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Assessment of Potato Production Constraints on Yield of Potato (*Solanum tuberosum* L.) in North Shewa Central Ethiopia

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Abstract

Potato (*Solanum tuberosum* L.) serves as a food security crop in Ethiopia. However, its yield is constrained by a number of factors. Lack of quality seed, disease prevalence, unaffordable price of fertilizer, and use of slapdash seed tuber size by farmers are among the contributors to the low yield of the crop in the study area. The objective of this study was, to assess the constraints of potato production on yield. Accordingly, household survey was carried out in three districts of north Shewa zone namely Degem, Girar Jarso and Debrelibanos and nine total kebeles. The SPSS version 20 was used to analyze survey data. Regression analysis indicated that potato production was positively and significantly affected by family size, selection of tuber size, inflorescence removal, education level and production experience whereas land hold size have a negative and significant effect on potato production. The results of this study showed that potato production is constrained by a number of factors namely Insufficient high-quality seed, disease prevalence, a lack of inflorescence removal, a lack of fertilizer, and a lack of knowledge about potato production systems were the five major constraints challenging potato production in the study area, according to the index ranking method.

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Challenges, identification, Survey, productivity, *Solanum tuberosum* L.

Introduction

The nightshade or solanaceae family, which includes the potato (*Solanum tuberosum* L.), has its roots in South America (Lutaladio *et al.*, 2009; CIP, 2017). Next to rice and wheat, potatoes are the third-most important food crop in the world in terms of consumption (FAOSTAT, 2019; Salim *et al.*, 2023). Potato production in the world has increased from 270 million tonnes in 1961 to 370 million tons in 2019. The increase in production is primarily because of a consistent increase in yield potential of potato cultivars, as the area harvested for potato production decreased from 22.14 million hectares to 17.34 million hectares in the same period (FAOSTAT, 2020). It is a significant tuber crop that is grown extensively in the humid tropics and is utilized as a source of carbohydrates by a large number of people in the tropical and subtropical region (Bilate and Mulualem, 2016). More than a billion people use potatoes practically every day in raw or processed form, and they are widely grown in more than 164 countries (Eid *et al.*, 2020). By German botanist Schimper in 1858, it is found across numerous African continents and is known in Ethiopia (Asalfew and Geletaw, 2016). It is one of the most significant food crops among root crops, both in industrialized and developing nations (Asfaw *et al.*,

2017). It is Ethiopia's main food and cash crop, especially in the high and middle-altitude areas. It is also one of the leading vegetables produced in the country (Yazie *et al.*, 2017).

Potato is one of the most important crops in the national food security program and, because of its significant yield potential and environmental adaptability, can completely meet Eastern Africa's nutritional needs (Isaac *et al.*, 2016). It also one of the major staple crops in the Eastern and Central Africa sub-region and its importance continues to rise due to increased urbanization and uptake of processed potato products such as French fries (chips) and crisps (Agerie *et al.*, 2019). In the months of limited food production (July to August), before the grain harvests are gathered, over 3.5 million smallholder farmers in Ethiopia's highlands grow potatoes, which have been shown to lessen food insecurity (Tebabal, 2014). Potatoes are essential for ensuring national food security, nutrition, reducing poverty, and creating income (Gedif *et al.*, 2013; Ayalew, 2014). Along the crop's production, processing, and marketing chains, it contributes significantly to the reduction of poverty, the creation of income, and the provision of jobs for many societies (Devaux *et al.*, 2021; Menza *et al.*, 2014). According to Fayera (2017), potatoes have a yield potential that is around six to seven times more than that of rice and wheat from a unit area and time, giving them a five-fold bigger advantage.

According to Shibire *et al.*, (2001), Ethiopia has favorable meteorological and environmental conditions for growing potatoes. Since 70% of Ethiopia's arable land is suited for potato farming, mostly in highland regions above 1500 meters of altitude, the country has significant potential (Gebremedhin *et al.*, 2008). Due to its favorable agro-ecology and high levels of domestic consumption, the nation is also one of the main producers in Eastern Africa (FAO, 2019). In all, 1,141,871.725 tons of potatoes were harvested from an area of about 85,988.43 hectares (CSA, 2020/21).

According to FAOSTAT (2019), 388.19 million tons of potatoes are produced worldwide each year. The total volume of production increased from 3.65 to 29 million tons (CSA, 2016). With the current area coverage, potatoes are second only to red peppers among all other horticultural crops farmed in Ethiopia (CSA, 2020). It made up 28.5% of all horticulture crops combined and 60% of the root crops. Similar to how potato accounted for 50.7% and 43.2% of the total production of root crops and all horticultural crops added together (CSA, 2020). When compared to the average global productivity of 21.77 tons per hectare, Ethiopia's national potato productivity of 13.27 tons per hectare is still low (FAOSTAT, 2020). It provides a good yield of high-quality products per unit and input with a shorter crop cycle compared to the majority of cereal crops like maize (Adane *et al.*, 2010).

Despite the country's extensive potato-growing land, the low productivity of potatoes is due to a number of factors, including unsuitable planting materials, prevalence of disease and pests, poor soil fertility, variability in climatic patterns, lack of water, and poor post-harvest handling practices (Tesfaye *et al.*, 2011; Misrak *et al.*, 2014; Dereje *et al.*, 2013; Ephrem, 2015; Hailu *et al.*, 2017 and Adem *et al.*, 2021). Lack of high-quality seed, uneven mineral nutrition, poor fertilizer application, inconsistent rainfall and/or irrigation water availability, and conventional irrigation schedules and schemes are the main causes of low potato yield (Alegheleye *et al.*, 2022). However, some of the biggest challenges faced by small-scale potato farmers include the absence of superior varieties, reliance on traditional management practices, and inappropriate seed tuber size. So, the aim of this research was to assess and identify constraints of potato production in the study area.

Materials and Methods

Description of the Research Area

The study was conducted in the three districts of north Shewa zone of Oromia regional state, Ethiopia, namely Degem, GirarJarso, and Debrelibanos (Figure 1). The administrational towns of the districts namely, Hambiso, Fitche and Shararo are 125, 112 and 90 km from Addis Ababa to the north direction.

The districts are characterized by their longitudinal, latitudinal and altitudinal locationfrom$9^0$40’00’’N to $38^0$40’00’’ E, $9^0$37’0’’ N to $38^0$50’ E and $9^0$36’0’’ N to $38^0$40’0” E, in that order. The mean annual temperature and rainfall are 15^0C and 900 mm for 21^0C and 1400 mm with altitude 2905 m.a.s.l for Degem15^0C and 1200 mm and 18^0C and 1400 mm for GirarJarso and 15^0C and 800 mm for 23^0C and 1200 mm with altitude of 2100 m.a.s.l for Debrelibanos, in that order.

The primary source of income for most households is mixed farming, which is actively practiced by individuals who own both land and livestock. The rain fed agricultural sector is characterized by low

productivity as a result of traditional farming methods, low input usage, poor soil fertility, water logging, and other related issues. The main crops grown include Cereals (barley, wheat, maize, sorghum, and *teff*), pulses (bean, pea, and lentil), fruits, and vegetables grown (apple, cabbage, kale, onion, potato). A portion of agricultural goods are sold and consumed at home to provide income for social welfare, education, and other family expenses. It also makes a significant contribution to agricultural production by offering transportation, manure, and drought power (Hana and Dereje, 2016).

Study Procedures

The study was designed to generate the required information using survey on farmers perception on the challenges and determinants of potato production.

Study Design and Selection of Respondents

By using cross sectional study design, both primary and secondary data sources were used in this study. Multi-stage and stratified random sampling approaches were used incorporating both purposive and random selection techniques. Accordingly, three districts namely, Debra Libanos, Degem, and GirarJarso were purposefully selected for the first stage. Three kebeles from the Debra Libanos district (Wakene, Tumano, and GoroWartu), four from the Degem district (AnoKere, TumanoAbdi, AnoDegem, and ElamuEferso) as well as two from the GirarJarso district (Gino AnoBoneya and GirarGabar) were purposefully chosen based on their potential for producing potatoes. The list of farmers in each kebele was provided during the survey with assistance from the heads of the peasant associations and the development agents employed by each peasant association. From the list, informants were selected randomly and this random sampling was permitting all wealth, sex and age categories to be represented.

The primary data on the household's opinions on potato production and agronomic practices, issues of inflorescence removal, challenges of potato production were gathered using structured and semi-structured interviews. To determine the required sample at 91% confidence level and 9% level precision, a formula developed by;

Yamane (1967),

$$n = \frac{N}{1+N*e^2} \quad \ldots(1)$$

Where the n is sample size for the research use, N is total number of households in the selected kebeles and e is the level of precision (0.09).

Accordingly

$$= \frac{8378}{1+8378*(0.09)^2}, \text{ n=121.6~122}$$

Sampling interval (K) will be determined by dividing the total number of households in the population by the desired sample size of each kebele. Next, a number will be selected between one and the sampling interval (K) using lottery method, which is called the random start that will be used as the first number included in the sample. Then, every K^{th} household head after that first random start will be taken until reaching the desired sample size for each kebele.

According to the Yamane formula, the actual sample size of farm households to be questioned (122 Total HH) and for avoiding the missing data from farmers registration list during sampling interval due to some HH might not be identified himself, died, and displaced from area, 8 HH were added, and total 130 sample households were selected randomly for interview. This was based on the potential for potato production and the registration list of potato farmers from each kebeles.

The sample households from each kebele were randomly selected in the third stage using probability proportionate to size i.e.

$$ni = \frac{Ni*n}{\sum N} \quad \ldots(2)$$

Where Ni is number of households in the selected kebele, n is total population selected from districts, $\sum N$ is the sum of households of selected nine kebeles and ni is number of respondents selected from each selected nine kebeles (Table 1).

Data Collection Procedures

Multiple data gathering methods including interview, personal observation, group discussion and document analysis were employed to collect qualitative and supportive data. Primary data were obtained through a structured and semi-structured interview schedule, personal observation, whereas secondary data were largely collected from published sources. These

techniques were used to collect data with regard to household demographic characteristics, livelihoods, asset ownership, potato production, constraints of potato production, removal of inflorescence, and practices of using different seed tuber sized. In addition, secondary data from published documents, relevant organizations and offices were collected to supplement the primary data.

In addition, key informant interviews and focus group discussions (FGD) were carried out to strengthen the data collected from individual farmers. Five community members and five key informants from each kebele participated in two FGDs each, during which in-depth interviews on farmers' perceptions of potato production, problems, and its determinants were conducted based on their practical knowledge of the crop and availability. The identities of the focus group's members were identified with assistance from the local administration and development agents. Three people were participated in data collection as a facilitator. All of the participants were native to the study area, and fluent in the local language. The interview schedule was pre-tested and created by administering it to farmers who weren't in the sample, which facilitated the data collection procedure.

Statistical Analysis

The statistical packages for social sciences (SPSS) version 20.was used to analyze survey data. The important descriptive statistical measures such as percentage, frequency, mean and standard deviation were used to summarize and categorize the research data. The multiple linear regression analysis was used between average yields (t ha^{-1}) as a dependent trait and other studied variables as independent variables to study the effect of each variable on productivity of potato in the study area. The major constraints in production of potato were ranked by using index ranking that employed using the formula: -

Index = Sum of (8 x Number of Household Heads Ranked 1^{st}, 7 x No of household Heads Ranked 2^{nd}, 6 x No of household Heads Ranked 3^{rd}, 5 x No of household Heads Ranked 4^{th}, 3 x No of household Heads Ranked 5^{th}, 2 x No of household Heads Ranked 7^{th}, and 1 x No of household Heads Ranked 8^{th}) for each constraints divided by sum of (8 x Total No of house hold head ranked 1^{st} + 7 x Total No of house hold head ranked 2^{nd} + 6 x Total No of house hold head ranked 3^{rd} + 5 Total x No of house hold head ranked 4^{rth} + 4 x Total No of house hold head ranked 5^{th} + 3 x Total No of house hold head ranked 6^{th} + 2 x Total No of house hold head ranked 7^{th} + 1 x Total No of house hold head ranked 8^{th}) for all constraints (Hailu *et al.*, 2017)

Results and Discussion

Demographic Characteristics of Households

The majority of the respondents were from male-headed households (85.38%), and the remaining 14.62% were females who were widows or divorcees. People of working age (15–65) made up the majority of households with interviewees (94.62%), while those with older people (>65) made up 5.38% of the households (Table 2). The results showed that individuals in this age range are more likely to be productive and independent employees who are also known for having the physical stamina required for agricultural productivity. Similarly, Hailu *et al.*, (2017) found in the study conducted in Wolaitazone of Ethiopia that potato production is predominantly handled by the active age group of the society, which is between 15 and 65 years old.

In comparison to Degem, households in the G/jarso and D/libanose districts had an average family size of less than six (Table 2). According to a report by Agerie *et al.*, (2019), relatively large household sizes are vital for potato production, and the majority of farmers rely mostly on family labor. In reality, when the number of household size increases, families may also complete agricultural activities in time due to the sharing of responsibilities among household members.

Most households interviewed (48.5%) had children who had completed primary school (Table 2). Accordingly, Hailu *et al.*, (2017) stated that most farmers have a fairly high level of education to understand the basics of farming. Additionally, due to the high literacy rate, farmers can be targeted with improved potato production practices through reading materials like booklets, leaflets, and other help, according to the paper by Kateta *et al.*, (2015).

Land Holding and Potato Production Experience

The surveyed area clearly showed signs of land fragmentation forced on by population pressure. The amount of land owned by each household has decreased significantly as a result of these and other circumstances. Between 0 and 1 hectares of land are owned by more than 50.7% of the households (Table 3). The mean size of land owned by a household was only 1.76 ha, with a

standard deviation of 1.22. The average household experiencing potatoes production had been more than 8 years. This is consistent with the finding of Hailu *et al.*, (2017) that high production experience has a positive correlation with an increase in potato production because it enables farmers to learn how to enhance their farming operations.

Farmers Perception on Agronomic Management Practices

Use of Improved varieties

According to data on improved varieties, the majority of farmers (66.9%) accepted them (Table 4). The improved seed tubers, however, were quite old and had been in the farmers' hands for a very long time. Selected households (33.1%) respondents utilized an unknown variety of potatoes from an unidentified market source that was left over from a food aid project.

Additionally, some responses were utilized to establish volunteer potato plants from tubers that remained in the ground after harvesting. This indicated a lack of access to a better selection, a higher price, and a lack of information regarding the selection of potato seed tuber varieties in the research area.

Choosing the right seed tuber size

The majority of farmers (71.5%) selected medium seed tubers for their potato farms (Table 4). The majority of farmers, according to the findings, were aware of the ideal potato tuber size for planting. This is mainly due to farmers could plant larger area with one bag of seed than large seed tuber size. This means they could save money on their farms. And also, seed tubers having many eyes, higher survive rate and being sprouted, would produce more stems ensuring efficient use of resources, eventually leading to higher yield were frequently mentioned more than small seed size.

Fertilizer use

The majority of farmers (66.9%) used fertilizer on their potato farms. A large percentage of respondents were aware of the methods and schedules for applying inorganic fertilizer. This study in line with the findings done at Wolaita zone, southern Ethiopia by Hailu *et al.*, (2017), showed that 88.5% of farmers applied fertilizer at the proper rates. However, the majority of the farmers in the stud region were unable to pay for the fertilizer.

Control of disease

Despite the disease has already developed, the majority of farmers (56.9%) chose not to handle it with a pesticide. This showed that a sizable fraction of farmers replied as a result of their ignorance of the chemical types, source, and management method. Only (43.1%) respondents employed insecticides (Ridomil and Mancozeb) despite the prohibitive expense of pesticides. Potatoes may suffer significant damage from the signs of late blight, which frequently occur (*Phytophthora infestans*). It is pervasive throughout all of Ethiopia's potato-growing regions and is the most severe and aging potato disease in the world (Bezabih and Mengistu, 2011).

Inflorescence removal

According to a study on inflorescence removal, only about 31.5% of respondents are aware of how to remove potato flowers. The majority of farmers in the study area (68.5%) were found to be unaware of the kind, method, and timing of inflorescence removal and asserted it had no impact on crop productivity.

Productivity and Production Status of Potato in the Study Area

The majority of respondents (75.4%) produced less than national average yield ton per hectare (Table 5). The result showed that potato production was low when compared with national average (13.27 ton ha^{-1}). This finding also indicated that only 33.8% of respondents reported that potato yield had increased, while 66.2% claimed that production had decreased in the study area, according to the results on production status.

Poor seed quality, disease prevalence, rising fertilizer costs, frequent hedgehog attacks, erratic rainfall patterns, ignorance of agronomic practices like inflorescence removal, and the substitution of potatoes in the study area during the off-season with other crops like carrot and wheat are the causes of this.

The majority of respondents (59.23%) claimed that hedgehogs accounted for the decline in potato yield due to the vast expanse of land covered by eucalyptus trees and the fact that potato production systems were distributed rather than concentrated in the research locations. Key informants also pointed out during group discussions that potato production was decreased from time to time. This is mainly because of it was substituted

by other crop, attacked by wild animals, fertilizer cost, lack of newly released improved variety and lack of awareness on potato production systems.

Main Constraints on Potato Production

Growing and using potatoes presents a variety of challenges for farmers in the field of study. The most significant (1–5th rank) factors limiting potato production in the study area included a lack of high-quality seed, disease prevalence, a lack of inflorescence removal, a lack of fertilizer, and a lack of awareness on potato production system (Table 6). Similarly, Muzari *et al.*, (2012) revealed that the main factors limiting the low reported national mean yield of potatoes include the lack of superior varieties, drought, poor cultural practices, disease, and environmental degradation. The production of potatoes is substantially hindered by the presence of diseases, storage problems, low market prices at harvest time, and a lack of seed tubers during planting, according to research conducted in the Wolaitazone by Hailu *et al.*, (2017). Key informants and FGD also confirmed during group discussions that production of potatoes is mainly constrained by the presence of diseases, storage problems, low market prices at harvest time, and a lack of seed tubers during planting, lack of awareness, poor soil fertility, fertilizer cost and soil physiochemical property problems in Girarjarso and Debrelibanos Districts due to potato is sensitive to water logging.

Determinants of Potato Production in Study Area

Identification of issues limiting potato output was found to depend on analysis of factors impacting potato production. Prior to fitting multiple linear regressions, the hypothesized explanatory variables were checked for existence of multicollinearity. The Variability inflection factor(VIF) results (Appendix Table 1) indicate that, was no serious multicollinearity problem among the explanatory variables included in the model because all VIF values are less than 10 due to VIF more than 10 has collinearity problem (James *et al.*, 2017).

It is crucial to test for multicollinearity across explanatory factors because if there is multicollinearity between independent variables, it will be hard to isolate the effects of each parameter estimate on the dependent variables (Asfaw, 2022). Outliers were assessed using a box plot graph to make sure that there weren't any serious problems with them and that no data were lost as a result of outliers. The regression model's results showed that factors such as family size, tuber size, inflorescence removal, education level, land hold size, and production experience had a significant impact on potato production (Table 7).

Family size

A family size indicates the total number of individuals in the households. Large family size was expected to positive impacts on potato production to indicate the higher the number of household members, the more they were produced. The result showed that Family size has significant effect at 10% significant level on potato production with expected positive sign. Thus, the result implied that farmers' family size increase by one person, the potato production increased by 0.047 ton per hectares, keeping others factors constant.

Seed tuber size selection

It was found that, at the 1% level, the selection of seed tuber size for potato production had a positive and significant impact on potato yield (Table 7). This suggests that choosing medium seed tubers would boost potato yield by 0.366 tons ha^{-1} while holding all other variables constant. This is so that the duration of an emergency can be shortened, more stems can be produced per hill, and a higher yield of tubers can be produced. Medium seed tubers may have more food reserves than smaller seed tubers.

Inflorescence remove

It was found that the inflorescence removal had a positive and significant effect on potato yield at the 1% level (Table 7). Consequently, it appears that enhancing inflorescence removal methods would increase potato output by 0.889 tons ha^{-1} while holding all other factors constant. This is due to the possibility that removing the inflorescence could reduce competition among different organs, such as flowers and tubers, for a finite resource known as sucrose. According to this study, removing inflorescence improved the way resources were allocated to the tubers and improving their productivity.

Education level

Education is a continuous variable in human capital that is reflected in the household head's formal school years. Education is predicted to improve one's knowledge of production system, how to market information, use the production system more effectively, and transform commercialization into a profitable endeavor. The results

showed that family education has a positive sign with a 1% substantial effect on potatoes. The results implied that when farmers' education improved by 1 unit, the number of potatoes produced increased by 0.266 tons per hectare while holding other variables constant.

This is due to the fact that farmers who are more educated have the knowledge to produce more products than those who are less educated or have no education at all, as education makes it easier for farmers to request extension services. This supports the findings of Hailu *et al.,* (2017), who revealed that farmers in households with the highest literacy rates have enough education to understand the basics of farming.

Land Hold size

Contrary to expectations, it was shown that the amount of land set aside for potato farming has a negative and significant impact on potato cultivation at the 10% level of significance. The rise in family size and land fragmentation are factors in the decrease in the amount of land owned by each household in the study area. This finding is contrasts with that of (Asfaw, 2022) who asserted that the rise in land allocation may be due to farmers having access to more arable land, which encourages them to expand potato production.

Production Experience

It is found that, at a 1% level, expertise in potato cultivation has a positive and significant influence on potato production. According to this, each additional year of production experience would increase potato yield by 0.049 tons per hectare, assuming that all other factors remained unchanged. The findings of Hailu *et al.*, (2017) that farmers with experience in potato cultivation have a favorable association with potato quality improvement are supported by this result. This is so that even farmers with a lot of producing expertise can learn to improve their farming methods.

Recommendations

Research on the effects of seed tuber size and inflorescence removal to improve potato yield and yield components does not support the potato production in the study area. The main purpose of this research was to examine the production issues of potatoes. With the use of a survey on farmers' perceptions of the difficulties and factors that affect potato production, the study was created to produce the required information.

Farmers would do better to raise the land allocation for the commodity to increase their production potential as it had a big impact on the number of potatoes produced. Family size had a good impact on farmers' potato yield. By enhancing family participation in production activities including cultivating, earthing up, and inflorescence removal, the farmer can increase potato productivity. According to the study, farmers with experience in potato production have a positive relationship with the improvement in potatoes because they have a wealth of production knowledge. Agricultural development offices should collaborate with other farmers to help farmers become more knowledgeable about improving potato production practices. According to regression analysis linear model (OLS), land hold size for potato production had a negative impact on and was strongly associated with significant education level, family size, and acreage allotted for potato cultivation.

By raising awareness and providing extension assistance on production practices and access to new improved varieties, access to pesticides, it is vital to avoid the existing gap realized in the farmers in order to increase potato production in the research region.

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