



POTATO PRODUCTION IN ERITREA: STATUS, CHALLENGES AND PROSPECTS

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Abstract

Potato (*Solanum tuberosum*) is a popular food crop for home consumption and a cash crop for growers in Eritrea. The potato grows quickly, has a high yield, and produces more energy and good-quality protein per unit area compared to a cereal crop per unit time. Potato production in Eritrea is low compared to neighbouring countries in East Africa and the issue is barely addressed sufficiently. This review study collates information on potato production status, cultivation systems, challenges and opportunities in Eritrea so as to assist researchers, academics and authorities in mitigating the issues. The study was conducted through a primary interview with farmers and an analysis of archived data at the Ministry of Agriculture of Eritrea and published resources. The production and cultivated areas are mainly dominant in the Debub and Maekel regions of Eritrea, with altitudes ranging from 1826 to 2490m above sea level. An increase in the production and expansion of farming areas have been observed from 3,619 tonnes in 1993 to 34,063 tonnes in 2022 with farming area rising from 648 to 2,227 hectares, respectively. The observed increase in production could be due to the increasing number of farmers using improved potato varieties. However, the production in the country still faces numerous challenges. The major constraints are the unavailability of enough improved seed, a shortage of fertilizer, and pesticides. The seed potato supply is still very low, amounting to only 14% of the demand. Potato is considered a hunger-busting crop that can contribute to the sustainable food security of the growing population and has a high potential for raising the live hoods of small-scale farmers. Thus, potato intensification is one of the key alternatives to improving the country's food supply situation and alleviating malnutrition and undernutrition, particularly in rural areas.

Key words: Seed Potato, *Solanum tuberosum*, Agricultural Production, Crop

1. Introduction

Eritrea is a country located in the Horn of Africa with a total land area of about 124,432 sq. km. It is bordered by Ethiopia to the south, Sudan to the west, Djibouti to the southeast, and the Red Sea to the east. Agriculture is the mainstay for more than 65% of Eritrea's population and one of the most important economic sectors of the country. The main food crops cultivated in Eritrea are sorghum, wheat, barley, maize, and pearl millet, and vegetable crops include tomato, cabbage, onion, pepper, and potato.

The potato (*Solanum tuberosum*) is one of the most important crops in the world today. The potato grows quickly, has a high yield, and produces high energy and good quality protein per unit area compared to a cereal crop per unit time (Jessie, 2017). Potato has been cultivated in the South American Andes on the border between Bolivia and Peru for 8,000 years (Birch et al., 2012). It is ranked third after rice and wheat in terms of human consumption (CIP, 2024) and is grown on 18 million hectares worldwide, producing 375 million tonnes of ware potato (FAOSTAT, 2023). Nutritionally, potatoes are excellent sources of carbohydrates, protein, vitamin A, potassium, vitamin C, B6, riboflavin, copper, pantothenic acid, and folic acid (Burke, 2017). Potatoes are grown under a wider range of altitudes, latitudes, and climatic conditions than any other major food crop. They are cultivated between the equator and more than 40 degrees north and south, as well as between sea level and elevations of more than 4,000 meters.

Originated in the Andean Mountain, potato arrived in Africa late around 20th century. In Africa, potatoes are grown in a variety of environments, from heavily farmed tropical highland zones in Eastern and Central Africa, where they are primarily a small farmer's crop grown under rainfed conditions, to irrigated commercial farms in Egypt and South Africa (Muthoni & Shimelis, 2022). In recent decades, world potato production has been in continual expansion, rising from 2 million metric tonnes in 1960 to a record of 27 million metric tonnes in 2022 (FAOSTAT, 2023) and mainly in Sub-Saharan Africa, where it has more than doubled since 1994, with 70% of that growth concentrated in Eastern Africa (Cromme et al., 2010). In Eritrea, the time of introduction of the crop is not clearly documented unless not cited, it is thought to be introduced with Italian colonization (Biniam et al., 2016). However, it might have been introduced way earlier, as some experts' suggestions which align with the introduction of the crop to Ethiopia by a German botanist, Schimper, in 1858 (Kolech et al., 2016; Pankhurst, 1964).

Potato has an important high nutritional value and is a popular food crop for home consumption and a cash crop for growers in Eritrea. Because of its dual role, the potato crop plays an important role in the rural livelihood systems of many countries (Gildemacher, 2012). It is one of the priority crops selected for its economic and food security value in the country. The need for diversifying the local food habits was earlier released and paved the way for the increased production and consumption of potatoes, which seems to have been realized by policymakers in the late 1990s (Tuku, 2000). Most of the climatic conditions of Eritrea are favorable for all-year-round potato production in the highlands and midlands, ranging from 1,500m to 2,500m above sea level, and are well adapted to various soil types by subsistence and commercial farmers under irrigation systems.

Average annual potato productivity on a 10-year average (2013–2022) is estimated at 13.6. The problem of low productivity and production of potatoes in Eritrea is mainly attributed to an inadequate supply of clean seeds and a poor seed supply system in the country. The seed used is mainly imported and multiplied more than three times in farmers' fields (Ghebreagziabiher et al., 2022). The degeneration of seeds is the main cause of lower productivity in Eritrea in particular and in East Africa in general. This degeneration of seed potatoes is mainly attributed to diseases caused by viruses transmitted through vectors like aphids. Although the Ministry of Agriculture has a several raw data set, there is a scarce of published or widely shared information that might assist researchers, academics and authorities in mitigating the challenges. Hence the issue of low production and productivity is barely addressed sufficiently. It has been demonstrated that comprehensive surveys and studies help in the effective targeting of research and development initiatives (Gildemacher et al., 2009). This paper therefore collates information on potato production status, cultivation systems, challenges and opportunities in Eritrea. Potato based systems are argued that it is increasingly creating opportunities for the rural poor in terms of poverty alleviation, food security, and improvement in health status. Thus, the study was envisaged that the information gathered would support the design of future research initiatives and the development of the potato value chain in Eritrea to contribute in alleviating food insecurity.

2. Materials and methods

This study comprehensively gathered information from the main sources through primary interviews and analysis of secondary data. The primary source included an interview of 79 farmers conducted in the year of 2023. The secondary data was mainly sourced from the prevalent data on production and cultivated area from the Ministry of Agriculture from 1992–2023, published articles, the horticulture research unit of the National Agricultural Research Institute (NARI) of Eritrea, annual reports of the agricultural extension department, and project documents. Soil samples were analysed at the soil research laboratory of NARI. A map of the surveyed areas was tracked using GPS (GARMIN, etrex, Taiwan) and drawn in ArcGIS 10.8. All the primary and secondary data were thoroughly cross-checked, and outliers that don't represent the main data have been removed from estimating the averages. Data collected on farm size, soil type, production, productivity, usage of varieties, and area were analysed using SPSS version 26.0 (IBM, 2019) for descriptive statistics.

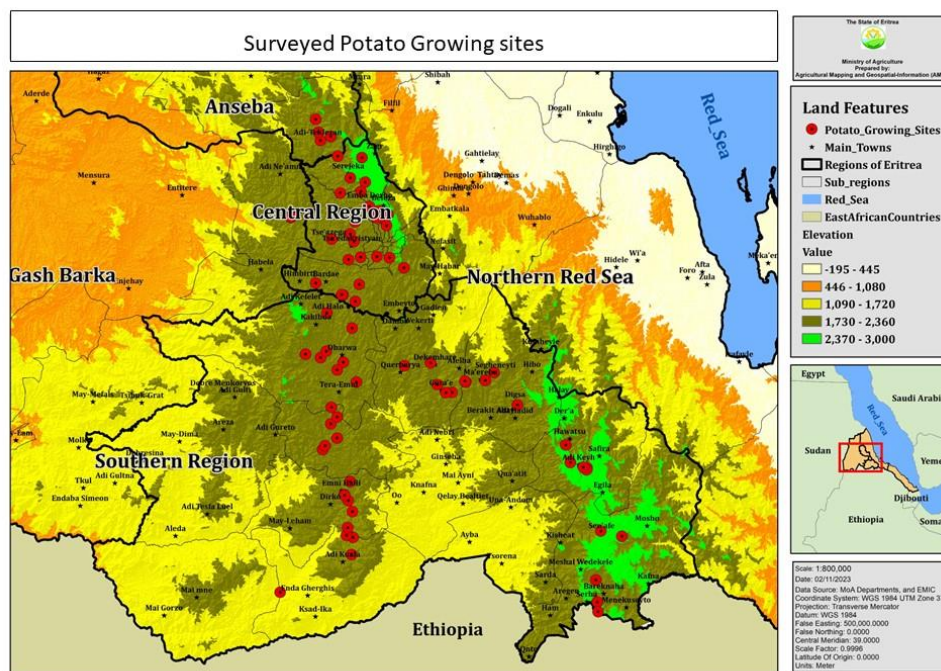


Figure 1. Map of surveyed potato farms during June-August, 2023

3. Results and Discussion

3.1. Climatic zones and distribution of potato in Eritrea

Eritrea is divided into six agro-ecological zones namely; Moist Highlands, Arid Highlands, Sub-humid Highlands, Moist Lowlands, Arid Lowlands and Semi-deserts (Figure. 2). While a temperate climate prevails over the highlands and midlands, the eastern escarpments are cool and moist, the northwestern lowlands are hot and dry, the southwestern highlands are hot and humid, and the coastal plains are hot and arid.

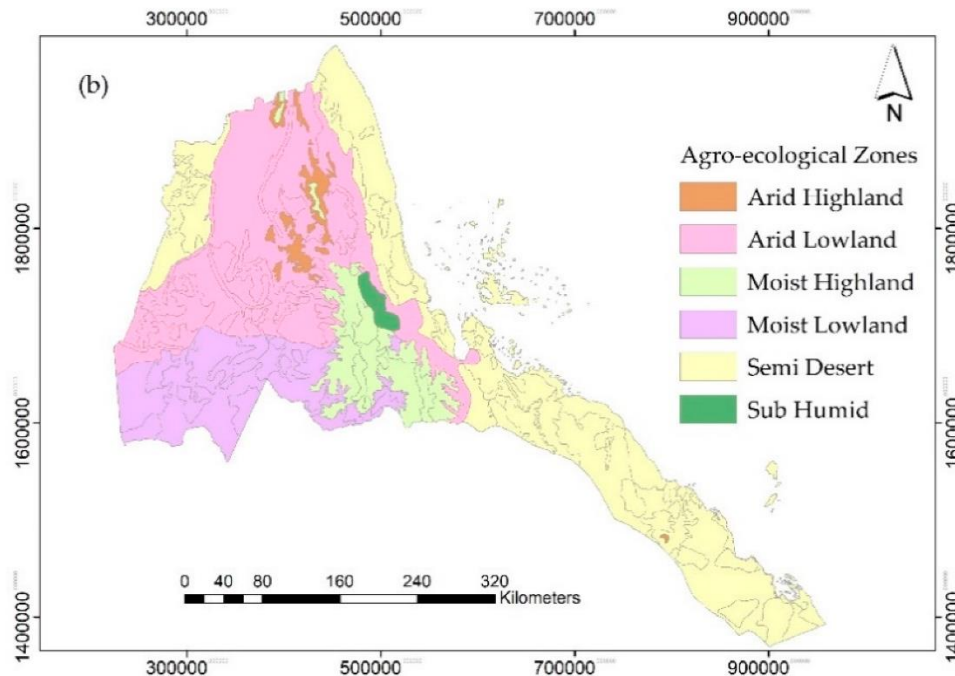


Figure 2. Agroecological zones of Eritrea. (Measho et al., 2019, used with permission)

The highland and midland parts of Eritrea are favorable for year-round potato production (Table 1). In the highlands and midlands, most of the farmers grow potatoes throughout the year, but usually the yield in the summer is low due to a high infestation of pests (Ali, 2007). Production and cultivated areas are mainly dominant in the Debub and Maekel regions of Eritrea. These regions are composed of flat (79%) and gentle slope (21%) topographic features and have soil types of clay (55.1%), sandy loam (10.9%), loam (12.3%), silt clay (21.0%), and sandy clay (0.7%) (Ghebreslassie, 2017). The results of the soil analysis indicate that the 79 farms surveyed had a pH range of 7.31 to 9.91. Thus, it indicates that most of the potato farms in the highlands of Eritrea are alkaline. Potato doesn't grow at all in the southern Red Sea region, while it is partially grown in the Gash Barka, Northern Red Sea (NRS), and Anseba regions. The months from November to mid-February are the coolest months (night temperature below 10°C) in the highlands; hence, most of the highland farmers do not grow potatoes during these cool months.

Table 1. Cropping seasons by months in five potato growing regions of Eritrea

Region/ Zoba	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Debub	--	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣
Maekel	--	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣	♣
N/R/S	♣	--	--	--	--	--	--	--	--	♣	♣	♣
Anseba	♣	--	--	--	--	--	--	--	--	♣	♣	♣
Gash Barka	♣	--	--	--	--	--	--	--	--	♣	♣	♣

The western parts of Zoba Debub and NRS represent midlands and are suitable potato production areas, but the NRS is characterized by a long dry season; hence, it gets only one potato growing season. All parts of Zoba Maekel are suitable for potato production (Azieb et al., 2012). In the Anseba and Gash Barka regions, these areas border Maekel, which are the subzones of Adi Tekeliezan and Logo Anseba, respectively, and follow the same pattern of cropping season as Zoba Maekel. The majority of the areas of Anseba and Gash Barka, regions however, plant in around October due to the hot weather conditions in the remaining months.

3.2. Area coverage and Production of potato in Eritrea

In Eritrea, potato grows well in the high lands, midlands, and in the cool months at the lowlands under various soil types by subsistence and commercial farmers. It mainly grows at altitudes between 1826 and 2490 meters above sea level. In 2022, the Ministry of Agriculture estimated that about 2,227 hectares of land were under potato cultivation and produced 34,015 tonnes of ware potato (MoA, 2023). This covered 13.2% of the total vegetables produced and 12.8% of the total area coverage of the vegetables in the country. On the basis of production, potato is ranked sixth out of all crops produced in the country and third among vegetable crops. In the highland regions of the country that hold 93% of potato production, it was estimated that potato was cultivated under irrigation by 64% of the 5561 small and medium-scale vegetable farmers in 2022.

Potato cultivation in developing countries has increased by 25 percent from 1997 to 2007 (CIP, 2011) and is the fastest-growing food crop in Sub-Saharan Africa (Haverkort et al., 2012; Muthoni & Shimelis, 2022). Now, potato is grown in 159 countries throughout the world, with China ranking first, accounting for 21.8% of world production, followed by India at 14.3% in 2020. The notable increase in potato production in developing nations confirms the crop's growing significance as a food source for the region's expanding population, rural jobs, and revenue (Khurana & Garg, 2003). Similarly, in Eritrea, an increase in production and expansion of farming areas have been observed in the past thirty years. The production has increased by tenfold from 3,619 tonnes in 1992 to 34,063 tonnes in 2022, and the productivity has increased by threefold from 5.6 ton/ha in 1992 to 15.3 ton/ha in 2022 (Figure 4). Likewise, the area has increased from 648 to 2227 hectares in 2022. The bulk of potato production comes from the central highlands, mainly the Debub and Maekel regions. On a ten-year average from 2013 to 2022, the Debub region holds the highest share of production (63%), followed by the Maekel region (23%). The regions in the lowlands of Anseba, Gash Barka, and the Northern Red Sea share the remaining 14% (Figure 3).

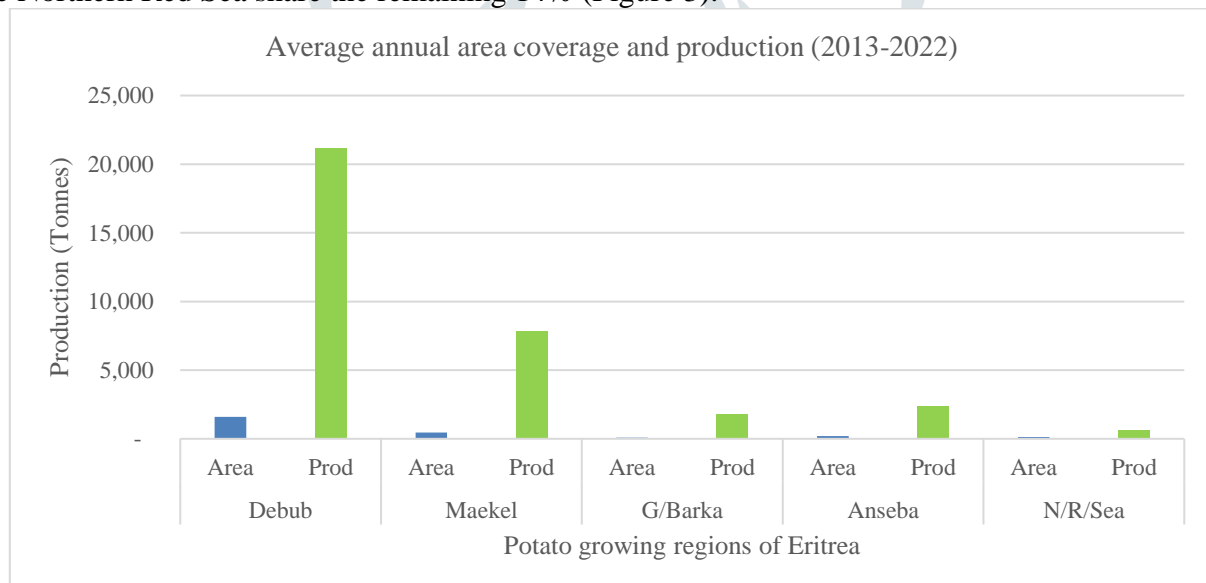


Figure 2. Average annual area coverage and production of potato in the five regions of Eritrea (2013-2022)

(Source: MoA Planning and Statistics Division, 2013-2022)

The national potato productivity, however, on a 10-year average (2013–2022) is estimated at 13.6 ton/ha and is below the world average (2013–2022), which is 20.9 ton/ha (FAOSTAT, 2023). Moreover, this low yield was observed to be below the yield obtained by farmers who have benefited from interventions (with yields of 20–30 tonnes/ha) such as improved varieties, agricultural inputs, formal training, and close supervision (EIDP, 2021). The yield of a crop is a function of many factors, such as timely planting and weeding, moisture, the use of improved seed, fertilizer, and pest control. Whenever any of these are missing, the yield is equally affected. The problem of low productivity and production of potatoes in Eritrea is mainly attributed to the inadequate supply of clean seed and the poor seed supply system in the country. The farmers are aware of the advantages of improved seeds over local seeds and experienced increased production when they planted improved potato seeds. This was confirmed with the studies conducted by Ghebreslassie et al., (2014b) and Tuku (2000), where the potato yield was 5 ton/ha in 2000, and in 2016, the maximum yield was observed to be 40 tonnes/ha in Zoba Debub and 30 tonnes/ha in Zoba Maekel.

After the year 2014, however, a decline was observed in productivity and cultivated area until 2017 (Figure 4). Such declines and increasing trends in these years were also observed in Africa generally and East Africa specifically. This could be due to droughts, heat waves, unseasonal rainfall, and an increase in the frequency of extreme weather events in the sub-Saharan region of Africa (Krüger & van der Waals, 2020). Even though potato productivity in East Africa in the past decade has shown an increasing trend, it is far below the attainable yields of 25–35 ton/ha (Muthoni & Shimelis, 2022). Whereas, the yields obtained by model farmers in Eritrea was 30–40 ton/ha (EIDP, 2021).

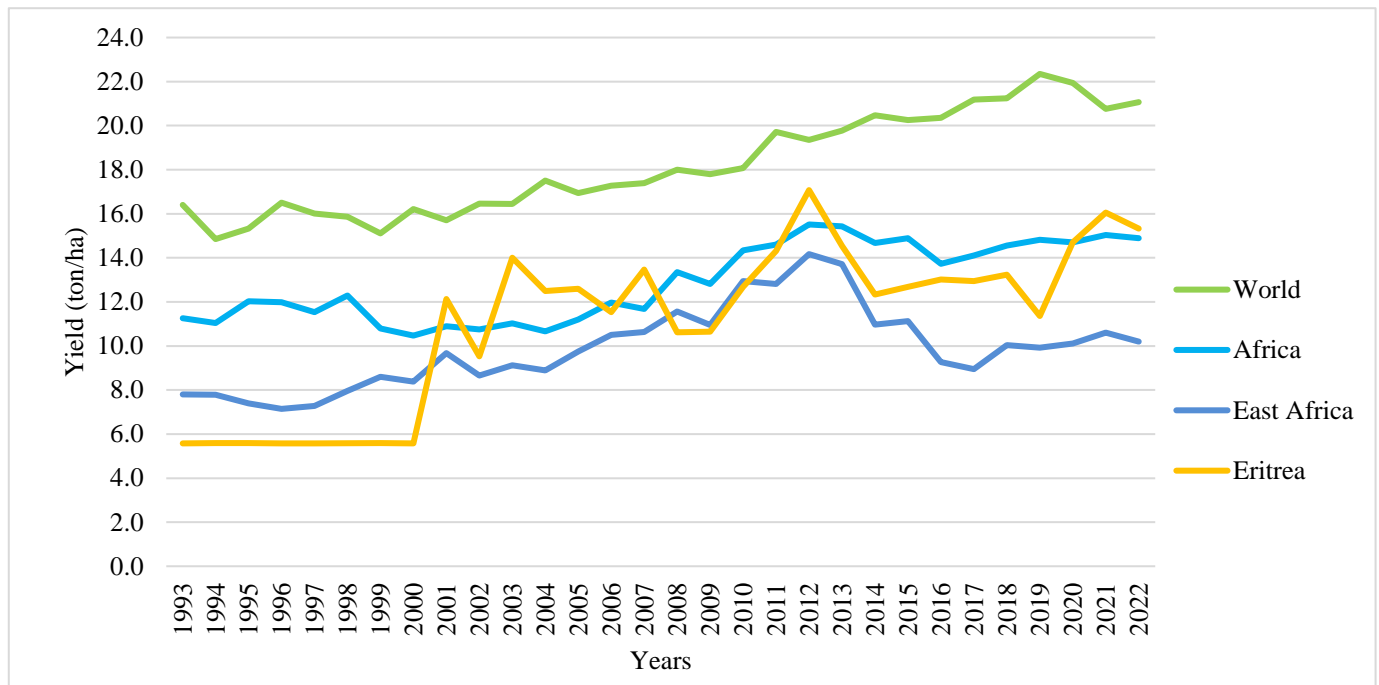


Figure 3. Potato yield in Eritrea, East Africa, Africa and the World during the past 30 years (1993-2022)

(Source: FAOSTAT, 1993-2022: MoA Planning and Statistics Division, 1993- 2022)

3.3. Farm resources

Farm resources encompass the resources that are used in the production process, mainly the physical resources such as land with its soil, climate, vegetation and topography, water, and other fixed resources. The agricultural sector is dominated by smallholder farmers whose average holdings are 0.5 to 1.0 ha in the highlands and about 2.0 ha in the lowlands, divided into three or more plots (Habtetsion, 2023); this excludes the vast areas under cultivation by state-owned farms in the lowlands. The subsistence farmers own small pieces of land and grow all their crops in the small fragments with little rotational practice. Zoba Maekel is densely populated and thus, has high farm land fragmentation. Hence, most commercial farmers do not own land but rent it for a specific period of years from subsistence farmers who have a shortage of capital to cultivate their land (Mehretab, 2015). This study revealed that currently majority (94%) of the farms cultivate potatoes on less than 0.5ha, and only 6% cultivate potatoes between 0.5 and 1 ha.

Farm size in Eritrea is affected by past land tenure practices that were common during colonial times. After independence, land was declared state-owned, but citizens have the right of usage. The tenure system influences the size of land that farmers have. The main characteristics of the system are that the land is basically owned by the community, so every permanent resident is entitled to share it equally through a periodic redistribution to all community members usually every 7 years, a land tenure system known as 'Dessa' (Negassi et al., 2002). In other words, farmers only have the right to cultivate the land but not own it. But still, farmers can obtain additional farmland through a variety of tenancy arrangements, mainly by renting them in kind, where the farmer shares a predefined and agreed-upon amount of production with the owner (Tewolde & Ghebreyohanes, 2003). In another tenure system, the 'Tsilmi' (conscione 'Conclusione') where farmers own their land, they are encouraged to make investments in the soil (Azieb et al., 2012). The study observed that land scarcity and fragmentation, in terms of the number of plots, are serious problems in the highland areas and specifically in the Maekel region.

Water is one of the limiting factors that restricts the growth of any crop. Rainfall distribution in Eritrea is erratic; hence, farmers rely mainly on irrigation for potato production. A study conducted by Ghebreslassie et al (2014) indicates that 91% of potato growers in Zoba Maekel and Zoba Debub use furrow irrigation from wells and few drip irrigation and overhead rainfall. During the rainy season, however, close to three-fourth (68%) of the summer rain goes along with the irrigation water from wells (Mehretab, 2015). These previous studies were confirmed by this study, where all farms were observed relying on irrigation water.

3.4. Potato varieties and access to seed

The Eritrean potato cultivars are thought to be introduced from a *Tuberosum* origin from European germplasm rather than an *Andigenum* origin from CIP breeding materials (Biniam et al., 2016). However, the varieties that were growing during these years are not well documented (Ghebregziabiher et al., 2022b), and farmers name them after their place of importation, their flower colors, or the shape of their tubers (Biniam, 2006). The commonly grown varieties in the 1990s were *Hollanda*, *America*, *Israel*, *Cara*, *Diamant*, *Spunta*, *Ajiba*, *Picasso*, *Zafira*, and *Electra*, and the local varieties *Keih-Embaba*, *Tsada-Embaba*, *Karneshim*, *Shashemene*, and *Yeha* (Ghebremeskel, 2016; Ghebreslassie et al., 2016; Tuku, 2000).

According to a molecular and morphological study conducted in 2015, there are 21 accessions commonly grown and known as farmer cultivars that are characterized by having high genetic diversity, intermediate maturity, good performance, and better tuber quality (B. M. Ghebreslassie et al., 2015, 2016). It's also indicated that the old cultivars *Tsaeda Embaba*, *Keyih Embaba*, *Shashemanie*, and *Yeha* have higher nutritional quality, specifically protein and dry matter content (DMC), than the imported European varieties (Ghebreslassie, 2017). However, these local potato varieties have largely disappeared and were replaced by foreign potato varieties, which were originally sourced from European seed companies (Ghebregziabiher et al., 2022b) due to their early maturing and high yielding potential (Ghebreslassie et al., 2014a). The fate of both local and new varieties is determined by the decisions that farmers make. Jarvis & Hodgkin (1997) noted that decisions made by farmers in the process of planting, managing, and harvesting crops affect crop genetic diversity; these decisions in turn are influenced by a complex set of environmental and socioeconomic factors (Kolech et al., 2015). Even though the old cultivars, which include *Keih Embaba* and *Tsaeda Embaba*, have largely disappeared due to their low productivity as indicated in Figure. 6, few farmers in a small area have conserved them due to their assumed resistance to viral diseases, as observed by the farmers (Figure. 5). The locally available potato varieties produce low yields, but they are consistent in terms of maintaining that level of production. Their consistency in yield over a long period suggests tolerance to the particular viruses present in the country (Biniam, 2006), even though they are reported to have a higher level of viral infection than the imported ones (Biniam & Tadesse, 2008). As such, farmers are observed planting these local varieties alongside the imported high-yielding varieties as an insurance against the failure or degeneration of the imported ones.

A study conducted in 2021 revealed that Eritrean farmers prefer varieties with characteristic features of early maturing, disease resistance, high yield, and white skinned with white fleshed tubers (Ghebregziabiher et al., 2022b). This characteristic preference is mainly because the potato crop in Eritrea is an irrigated crop due to short and erratic rainfall. Farmers prefer short-duration varieties, (around three months), so that it doesn't incur them extra costs for fuel for irrigation and escapes any disease or pest attack early.

In the past 30 years, the national agricultural research institute has tested 59 potato varieties sourced from Europe and CIP and recommended 14 high-performing varieties at different times (NARI, 2023). Most of the recommended and preferred varieties by the farmers were short-duration varieties, mainly European. The varieties include *Cosmos*, *Picasso*, *Zafira*, *Condor*, *Ajiba*, *Spunta*, *Temet*, *Electra*, *Banba*, and *Burren*. However, these varieties have been replaced frequently due to the absence of proper variety conservation systems, and potato farmers are subject to accepting some approved potato varieties without comparison, either with the previous or other varieties, due to the absence of any alternative access to better varieties (Ghebregziabiher et al., 2022b). The research institute has low international linkages and institutional arrangements to source technical backstopping and funding for agricultural research (Ghebregziabiher et al., 2022a; Habtom, 2020). Hence, research on potato is mainly focused on adaptation trials of new varieties, and conservation of the old varieties gets little attention.

Farmers in Eritrea are increasingly using improved potato varieties. A survey conducted in 2015 and 2017 showed that, on average, 59% of farmers in the Maekel, Debub, and Anseba regions were using improved imported varieties (Haile, 2017; Mehretab, 2015). In an assessment conducted in this study,

however, the usage has increased to 95%. These figures however do not reflect the usage of certified seed. It implies the usage of new developed varieties either certified seed or farmers saved seed. According to the farmers responses, a wider area coverage (70%) and preference for the variety named *Electra* were observed (Figure 5). *Electra*, an IPM(Irish Potato Marketing group) variety, is preferred mainly for its short maturity period, disease resistance, and good market preference because of its shape and white skin color, followed by *Arizona*, an AGRICO(A Netherlands seed potato company) variety(Figure 5).

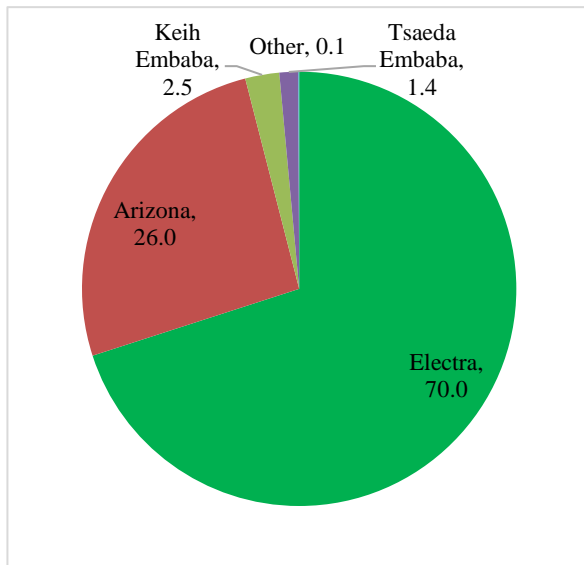


Figure 4. Percentage of varieties usage by farmers (2023)

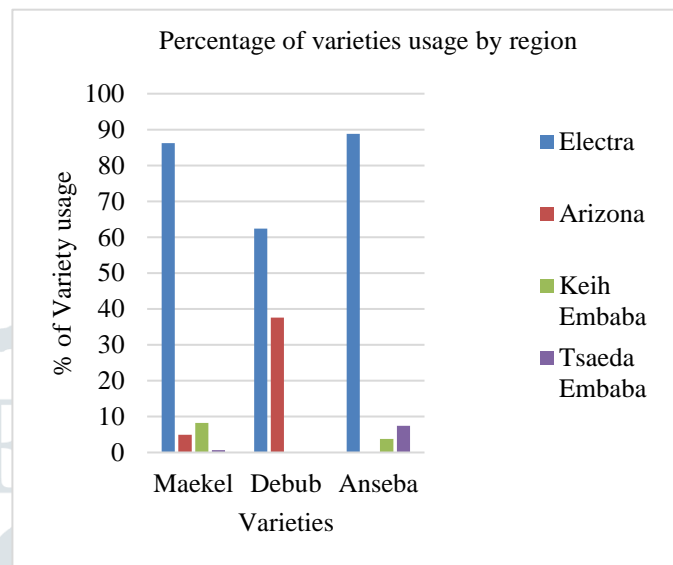


Figure 5. Percentage of varieties usage by region (2023)

Seed is a critical agricultural input that has great potential to improve crop production and productivity. The current main source of certified seed is the mandate and responsibility of the Ministry of Agriculture. Thus, the imported seeds are subsequently multiplied by contract farmers, mainly smallholder farmers, and distributed to ware growers as quality-declared seeds (QDS). The farmers are selected based on criteria set by the Ministry of Agriculture, which include size of land, water availability, resource availability, experience, and willingness to grow potatoes. The multiplied seed is then collected at a premium price of 25% above the market ware price. The formal seed supply from the centralized stores to the farmers covers 14% of the farmers' demand. On average, 58.3% of farmers also save their own seeds for next season (Ghebresslassie et al., 2014a). The total national seed demand, based on cultivated areas, is estimated at 4000 tonnes of seed annually. The mismatch between demand and supply is leading farmers to illegally import seed potatoes from neighboring countries.

3.5. Diseases and insect pests

Potato diseases are caused by a variety of plant pathogens, including viruses, fungus, bacteria, oomycetes, and nematodes (Oyesola et al., 2021). Worldwide, about 40 soil-borne diseases affect potato and at least 75 diseases (PAA, 2010) and nonparasitic disorders caused by insects, nematodes, viruses, bacteria, and fungi cause severe damage, especially on tubers, the economically most important part of the plant (Fiers et al., 2012). Although documented studies are not available on the potential of microorganisms causing yield loss, it is a general assumption that there is substantial potato yield loss in Eritrea due to several pathogens (Biniam & Tadesse, 2008). Currently, the recorded diseases in the country are bacterial, consisting of Blackleg disease (*Erwinia carotovora*), tuber soft rot (*Erwinia* spp.), collar rot (*Erwinia* spp.), and fungal, consisting of Late Blight (*Phytophthora infestans*), Early Blight (*Alternaria solani*), Verticillium Wilt (*Verticillium albo-atrum*, *V. dahlia*), Fusarium Dry Rot and Wilt (*Fusarium* spp.), Powdery Mildew (*Erysiphe cichoracearum*), Rhizoctonia sps, Scelerotium sps, Septoria leaf spot (*Septoria lycoperhe csici*), common scab (*Streptomyces scabies*), and common rust (*Puccinia pittieriana*) (Ghebresslassie, 2017; NARI, 2016). Furthermore, the viral diseases of potatoes detected, according to a survey conducted in 2007 by Biniam & Tadesse (2008), are PVX,

PVY, PLRV, PVS, and PVA. Moreover, a recent unpublished report by the Ministry of Agriculture indicates that PLRV and PVY are now the dominant types of viruses circulating in the country, causing dramatic yield losses, while PVS and PVX have become significantly less important. The reasons for increased disease pressure from PVY remain unknown. PVY viruses are non-persistently spread by aphids, which means virus transmission between plants is a matter of seconds to minutes.

The insect pests, on the other hand, attack potatoes in both the field and stores. The distribution and frequency of pests might vary depending on factors such as the season of the year, location, and cultivation method. The most common insect pests in the country include cutworms, aphids, potato tuber moths, whiteflies, and stinging bugs, in order of their economic severity (Ghebresslassie, 2017). And recently, a spider mite was observed, causing significant damage to the crops in the field and store. Controlling pests mainly depends on the application of chemicals, which obviously damage the environment if not used properly. As Ghebresslassie et al (2014b) found, 95% of the farmers in Dehub and Maekel use chemicals. However, the type and dosage of chemicals used are not monitored regularly, which allows farmers to use and apply whatever is cheaper, easier, and more accessible to them.

4. Challenges

Potato production in the country faces numerous limitations. Smallholder farmers practice low-input, low-productivity, rain-fed, subsistence farming, which gives a low crop harvest through labour-intensive cultivation practices, with labour provided by people and draft animals (Habtetsion, 2023). Some of the constraints that were identified during visits, reports, and surveys in the highlands and midlands included: weak seed variety, high cost of inputs, limited access to extension services, unreliable weather, low produce price, lack of storage facilities, fragmented plots of farmlands, limited or no access to investment loans, and weak seed provision systems. The gap in the yield was mainly due to the unavailability of good potato seed, which is technically called the yield-limiting and reducing factor. The major constraints of potato production as farmers interview and focus group discussion conducted at different times indicate that the unavailability of enough improved seed (19%) is a major obstacle, followed by shortage of fertilizers (14%), and pesticides (14%) (Figure 7). Potato is a high-input crop; hence, enough fertilizers that have nitrogen, potassium, and phosphorus, either organic or inorganic, are required to produce the needed yields. The land tenure system is one of the limiting factors discouraging farmers from properly amending the soil fertility levels of their farms sustainably.

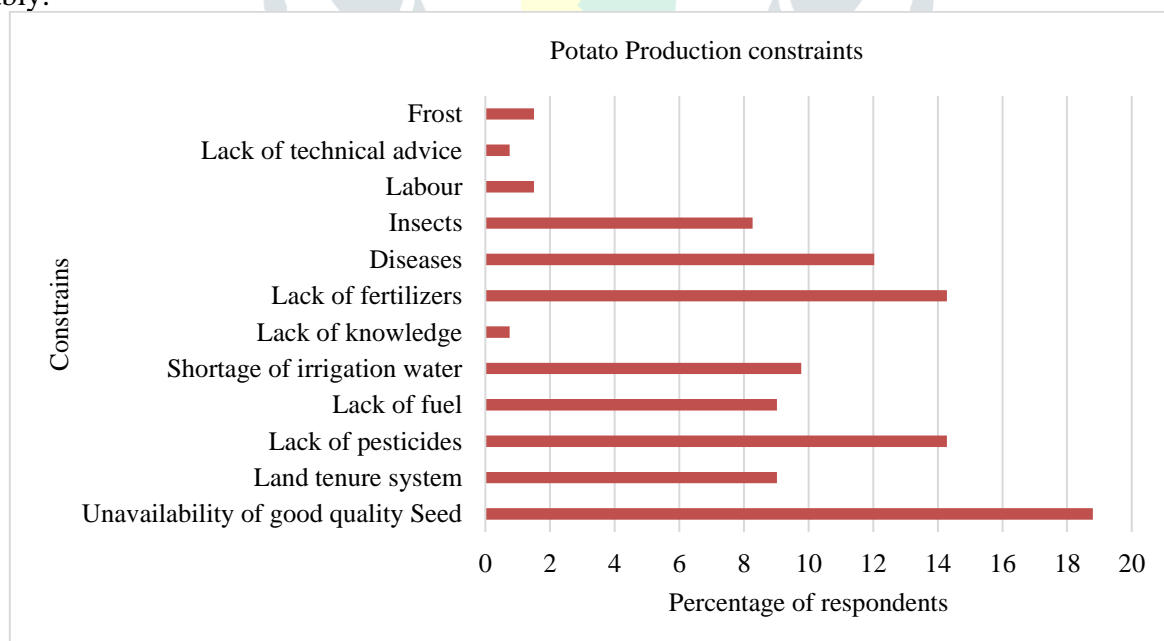


Figure 6. Production constraints of potato as responded by 149 farmers.

Eritrea is a drought-prone country located in the arid and semi-arid Sahelian area; hence, it experiences reductions in yield and failures in the production of not only potatoes but all major crops. The other reducing factors include insects, diseases, and weeds. With a shortage of pesticides and poor management practices, pests are increasing, damaging potato crops at different stages, starting from storage until harvest.

5. Opportunities

Potato is considered a cash crop for many smallholder farmers and a source of income for their livelihood, having a high return from a unit of land and a unit of water. Potato is a cash crop for the future of the densely populated sub-Saharan African countries, with a high potential for raising the lives of small-scale farmers and their families (CIP, 2011). The Eritrean potato farmers are highly market-oriented. Hence promoting the consumption of the potato and supporting the farmers can lead to the desired supply level of productivity and production (MoA, 2012). Eritrea is located in the sub-Saharan region, which is prone to the effects of climate change. With the small fragmented available land of farmers and the prevailing shortage and erratic rainfall, there is less available ground water for irrigation, so maximizing the crop yield per unit area is crucial. Potatoes can play a vital role in feeding the population of the future, overcoming the adverse effects of climate change, and providing a higher yield per drop of water and unit of area than any other crop (Devaux et al., 2014).

Eritrea's diverse climatic and topographical features range from 0 m up to 2600 m above sea level, suitable for diverse horticultural crop production. The range of altitude, temperature, and soil variability in the country has created enormous ecological diversity and a huge wealth of biological resources (MoA, 2012). Currently, potato is produced in Eritrea on around 2000 hectares only; however, the estimated irrigable potential is about 7500 ha (Ghebregziabihier et al., 2022b). The untapped, suitable regions of seed and ware potato production are an opportunity considering the good adaptation of different potato varieties to diverse climatic conditions.

Seed potato supply is still very low compared to the demand, which is around 4000 tonnes. The centralized public stores supply only 14% of the total demand. The potatoes supplied are mainly Quality Declared Seeds (QDS), and this opens an opportunity for certified seed production. Moreover, basic seed production through tissue culture is currently operated by a public institute with low capacity, which shows an opportunity for investors to enter the technology. Furthermore, seed potato production and demand in the neighbouring countries and the suitable high altitudes of the country can open up a market for export.

Market opportunities for potato consumption are a big plus. Potatoes are one of the main dishes of the Eritrean population. Even though an extensive survey of consumption is required, the current production doesn't match the demand or population. According to MoA reports, there is a deficit of 55.5% vegetables in accordance with the recommended nutritional requirements. This is a strong indication of the existence of a large potential demand for fresh produce supply in the country. Moreover, the unpolluted environment of Eritrea provides a conducive environment for organic production and is suitable for organic markets regionally and internationally.

Potato value addition is a little-exploited area of interest. During the surplus production of the season, farmers are prone to selling their produce at a reduced price. The unavailability of storage structures and processing industries create a loss of the perishable produce. In recent years, it has been observed that a small-scale homestead potato processor has been emerged, producing chips and crisps for local markets. This has untapped potential in the area of processing.

Although the records so far show that potatoes are grown in mid and highland areas, different assessments and a few experiments suggest that potato can also grow in a large part of the western lowlands (Gash Barka and Anseba) by using lowland potato varieties during the cool seasons of the region.

6. Conclusion and recommendation

This paper has covered the several aspects of potato production in Eritrea. Potato is an important food crop that can support many farmers' income and improve household dietary intake. In view of the existing scarcity of food crops due to the adverse weather conditions, the need for developing new techniques of production and diversifying commodities to increase production and productivity in both high- and low-potential areas is of paramount importance. Food and nutrition self-sufficiency can only be brought about through the diversification of production, adopting of climate smart innovations, keeping the farmers at the forefront of initiatives of agricultural transformation by encouraging, teaching and supporting them. Thus, potato intensification is one of the key alternatives and contributors to improving the country's food supply and improving nutrition, particularly in rural areas. One of the main constraints discussed is the sourcing system for potato varieties and the seed supply system. To alleviate the variety sourcing challenges, the research institutes need to develop a long-term strategy to develop their own variety in collaboration with the

well-equipped and resourced international research institutes. Moreover, several countries in Asia, Africa and Latin America is observed to revolutionize their seed potato production system through the production of rooted apical cuttings(RAC). RAC is a new techniques of seed potato production promoted in the past years by several agricultural research, extension and business institutions such as CIP. It is rooted transplants produced in a protected cultivation system such as greenhouse, shade house or plastic house from tissue culture plantlets. RAC is low-cost and rapid techniques of seed potato production as compared to minituber production. Adopting and promoting such techniques can be a game changer in alleviating the challenges of potato planting material from tissue culture and can support farmers in a shorter period of time.

With the increase in population, erratic rainfall, and increasing climatic conditions and disease pressure, the gap between production and consumption will increase. Agricultural research institute has, therefore, the enviable task of helping to ameliorate this situation through a well-planned research strategy. The national agricultural research institute needs to be strengthened in all aspects of potato research: agronomic, variety development, disease and insect protection research, postharvest handling research, and nutritional and cooking quality research. The improvement needs to cover structural, professional, and technical backups from international sister organizations.

Considering the suitable climatic conditions, cheap labor and clean water, farmer's interest in producing, nearby market potential for export, and high demand for the crop, intensification and expansion of potato production and productivity are easy exercises to boost potato production and productivity in Eritrea.

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