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Review Article

Nutritional and Specialty Maize Production, Consumption, and Promising Impact on Ethiopia's Food and Nutrition Security: A Review

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Abstract: In this paper, the significance of maize as a staple grain in Ethiopia is reviewed. Additionally, it advances our understanding of the relationship between the nutritional composition of maize and the high incidence of micronutrient deficiencies in Ethiopia. Malnourishment is still a serious problem in the population, especially for women and children. Maize is a crucial crop within cereal crops as it is a significant source of proteins and carbs, delivering 17–60% of people's daily protein needs. Vitamin A has a vital part in human growth, the immune system, and eye, vision, and ocular health. Vitamin A deficiency is the main contributor of blindness worldwide and has been linked to immune system development and cell differentiation. Thus, for good health to be attained, maize kernel contents like carbohydrate, protein, and several micronutrients are vital. In white maize constituted 90% of all maize production in Africa, whereas yellow maize accounted for 90% of global production, implying that there is still a shortage of specialty maize in Africa in particular Ethiopia. In Ethiopia, a variety of technologies have recently been made accessible in terms of maize varieties in the aim to alleviate malnutrition in regions where maize is the primary crop. Nutritious and specialty maize varieties like QPM, PVA, sweet corn, and popcorn are released in Ethiopia, but government and extension sector attention is still needed to promote the technology.

Keyword: Corn, Nutritious, Malnourishment, specialty.

1. INTRODUCTION

Food and nutrition security is a critical concern that our world is currently dealing with. Agriculture is a key component in achieving the demand for food security for both developed and developing countries by improving food and nutrition security by boosting food availability and incomes, supporting livelihoods, and enhancing the overall economy (World Bank, 2008). Food availability attributable to household production, household income due to agricultural pursuits, changes in how women use their time, their level of empowerment, or their status in the household, as well as environmental exposure due to agricultural activities, are all ways that agriculture can have an impact on nutrition (Seife Ayele *et al.,* 2020). For instances, 85 percent of jobs are found in the agricultural sector, which contributes 55 percent of the GDP. Ethiopia primarily cultivates a wide range of grains, pulses, oilseeds, and coffee. The most significant field crops and the primary component of the diets of the majority of Ethiopians are grains and pulses (Mintesnot *et al.,* 2016). Food security is a major sociopolitical issue in Ethiopia and throughout Africa. Its economic well-being is also dependent on agricultural success. Despite having a diverse crop and agro ecological diversity, Ethiopia has long suffered from food scarcity and economic underdevelopment (Abate T *et al.,* 2015). Therefore, fixating on strategic crops is especially essential for alleviating poverty in developing countries like ours, Ethiopia. Cereals are the most important food crops for achieving food security in Ethiopia because they are the main component of the majority of the population's staple diet and account for roughly 70% of the average Ethiopian calorie intake (Solomon, 2011). Cereal consumption is slightly higher in rural areas (152 kg) than in urban areas (137 kg) (Bart *et al.,* 2012). In terms of calorie intake, maize is the most important cereal staple in rural Ethiopia. Maize is the third most important cereal crop in the world, after wheat and rice (Zamir *et al.,* 2013, FAOSTAT, 2017). It is widely grown throughout the year in tropical, subtropical, and temperate regions of the world, due

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mainly to its photo-thermo-insensitive nature (Kumar Verma, 2013). In many developing countries, it is a foremost staple food crop (Kandil, 2013). According to the 2004/5 national survey of consumption expenditure, maize accounted for 16.7 percent of national calorie intake, followed by sorghum (14.1 percent) and wheat (12.6%), in that order (Berhane *et al.,* 2011). Maize is accounts for 40% of the cereal production in Sub-Saharan Africa, where more than 80% is used as food, feed and for industrial uses (FAOSTAT 2016). The high value of maize as a food crop and the rising demand for grain as animal feed and a fuel source for rural families are both contributing factors to its popularity in Ethiopia. The amount of maize grown in Ethiopia that is consumed as food, both as green and dry grain, is about 88 percent (Abate T *et al.,* 2015). Thus, in Ethiopia, maize is one of the five (maize, rice, wheat, sorghum and teff) strategic crops for food security in Ethiopia. In 2018, maize grown on 21% of the total cereals area and it ranked 2nd following teff (30%) in terms of total production contributing 31% of the total cereals grain produced in the country. About 8.4 MT of maize produced from 2.1 million hectares with an average yield of 3.94 t ha^{-1} (CSA, 2017/18). Currently, Ethiopia's total annual production and productivity in the 2020 cropping season reached 10.02 million tons and 4.24 t ha^{-1}, respectively (FAOSTAT, 2021), the second highest national average yield reported in Sub Saharan Africa (SSA) only after South Africa (Abate *et al.,* 2015). Improved varieties created by the national maize breeding program, along with hybrids introduced by international seed companies, have greatly facilitated in the country's rapid increase in maize production, which has led to these positive results (Ertiro *et al.,* 2017).This implies that there are still promising products that persuade us to export maize in order to generate outside income for national growth, such as coffee and other cash crops, rather than produce for domestic consumption, the local market, and industries.

Maize is the staple food in major maize-producing areas (Mosisa *et al.,* 2011). It accounts for approximately 16.7 percent of national calorie intake, followed by sorghum (14.1 percent) and wheat (12.6%). (Guush *et al.,* 2011). Moreover, maintaining proper amino acid balance can be achieved by substituting high lysine maize for regular maize on an equal weight basis (Reddy, 2015). For groups whose primary source of food is maize and who cannot afford to supplement their diet with protein-rich foods, QPM can significantly improve their nutritional status (Priya *et al.,* 2015). Provitamin A maize seems to be another biofortified crop that is a logical crop for biofortification with provitamin A carotenoid because it exhibits significant natural variation in carotenoid content and profiles that is used to reduce hide hunger. Some maize genotypes have total carotenoids levels as high as 66.0 g/g (Harjes *et al.,* 2008). The other bio fortified crop is provitamin A maize, which is a logical crop for bio fortification with provitamin A carotenoid due to its significant natural variation in carotenoid content and profiles. Some maize genotypes have total carotenoids levels as high as 66.0 g/g (Harjes *et al.,* 2008). Lutein and zeaxanthin are the most abundant carotenoids in maize kernels, followed by carotene, cryptoxanthin, and carotene. In general, provitamin A carotenoids account for only 10-20% of total carotenoids in maize, whereas zeaxanthin and lutein each account for 30-50%. Provitamin A levels in traditional yellow maize varieties range from 0.25 g to 2.5 g/g dry weight. The majority of yellow maize contains less than 2 g/g, whereas white maize contains almost no provitamin A carotenoid (Pixley *et al.,* 2013). As a result, food security is a complicated issue that requires a diverse approach that includes both increasing crop yields and designing a successful economy. As a result, the goal of this review is to investigate available information on the status of output, usage, and contribution of nutritional and specialty crops, as well as to determine the role of maize in food and nutrition security in Ethiopia. In general, due to rapid population increase, the effects of climate change, and evolving geopolitical circumstances, there is a greater need to address Ethiopia's food security.

1.1. LITERATURE REVIEWS

1.2. Nutrition, Malnutrition and Role of Maize

Maize is one of the most important and widely grown crops in the world. While maize is a major source of feed and industrial products in the high-income countries, it provides food, feed, and nutritional security in the world’s poorest regions in sub-Saharan Africa (SSA), Asia, and Latin America. The crop accounts for 40% of the cereal production in SSA, where more than 80% is used as food, providing at least 30% of the total calorie intake to the people, with intake ranging from 52 to 450 g/person/day (Prasanna *et al.,* 2021). In Latin America, maize consumption varies from 50 to 267 g/person/day (Poole *et al.,* 2020).

Meeting future food needs and combating hunger and malnutrition in the context of climate change and growing populations is one of the most pressing global challenges of our time. According to a widely accepted definition, food security is a condition in which everyone always has physical, social, and economic access to enough food that is safe, nutritious, and meets their dietary needs and food desires for an active life (Leroy *et al*., 2015). The other aspects of hunger and food security that are commonly neglected and ignored relate to micronutrient deficiency, as well known as hidden hunger, which is characterized by a lack of the minimum required caloric intake (1800 calories/day/person) (von Grebmer *et al.,* 2014). Malnutrition, which affects one in every three people worldwide and is most prevalent in low- and middle-income countries, is generally defined as the single biggest cause of morbidity and mortality worldwide (Kassebaum 2014). Underweight, micronutrient deficiencies, overweight, obesity, and no communicable diseases are all examples of this malnutrition (Baker *et al.,* 2018). Thus, many governments, especially those in the developing world where the vast majority of the world's malnutrition reside, persist to place a high priority on global food security in their political and development agendas (FAO, 2010). As a result, there is increased interest in strategies to accelerate global malnutrition reduction. Agriculture is one of the only remedies since agriculture and nutrition are intimately connected even though agricultural output, in either form, provides a source and agriculture supports the rural population in developing countries. Agricultural production is a crucial component of acquiring food and nutrition security. Improving agricultural productivity has the potential to improve household food security and population nutrition. A more productive and well-nourished agricultural labor force earns more money and contributes to further economic growth and development. Nutrition makes a significant contribution to raising agricultural labor force productivity **(**Alehegn M and Shibru A,2021). To assure more such issues, maize is a strategic crop among cereal crops, primarily in cereal crop dominant areas and Sub-Saharan Africa countries including my attractive country Ethiopia. Maize is an important source of carbohydrates and proteins, accounting for 17-60% of people's total daily protein supply (Krivanek *et al.,* 2007). It is the primary crop for household consumption and income generation for millions of farmers (Prasanna, 2014), and it is used to make corn starch, corn oil, and corn syrups (Selvi *et al.,* 2013). Maize is the primary source of calories (466.5 kcal/capita/day) and the second most important source of protein (12 g/capita/day) in Sub-Saharan Africa, trailing only wheat (Dagne *et al.,* 2019). Ethiopia is Africa's fifth largest producer of maize, with smallholder farmers accounting for 94% of crop production (Mitiku & Asnakech, 2016). Maize is one of the most important cereal crops grown by the greatest number of households (Abate *et al.,* 2015). Maize is the staple food in major maize-producing areas (Mosisa *et al.,* 2011). In terms of area covered, production, and economic value, maize is currently one of the most significant field crops in Ethiopia for ensuring food security (Legesse *et al.,* 2012). It is a source of nutrients as well as phytochemical compounds such as carotenoids, phenolic compounds and phytosterols which play an important role in preventing chronic diseases (Demeke 2018; Kumar 2015). Currently, diverse QPM genotypes adapted to Sub-Saharan Africa have now been developed among maize types (Krivanek *et al.,* 2007; Musila *et al.,* 2010), and their nutritional benefits for children have been documented (Akalu *et al.,* 2010). In terms of nutrition, vitamin A is essential for maintaining immune system health, vision, ocular health, and reproduction in humans (Awobusuyi *et al.,* 2016). The leading cause of blindness in the world is vitamin A deficiency (VAD), which also tends to affect immune system achievement and cell differentiation (Bailey *et al.,* 2015). Maize kernel constituents, such as starch, protein, and some micronutrients, are required for human health to achieve the issues. Maize has become ingrained in global agriculture, human nutrition, and cultural traditions (Nuss and Tanumihardjo 2010). White maize made up 90% of Africa's total maize production in 2007, whereas yellow maize made up 90% of global production (Harashima 2007) which implies that still there is a gap to supply specialty maize in Africa including Ethiopia. Most of the maize consumed in East and sub-Sahara Africa nations is white-grained, and only a small amount is yellow-grained maize (Smale *et al.,* 2015). Finally, as it naturally contains a range of nutrients at once, maize has become a popular target for bio fortification programs aimed at populations at risk of micronutrient deficiencies. Maize is a staple food crop across many developing countries. And also, agriculture in general, remains to be the leading sector in Ethiopia's economy with addition to nutrition, with cereals, specifically maize playing an essential role. Particularly at the present time, it appears maize demand is rising exponentially throughout all Ethiopian urban areas. Increasing maize productivity and production in both quality and quantity is crucial to meet intensifying demands.

1.3. Importance of Maize in Ethiopia

The most widely produced food in the world, maize or corn ranks third in terms of cereal crop importance behind rice and wheat in terms of global consumption (FAO 2020). More than a billion people eat maize regularly, with this crop providing nearly one-third of the caloric needs of populations in Central America and Southern Africa (Suri DJ, Tanumihardjo SA 2016). White maize, which lacks carotenoids and is typically used to make maize meals in sub- Saharan African nations, may be a factor in the prevalence of VAD in these populations (Nuss ET, Tanumihardjo SA, 2010). It is a major food source in sub-Saharan Africa, where it significantly contributes to trying to eradicate poverty and improve food security for low-income families (Zuma, Kolanisi, and Modi 2018). Additionally, maize for industrial use has helped meet rising demand. Currently, very little maize is used as feed, but this is changing as well to support the rapidly expanding poultry industry and urbanization (Abate *et al.,* 2015). The large percentage of small-scale farmers in Ethiopia's major maize growing regions rely on maize for their daily food, and they have limited access to animal protein (Leta *et al.,* 2003). In Ethiopia, maize ranks second in terms of area coverage and first in terms of total production among cereal crops. In Ethiopia, it is not only used in the food and poultry industries, but it is also a source of income in most towns, particularly at the fresh grain stage. Maize plays an important role in rural Ethiopian diets and has gradually spread to urban areas. This is particularly evident in the sale of green maize along roadsides throughout the country as a hunger-relieving food available from February to May each year (Twumasi *et al.,* 2012). Maize is a staple food and one of the main sources of calories in Ethiopia. Farmers eat maize by making bread, injera, thick porridge, boiled maize, roasted maize, and regional beer, among other foods. Also available in large cities and towns are green cobs (Berhanu, 2009). Also, Maize has the potential to become an increasingly significant pro agricultural export crop, in addition to existing demand as a staple food (Demissew, 2014). Finally, Maize is now widely cultivated in most parts of the world, across a wide range of environmental variables, indicating its global and regional importance to millions of people who rely on the crop for food security and a living (Demissew, 2014) including Ethiopia.

1.4. Maize Production and Challenges in Ethiopia

The high value of maize as a food crop, as well as the growing demand for stover as animal fodder and a source of fuel for rural families, contribute to its popularity in Ethiopia (Abate *et al.,* 2015). Maize is more versatile than any other cereal. It is used as human food (62 percent of total household cereal consumption), a source of cash income (about 54 percent), fuel (about 25 percent), livestock feed, and for industrial purposes (Mosisa *et al.,* 2002). For these reasons, Ethiopia is Africa's fifth largest producer of maize, with smallholder farmers accounting for 94% of crop production (Mitiku & Asnakech, 2016). Maize is grown in a variety of altitudes, moisture regimes, soil types, and terrains by smallholder crop producers. It is primarily produced in Ethiopia's southern, western, central, and eastern regions [MoARD], 2009). The most significant maize producing environment in Ethiopia is the mid-altitude, sub-humid agro- ecology (1000-1800 m.a.s.l.) (Wende, 2013). Ethiopia's average maize yield is 3.67 t ha-1 (CSA, 2017), which is lower than the global average of 5.65 t ha-1 (USDA, 2018). The wide yield difference is due to a number of abiotic and biotic stresses. Biotic and abiotic stresses account for a sizable portion of this yield gap (Abate *et al.,* 2017). Numerous abiotic, biotic, and socioeconomic limitations may be to suspect for the low productivity of maize in several maize-growing low and middle-income countries, compared to the global average of nearly 5 tons ha1 (Shiferaw *et al.,* 2011). Drought, heat, soil acidity, frost, and poor soil fertility, particularly in N and P, are some of the main abiotic factors affecting maize production and productivity, according to Keno *et al.,* (2018). Production of maize is increasingly being hampered by heat stress, either on its own or in combination with drought (Cairns *et al.*, 2013a). According to Lobell and Burke (2010), a 2°C rise in temperature would lead to a greater decline in maize yields than a 20% drop in precipitation. In addition to being particularly susceptible to early development, the maize crop's flowering stage is also particularly susceptible to cold temperatures, which leads to extremely poor anthesis and, as a result, poor grain set (Enders *et al.,* 2019). Wherever there is irregular and heavy rainfall and poor soil drainage, soil waterlogging is a common occurrence. Since maize is a tropical non-wetland crop, waterlogging can affect it at practically any stage of growth, but especially before tassel emergence (Kuang *et al.,* 2012). In many regions of the world where maize is a key crop, a rise in soil salinity and/or irrigation water is one of the factors affecting maize productivity (Bänziger and Araus 2007). In general, maize is thought to be only moderately sensitive to salt (Chinnusamy *et al.,* 2005). Maize seed germination, the growing season, and reproductive capability are all significantly impacted by salinity stress (Kaya *et al.,* 2013). Due to the strong interactions between too much sodium and chloride ions and other crucial mineral elements in the rhizosphere, maize suffers from severe nutritional imbalances (Turan *et al.*, 2010).

The main biological stressor limiting Ethiopia from producing maize is Striga hermonthica, along with parasitic weeds, insect pests such the maize stem borer, maize weevils, and the recently introduced autumn armyworm (Keno *et al.,* 2018). Maize lethal necrosis is a viral maize disease produced by a combination of maize cholorotic mottle virus and sugar cane mosaic virus, or any other cereal virus in the potyviridae family. MLN was discovered in the Kenyan Rift Valley in 2011 (Wangai *et al.,* 2012) and quickly expanded throughout East Africa including Ethiopia. Infected farmers' fields had nearly full yield loss primarily a result of MLN infection (Wangai *et al.,* 2012). The majority of commercially available East African types, as well as pre-release hybrids and elite inbred lines in eastern and southern (ESA) Africa, were susceptible to MLN (Marenya *et al.,* 2018). As the disease spreads, it is critical that new lines entering maize breeding pipelines in SSA have a high level of MLN tolerance (Gowda *et al.,* 2015).

Regardless of its extensive adaptation and efforts to develop improved maize technologies for different maize agro- ecological zones, many biotic and abiotic constraints continue to limit maize production and productivity in different maize producing areas of Ethiopia (Abate *et al.,* 2017). Frost, hail, and waterlogging are the most significant abiotic stresses in the highlands. The soils are characterized by undulating terrain and low fertility, and the region is characterized by wide variations in climatic conditions (Twumasi *et al.,* 2002). Actually, the low yield of the crop is caused by a number of factors. Low yield of maize is primarily caused by improper crop nutrition management and poor soil fertility (Shah *et al.,* 2009). Repeated cultivation of land using improper farming techniques, including in Ethiopia, is severely depleting soil organic matter and nutrients, endangering agricultural productivity and sustainability (Endris & Dawid, 2015).

Ethiopian crop production is severely restricted by diminishing soil fertility. Loss of organic matter, depletion of macro- and micronutrients, soil acidity, topsoil erosion, and deterioration of the physical properties of the soil are the main causes (Zelleke *et al.*, 2010). Future climate change effects in Ethiopia will aggravate the effects of current biotic and abiotic stresses on maize production. Ethiopia is a country that is particularly vulnerable to climate change because of its reliance on agriculture. Climate change is also anticipated to diminish maize yields by 7.4 percent for every 1°C increase in mean world temperature (Zhao *et al.*, 2017). Due to enhanced population growth and metabolic rates, maize production losses from insect pests are expected to increase by 10-25 percent for every 1-degree Celsius increase in temperature (Deutsch *et al.*, 2018). Due to Ethiopia's unique geography and climate, current agricultural systems will respond to climate change in a variety of ways, necessitating additional efforts and sophisticated breeding techniques. Aside from climate, agricultural inputs are the other factors in Ethiopian maize production. And also payable to costs and other preconceptions, the majority of Ethiopian farmers continue to cultivate maize in nitrogen (N)-deficient fields.

The creation and adoption of maize varieties with greater tolerance to Low-N levels would enable an immediate intervention to moderately increase yields in the fields of smallholder farmers (Cairns *et al.*, 2012a). There are very few breeding programs in the world that target this level of N stress intensity that is reflective of on-farm conditions in SSA (Banziger *et al.*, 2000). The genetic control of grain yield under optimal and Low-N stress is partially independent (Ribaut *et al.*, 2007), with the genetic correlation between grain yield under low- and High-N decreasing as yield under Low-N decreases. Thus, direct selection for Low-N tolerance is more efficient under Low-N conditions where yields are at least 40% less than those of optimal conditions. If yields under Low-N stress are greater than 60% of those in well- fertilized trials, selection is partly for genotypic yield potential rather than mechanisms of Low-N stress tolerance, and N stress tolerant genotypes cannot be easily discriminated (Banziger *et al.*, 2000).

More research is needed to understand the mechanisms of Low-N stress tolerance and to guarantee that Low-N stress tolerant donors capture nitrate that would otherwise be lost to the system rather than impairing soil N-supplying capability. The fivefold rise in maize production is mostly attributable to higher yields in various parts of the world. However, in other regions, such as SSA, higher output is connected with a huge increase in maize production area (187%), rather than a threefold rise in maize yields (Prasanna *et al.*, 2021).

Improving crop productivity and smallholder livelihoods in the face of increased climate unpredictability would necessitate a multidisciplinary approach to crop genetic modification (Hansen *et al.*, 2019). A recent study found that innovations in maize breeding have benefited an estimated 53 million people in Southern Africa (Cairns and Prasanna 2018). Increasing genetic gain, including shorter breeding cycle durations, is crucial for providing farmers with a steady flow of improved varieties (Andorf *et al.*, 2019). In short, the Ethiopian government has employed biotechnological approaches to plant breeding to address these difficulties, which can assist decrease time and costs while potentially enhancing efficiency in the advancement of new technologies. Examples of such technologies include genetically modified (GM) crops that are insect resistant or Bacillus thuringiensis (Bt) and drought tolerant (Juhar and Semere 2017). Until recently, the development and use of transgenic (GM) crops suffered by a lack of locally established facts concerning feasibility studies, financial viability, and environmental norms, as well as by erroneous public perception.

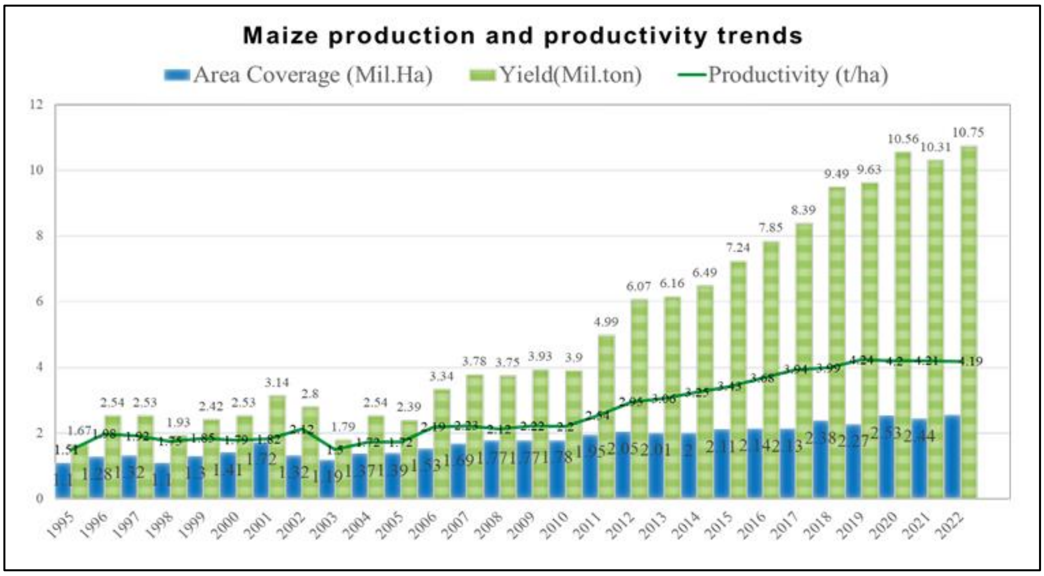

Figure 1: Maize production and productivity trends in Ethiopia (CSA,1995-2022)

1.5. Prospects for Tackling Malnutrition in an Area of Ethiopia Wherein Maize Is a Major Crop

1.5.1. Quality Protein Maize

Maize is a more versatile and multifunctional crop when compared to other cereal crops. It serves a variety of purposes, including as an industrial and energy crop in wealthy economies and as a food security measure in underdeveloped economies. Thus, maize contributes in a variety of ways to the global agri-food systems and the security of food and nutrition (Poole *et al.*, 2021). Over the past ten years, agri-food systems have drawn more attention (Fanzo *et al.*, 2021). It is an important crop for household consumption and income generation for millions of farmers (Prasanna, 2014), as well as a raw material for the production of maize starch, corn oil, and corn syrups (Selvi *et al.*, 2013). Maize is the leading source of calories in Sub-Saharan Africa (466.5 kcal/capita/day) and the second most important source of protein (12 g/capita/day) just behind wheat (Dagne *et al.*, 2019).

Maize is one of Ethiopia's five strategic crops for food security (together with rice, wheat, sorghum, and teff). It is an essential staple crop, placing first for overall production of grains (27.43%) and second in coverage of area (16.79%) among cereals (CSA, 2018). Ethiopia is Africa's fifth largest producer of maize, with smallholder farmers accounting for 94% of crop production (Mitiku & Asnakech, 2016), and it is one of the two cereal crops farmed by the greatest number of households (Tsedeke *et al.*, 2015). It is the staple diet in major maize producing areas (Mosisa *et al.*, 2011). It contributes to around 16.7% of total national calorie consumption, with sorghum (14.1%) and wheat (12.6%) following (Guush *et al.*, 2011).

Although it’s increasing use as a carbohydrate source, maize grain, like all other cereals, is known to have low protein quality, notably in two vital amino acids, lysine and tryptophan (Sarika *et al.*, 2018). Insufficient levels of tryptophan and lysine consumption from conventional maize, primarily by infants, can result in initial growth failures such as 'kwashiorkor,' a weakened immune system, and, ultimately, death (Sultana *et al.*, 2019). Due to the high cost of animal protein, small scale farmers in major maize growing areas have limited access to protein sources such as meat, eggs, and milk for daily consumption (Dereje *et al.*, 2001). CIMMYT developed quality protein cultivars of maize with increased protein quality and desirable yields to fix this issue. The high protein quality in QPM is due to a recessive gene opaque-2, which causes maize grain to have increased protein quality. Through subsequent breeding, scientists at CIMMYT were able to develop QPM varieties with superior yield, vitreous endosperm, disease and insect resistance, and improved storage qualities, which are comparable to those of superior conventional maize varieties (Adefris *et al.*, 2015). The o2 mutation, which is associated with higher levels of vital amino acids, is the main conduit of QPM nutritional benefits. QPM varieties with greater lysine and tryptophan contents provide a more balanced protein for humans and other monogastric animals (Girma *et al.*, 2010; Dufera, 2017). While the nutrient content of the protein in QPM grain is similar to that of the protein in cow's milk, it is largely used as food in underdeveloped nations where maize is a staple diet and frequently the only source of protein (Krishna, 2019). As a result, replacing regular maize with high lysine maize on an equal weight basis can help to maintain adequate amino acid balance (Reddy, 2015). Thus, creating and encouraging QPM cultivars with enhanced levels of protein is crucial for fixing protein shortcoming in individuals who utilize maize as a staple meal, particularly children and women (Agrawal *et al.*, 2015).

1.5.2. Provitamin A

Hidden malnutrition or micronutrient sufficiency continues to be a major global public health issue. Bio fortification of staple crops has the potential to lessen the impact of micronutrient deficiencies in less fortunate areas. Bio fortification is the use of conventional breeding and current biotechnology to create staple food crops with higher concentrations of bioavailable micronutrients in edible sections (Miller and Welch, 2013). Maize is one of the most important staple crops in the developing world, supplying hundreds of millions of people. Though maize has the ability acquire carotenoids in the endosperm, the commonly cultivated maize used for human consumption is insufficient in provitamin A (Ranum *et al.*, 2014). A variety of maize bio fortification breeding initiatives have been established and used to develop hybrids from maize inbred lines with high levels of endosperm provitamin A (Pixley *et al.*, 2013). Rural inhabitants in Sub- Saharan Africa (SSA) face significant issues in terms of food security and hunger. Vitamin A insufficiency is a significant health issue in the sub-region, impacting more than 43 million children under the age of five (Pillay *et al.*, 2014). Carotenoids, in addition to provitamin A activity, play important biological roles in human health (Mishra and Singh, 2010). Menkir *et al.*, (2013) state that the maize plant naturally accumulates carotenoids with provitamin A activity, making it a good source of this nutrient in the diet. Breeding maize with high levels of carotenoid provides a more sustainable alternative to direct vitamin intake. Malnourishment plagues millions of people worldwide, with the majority living in underdeveloped nations, including Asia and Africa, particularly Sub-Saharan Africa (SSA) (Jauhar, 2006).

In Ethiopia, although maize output and productivity have steadily increased over the past 20 years, practically all of the types grown and consumed in the nation are white kinds, which are poor in provitamin A and other vital elements (Azimach *et al.*, 2011).This would lead to the emergence of vitamin-A deficiency (VAD)-related ailments as a result of insufficient consumption of foods high in vitamin A, such as animal products, vegetables, and fruits, as well as an excessive reliance on diets based on cereal which offer little to no vitamin A to meet the body's daily minimum requirement (Menkir *et al.,* 2012). According to several studies conducted in Ethiopia (Tariku *et al.*, 2016; Yisak *et al.*, 2020), VAD is a major threat to public health, and greater than one-third of children under the age of five have symptomatic VAD. This deficiency causes a variety of health issues in kids, including immune system deterioration, predisposition to infectious diseases such anemia, diarrhea, and measles, stunted growth, and an increase in the incidence of night blindness (Mengesha *et al.*, 2019). VAD has also a great contribution to maternal mortality and poor outcomes of pregnancy and lactation (Menkir *et al.*, 2012). Therefore, a complementary strategy to the traditional interventions of supplementation, fortification, and dietary diversity has been advocated: improving the nutritional value of maize via bio fortifications, such as provitamin A content (Menkir *et al.,* 2021). Harvest Plus has set a target PVA concentration level of 15 g g^{-1} of dry weight (DW), which is analyzed significant to have an effect on human health (Prasanna *et al.,* 2020). To facilitate the release of the bio fortified maize varieties, this level of PVA presence needs to be coupled with considerable grain production potential that is stable under several environmental circumstances (Mengesha *et al.,* 2019). As a result, quality enhancement (bio-fortification) of this crop plays a critical nutritional role in alleviating some of Africa's malnutrition concerns. Kernels of some maize varieties, special yellow and orange maize, contain pro-vitamin A (PVA) in the form of carotenoids in the endosperm, which has a high level of genetic variation and can be raised via plant breeding.

1.5.3. Pop-Corn

Popcorn is not only a popular snack meal throughout the world, but it additionally serves as a very nutritious food because it is low in energy and high in fiber (Schepers, 1989). Popcorn is a little flint maize (Zea mays everta) food that is extensively enjoyed worldwide. Popcorn is the original American snack (Eckhoff and Paulsen, 2003). Corn cultivars differ in content and appearance. Yellow popcorn has become a popular snack meal, and there are currently variations in white, yellow, brown, green, red, purple, and blue. Purple corn is a pigmented type that was originally grown in Latin America (Yang & Zhai, 2010). Popcorn's popularity has grown over time all around the world (Hallauer, 2004). The development of the huge fine "flake" while heating the grain is the most important characteristic of popcorn that distinguishes this type of corn from others. Because commercial customers purchase popcorn hybrids by weight and sell popped corn by volume (Ceylan and Karaba, 2002), maximizing final popped volume for a given initial popcorn weight enhances popcorn sellers' profitability (Shimoni *et al.,* 2002). Popcorn, which has been expanding day by day, is now recognized as one of the globe's favorite snacks. Grains of popcorn cultivars differ from other maize varieties by their small size and hard coat, as well as their relatively soft endosperm starch (Ziegler 1994). Also, popcorn is a massive formation of "flakes" or "popcorn" after an explosion in reaction to warmth by heating grains at high temperatures (180- 190 C) (Zunjare *et al.,* 2015).

Popcorn sales in the United States are about approximately one hundred million dollars per year, and this product is also in significant demand in Brazil (Kist *et al.,* 2019. Several investigations have been performed to explain the physiochemical features of popped popcorn, which include carbohydrate, protein, fat, crude fiber, and ash content. They also reported the mineral, vitamin, fatty acid, and amino acid content (Park D *et al.,* 2000, Srdic J *et al.,* 2018). Popped kernels are high in vitamins, insoluble fiber, and antioxidants, particularly phenolic acids (Coco & Vinson, 2019). The nutritional content of this snack is significantly larger than that of many regularly consumed grain or potato-based snacks. According to Nguyen *et al.,* (2012), consuming popcorn as an appetizer is more helpful as a means of lowering cardiovascular incidence in humans. The kernel is a lower calorie and higher nutrient supply than vegetables, fruits, and some whole grains such as wheat (de Graaf, 2006; Grandjean, 2008). Popcorn belongs to the family poaceae and performs excellently well on well drain fertile soil. Maize is an important cereal in Ethiopia, whose productivity has steadily increased over the years. Maize has enormous potential in Ethiopia to provide resilience and food security due to its distinctiveness for different purposes as well as reactivity to inputs.

Popcorn (*Zea mays var. everta*) is a variety of maize that is widely used as a snack food around the world. Most of the time, popcorn is brought to Ethiopia from western countries such as the United States, Mexico, and others who cultivate popcorn by spending huge amounts of dollars every year as it is the most popular crop utilized in various festivals with coffee to celebrate holidays and other concerns. To tackle these concerns, the Bako National Maize Research Center introduced in 2012 an open pollinated popcorn variety developed by Nigeria's International Institute of Tropical Agriculture (IITA). These popcorn genotypes were evaluated in mid-altitude agro ecologies, and the center was released one of the best variety among the introduced genotypes, that called in name Gibe-Awash. Though, Ethiopia continues to introduce popcorn at exorbitant prices every year due to a lack of understanding about using native products. As a result, it requires attention and awareness creation to reduce money wasted on introducing popcorn from foreign countries.

1.5.4. Sweet Corn

Approximately 50 to 55 percent of total maize production is consumed as food, with the remaining percent going to the poultry, piggery, and fish meal industries, and the remaining 10 to 12 percent going to wet milling processing businesses. In 100 g of maize seeds, there is 10% protein, 4% oil, 70% carbohydrate, 2.3% crude fiber, 10.4% aluminides, and 1-4% ash, as well as vitamin A, riboflavin, and vitamin E (Manideepthi *et al.,* 2021). The other type of corn that we call sweet corn was initially recognized in the 1950s, with the first viable hybrid released in the last decade of the 1970s. Sweetcorn is also known as the "Queen of Cereals." It is one of the most frequently farmed cereals in the world, with important applications as human food, animal feed, and raw material in many industrial industries (Manideepthi *et al.,* 2021). Modern sweet corn relies on various altered alleles that alter endosperm starch production, raising sugar content and altering polysaccharide composition (Tracy *et al.,* 2020). As therefore, such alterations tend to be the result of functioning variant elimination. Some of these alleles can cause problems with germination and emergence, especially in unfavorable settings. The genetic base of temperate sweet corn germplasm is small due to a number of genetic bottlenecks during its evolution and mainly relies on the maize race (Tracy *et al.,* 2001). Sweet corn (*Zea mays L. var. saccharata Bailey*), notably exceptionally sweet (sh2) and sugar-enhanced (se) sweet corn (Zhao *et al.,* 2007), is a popular and commonly produced variation. It is a warm-season crop suitable to temperate areas, however it is typically plagued by weak seed vigor as well as slow emergence rates (Zhao *et al.,* 2007).

Sweet corn consumption, whether fresh or processed, has contributed to a large growth in its cultivation in recent years (Rahmani *et al.,* 2010). Sweet corn of high grade is a highly regarded vegetable. Small-scale produce is typically available for purchase directly from the farm or at roadside stands, farmer's markets, or local supermarkets. Large-scale production requires significant expenditures in harvesting equipment as well as packing and hydro cooling facilities in order to prepare shipments for terminal markets or supermarket distribution centers. Sweet corn is a small plant that provides green ears 65 to 75 days after planting. It is harvested 35 to 45 days early than the regular maize cropping cycle. Sweet corn is in high demand as a crunchy commodity in displays, circuses, theaters, and amusement parks, and this need is growing in step with the urban population. Sweet corn is being grown for use in business due to its high demand (Thakur *et al.,* 2015). It is a significant business that targets diverse and value-added products. Green cobs of sweet corn that have been steam boiled and fire baked are becoming more popular as a favorite dish with urbanites, resulting in a higher price for growers (Shanti *et al.,* 2012).

Sweet corn has tremendous nutritional value and is grown mostly for human use, so the national demand for it is increasing. According to Arianigrum (2013), 100 g of sweet corn has 19 g of carbohydrates, 3.2 g of sugar, 2.7 g fiber, 90 kcal, 3.2 g of protein, 1.2 g fat, 1% vitamin A, 12% vitamin B9, 4% iron, 10% magnesium, 6% potassium, and 24 g of water. As a result, this agricultural item is in plentiful supply in developed countries. However, in underdeveloped countries such as Ethiopia and Sub-Saharan Africa, there is still a lack of excitement in beginning to consume sweet corn, as well as a lack of production and accessibility of improved varieties. In Ethiopia, it is only recently that open pollinated sweet corn genotypes population have been introduced, evaluated under national agro ecologies, and best varieties were released to diversify Ethiopia's food consumption behavior and ameliorate the country's malnutrition scenarios. The best sweetcorn varieties are now BOS20W and BOS20Y, which are white and yellow, respectively, and have been released by the Bako National Maize Research Center. Fortunately, the government and the extension sector is not yet giving the technologies adequate attention to popularize, and as a result, endeavors to make them become more prevalent have become shelved. Finally, Sweetness is an economically crucial nutritional characteristic for sweet-corn breeding.

2. Available Improved of Nutritious and Specialty Maize Varieties in Ethiopia

If maize hybrids with high provitamin a concentration are to be appealing to seed producers and farmers, they must also have high grain production potential and favorable agronomic features. While maize is recognized for its strong heterotic manifestation for grain yield and other significant agronomic variables, heterotic effects for carotenoid concentration in maize endosperm have only been observed in a few studies (Burt *et al.,* 2011; Alfieri *et al.,* 2014). It is crucial to identify inbred lines that produce hybrids with heterotic for both agronomic characteristics and carotenoids in order to harness heterotic effects for bio fortification breeding. Pro vitamin A maize is a variety of maize that has been bio-fortified with more beta-carotene, a precursor of vitamin A. In many parts of the world, notably East Africa, where maize is a staple meal, vitamin A insufficiency is a major public health concern (Low *et al.,* 2007). Conventional plant breeding procedures were used to make pro vitamin A maize, which involves choosing maize lines that naturally contain greater levels of beta-carotene and crossing them to create new types with even higher levels (Bouis and Saltzman, 2017). Despite the benefits of PVA maize, adoption and distribution remain difficult in Ethiopia. These include a lack of PVA maize seed availability, a lack of awareness among farmers and consumers about the nutritional benefits of PVA maize, and a lack of support for increasing PVA maize production and marketing. To solve these scenarios, the National Maize Research Program has been working to identify varieties that perform better than the standard check white maize varieties in terms of grain production, response to major disease, and other significant agronomic features since the beginning of PVA maize research in Ethiopia. In order to find varieties that have a better yield or are comparable to the commercial white maize check varieties currently grown in the nation, a number of PVA maize genotypes from the International Institute of

Tropical Agriculture have been introduced. These genotypes have been evaluated for grain yield, disease resistance, and other desirable agronomic traits. Currently, the Bako National Maize Research Center has launched competent Provitamin A maize variety hybrid BHA521 which we call it Bilen(Agertu) with which having equivalent grain yield and other agronomic performance to the commercial white maize check hybrid 'BH546' which is the normal maize and competent in seed market. In order to commercialize the first generation of PVA hybrid in the mid- altitude sub-humid agro-ecologies of Ethiopia, the NVRC selected the BHA521 hybrid. As a result, in Ethiopia, boosting the level of PVA in maize through breeding is a feasible technique for handling malnutrition caused by its shortage if farmers and private seed businesses become aware of the issue.

Maize the relevance of QPM in alleviating protein deficit, normal maize accounts for the great majority of maize farmed in Ethiopia. QPM research began in Ethiopia in 1994 (Adefris *et al.*, 2015) with the introduction and evaluation of open- pollinated varieties and pools introduced from CIMMYT QPM pools (Gudeta *et al.*, 2017). Ethiopia's National Maize Research Program released six QPM maize varieties (BH542, BH545, BH548, Melkassa-1Q, Melkassa 6Q, MH138Q, AMH760Q, and AMH852Q) that have been adapted to the country's mid-altitude, low moisture stress, and highland agro-ecologies. Yet, their share of the market tends to be inadequate because of several drawbacks that have restrained their acceptance by farmers, including: - high susceptibility to CLR, e.g., BH542, notably when grown in rust hot spot; susceptibility to TLB (AMH760Q); and low seed yield of BHY545 (Adefris *et al.*, 2015). The development of new QPM varieties and germplasm augmentation should therefore continue while putting an intense focus on fixing the aforementioned identified shortcomings of QPM cultivars. Breeding for QPM variants is a difficult process when compared to normal maize because to the low genetic basis of QPM germplasm, complex genetic system, and limited funding (Yadesa L. and Debela D., 2022). To address these issues, Ethiopia's national maize program introduces new finished and early generation inbred lines from CIMMYT and IITA every year to utilization in breeding and hybrid development to tackle the nutrition problem, mostly for corn-dominated areas.

3. CONCLUSION

Ethiopian maize output is steadily increasing for each year to meet rising demand and alarmingly increase populations, mainly for human consumption. Depending on environmental, cultural, and genetic factors, maize kernels can be white, yellow, orange, red, or black, with various nutritional specializations. For example, like other seeds, these kernels are storage organs that hold critical components for plant growth and reproduction. Many of these kernel ingredients are necessary for human health, including carbohydrate, protein, and some micronutrients. Maize has become heavily ingrained in Ethiopian agriculture, human food, and cultural traditions for festival festivities. Recently, various kinds of maize have become accessible in Ethiopia according to these traits, such as regular maize, which can provide carbohydrate mostly, high-protein maize, which can provide amino acid, sweetcorn, which is used as a vegetable as a result of its sweetness, and popcorn, which is used for festivals (in cinema) and holiday celebrations. Many attempts have been made in Ethiopia to boost product productivity, such as germplasm enhancement, variety release for each type of maize, and various agronomic approaches with whole package were investigated to alleviate malnutrition surrounding the maize mostly farmed. It contains minerals as well as natural substances such as phenolic substances, carotenoids, and antioxidants, which are useful in preventing chronic diseases such as diabetes and night blindness.

In other way maize is one of the business crop and used as creating of job for jobless in Ethiopia. Currently, urbanism has progressed and it gets sold as a roadside snack and also used to make Enjera by combining it with teff. Because teff is expensive, it is utilized as an alternative crop that substitutes other crops because its price is low in compared to others. However, there are still many lags to properly use the existing technologies in Ethiopia due to a lack of awareness and consuming culture, such as no awareness of consuming sweetcorn excluding in well-known hotels the fact that import it from other countries currently with high cost rather than using domestic technology, and sometimes the yield of nutritious and specialty maize is inadequate yielders when compared to regular maize due to farmers' willingness is less an issue. Not only farmers, but government and private seed companies fail to generate sufficient seed to satisfy needs each year, and the extension sector isn't focused on popularizing such technologies, despite the government's stated objective to address malnutrition.

4. Perspectives for the Future

Because maize is not an indigenous crop in Ethiopia, it is essential to introduce more diverse golden materials in order to improve the germplasm of nutritious and specialty maize. There are numerous initiatives to tackle malnutrition in the maize-dominantly cultivated area, but due to a lack of awareness for the technologies, no adequate attention is paid to the technology at hand by the government and non-government organizations particularly for Provitamin A and QPM or quality protein maize. As a result, focus should be devoted to it, and an awareness platform must be suggested by the government, namely the extension and seed enterprise sector, to disseminate the shelved technologies of nutritious and specialty maize.

In addition, as the population grows and urbanization occurs, the Ethiopian feeding culture (feeding/consuming fresh maize or sweetcorn as vegetable) must be transformed. However, maize cannot provide the daily requirements of children for total lipids and fatty acids, calcium, salt, selenium, and vitamins C, A, and E. The rise in cases of vitamin A deficiency among these groups may be tackled by advancing intake from white maize to provitamin A- rich orange maize with adequate policy frameworks, full commercialization, and initiatives toward broader social acceptability. For the remainder of nutrients, agricultural and food diversification, fortification, and biofortification will continue to improve dietary quality and overall population health. Optimizing methods for processing as well as promoting the use of whole grain maize products rather than degermed and refined goods will help minimize micronutrient deficits throughout preparation while additionally decreasing anti-nutritional factors in meals.

Ethiopia invests millions of dollars each year in purchasing popcorn, but there is a novel variety that is compatible with Ethiopian agro ecologies, thus the government ought to suggest people to utilize domestic products rather than importing it from other countries. Breeding for nutritious and specialty maize is a difficult process when compared to normal maize because of the low genetic basis of QPM, PVA, sweetcorn, and popcorn germplasm, complex genetic system, and limited funding, so encouraging investigators who dedicate themselves to the crop and providing adequate funding is the other prospective solution. Generally, these are only may not be able to properly apply domestic technologies to nutritious and specialty maize. When making one or more appropriate decisions, the already invested cost and context of the measures to alleviate malnutrition should be considered: cost, feasibility of implementation, and techniques for monitoring and assessment.

5. Conflict of interests

The authors have not acknowledged any conflict of interests.

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