely to benefit from the adoption of improved potato production technologies since it boosts productivity, income, and ensures the sustainability of their livelihood. Farmers consider the types and advantages of the technology before deciding whether to adopt them. Many empirical studies have found that adoption of potato technology is hampered by different factors in Ethiopia; some of the factors were financial difficulties in purchasing improved varieties, fertilizers, high-quality seed, diseases, and weak extension systems.

The literatures also identified that different demographic, institutional, socio-economic and technological factors directly or indirectly contributed to less adoption of potato technology. To achieve the expected level of improved potato technology adoption in Ethiopia, it is recommended that farmers should be made aware about the overall improved potato technologies available and the technique to use subsequently. Timely provision of refreshment training for farmers by experts or extension workers, supplying new and environmentally adaptable improved potato varieties, reducing the price of seed, supplying the required quantity of fertilizer with affordable price at the right time, and training farmers to protect their crop from diseases and pests. Hence,

considering all of these factors is crucial for advance adoption of potato technology in Ethiopia.

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