

## Assessment on Potato Production Practice, Opportunities, and Constraints, in Semi-arid areas of Tigray, Northern Ethiopia

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### Abstract

Potato is widely grown in mid and highland areas of Tigray. However, productivity is below the national average due to many factors. To address this issue, a survey was conducted in Tigray's major potato production districts to assess potato production practice and identify key constraints, and opportunities related to potato production. A purposive sampling technique used to select Zone, Wereda, and Kebeles. Accordingly, three zones, eight weredas, and 386 farmers were selected. Structured questionnaires were employed to gather data on potato production practices, constraints, and opportunities. The collected data were analyzed using descriptive statistics and index ranking. The result of the survey indicated that 83.4% of the farmers interviewed produce potatoes under irrigation and rainfed conditions. Potato produced as a primary crop by 98.7% of farmers for sale purposes. Potato planting occurs between December 15 and January 15, as well as May 15 and June 30, depending on the irrigation and rainfall conditions respectively. Among the farmers interviewed, 98.9% use inorganic fertilizers, while 82.2% use organic fertilizers for potato production. 72.3% of the farmers interviewed used the Shashemene cultivar as planting material and obtained it from the local market, while 36.01% of use improved Gudanie variety. The study showed that under irrigation and rainfed conditions, farmers achieved an average potato tuber yield of 13.9 t/ha and 13.4 t/ha, respectively, with variability among individual farmers. The key opportunities in the study areas, as ranked by the index, include favorable agroecology, good soil type, access to irrigation water source and available labor. On the other hand, the most significant constraints in potato production are diseases and pests, drought, lack of improved varieties, and market demand. Therefore, it is recommended that research centers and higher educational institutions should focus on development of improved varieties.

**Key words:** Interview, Farmers, Purposive, Sample

**Original submission:** December 20, 2024; **Revised submission:** December 20, 2025; **Published online:** April 20, 2026

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### INTRODUCTION

Potato (*Solanum tuberosum* L.) is an important crop that contributes to food security, poverty alleviation, and income generation (Nyunza and Mwakije 2012). Potato production provides food, employment, and income as a cash crop and helps in increasing food availability while contributing to a better land use ratio by raising the aggregate efficiency of agricultural production systems (Gastelo et al., 2014). It is rich in easily digestible

carbohydrates, essential vitamins, and high-quality plant proteins, including lysine, which is often lacking in other crops (Peķsa et al., 2013; Waglay et al., 2014). It has a short growing period, high yield potential, and nutritious tubers with high edible dry matter content. Additionally, potatoes are used in various food-processing industries and can supplement diets when other grains are less available or unaffordable (Camire et al., 2009). They are affordable to buy, easy to grow, and can

thrive in challenging conditions where other crops may fail (Lutaladio and Castaldi, 2009). Factors affecting potato yields include water and soil management, seed quality, fertilization, soil moisture, elevation, slope, and irrigation (Maqsood et al., 2020.). Potatoes require 400 to 800 mm of rainfall or water, depending on meteorological variables, and suitable temperatures ranging from 14-23°C with a suitable daytime temperature of 23–24 0C (Xu et al., 2020)

Potato is the fourth most important food crop worldwide in terms of the volume of production after rice, wheat, and maize (Adane et al., 2010). It is also the most important tuber crop, ranking first in volume produced among root and tuber crops (Kebede, 2024). Ethiopia has the largest potential for potato production, with approximately 70% of its arable land deemed suitable for cultivation (Shamil & Dereje, 2021). This high potential is attributed to the country's favorable climatic and soil conditions, which enhance both productivity and yield (Chen, 2023). In addition, the Ethiopian government and research institutions have invested a significant amount of money and time in upgrading potato technology and quality to enhance smallholder production (Basha et al., 2017).

In recent years, Ethiopia has experienced a substantial rise in potato exports, both in volume and value. The country exported around 71,000 tons of potatoes to regional markets, with Djibouti being the primary destination, accounting for 80–90% of total exports (Brasceso et al., 2019). Ethiopia's annual potato production has also increased from 349,000 tons in 1993 to 743,153 tons in 2018 (Kebede, 2024). Despite this growth, Ethiopia's average yield of 13.77 tons per hectare (CSA, 2017) remains low compared to average yield of 35 and 45 tons per hectare in Europe and North America respectively (CIP, 2017). In Tigray, Ethiopia, potato is cultivated on nearly 622 hectares of land, approximately 12,156 small-scale farmers, with an average yield of 8.10 tons per hectare (CSA, 2017). The productivity of potato in the region is very low compared to the national average yield of 13.77 tons per hectare (CSA, 2017), as well as the yields obtained under experimental

conditions, which can reach up to 40 tons per hectare (Amare et al., 2022). Despite suitable agro ecological conditions and available labor, potato yields remain low in the region, hindering its potential benefits. The potato sector faces various challenges, including a lack of improved tuber seeds, disease and pest issues, water stress, and market limitations (Meresa et al., 2024; Merga and Haji, 2019). Moreover, there is a lack of area-specific information on potato production practices, potentials, and constraints in the study areas. In addition, there are some studies and observations of the area's suitability for potato production but not proved. Therefore, assessing potato production potential, major constraints and practices is important to identify the major constraints and tackle the problems in the future. The objective of this survey was to assess the production practices of potato by smallholder farmers in the study areas and identify the major opportunities and constraints associated with potato crop production.

## **MATERIALS AND METHODS**

### **Survey Sites and Descriptions**

The assessment was conducted in eight districts across three major potato producing zones of Tigray namely, East, South-East and South zones, of Tigray regional state between Feb-May 2020, which is in the northern escarpment of Ethiopia between 36<sup>0</sup> – 40<sup>0</sup>E longitude and 12<sup>0</sup> – 15<sup>0</sup> N latitude. It borders with Amhara Regional State in the southwest, Afar Regional State in the east, Eritria in the north, and Sudan in the west. The zones were selected purposively based on the Regional Bureau of Agriculture expertise perception and ranked potato as their most important crop in the areas. It has diversified agro ecological zones with varying soil, vegetation, and natural resources. The climate is mainly semi-arid, with the main rainy season (kiremt) from June-mid September (Araya et al., 2010; Gebrehiwot and van der Veen, 2013). According to CSA (2016/17), in Tigray 16,564 households cultivated potatoes on 622.22 hectares. In addition to potato, Wheat and Barley are the dominant crops grown in the study

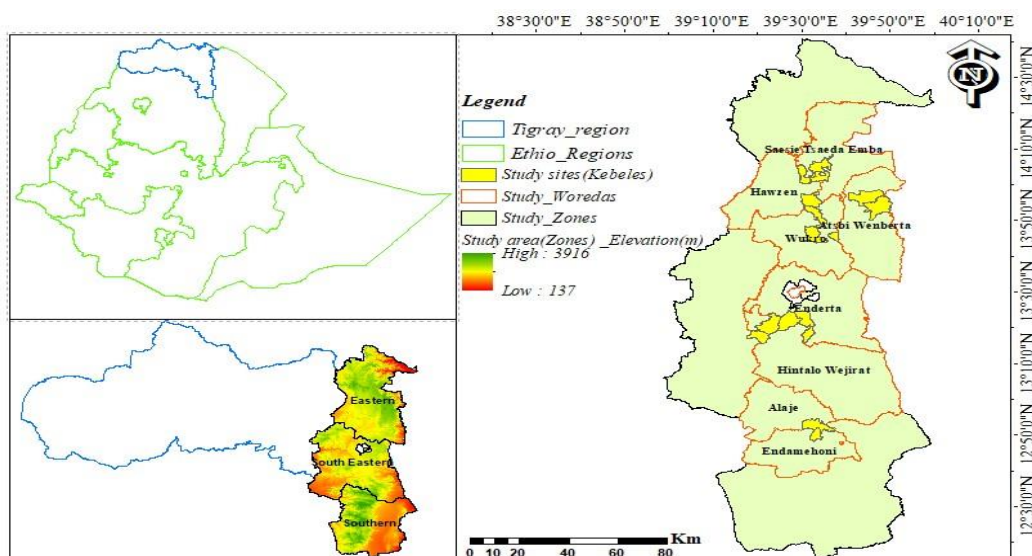


Figure 1. Study areas

### Sampling Procedures and Sample Size

To study the Survey, I obtained permission letters from Tigray Agricultural Research Institute and from Tigray Agricultural Bureau to districts and kebeles. I prepared questionnaires, discussed them with experts, and engaged farmers and development agents."

The assessment covered eight districts within the three zones such as Saesi-Tsadaemba, Hawzen, Kilti Awlalo, Atsbi, Enderta, Hintalo-Wejerat, Enba-Alaje, and Endamehoni Districts (Woreda) (Figure 1). Two kebeles were chosen from each district for the study. The population for the study consisted of the household heads, especially men and women. A purposive sampling technique was adopted to select Zone, Wereda and kebeles. A total sample size of 386 farm households was drawn from a population of 11,595 potato-producing households, which represents 70% of the total 16,564-potato producer households identified in the Tigray CSA report for 2016/17 by employing equation 1.

The distribution of the population size to each district had been obtained from the total potato producer in Tigray by using proportional sampling. The number of farmers ( $n$ ) selected from the potato-

producing farmers was calculated as sample size by using a simplified formula of Yemane (1967).

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

Where  $n$  = sample size,  $N$  = population size, and  $e$  = level of precision (0.050).

The interviewer conducted randomly from a list of farmers who produce potato in the kebele.

Focal group discussions had conducted in 16 kebeles comprising a diverse group of 8-10 members, including model farmers representing various demographics such as men, women, youth, and individuals with different administration levels in the kebele.

### Survey Data Collection Procedures

The primary data had collected by using a structured questionnaire. During the preliminary survey, a list of relevant guidelines and questions was used to guide the discussions with the focal groups. The main reason for pretesting was to identify any shortcomings and assist in making modifications to some questions before the actual data collection. The second stage was basic data collection. These data included information of households on demographic characteristics, production experience, production and productivity, use of potato production inputs (improved varieties, recommended spacing,

Fertilizer, soil fertility management), opportunities, constraints and variability. The survey was implemented through face-to-face interviews in individual households and focus group discussion (FGD) in each Kebele. Interviews conducted carried out in the local language Tigrigna. Open-ended questions added to investigate deeply for additional insights into the information collected. The focus group discussion had used to get more insight in certain topics and to check whether the group validates patterns found in the surveys. FGDs are very suitable to analyze a certain situation or problem in more detail and to identify and evaluate potential solutions to these problems. Specific topics discussed under my guidance. The observed data on what was happening in the field and general appearance of the area were noted in a notebook. Secondary data was obtained from CSA, Bureau of Regional Agriculture and Natural Resources and Research reports and other documents from various offices of bureaus of agriculture at different levels. Family size categories and age group was grouped according to (Jirčíková et al., 2013, Butani, 2006)

$$\text{Sum} \{ (w * N \text{rank}1^{\text{st}}) + (w - 1 * N \text{rank}2^{\text{nd}}) + \dots + (w - n * N \text{rank}n^{\text{th}}) \} / (\text{over all sum} (\text{Sum}1 + \dots + \text{Sum}n)) \quad (\text{Eq } 2)$$

Where N number of respondents in each specified rank, w...wn the weights assigned to each variable (number of variables in the computation), rank1, ... rank n are the rankings given by the respondents for each variable and Sum1...Sumn is the sub total of the individual variables under computation (sum) of all individual variables. The weighted sum formula allows you to give more importance to certain variables by assigning higher weights to them. Similarly, this technique also applied to determine the major horticultural crops.

## RESULTS AND DISCUSSION

### Demographic Characteristics of Households

The result revealed that the majority (87.3%) of respondents were male household heads, while the remaining were female household heads (Table 1). Similar results were reported in previous studies by Muthoni et al., 2013, and Gebru et al., 2017, which found that a large majority of farmers interviewed

### Data Analysis and Interpretation

Data analyzed using the Statistical Package for Social Science (SPSS, version 20). The important descriptive statistical measures such as percentage, frequency, and mean used to summarize and categorize the research data. In addition, chi square test was used to assess the association between potato production variables. Potato production opportunities and constraints had ranked by using index ranking based on the respondents' rankings of variables that calculated using the formula adopted from (Kosgey et al., 2004) ranking technique. According to this method, farmers were asked to specify the rank of all factors of potato production constraints and opportunity, and the results of such ranking have been converted into index value with the help of the following formula:

Index = sum of the number respondents ranks the variable in each rank divided to the sum of all variables ranked in each rank that is the weighted sum formula as indicated in equation 2.

$$\text{Index} =$$

in Welayta Zone, Ethiopia, and Kenya were male. Additionally, in the study area, men typically handle land preparation, plowing, planting and harvesting while women are involved in cultivation, weeding, marketing of farm products, and purchasing food and non-food items for consumption, indicating women's involvement in potato production. Furthermore, the survey revealed that most farmers (97.5%) were married, while a small percentage were unmarried (2%) and divorced (0.5%). Given the labor-intensive nature of potato crop farming, the involvement of multiple individuals is necessary, and this could be facilitated by the participation of the wife, husband, and children.

About 55.18% of farmers interviewed had family sizes >7, regardless of their active participation in the labor force. Whereas 31.87 and 12.95% had family sizes ranging from 4-6 and 1-3 respectively (Table 1). In the same way, Simonyan and Obiakor (2012) reported that majority of the rural residents had family sizes of more than five. According to

FGD, the labor available for work per household had influenced by family size and relies on the participation of household members in agricultural activities.

As the number of household members increases, tasks related to agriculture, including potato production, could be completed in a timely manner due to shared responsibilities. The amount of labor available for agricultural activities is also determined by factors such as family size, age, and gender. This suggests that farmers with a higher labor equivalent are more likely to engage in agricultural and potato production activities,

leading to increased income, regardless of having a large family size. Similar to the findings of this study, Simonyan and Obiakor (2012) observed that a large household size does not necessarily guarantee increased labor efficiency, as the family members may have different ages, sexes, and labor capacities. However, Okoye et al. (2008) and Udensi et al. (2011) reported that relatively larger household sizes are more likely to provide the necessary labor for farm operations, such as weed control and fertilizer application.

**Table 1. Demographic characteristic of the respondents**

Variable	Zones			Total (Frequency)	Percent (%)
	East	South east	South		
<b>Sex of HH head:-</b>					
• Male	159	91	87	337	87.3
• Female	28	11	10	49	12.7
Total	187	102	97	386	--
Percent (%)	48.6	26.3	25.1	--	100
<b>Age of HH head</b>					
• 18-24	2	0	0	2	0.52
• 25-54	152	95	68	315	81.61
• 55-65	16	7	26	49	12.69
• >65	17	0	3	20	5.18
Total	187	102	97	386	
<b>Family Size</b>					
○ 1-3 (small)	37	12	1	50	12.95
○ 4-6 (medium)	60	27	36	123	31.87
○ >7 (large )	90	63	60	213	55.18
Total	187	102	97	386	100
<b>Educational level of HH head</b>					
▪ No education	65	25	33	123	31.9
▪ 1-5	62	34	27	123	31.9
▪ 6-8	39	23	23	85	22.0
▪ 9-10	17	9	6	32	8.3
▪ 11-12	1	7	0	8	2.1
▪ Diploma and above	3	4	8	15	3.9
Total	187	102	97	386	100

About 31.9% of household heads lacked formal education, while the majority (68.10%) had received formal education at various levels ranging

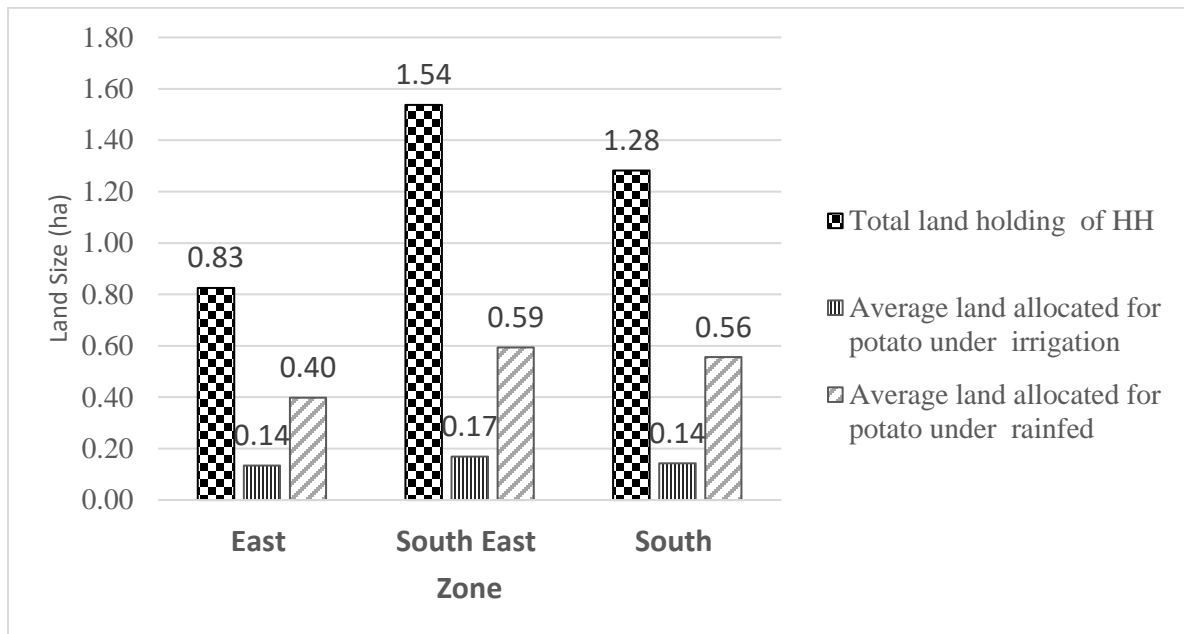
from Grade 1 to BSc. This proportion (68.1%) is notably higher than the national adult literacy rate of 46.7% (Doss, 2003). Education and training

contribute to increased productivity among farmers and facilitate the adoption of new production technologies. Similarly, Kateta et al. (2015) reported that high literacy level, improved potato production practices can be reached to the farmers through reading materials such as pamphlets, leaflets, and other aids. Additionally, literacy enables farmers to access reading materials such as pamphlets and leaflets, facilitating the dissemination of improved potato production practices. Fikadu and Gebre (2021) reported that farmers with higher levels of education and skills in farm organization tend to achieve better productivity. In addition, they reported that literacy levels positively affect the adoption of agricultural technologies.

Land scarcity is a significant constraint on agricultural production in Ethiopia, particularly in the study area. The average land holdings of farmers in the eastern and southeastern zones of Tigray had found to be 0.83 to 1.54 hectares, respectively (Figure 2). When it came to potato production, farmers allocated 0.4 to 0.46 hectares of land for rainfed cultivation and 0.14 to 0.17 hectares for irrigation. These findings indicate that most farmers in the region operate on smallholdings of less than 2 hectares, likely due to the prevailing land tenure system. Furthermore, there were variations in land size between zones, with farmers in the southeastern zone owning larger plots, averaging 1.54 hectares (Figure 2). In contrast, those in the eastern zone owned less than one hectare and allocated smaller areas for potato

cultivation, whether under irrigation or rainfed conditions. This discrepancy could be attributed to water scarcity for irrigation and farmers prioritizing other crops with lower water requirements, such as barley and chickpea. In agreement to this result, Girma and Ayalew (2024) reported that Ethiopian farmers manage small plots of land, often less than 2 hectares, due to historical land tenure systems and population pressures. They also reported that smallholder farmers often operate below their potential due to limited land availability, which affects their efficiency and productivity. The allocation of land for potato cultivation was consistent with the study (Senbeta and Worku, 2023) who reported that farmers allocate limited resources like land based on water availability and market demand.

Farm size is supposed to correlate positively to family size in most rural areas only and only when the family members are available and aged during the land allocation; this implies that large family size is not guaranteed to have large land. In General, the present study implies that land size is one factor for potato production of in the region either under irrigation or under rainfed condition. Therefore, it is important to introduce high yielding, disease and pest tolerant variety with appropriate agronomic practice to increase productivity in small land. In addition, there are mountain-traced areas in the study areas as a potential, this could be important to allocate the mountain-traced areas for youths to produce potato.



**Figure 2. Land holding of the household**

### Potato Production Condition and Practice

More than 80% of the farmers in each Zone grow potatoes under both rainfall and irrigation conditions. Specifically, 83.4% of the farmers interviewed cultivate potatoes using both irrigation and rainfall, while 14.5% rely solely on rainfed conditions and 2.1% solely on irrigation (Figure 3). About 81.7, 86.3 and 83.5% of the interviewed farmers in East, Southeast and South zones produce potato under both rainfed and irrigation conditions respectively and less than 10% of the farmers interviewed produce only under irrigation conditions (Figure 3). This suggests that only a small number of farmers exclusively use irrigation for potato production. According to farmers' perception and focal group discussions, the agroecology of the study area is suitable for cultivating potatoes under both irrigation and rainfall conditions. Most farmers plant potatoes between May 15 and June 30 in rainfed conditions, although some wait until June 30 to July 15, depending on the onset or expected onset of rainfall. A few farmers plant potatoes based on the start of rainfall. In the highlands, especially in the

South zone, farmers plant potatoes earlier compared to farmers in the Southeast and East zone mid-highlands. Furthermore, most interviewed farmers' plant potatoes from December 15 to January 15 under irrigation conditions. Some farmers also plant potatoes between September and October when the land becomes flooded during the main season, and they supplement irrigation. Therefore, adjusting the planting time of potatoes to coincide with the low temperatures required for tuber formation is critical for potato production.

All the farmers interviewed used the furrow irrigation method for irrigating potato crops. The main sources of water in the study area were streams (through diversion and water pumps), dams, groundwater (shallow well/borehole), and ponds. Most farmers obtained their irrigation water from diversion, while a smaller percentage relied on dams and shallow well/boreholes. A few farmers in the eastern zone (2.14%) depended on rivers through water pumps. Some farmers (7.81%) used multiple water sources. To increase potato productivity, it recommended improving streams,

implementing water, and soil conservation measures. The predominant planting methods for potato among the farmers in the study area were flat and ridge planting. Ridge planting is commonly practiced under both rain-fed and irrigation conditions, while some farmers used flat planting and later created ridges during cultivation in rainfall conditions. The spacing between potato plants ranged from 30 -40 cm, while the spacing between

rows varied from 50-75 cm. Focal group discussions revealed that the recommended spacing for potato was 30 cm between plants and 80 cm between rows in the study area. Therefore, it is important to provide training and advice to farmers on the significance of spacing and ridge creation.

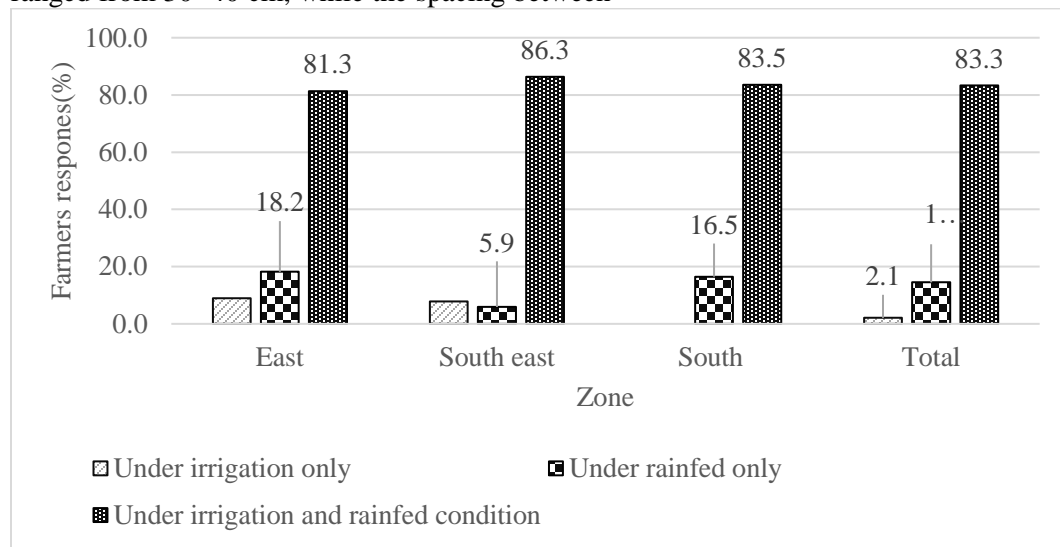


Figure 3. Farmers that Produce Potatoes under Irrigation and Rainfall Conditions in Each Zone

**Potato Production Inputs and Management Practices in the Study Areas**

The result of multiple responses of the farmers indicated that inorganic fertilizers, organic fertilizers, agro-chemicals and improved seed are the major inputs used to increase potato production in the study areas (Table 2). According to the focal group discussion on inputs for potato crop production, organic and inorganic fertilizers, chemicals and improved seed had a significant effect on potato production. Table 2 indicates that 98.9, 100 and 97.94 % of the farmers interviewed in East, Southeast and South Zone used inorganic fertilizer for potato production. According to the chi-square ( $\chi^2$ ), result there is no statistically significant difference in the use of inorganic fertilizer among the zones. The variation in the use of inorganic fertilizer across the zones is not statistically significant, indicating that the differences in usage are likely due to random variation rather than a systematic difference

between the zones. 82.1% of the farmers in the study areas used organic fertilizer for potato production: There is a statistically significant difference in the use of organic fertilizers across the zones. This suggests that different zones may have varying practices or preferences regarding organic fertilizer application. This study agrees with the findings by Gebru et al. (2017) who reported that most of farmers (88.5%) in Wolaita zone, southern Ethiopia used fertilizers for potato production. In addition, Nyamwamu et al. (2014) in Kenya who reported that farmers using recommended types of fertilizers were 96 %and farmers using recommended fertilizer rates were 58 % for potato production.

**Table 2. Potato production inputs used by the farmers (%) in the study areas**

Potato production inputs	Zones				$\chi^2$
	East	Southeast	South	Average	
Inorganic fertilizer	98.93	100.0	97.94	98.96	2.06 <sup>ns</sup>
Organic fertilizer	82.35	74.5	89.69	82.12	7.82*
Improved tuber seed	48.66	18.6	42.27	39.12	25.54***
Agro-Chemicals	67.91	78.4	35.05	62.44	44.54***
$\chi^2$	79.96***				

$\chi^2$  is Chi-Square, Source: Compiled by the author

**Note:**  $\chi^2$  is Chi-Square, ns is Not significant association between categorical variables at 5% probability level ( $P > 0.05$ ) \* is a significant association between categorical variables at 5% probability level ( $P \leq 0.05$ ), \*\* is highly significant association between categorical variables at  $0.01 \leq P > 0.001$  and highly significant association between categorical variables (\*\*\*)  $P \leq 0.001$ .

About 48.7%, 18.6%, and 42.3% of the farmers interviewed in the East, Southeast, and South zones, respectively, used improved seeds. This indicates that most farmers in all zones, especially in the Southeast, did not use improved tuber seed in potato production. Additionally, there is a highly significant difference in the use of improved seeds among the zones, suggesting that the availability and adoption of improved seeds vary greatly by zones. In the Eastern and Southern zones, there are some seed tuber multiplier cooperatives and individuals. The use of improved tuber seeds shows a highly significant difference across the zones. This indicates that some zones may be more effective or willing to use improved seeds than others may which could affect overall potato production. Regarding agro-chemicals, there is a highly significant difference in the use of agro-chemicals across the zones, indicating that some zones rely more heavily on these inputs than others. Ridomil and Mancozeb were the common chemicals used by the farmers in all study areas. Moreover, over 60% of farmers used chemicals to protect their potato crops from diseases and pests (Table 2). There is a highly significant difference in the use of agro-chemicals among the zones. This discrepancy could reflect varying agricultural practices, pest pressures, or economic factors influencing the use of these chemicals. Gebru et al. (2017) reported that 43.05% of the respondents applied chemicals (Ridomil and Mancozeb) to

control late blight in potato farms. The overall chi-square indicates that the inputs for potato production differ significantly across the zones. This suggests that factors such as geography, local agricultural policies, and farmer preferences affect how inputs are utilized in potato production.

In general, the data suggests that while the use of inorganic fertilizers is consistent across zones, organic fertilizers, improved seeds, and agro-chemicals show significant variation. This could be due to local agricultural practices, preferences, or availability of resources. The highly significant differences in improved seeds and agro-chemicals could warrant further investigation into the factors influencing these disparities.

#### Potato Variety (ies) in the Study Areas

Most farmers interviewed, commonly used cultivar was Shashemene (72.28%), which introduced from Shashemene, Oromia Region, Ethiopia, followed by local (55.70%). Gudene (36%), and Belete (20.5%) have moderate usage, while Jalene (8.8 %) and Gera (5.96%) are the least used. The Chi-square values indicate the statistical significance of the differences in variety usage across Zones (Table 3). All varieties show a highly significant difference (indicated by \*\*\*), meaning the distribution of potato varieties used is not uniform across the Zones. The highest number of farmers in Southeast and East Zone used Shashemene is notably favored, especially in the East and Southeast. This is due to

lack of access to improved seeds in the study areas related to problems with seed. Farmers selected and used the Shashemene cultivar based on criteria such as high yield, market demand, early maturity, low seed cost, access to seeds in the market, but its drawback is susceptibility to diseases and pests was not considered. On the other hand, the criteria for selecting and using improved varieties were high yield, quality, market demand, and tolerance to water stress, disease and pest resistance. However, the drawbacks of improved varieties were limited access to seed tubers and high seed costs, which led to most farmers not using them. Gudanie also has strong usage, particularly in the East, but shows less

preference in the Southeast. Belete and Jaleni are used less frequently, indicating they may not be as popular or well adapted in these regions. Gera is rarely used, which could suggest poor performance or lack of awareness among farmers. The significant Chi-square values reveal that the choice of potato variety is influenced by Zonal factors, emphasizing the need for targeted agricultural strategies that consider local preferences and conditions. In other studies (Gebru et al., 2017) reported that Gudene (32.2%) and Jalene (31.0%) were cultivated more than the other by smallholder farmers in Welayta Zone, Ethiopia.

**Table 3. Potato varieties used by the farmers in the study areas (%)**

Potato varieties and cultivars	East	Southeast	South	Total	$\chi^2$
Gudene	47.06	16.67	35.05	36.01	26.508***
Belete	24.60	4.90	28.87	20.47	21.346***
Jalene	14.97	0.00	6.19	8.81	19.531***
Gera	12.30	0.00	0.00	5.96	26.027***
Shashemene	73.26	92.16	49.48	72.28	45.360***
Local	59.89	31.37	73.20	55.70	39.799**
$\chi^2$		169.943***			

Source: Compiled by the author

**Note:**  $\chi^2$  is Chi-Square, ns is Not significant association between categorical variables at 5% probability level ( $P > 0.05$ ) \* is a significant association between categorical variables at 5% probability level ( $P \leq 0.05$ ), \*\* is highly significant association between categorical variables at  $0.01 \leq P > 0.001$  and highly significant association between categorical variables (\*\*\*)  $P \leq 0.001$ .

The data suggests a clear Zonal preference for specific potato varieties, primarily influenced by factors such as suitability to the environment, farmer experience, and market dynamics. This information can be crucial for agricultural development programs focusing on improving potato cultivation and ensuring food security.

The overall chi-square indicates that the varieties or cultivars used for potato production differ significantly across the zones. This suggests that factors such as seed availability, market, cost of seed, and farmer preferences affect the variety /cultivar used for potato production

### Seed Sources of Potato

Local market, farmers' seed multiplier associations, non-governmental organizations (NGOs), and research centers are the main sources of seed potatoes in the study areas (Table 4). The local market is the predominant source across all zones, with a perfect response rate in the Southeast and South. A high chi-square value indicates a significant association between the source and the zones, as 100% of interviewed farmers in the Southeast and South zones obtained their seed from the local market. In the East zone, 87.7% of farmers relied on the local market, while 30.6% obtained their seeds from farmers' seed multiplier associations. The latter source is less utilized, particularly in the Southeast zone, where no respondents reported using it; however, 33.7% of farmers in the East zone did use it. NGOs have

moderate usage, especially in the Southeast, with significant differences among zones, albeit less pronounced than the previous sources. Research centers are minimally utilized, with no responses from the Southeast or South zones, indicating that this source is not favored in these areas (Table 4). In general, most farmers in the study area acquired their seed potatoes from the local market, while small number of farmers received them as gifts from NGOs. A small portion of farmers obtained their seed from research centers, particularly in the East zone's Atsbi district, where a seed multiplier association exists. Research institutions played a minor role, representing only 8.6% as a source of

potato seed (min-tuber). Farmers primarily purchased seed potatoes with cash from the local market and seed multipliers, whereas NGOs and research institutes provided seed potatoes as gifts. Most respondents purchase potato seeds every year instead of keeping seed from their harvest. Some farmers interviewed, however, do keep their potato seed from their harvest and use it for 2nd and 3rd seasons, renewing their seed every two to three years. Farmers perceive that changing the soil texture for potato crops, such as planting potatoes in different types of soil each year; can also renew the potato seed tuber.

**Table 4. Seed sources of potato**

Source of potato seed tuber	Zone						$\chi^2$
	East		Southeast		South		
	N	%	N	%	N	%	
Local market	164	87.7	102	100	97	100	26.027***
Potato seed tuber multiplier	63	33.7	0.0	0.0	8.0	8.2	58.791***
Non-government organization	20	10.7	28	27.5	20	20.6	13.572**
Research centers	16	8.6	0.0	0.0	0.0	0.0	16.977***
$\chi^2$			116.153***				

$\chi^2$  is chi-square, N is number of respondents, Source: Compiled by the author

Note:  $\chi^2$  is Chi-Square, ns is Not significant association between categorical variables at 5% probability level ( $P > 0.05$ ) \* is a significant association between categorical variables at 5% probability level ( $P \leq 0.05$ ), \*\* is highly significant association between categorical variables at  $0.01 \leq P > 0.001$  and highly significant association between categorical variables (\*\*\*)  $P \leq 0.001$ .

The data indicates substantial variation in the sources of potato seed tubers across different zones. The local market is the most common source, particularly in the Southeast and South zones. There is marked preference sources in specific regions, highlighting the importance of geographical context in agricultural practices. The high chi-square values across categories suggest that interventions or policies could be tailored based on these regional preferences. This study reveals that most farmers in the area do not have access to clean and healthy improved seed in local market, which negatively affects potato crop production and

productivity. The study recommends that research centers, seed producer associations, agro-industrial organizations, and other non-governmental organizations collaborate to improve the production of quality seed tubers. This result supported by the result (Forbes et al., 2020) they reported that in many low-income countries, farmers often rely on informal seed systems, which include local markets and farmer-to-farmer exchanges. These informal systems are crucial for providing access to planting material, especially in regions where formal seed systems are underdeveloped or inaccessible. In addition, they indicated that in some areas, farmers might prefer local markets due to familiarity and immediate access, despite the potential benefits of organized seed multiplication. Furthermore, (Forbes et al., 2020) reported that in many agricultural systems formal research does not adequately address the realities faced by smallholder farmers.

### Inorganic and Organic Fertilizer Use and Management in the Study Areas

Farmers use chemical fertilizer, such as NPS and Urea, along with animal manure and compost to improve soil fertility and increase crop production. The use of manure and compost had been found to enhance crop productivity in the study areas. Most farmers in all zones use this combination Urea and NPS, with the highest usage in the East (94.7%) and Southeast (91.2%). This suggests that farmers prefer combining these fertilizers for better yield. A small percentage of farmers do not use inorganic fertilizers, notably higher in the South (4.2%). The Chi-square statistic (105.549,  $p < 0.01$ ) indicates a significant association between the type of

inorganic fertilizer used and the zone, suggesting that the choice of inorganic fertilizer varies significantly by zone (Table 5). According to discussions with farmers and interviews conducted, both inorganic and organic fertilizers have a significant impact on improving potato crop production. While most farmers interviewed use both types of fertilizers, some are unable to afford inorganic fertilizer due to financial constraints. Additionally, a few farmers do not use organic fertilizer because they have a limited number of animals and lack the necessary materials to make compost. Although farmers in the three zones apply similar rates of inorganic fertilizers, they have different soil types and fertility levels.

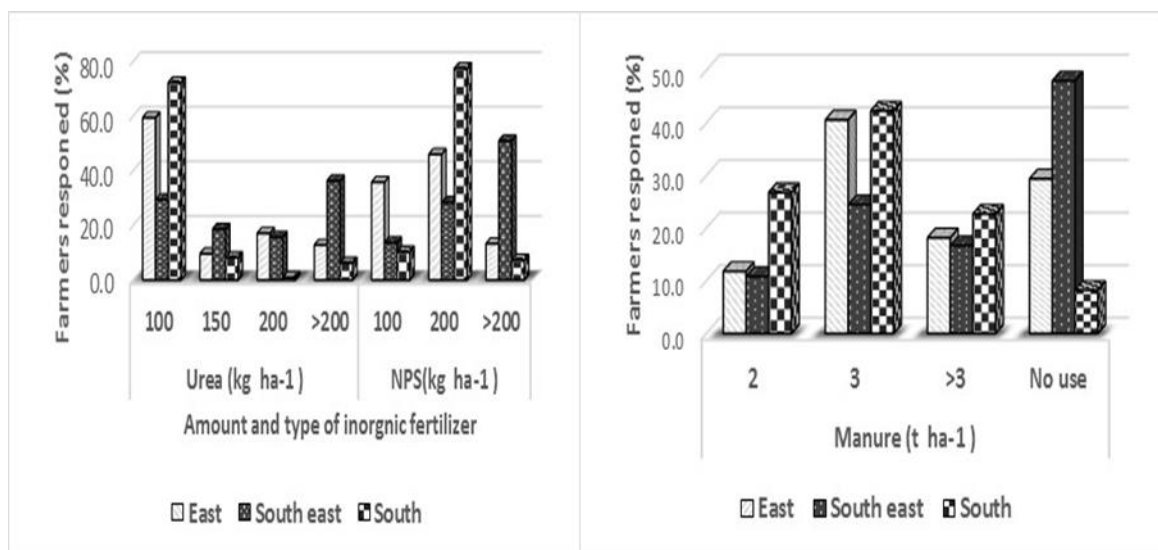
**Table 5. Type of Inorganic and organic fertilizer used by the farmers in each Zone (%)**

Fertilizer		Zone		
		East	Southeast	South
inorganic	Urea only	3.73	7.8	1.0
	NPS only	0.54	1.0	22.9
	Both urea and NPS	94.7	91.2	71.9
	Not used inorganic	1.1	0.0	4.2
Chi-square ( $\chi^2$ )		105.549**		
Organic	Manure only	43.0	63.7	78.4
	Compost only	4.8	2.9	1.0
	Both compost & manure	32.8	7.8	8.2
	Not used	19.9	25.5	12.4
Chi-square ( $\chi^2$ )		80.068***		

Source: Compiled by the author Note:  $\chi^2$  is Chi-square, \*\* is highly significant association between categorical variables at probability level  $0.01 \leq P < 0.05$  \*\*\* is highly significant association between categorical variables at probability level ( $P \leq 0.001$ )

Most interviewed farmers in in East and South zones apply (100 kg ha<sup>-1</sup>) urea and 200 kg ha<sup>-1</sup> of NPS for potato production, while in Southeast 36.3 and 50.9% of the interviewed farmers apply >200 kg ha<sup>-1</sup> urea and NPS respectively. Conversely, some farmers exceed the recommendation by applying higher amounts urea greater than 165 kg ha<sup>-1</sup> and 200 kg ha<sup>-1</sup> NPS. Regarding NPS, most respondents (200 kg ha<sup>-1</sup>) follow the recommended regional and national dosage for potato production. However, a significant portion applies a lower amount of NPS

kg ha<sup>-1</sup>, and only a few farmers exceed the recommended dosage (Figure 4). According to FGD, all farmers apply a full NPS rate and half urea rate at planting, with the remaining urea applied at early flowering. Most farmers use the drill application method at planting, while a smaller percentage employ spot application. Some farmers also use spot and broadcast methods for applying inorganic fertilizers. These findings suggest that farmers possess awareness of the importance of fertilizers, but economic constraints limit their usage among some individuals



**Figure 4. Amount and type of inorganic and organic fertilizers**

Farmers in the study area utilize both inorganic and organic fertilizers, including manure and compost, for their potato farms. Among the farmers surveyed, most of them apply manure only while small percentage of farmers apply or use both manure and compost and compost alone (Table 5). The Chi-square statistic (80.068,  $p < 0.001$ ) indicates a significant association between the type of organic fertilizer used and the zone, highlighting regional differences in organic fertilizer practices. In general, both inorganic and organic fertilizer usage varies significantly by zone, with distinct preferences observed. Farmers in the East and Southeast predominantly use both urea and NPS, while manure is the favored organic option, especially in the South. These findings can inform targeted agricultural policies and support programs to enhance fertilizer use efficiency in the respective zones. Like this result Gebru et al. (2017) reported that most farmers in Welayta Zone use fertilizer for potato production and most of the respondents were aware on the method and time of application. Furthermore, (Nyamwamu et al., 2014) reported that most farmers use recommended fertilizer type for potato production

The quantity of manure applied to potato fields varies greatly, ranging from 2 to 3t ha<sup>-1</sup> depending on factors such as the availability of resources like animals and the distance of the farm from home The

majority of farmers apply manure at a rate of 2-3 t ha<sup>-1</sup> 40.6, 24.5 and 42.3 % of the interviewed persons in East, Southeast and South zone respectively apply 3 t ha<sup>-1</sup> of manure for potato production (Figure 4). Small percentage of the farmers apply greater than 3 qt ha<sup>-1</sup>. According to the farmers' response there was no difference in the amount of manure and compost applied to potato fields. In agreement to this, (Gebru et al., 2017) reported that farmers in Welayta Zone, Ethiopia apply 2.1 t ha<sup>-1</sup>compost to potato farm but small amount farmyard manure of 1.1 t ha<sup>-1</sup>. In addition, Negasi et al (2013) reported that farmers in the central rift valley of Ethiopia applied 1.71 and 1.56 t ha<sup>-1</sup> of FYM and compost, respectively, to their onion farms. In general, most farmers use inorganic and manure fertilizers, which contribute to increased potato yield and quality, as well as the improvement, soil organic carbon levels. However, most farmers do not utilize compost fertilizer. Therefore, further research is necessary to determine the optimal rates, types, and timing of organic fertilizer application to fully maximize potato productivity.

#### Potato Productivity in the Study Areas

Timely harvesting and careful handling are crucial for the perishable potato crop. In this study, most potato varieties reached maturity between 90 and 120 days after planting, regardless of the season.

Under rainfall conditions, tuber yields ranged from 12.4 to 14.6 t ha<sup>-1</sup> in the South zone and the Eastern zone respectively, and from 12.6 to 15.0 t/ha in the South zone and the Eastern zone, respectively (Figure 5). The average yield of potatoes under irrigation was 13.9 t ha<sup>-1</sup>, while under rainfall conditions it was 13.4 t/ha. The highest average tuber yields of 15.0 t ha<sup>-1</sup> and 14.6 t ha<sup>-1</sup> were recorded in the East zone under irrigation and rainfed conditions, respectively. The lowest yields were observed in the South zone, with average tuber yields of 12.4 t ha<sup>-1</sup> and 12.6 t ha<sup>-1</sup> under rainfed and irrigation conditions, respectively (Figure 5). Farmers achieved higher average yields

under irrigation due to sufficient water, fewer disease and pest issues, and better management practices.

In agreement to this, (Gebru et al., 2017) reported that most of the farmers obtained 11.5 to 17.2 t ha<sup>-1</sup> yield of potato in Welayta Zone, South Ethiopia. Furthermore (Bezabih and Mengistu, 2011) reported that yield of 14.2 t ha<sup>-1</sup> in Southern Nations, Nationalities and People Region, but lower yield of 9.3 t ha<sup>-1</sup> in Tigray Regions of Ethiopia. In another study conducted in southern Ethiopia, (Mitiku et al., 2015) reported average tuber yields of 16.6 t ha<sup>-1</sup>.

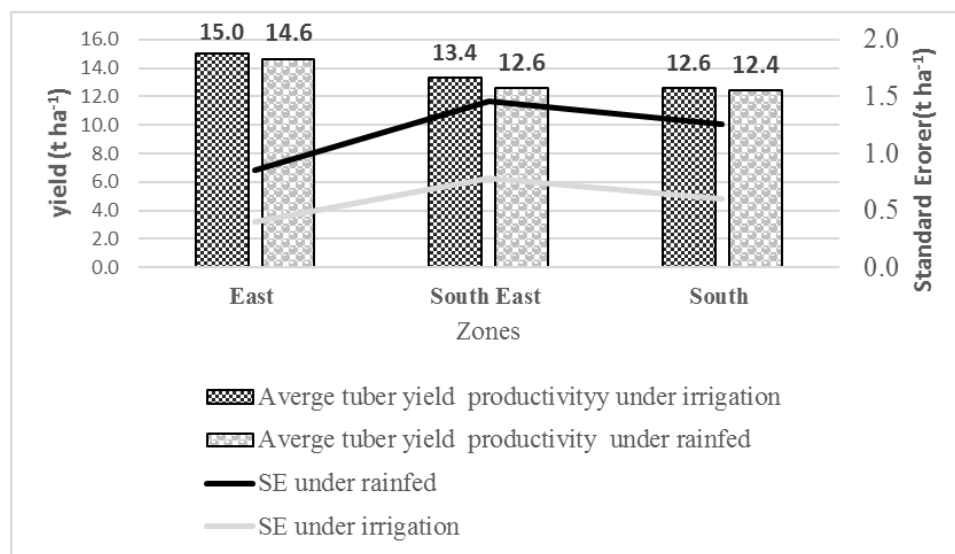


Figure 5. Average productivity of potato in the study areas under rainfall and irrigation condition

According to a survey, farmers agree that there is variability in potato production. Factors contributing to this variability include management practices, input quantities and types, soil fertility, access to water and improved seed, knowledge, and income. To enhance productivity among all farmers, the study suggests promoting experience sharing on potato crop management and protection measures, improving technical knowledge and skills through training on agronomic practices, water and fertilizer management, and providing effective extension services to increase potato yield.

### Potato Production Opportunities in the Study Area

The study findings highlight key opportunities for potato production in the study areas (Table 6). These opportunities include suitable agro-ecology, good soil type, access to irrigation and labor, availability of improved seed, rainfall, access to local markets, and transportation. The most mentioned opportunities by farmers had related to suitable agro-ecology, good soil type, access to irrigation water, and labor across all study areas. However, certain opportunities, such as availability to improved seed, access to market and transport

and rainfall are ranked lower and may pose challenges for potato production. It is important to note that opportunities identified by farmers in one area may not necessarily apply to other areas within the same zone. For example, an available improved variety may be an opportunity in one Wereda but a constraint in another. Overall, the analysis indicates that suitable agro ecology, good soil type and access to irrigation are the most significant factors for enhancing potato production in the semi-arid regions of Tigray. While access to improved seeds, market, and transport are less favorable, improving these areas could potentially enhance overall production opportunities. Addressing these key factors can facilitate better agricultural practices and increase potato yields in the region. Furthermore, developing and promoting potato production will require research and development of improved varieties adapted to different stresses and enhanced management practices. Similar to this study, previous research has shown that certain regions in Ethiopia, such as west and southwest Shewa zones of Oromia, have favorable conditions for potato production, including suitable agro-ecology, soil types, water sources, and fertile lands (Alemayehu, 2016). Ethiopia also has opportunities for various vegetable commodities due to favorable climate, proximity to markets, government policies, and cheap labor, as reported by Hunde, 2017. In summary, identifying and capitalizing on the specific opportunities in each region, such as agro-ecology, soil quality, and access to resources, will play a crucial role in advancing potato production and productivity in Ethiopia

**Table 6. Potato production opportunities in Semi-Arid Areas of Tigray**

List of production opportunities	East Zone			Southeast Zone			South Zone			Overall, in the study area		
	Sum	Index	Rank	Sum	Index	Rank	Sum	Index	Rank	Sum	Index	Rank
Suitable agro ecology	1478	0.220	1	802	0.217	1	772	0.221	1	3052	0.219	1
Good soil type	1303	0.194	2	728	0.197	2	683	0.195	2	2714	0.195	2
Availability of improved seed	633	0.094	6	236	0.064	7	166	0.047	8	1035	0.074	7
Access to irrigation	981	0.146	3	561	0.152	3	564	0.161	3	2106	0.151	3
Enough rainfall	820	0.122	4	419	0.114	5	417	0.119	4	1656	0.119	5
Access to labour	749	0.111	5	467	0.127	4	462	0.132	5	1678	0.121	4
Access to market	511	0.076	7	300	0.081	6	257	0.073	6	1068	0.077	6
Access to transport	256	0.038	8	178	0.048	8	176	0.050	7	610	0.044	8

Source: Compiled by the author

### **Production Constraints in the Study Area**

Potato production faces numerous constraints, including biotic and abiotic factors as well as institutional issues. In the study area, all farmers (100%) identified drought, disease, pests, lack of improved seed varieties, market challenges, soil fertility, frost, input availability, and lack of extension services (training, advice and access to credit) were identified as major constraints in producing potato production despite of their rank difference (Table 7). Regardless of the vast merits of potato to farmers, their production has been constrained by numerous factors. According to the index ranking among the different production constrains the farmers were identified diseases and pest, water stress(drought), improved variety seed tuber and market were the most important (1st–4th rank) constraints related with the production of potato in the study areas in general and in eastern zone in particular (Table 7).

Farmers in the South and East Zone face disease and pests, water stress, improved variety, and market as their main challenges. In the Southeast Zone, the major constraints are Disease and pests, improved variety, water stress, and market. This indicates that the primary issues in one area may not be the same in another, requiring location-specific solutions. However, regardless of location, Disease and pest, water stress (drought), improved variety seed, and market consistently emerge as the four major constraints across all districts and zones. The study highlights that diseases, pests, water stress, and insufficient quality seed tubers hinder potato production in semi-arid areas of Tigray. Some farmers also struggle with water scarcity during dry seasons, leading to reduced potato production. The analysis indicates that disease and pests, along with water stress, are critical challenges facing potato production in Tigray. Addressing these issues may significantly improve agricultural productivity in the region. To address these challenges, there is a need to strengthen the research-extension linkage and develop improved varieties and management practices that can withstand various stresses affecting potato production. In general, the study highlights the constraints faced by potato farmers, the ranking of these constraints, the location-specific challenges, the common constraints across different areas, and the need for tailored solutions

and recommendations to improve potato production. (Gebru et al., 2017) identified key constraints in potato production in Welayta Zone, south Ethiopia, including diseases, storage problems, low market prices, and insufficient seed tubers. Another study by (Emana and Gebremedhin, 2007) highlighted major constraints in horticulture production in Ethiopia, such as pests, drought, limited seed variety, high fuel prices for irrigation, and fertilizer limitations. (Muzari et al., 2012) attributed the low national mean yield of potatoes to various factors, including low adoption of improved agricultural technologies, drought, and lack of improved varieties, poor cultural practices, diseases, and environmental degradation. Insufficient or irregular rainfall and limited irrigation water also led to moisture stress and reduced yields. (Alemayehu ,2016) reported that major challenges in fruit and vegetable production in West and Southwest Shewa Zones of Oromia Region, Ethiopia included the unavailability of improved varieties, price fluctuations, and diseases and pests.

**Table 7. Potato production constraints in Semi -Arid Areas of Tigray**

List of production constraints	East Zone			Southeast Zone			South Zone			Overall, in the study area		
	Sum	Index	Rank	Sum	Index	Rank	Sum	Index	Rank	Sum	Index	Rank
lack of improved seed	1068	0.159	3	700	0.194	2	576	0.166	3	2344	0.170	3
Disease and pest	1380	0.206	1	704	0.195	1	696	0.200	1	2780	0.202	1
Market	998	0.149	4	538	0.149	4	550	0.158	4	2086	0.151	4
Water stress	1290	0.192	2	558	0.155	3	582	0.168	2	2430	0.176	2
Frost	710	0.106	5	420	0.116	5	438	0.126	5	1568	0.114	5
Input (other than seed)	703	0.105	6	383	0.106	6	340	0.098	6	1426	0.103	6
Poor soil fertility	302	0.045	7	165	0.046	7	179	0.052	7	646	0.047	7
lack of extension service	259	0.039	8	141	0.039	8	112	0.032	8	512	0.037	8

Source: Compiled by the author

## CONCLUSIONS

The assessment confirms that potato is the main horticultural crop in the study areas, serving as cash food, and seed purposes under both irrigation and rainfall conditions. All farmers in the study have experience with potato production. In Tigray, potatoes were typically planted between Dec 15 and Jan 15, as well as May 15 and Jun 30, under irrigation and rainfall conditions. Most farmers use both inorganic and organic fertilizers for potato production, regardless of the amount and application method. The average land holdings allocated for potato was 0.83 to 1.54 ha, which is very small. The average tuber yield under irrigation ranges from 15.0 to 12.6 t ha<sup>-1</sup>, while it ranges from 14.6 to 12.4 t ha<sup>-1</sup> under rainfall condition. The study findings reveal that the availability of suitable agroecology, good soil type, access to irrigation water, and labor are the major opportunities for potato production in eastern, southeastern, and southern zones of Tigray. However, farmers face several challenges, including diseases and pests, lack of improved varieties, drought, and limited access to markets (low crop prices at harvest but high seed tuber prices at planting) in the semi-arid areas of Tigray, Northern Ethiopia. Moreover, the amount, type, and timing of fertilizer application, land size and fertility, access to improved seed varieties, and water availability (irrigation and rainfall) are the key factors influencing potato production and productivity variability among farmers in the study areas.

The agricultural bureau and research centers should support farmer-based seed tuber production in the region. Cooperation with nearby stakeholders such as higher education institutions and research centers is important for area-specific fertilizer use programs and appropriate land-use systems. This will help maintain soil fertility and ensure the availability of clean seeds. Training should provide farmers and development agents to improve their technical knowledge and skills in potato crop production, disease and pest protection measures, and agronomic practices. Collaboration between the International Potato Center (CIP), research centers, seed producer associations, agro-industrial organizations, and non-governmental organizations recommended focusing on quality seed production and overall potato productivity in Tigray, Ethiopia.

## DISCLOSURE STATEMENT

The authors declare that they have no conflicts of interest.

## AUTHORS' CONTRIBUTIONS

Niguse Abebe: Writing-review; editing, Writing-original draft, Visualization, Validation, Software, Methodology, Investigation, Formal Analysis, Data curation, Conceptualization. Derbew Belew: Writing-review & editing, Methodology, Validation, Visualization, Supervision, Conceptualization. Gebre Hadgu: Writing-review & editing, Methodology, Validation, Visualization, Supervision, Conceptualization. Hussien Mohammed Beshir: Writing-review & editing, Methodology, Validation, Visualization, Supervision, Funding acquisition, Conceptualization.

## FUNDING STATEMENT

Authors declare that no funding was obtained for the work.

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