Indigenous and Underutilized Crops Significance in Food and Nutritional Security in the face of Climate Change: The Case of Anchote

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Abstract

*Anchote (***Coccinia abyssinica***) is an indigenous Ethiopian crop with significant potential for enhancing food and nutritional security, as well as offering medicinal and socio-economic benefits. To meet the demands of Ethiopia's growing population and address climate change challenges, it is essential to increase food production by incorporating underutilized crops. Currently, only 30 crops account for 95% of human food energy, with five cereals (rice, wheat, maize, millet, and sorghum) supplying 60% of energy intake, while many beneficial genetic resources remain neglected. Climate change impacts crop yields through unpredictable weather, making the development of indigenous crops like anchote a viable adaptation strategy. Indigenous and underutilized crops contribute to sustainable food systems and agricultural resilience under climate change. This review highlights that these crops are nutritious, resilient, and well-suited to marginal environments. Integrating such crops into existing monoculture systems can promote sustainability and diversity in food sources for agricultural communities. The reduction of arable land due to climate change presents opportunities for expanding the cultivation of anchote in low-input environments, addressing socio-economic challenges. Anchote is particularly valuable in western and southwestern Ethiopia for its high productivity and nutritional value, aiding resource-poor farmers. Thus, policy support for research and development of underutilized crops is crucial for minimizing climate change impacts on agriculture and enhancing food security.*

Keywords: Anchote, indigenous and underutilized, food and nutritional security, climate change

Introduction

Underutilized crops is a phrase commonly used to describe crop species whose nutritional or dietetic utility has not been fully documented or understood, and not fully exploited to contribute to food security and poverty alleviation having a strong link to cultural heritage; poorly documented and researched; adapted to specific agroecological areas though underutilized in one region means not in another. ‘Indigenous crops’ is used to signify food crops that are native to specific places rather than coming from a different locale. Indigenous and underutilized food crops constitute the major source of food intake and nutritional requirement in most rural or traditional communities containing a very high nutrient content, especially in developing countries. The term ‘underutilized’ has been used among other several descriptions including “orphan,” “minor,” “new crops,” and “neglected” to represent crops species that have potentials but neglected by research and development various reasons (Padulosi and Hoeschle-Zeledon, 2004; Agulanna, 2020).

Most investments in agricultural research and development have centered on widely consumed crops that are traded internationally, such as maize, rice, wheat, cotton, soybean, and canola (Allouis *et al*., 2001); James, 2001; Bezabih *et al.*, 2023), produced 34.2 million tons of crops in 2020/21 (CSA, 2021), using 81% of the 13 million hectares of total cultivable land for cereals, 13% for pulses and the remaining 6% for oil seeds. Neither the public nor the private sector has invested significantly in genetic technologies in the more diverse indigenous and underutilized or understudied crops that are often critical in the world's most disadvantaged regions; mainly developing countries. Finding ways to alleviate hunger and poverty doesn’t always depend on new crop varieties that are bred in a laboratory. Instead, reigniting an interest in and a taste for indigenous and traditional foods can help improve nutrition, increase incomes, restore agricultural biodiversity, and preserve local cultures (Amanda *et al*., 2011).

The Green Revolution has enabled Asian countries to boost their crop production enormously; however, Africa has not benefited from since it did not consider locally important crops grown in the continent. In addition to their versatile adaptation to extreme environmental conditions, African indigenous crops provide income for subsistence farmers and serve as staple food for the vast majority of low-income consumers. These crops, which are composed of cereals, legumes, vegetables and root crops, are commonly regarded as under-researched crops as regarded as minors; highlighting the degree of attention paid by users and the level of research and conservation efforts spent on them. But very recently, these crops have received the attention of the national and international research community, and modern improvement techniques including diverse genetic and genomic tools have been applied in order to boost their productivity including the African Orphan Crops Consortium (AOCC) starting from 2011 (Howard *et al*., 2023). Hence, an agricultural revolution is needed to increase food production of these under-utilized crops in order to feed the ever-increasing population in Africa (Tadele and Assefa, 2012).

The changing economies, the change in weather, the increasing population in developing countries, and the degrading genetic diversity of our major crop plants all exert an increasing pressure on agriculture (Afari-Sefa *et al*., 2011). The most serious threat to the survival of humanity is the ever-increasing gap between population growth and food supply (Yadav and Sehgal, 2004). Ethiopia harbors an extraordinarily rich agro-biodiversity resulting from its geography, climatic differences, ethnic diversity and strong food culture; the unique is the great variation in altitude ranging from sea level up to 4500 meters (Kassa, 2015). Like other crops, an agricultural revolution is required to increase food production from indigenous and underutilized crop species in order to feed the ever-increasing population in Ethiopia. Hence, modern crop breeding techniques developed for major crops of the world also need to be applied to these indigenous crop species; primarily for food and nutritional security in the wake of climate change and to exploit the novel traits to improve other major crops. The application of these techniques is vital in order to boost productivity and feed the largely underfed and malnourished population of Africa (Zerihun, 2013).

Thus, this review paper stresses to assert the huge potential of indigenous and underutilized food crops such as anchote in attaining food and nutritional security in the face of climate change.

Methodology

Drawing on insights from indigenous and underutilized crops, particularly considering anchote, reviewed 152 journal articles accessed from Scopus databases, covering their potential in diversifying food sources to attain food and nutritional security in the face of climate change.

Ethiopian Indigenous Crops and their Significance

Indigenous food crops stand at the forefront in the struggle against climate change and relatively perform well than the common crops. Agriculture and food security are most vulnerable to climate variability and extremes mainly in Ethiopia. Ethiopian economy remains highly dependent on agriculture which contributes about 33 percent to GDP, 72 percent of foreign currency source, employs 77 percent of the total population, 90 percent of exports, the main source of raw materials and animal feed (CSA, 2021). However, the agricultural productivity is low due to use of low level of improved agricultural technologies, risks associated with weather conditions, diseases and pests, focus on only few crops, etc. Moreover, due to the ever-increasing population pressure, which is 126,527,060 (UN Population, 2023) and expected to double in 2050, the landholding per household is declining from 0.83 ha to 0.73 ha (CSA, 2021) and leading to low level of production to meet the consumption requirement of the households. As a result, the stunting problem in Ethiopia reached 38.5% (Mengesha *et al*., 2021) due to malnutrition that emanates from low diversity of foods that excluded indigenous and underutilized crops that are rich in essential nutrients. As a result, it is causing 16.5% loss of the total national GDP to deal with the problems associated to stunting (Solomon *et al*., 2019). As climate extreme events have been observed frequently throughout Ethiopia since 1970s (Gizaw *et al*., 2023), affecting the socio-economic development of the country, that almost dependent on agriculture, due to the over reliance on annual and seasonal rainfall; indigenous and underutilized crops production is becoming a means of promoting to increase the land productivity as they better adapt to the changing climate and low input (Bezabih and Hadera, 2007) and their high nutrient value is crucial in malnutrition and chronic diseases prevention(Balestrazzi, *et al*., 2024).

According to Padulosi and Hoeschle-Zeledon, 2004; and Amanda *et al*., 2011, indigenous and underutilized crops are defined as;

- wild and cultivated plants whose potential has not been fully realized,
- indigenous, local varieties of major crops currently abandoned by research and development, and
- versatile adaptation to extreme environmental conditions, provide income and serve as staple food for the vast majority of low-income consumers.

Roles of indigenous and underutilized crops in the improvement of food and nutritional security (Mayes *et al*., 2011);

- help the poor for subsistence and income
- reduce the risk of over-reliance on very limited major crops
- increase sustainability of agriculture-reduction inputs, climate change
- a contribution to food quality and preserves cultural and dietary diversity.

There are more than 45,000 species of plants in sub-Saharan Africa of which about 1000 can be eaten to be the mainstay of traditional African diets (MacCalla, 1994). Indigenous crops could make a positive contribution to the world food production because they adapt easily to harsh or difficult environments, perform well comparatively with lower inputs, and they are highly resistant to pathogens thus requiring fewer chemical pesticides (Abukutsa-Onyango *et al*., 2006). This makes them suitable and advantageous for people in areas with high population density like Ethiopia. Indigenous crops can act as a substitute for other cultivated crops to alleviate nutrient deficiencies by increasing nutrient supplies (Engle and Altoveras, 2000).

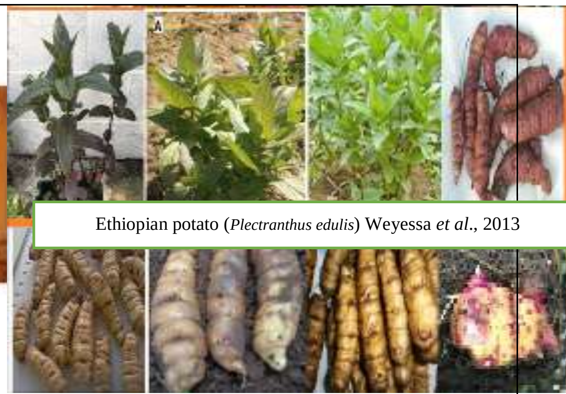
The indigenous and underutilized crops of Ethiopia include both cultivated species and non-cultivated wild/weedy plants. Although a full list of such plants has not yet been compiled, the more important species are well known (Table 1) and anchote is among the most nutrient dense and stress tolerant root crop.

Table 1. Some Ethiopian indigenous and underutilized nutrient dense crops

Species	**Venacular name**	**Habit**	**Category**	**Parts consumed**	**Major nutrients**	**Use (extent and potential)**
Allium sp.*(ursinum)*	Alangale(O)	Annual herb	Leafy	Bulb and leaf	Vit. A, phosphorus	Localized, could be developed
Brassica carinata	Yabesha gomen (A)	Annual herb		Young leaves and shoots	Vit.A,P,Ca,K	Widely used and could be developed more
Brassica nigra	Senafich(A)	Annual herb		Young shoots and leaves	Protein, vit. A, P, Fe, Ca	Widely used, also as a spice
Moringa stenopetala	Moringa, Cabbage tree(E), Shiferaw(A)	Perennial		Young leaves	Vit.A,B,C,E;Ca, K, Fe, health benefits	Limited, could be developed
Amorphophallus abyssinicus	Bagana (S)	Herb	Root and tuber	Root tuber	Carbohydrate	Limited
Coccinia abyssinica	Anchote (A, O)	Climbing perennial herb		Tuberous root, young leaves	Carbohydrate, protein, Ca, Fe, Zn, Mn	Limited, could be developed
Ensete ventricosum	Enset, koba(A), Warke (O)	Large perennial herb		Pseudocorm	Carbohydrate, Ca	Widely used staple, potential high
Plectranthus edulis	Oromo dinich(O), Wolaita dinich(A)	Annual herb		Tuber, leaves	Carbohydrate,P	limited, can be developed
Sphenostylis stenocarpa	African yam bean	Perennial climbing		Seed and tubers	Carbohydrate, protein	Limited, could be developed
Vigna unguiculata	Adenguare (A)	Annual herb		Young leaves and pods	Protein, carbohydrate, K, P, vit. A	Use as pulse wide, potential high
Abelmoschus esculentus	Okra,ladies' finger (E)		Fruit	Green seed pods	Vits. A,C,D, B-, Ca,Fe,Mg and 12	Limited, could be developed

***Key**: (O)- Afan Oromo, (A)- Amharic, (S)-Af Sidamu, (E)-English*

Anchote (*Coccinia abyssinica) (*Desta *et al*., 2023*)*



Ethiopian potato (*Plectranthus edulis*) Weyessa *et al*., 2013

Enset (*Ensete ventricosum)*

Ocra (*Abelmoschus esculentus)* (Mohammed *et al*., 2022; Peg Aloi,2024*)*

Much attention has been centered on the exploitation and utilization of unusual plant materials for food by International Plant Genetic Resource Institute (IPGRI / Bioversity) (IPGRI, 2004). However, totally no attention has been paid to the Ethiopian indigenous and underutilized crops at national and international level except some individuals are thriving to bring them to the conventional research.

Need for Improving Indigenous Crops

Indigenous vegetables are not produced widely around the world, they are not traded to any significant extent in international markets, and they receive considerably less attention than the major crops from international or regional crop research organizations (such as CGIAR, the Consultative Group on International Agricultural Research) (Rosamond *et al*., 2001). Nevertheless, indigenous crops are valued culturally, often adapted to harsh environments, nutritious, and diverse in terms of their genetic, agro-climatic, and economic niches. A large discrepancy exists between the potential role of indigenous and orphan crops in improving food security and the small amount of attention they have received (Atkinson *et al*., 2003). Ethiopia's major rural livelihood systems: pastoral, agropastoral, and cropping which are deeply rooted in seasonal change, dictated by the onset of rains, peak of the rainy season, and end of the season mainly for production of main crops and the productivity decline is subjected to the seasonal changes (WFP, 2024). Inclusion of underutilized and climate resilient crops such as anchote could alleviate the livelihood hurdles by providing food security for poor households, but also constitute an increasingly attractive food group for upper income groups.

Indigenous Vegetable and Underutilized Crops in a Development Context

Population growth over the next 30 years will be concentrated almost exclusively in the developing countries, where more than 1 billion people currently live on less than US$ 1 per day, more than 800 million people are undernourished, and 200 million children are underweight (Smil, 2000). According to Woldekidan *et al*., 2019; a study conducted on 190, 173 children under 5 in 2019; 57·2% deaths were attributed to malnutrition. Accordingly, the prevalence of stunting, underweight, and wasting was 37·0%, 27·0%, and 7·0%, respectively and the prevalence of anemia among under-5 children and women of reproductive age (15-49 years) was 62·0%and 20.4%, respectively.

Where the poverty is prevailed in rural areas where agriculture is the leading source of income and employment, some mechanisms such as diversification with indigenous and underutilized crops could be the best outlook for alleviation of hidden hunger (Desta *et al*., 2021).

The role of agriculture in food security extends far beyond the increase in crop yields and total production rather it promotes food security when it contributes to incomes and productive employment. Moreover, food security dictates a focus on poor people's crops:

indigenous and underutilized crops grown in marginal areas where the poorest segments of the rural population are concentrated (Rosamond *et al.*, 2002; Katinka, 2007).

Ethiopia is Largely Food Insecure

Food security is defined as the state in which people at all times have physical, social and economic access to sufficient food that meet their dietary needs for a healthy and active life (GFS, 2012). Due to the high population increase in Ethiopia, the demand for food is increasing over time. Despite some years of crop failures due to drought, crop production was significantly increasing year to year (FAOSTAT, 2012). The current Ethiopian population is 126,527,060 (UN Population, 2023), largely food insecure; 24.1 million people in dire food security situation in parts of Ethiopia due to unprecedented multi-season drought (FAO, 2023) and the population is expected to double in 2050 (CSA, 2021; UN Population, 2023).

In order to achieve agricultural sustainability, the increase in food production should be at least proportional to the rate of population growth. It is, however, expected that with the current level of crop productivity, it might be difficult to feed Ethiopian population, where it is growing at an alarming rate. The average farm size holding was about 1.02 ha in 2000, and reduced to 0.9 ha by 2008 (CSA, 2000) and 0.83 ha to 0.73 ha (CSA, 2021) which is largely dedicated to mostly five cereals; teff, wheat, maize, barely and sorghum; the core of the country's agriculture and food economy and dominate the Ethiopian smallholder agriculture (Chamberlin & Schmidt, 2012) which gradually pushing Ethiopian agriculture from small-scale to micro-agriculture that cannot reduce the poverty of the farmers. In order to achieve food and nutritional security to the majority of the population, Ethiopia must pay attention to the research and development of underutilized food crops in the production system of the agricultural sector with a pivotal motivation with policy.

Stunting caused by chronic malnutrition during a child's first 1,000 days is a severe public health problem in Ethiopia accounting 38.5%, the highest rate in the world causing 16.5 % of the GDP loss (UNICEF, 2018; World Bank Group, 2016; Solomon *et al.*, 2019; Mengesha *et al*., 2021). Terefe and Nigatu, 2019, explained the stunting, wasting and underweight prevalence among 0-59 months aged children from a sample of 9696 children due to chronic malnutrition was 16 %, 8 % and 3 % with severe stage. According to Tilman *et al.* (2011), the demand for global food is rising rapidly with about 100%–110% increase in crop demand expected from 2005 to 2050. In general, there is big gap between increase in population and crop production and the over dependence on few cereals and paying attention to production of indigenous and underutilized crops is becoming a gate way for attaining food and nutritional security mainly in developing countries such as Ethiopia.

Indigenous and Underutilized Crops fit the Agro-Ecology and Socio-Economic Conditions of the Society

The inclusion of indigenous and underutilized food crops in production and marketing, agro-industrial food system, could lead to improvements in food supply, and it also leads to a significant tradeoff with agro-biodiversity, dietary diversity, environmental sustainability, and socio-economic stability, especially amongst the rural poor where there is unstable environment.

Most understudied indigenous and underutilized crops perform better under adverse climatic and soil conditions than the major cereal crops. In addition, they are compatible with the agro-ecology and socio-economic conditions of the Ethiopian society. However, when these crops were replaced by other crops new to the locality, some problems were reported. The best example is from a study made in northwestern Ethiopia where the incidence of malaria increased when exotic crops, specifically maize, substituted large areas previously occupied by indigenous crops such as tef (Kebede *et al*., 2005; Ye Ebiyo *et al*., 2000; Pollack *et al*., 2007). Malaria is a major health problem particularly in Africa causing 655,000 deaths in 2010. The pollen from maize facilitates optimum conditions for the anopheles' mosquitoes, which carry *Plasmodium* parasites that cause malaria. Larvae of the mosquito had a survival rate of 93 percent when it fed on maize pollen, as opposed to a survival rate of only about 13 percent when it fed on other possible food sources. As a result, the cumulative incidence of malaria in high maize cultivation areas was 9.5 times higher than in areas with less maize (Kebede *et al*., 2005). This shows that the replacement of indigenous crops with new crops to the local community might bring some adverse effects on the health and livelihood of the population. As adaptation of indigenous and underutilized crops found to significantly and positively improve household food security, it is imperative to devise viable projects on conservation, research and development of these crops to attain sustainable food and nutritional security (Abayneh and Belay, 2017). The indigenous and underutilized food crops also offer opportunities for developing a sustainable and healthy food system, by achieving societal goals such as employment creation, wellbeing, and environmental sustainability (Tafadzwanashe *et al*., 2018).

Some Root Crops as Compared to Anchote in Nutritional Contents

Root and tuber crops such as cassava and enset produce high yields, however; the products are largely starchy materials that are deficient in other essential nutrients, particularly protein. Recent studies showed that children in Kenya and Nigeria who consumed cassava as a staple food were at greater risk of inadequate dietary protein (Stephenson *et al*., 2010), zinc, iron, and vitamin A (Gegios *et al*., 2010) intake than those children who consume less cassava in their staple diet. Although these crops are becoming staple food crops for a large number of Ethiopians, supplementation with other nutrients, especially proteins and vitamins, is required from other nutritionally rich indigenous crops such as anchote. Anchote is produced in western, southwestern, and southern Ethiopia as a minor crop and also found in a wild. It is a food and nutritional security crop due to its availability, accessibility, and sufficiency in terms of food and nutritional security. Productivity of anchote root yield and dry matter ranges 10.80 to 71.20 t/ha and 12.9 to 55g/100g, respectively (Desta *et al*., 2021).

According to Desta, 2021; Desta *et al*., 2021; Temesgen, Bakalo and Tamirat, 2019; Yenenesh *et al*., 2016; Abera, 1995; FAO, 1998; anchote is far better than other root crops in nutritional contents and could tackle the over-dependence on only few cereal crops and the food and nutritional security problems of the nation (Table 1 and 2).

Table 1. Anchote nutritional contents as compared to other root crops

Content	Root crops			
	Anchote	Cassava	Sweet potato	Yam
Energy, kcal	**334.42**	100-149	90.00	118.00
Protein(g)	**11.81**	0.3-3.5	1.57	1.4-3.5
Fat, (g)	**0.59**	0.03-0.5	0.05	0.0-0.4
Crude fiber(g)	**3.55**	0.1-3.7	3.00	0.1-0.4
Carbohydrate(g)	**72.13**	25.3-35.7	20.12	37.00
Starch (%)	**26-72.74**	74.60	20.78	63.54
Phosphorous(mg)	**465.42**	6-152	47.00	0.05
Magnesium(mg)	**191.36**	0.03-0.08	25.00	21.00
Potassium(mg)	**1558.37**	25-72	337.00	816.00
Sodium(mg)	**71.10**	7.6-21.3	55.00	9.00
Calcium(mg)	**416.15**	19-176	30.00	17.00
Iron(mg)	**15.33**	0.3-14	0.61	1.50
Zinc(mg)	**5.74**	1.4-4.1	0.16-0.32	0.49-0.97
Copper(mg)	**0.79**	0.2-0.6	0.30	0.08
Vitamin A(µg)	**53.30**	5.0-35.0	5.00	0.02
Vitamin B(mg)	0.08	0.03-0.06	0.21	0.09
Vitamin C(mg)	**8.00**	0.6-1.09	2.40	0.18

Source: Desta *et al*., 2021

Table 2. Essential amino acids content of anchote root and young leaves

Essential amino acids	Root	Leaf	Root + leaf	(WHO standard for 1-2-year-old)
Histidine	0.68	1.63	2.31	1.80
Isoleucine	3.14	3.70	6.84	3.10
Leucine	3.96	5.38	9.34	6.30
Lysine	2.67	3.80	6.47	5.20
Methionine	0.49	0.93	1.42	-
Phenylalanine	1.93	3.10	5.03	-
Threonine	3.06	3.46	6.52	2.70
Tyrosine	19.21	26.17	45.38	0.74
Valine	3.28	4.17	7.45	4.20
Sulphur amino acids	2.07	4.17	6.24	2.60
Aromatic amino acids	2.94	4.20	7.14	4.60

Source: Yenenesh *et al*., 2016; WHO, 2012; Melkamu *et al*., 2018

Prevalence of Large-Scale Biotic and Abiotic Stresses

Abiotic stressors, such as drought, soil salinity, soil acidity heat, cold, and biotic stresses diseases, pests (insects, nematodes, and weeds) are major limiting factors affecting crop production both qualitatively and quantitatively (Romana *et al*., 2023). Since most fertile lands are used to grow major crops other than indigenous and underutilized crops, the productivity of the indigenous crops under the less fertile and moisture-deficit soils is comparably low. There is some evidence that, in recent decades, agricultural land has been lost to desertification, salinization, soil erosion and other consequences of unsustainable land use that makes it less suitable to major crops production and results in sharp reduction of productivity (Godfray *et al*., 2010). From the total global arable area, a third is affected by salinity, and 40% by acidity. Thirty percent of Ethiopian total land area is affected by acidity and 15% with severely acidic level (Gale, 2002; Abu, 2021). According to Abu, 2021; soil acidity is currently predicted to harm around 43% of Ethiopia's total arable land, which covers 95 percent of cultivated area and nearly affects 85 percent of the Ethiopian population. Around 27.7% of these are moderate to weak acids with pH 5.8-6.7 and 13.2% are strong to moderate acidic soils with pH less than 5.5.

The adverse effects of biotic factors on crop productivity are more obvious in the tropical regions due to their presence in high density and diversity. These all adverse climatic variabilities in agriculture led socio-economy of Ethiopia necessitates the inclusion of indigenous and underutilized food crops in agricultural research and development as they could produce lower but stable yields even on marginal lands and under changing climatic conditions which in turn favors biotic and abiotic stresses (Gundel *et al*., 2004; Durst and Bayasgalanbat, 2014). The ever-changing climate, a growing population, and a reduction in arable land devoted to food production are all problems facing the world food security. The development of indigenous and underutilized crops that can yield under uncertain and extreme climatic and soil conditions can play a key role in mitigating these problems (Zerihun, 2018; Linares, 2002).

Climate Change Adversely Affects the Production of Major Crops

The consequences of climate change on agriculture have become a matter of crucial concern for the global scientific community and scholars, governments, and policy makers (Kang *et al*., 2014; O'Neill *et al*., 2020; Pravalie *et al*., 2020; Wang *et al*., 2023). Climate change poses a significant threat to the present African production systems, infrastructures, and markets (Muller *et al*., 2011). The yield of rice declines by 10% for every 1 °C increase in temperature during the growing season (Peng *et al*., 2004). The study by Funk *et al. (2008)* using *in situ* station data and satellite observations that the rainfall decreased by about 15% in the main growing-season in food-insecure countries in Eastern and Southern Africa. According to latest estimates, the drought is affecting about 36.4 million people, including 24.1 million in Ethiopia, 7.8 million in Somalia and 4.5 million in Kenya (FAO, 2023). It has been predicted that due to the warming in the central Indian Ocean, the continental rainfall in Africa will decrease, and this will create a drought, which, as a consequence, will increase the number of undernourished people by 50% by 2030. Further intensification of the climate change is predicted to reduce agricultural productivity by 15.9% globally, 19.7% in developing countries, and a staggering rate of decline of about 15–35% in Africa by the 2080s (Fischer *et al*., 2005; Pickson and Boateng, 2021). The long-term variability and changes of rainfall based on the global climate model, in Eastern and Southern Africa, indicated that droughts have become more intense and widespread (Fauchereau *et al.*, 2003; Shongwe *et al*., 2009). According to Sarr (2012), the most drastic effect of climate change on agriculture will be from the late onset and early cessation of rainfall, and reduction of the length of the growing period. The surge in attention to focus on indigenous and underutilized food crops, food security nexus tends to be influenced by the climate change impacts on food systems and needs a policy direction to focus on underutilized crops where they proved to be climate resilient (Nelson and Walter, 2022).

Agriculturally Important Traits of Indigenous and Underutilized Food Crops

In addition to their nutritional contents, indigenous and underutilized crops are the prime sources of valuable traits that contribute towards increasing crop productivity and enhancing resistance against a variety of environmental stresses. Most indigenous and underutilized crops are resilient to extreme environmental conditions. Due to this adaptability to marginal and low input environments, they offer opportunities for low greenhouse gas emissions (Mabhaudhi *et al*. 2019).

The primary goals of many crop-breeding programs are to improve the productivity of crops, especially the edible and/or economically important parts. Since yield is affected by multiple traits, breeding programs focus mainly on improving individual traits known as yield components or yield-related traits such as edible part size, number of leaves/roots/ fruits, seeds/pods, seed weight, and nutritional quality.

Due to the presence of extreme climatic and soil conditions, which adversely affect crop productivity, many breeding programs are geared towards developing crops, which are resistant to some of these environmental calamities. Breeding for effective use of water (EUW) is considered the best strategy towards mitigating the effects of moisture scarcity and to develop drought-tolerant crops (Blum, 2009). Several tools have also been developed to create crops tolerance towards or resistance against a variety of weeds, diseases and insect pests (Zerihun, 2009). But, due to lack of genetic improvement these largely neglected crops remain to produce inferior yields in terms of both quality and quantity. Indigenous and underutilized crops are named for the lack of genetic improvement, not for lack of use or incorporation into cultural diets. These crops play a vital role in the food security and livelihood of resource-poor farmers and consumers particularly in developing countries (Tadele *et al*., 2024). The wide genetic diversity, stress tolerance, significant contribution in cultural heritage and preferred taste with specific aroma are its important traits in improvement perspectives.

Nutritional Quality

Traits, which improve the nutritional level of food crops, are also important, as edible parts of some staple crops such as cassava are deficient in protein, fat, and vitamins. In addition, traits related to consumer preference (e.g., cooking and eating quality, color of grain, *etc.*) are useful to incorporate in the breeding program specially for indigenous and understudied vegetable crops in order to improve their acceptance to the consumers and marketing. Furthermore, indigenous and underutilized crops provide nutrient-rich biodiversity and healthier diets to resource-poor consumers due to their multiple dietary benefits and their tolerance to extreme environmental conditions, they are considered to be crops for the future (Hunter *et al*. 2019; Zerihun, 2009).

Anchote nutritional content is by far the highest as compared to many common root crops such as cassava, sweet potato, yam and taro. The major mean contents of anchote (%); protein, crude fat, carbohydrate, crude fiber, dry matter is 11.81, 0.59,72.13, 3.55, 11.79 respectively with 333.42 kcal of energy where the protein content of sweet potato is 1.4%, 0.5% cassava, 7.82% yam and 11% taro. In minerals the main contents of anchote (mg/100g) are calcium (416.15), phosphorus (465.42), potassium (1558.37), sodium (71.1), magnesium (191.36), boron (1.72), iron (15.33), zinc (5.74), and manganese (0.95) which are far more abundant than in other root and tuber crops (Desta *et al*., 2021). These nutritionally important traits of anchote could be enhanced through current plant breeding techniques such as efficient transformation and regeneration protocols using biotechnological tools, and improving elemental compositions using molecular breeding techniques and will be a gene source for nutritionally important elements in improving other food crops including indigenous and underutilized food crops. The most important trait needs to be improved in anchote is its cookability, as it takes more time to cook as compared to other edible root and tubers, which could be due to its higher calcium content.

Institutions involved in Crops Research and Development

National Agricultural Research Systems (NARS)

The importance of agricultural research and its impact on development in Ethiopia can hardly be over emphasized. Agricultural research started with the establishment of the Ambo and Jimma Colleges of Agriculture in 1947 and the Imperial College of Agriculture and Mechanical arts (today's Haramaya University) in 1953 (Bechere, 2007). Relative to other African countries, agricultural research in Ethiopia is quite young and working on mainly major food crops. Organized agricultural research activities and actual relations between agricultural research and development started with the inception of the Institute of Agricultural Research in 1966 (Tsedeke *et al*., 2004).

The Forum for Agricultural Research in Africa (FARA) website offers information about organizations, projects and experts in the agricultural research system in Africa (FARA, 2012). Information about organizations and projects present in each African country is also available. According to the website, the total number of national institutes in the continent are 867, while countries with over 50 institutes are only South Africa (71), Uganda (57), Kenya (54), and Egypt (53) (Ye-Ebiyo *et al*., 2003). NARS in Ethiopia includes Ethiopian Institute of Agricultural Research, regional agricultural research institutes, and universities which mainly focus on major staple crops research with little or no attention for indigenous and other understudied crops, even though universities pay more focus on indigenous and underutilized crops through students' research projects than the national and regional research institutes.

Consultative Group on International Agricultural Research (CGIAR) Centers

The CGIAR is a global network of 15 international research centers with a strategy to tackle the major global problems in agricultural development. In their research and development programs, the CGIAR centers give particular emphasis to

Africa. The recently revised CGIAR programs focus on improving: i) yields and profits of crops, fish, and livestock; (ii) sustainability and environmental integrity, and adaptation to and mitigation of climate change; (iii) productivity, profitability, sustainability, and resilience of entire farming systems; (iv) policies and markets; and v) nutrition and diets (CGIAR, 2012). According to Renkow and Byerlee (2010), the contributions of CGIAR to crop genetic improvement, pest management, natural resources management, and policy research gave strongly positive impacts relative to the investment, while crop genetic improvement research resulted in the most profound positive impacts including indigenous crops of the continent.

BecA (Biosciences Eastern and Central Africa) Hub

BecA was established in 2005 to provide a common bioscience research platform, research-related services and capacity building for 17 countries in the region, namely: Burundi, Cameroon, Central Africa Republic, Congo Brazzaville, Democratic Republic of Congo, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Kenya, Madagascar, Rwanda, Sao Tome and Principe, Somalia, Sudan, Tanzania, Uganda. The Hub is based at the International Livestock Research Institute (ILRI) in Nairobi (Kenya). In addition to the major staple crops, it pays attention to molecular breeding of African indigenous crops to be promoted and developed for further use and improving the livelihoods of Africans. what is the point in this paragraph??? The opportunity, the gap or what??

Successes in Improving African Crops: Case Examples

NERICA (New Rice for Africa): High Yielding and Stress Tolerant Rice

Improved cultivars of NERICA were developed in early 2000 by the Africa Rice Center (ex-WARDA: West Africa Rice Development Association) through crossing the high yielding Asian rice (*Oryza sativa* L.) with the locally adapted African rice (*O. glaberrima* Steud.) with high grain yield, high protein content, early-maturity, resistance to diseases and insects, and good taste NERICA.

'Quncho': A Popular Tef for Both Farmers and Consumers

Although tef is a staple food for over 50 million people in Ethiopia alone, it suffers from low productivity. Over 30 improved tef varieties were released to the farming community in the last several decades, however; the recently released *Quncho* variety received a nation-wide popularity; a cross between the two varieties with the objective of selecting lines combining the high yield of *Dukem* and the seed quality trait of *Magna*. *Quncho* was developed as a recombinant inbred line (RIL) through an F_2-derived single-seed descent method followed by a series of multi-environment yield tests in various major tef-growing regions of the country (MoA, 2013).

Through the use of on-farm seed production, efforts were made towards exploitation of the indigenous knowledge in tef seed production and maintenance (Assefa *et al*., 2011). Likewise, other indigenous food crops of Ethiopia need the research and extension strategy applied for tef.

Suggestions for Future Research and Development

Invest in Research and Development of Indigenous and Underutilized Food Crops

Ethiopian government need to implement policies, which support agricultural development through conducive policies on land, marketing, and credits, which favor productivity of indigenous and underutilized food crops.

Germplasm Collection and Utilization

The germplasms of many indigenous and understudied crops have not been properly collected and utilized by researchers. Hence, collections of these germplasms need to be done from diverse agro-ecologies. In order to harness the genetic diversity among the landraces, the germplasm also need to be available to researchers.

Identify the Right Breeding Tools

Among diverse types of tools developed for major crops of the world, those, which are efficient, cost-effective and easily applicable to the present conditions and institutions of Ethiopia should be selected and implemented to make the indigenous crops more utilizable by consumers, marketable and accessible to produce; seed sector development and extension.

Focus on Both Boosting Crop Productivity and Improving Ecosystem

Food security is becoming the major concern especially due to the high population growth and climate change. According to Parry and Hawkesford (2010), integrated and sustainable crop production approaches should be urgently implemented in order to achieve the projected doubling of population growth and food production by 2050.

Misselhorn *et al.* (2012) also suggested strong interaction between diverse actors and sectors ranging from primary producers to retailers and consumers, and the use of frontier technologies in order to obtain global food security through inclusion of indigenous and orphan crops in the research and development system.

Studies on the yield potential and gap for several understudied crops such as cassava and tef showed that crop productivity could be increased several-fold for these orphan crops using improved genotype and/or management (Assefa *et al*., 2011).

Select the Right Type of Strategy

The main reason for poor productivity of indigenous crops is related to little investment in research and development of these crops as they were not represented in the famous Green Revolution, which doubled or tripled productivity of major crops. According to Ejeta (2010), in order to achieve a Green Revolution in Africa, locally appropriate technologies need to be developed in addition to human and institutional capacity building as well as forming conducive policies. Due to the large diversity in agricultural systems and crops cultivated in Africa, some institutions or scholars suggest “rainbow evolutions” that differ in nature and extent among the many systems from a single “Green Revolution” type that occurred in Asia (Thompson, 2007). According to Horlings and Marsden (2011), the real green revolution will be realized in Africa by implementing an ecological modernization process, which includes social, cultural, spatial and political aspects. In this approach, also known as “agri-food eco-economy”, the collaboration of many stakeholders including farmers, consumers and those in the marketing is important (Horlings *et al*., 2011). Any latest update in this regard as all the references are old??

Develop Crops That Adapt to Changing Climate

Since abiotic stresses such as drought, salinity and heat as well as the changing of climate substantially affect the productivity of crops and food security, future research should also focus on developing resistance or tolerance against these environmental calamities. Ahuja *et al.* (2010) enumerated some physiological and molecular mechanisms involved in plant stress adaptation especially on how genes, proteins and metabolites change after individual and multiple environmental stresses.

Invest in Innovation Agriculture

Stakeholders involved in African agricultural research and development need to invest in agricultural innovation, as it contributes towards improving the production, marketing or distribution system. A study in Cameroon on plantain banana (*Musa paradisiaca* L.) indicated that both institutional and organizational innovations through including indigenous and underutilized food crops play key roles in increasing crop productivity and income in rural areas, and also in the production of human and social capital and the protection biodiversity (Temple *et al*., 2011).

Focus on Sustainable Agriculture

African countries also need to focus on achieving sustainability in their agricultural research and development. With the advances in agronomy and breeding, commercial crops like maize and soybean in the Africa are under threat from climate change, decreasing rainfall and degraded lands. Unlike commercial crops that are generally adapted from other regions, indigenous and underutilized crops are distinctively suited to local environments and are more resilient to climatic variations and tolerant to local pests and diseases (Luxon *et al*., 2022). 40 projects on sustainable agriculture from 20 African countries benefited over 10 million farmers and their families (Pretty *et al*., 2011). Accordingly, the outputs from sustainable intensification are two-fold: multiplicative (boosting yield per unit area) and additive (diversification through introducing new crops or other indigenous food items). Promoting indigenous and underutilized crops is a pathway to reduce water allocated to agriculture thereby enhancing drought resilience and ensuring water, food and nutritional security. Large areas of degraded agricultural lands deemed unsuitable to adapted major crops, and which may require costly land reclamation practices, can be used to cultivate indigenous and underutilized crops that are adapted to extreme local climatic conditions (Luxon *et al*., 2022). In order to make in effect, of promotion of indigenous and underutilized crops in production and food systems of Ethiopian agriculture; their role in ensuring food and nutrition security whenever adapted major crops fail in between harvests, nutritional importance in vitamins, proteins, and micronutrients and their contributions in alleviating the challenges of growth stunting in children in Ethiopia and they must be articulated with policy actions to be included in research and development agendas (Tadele *et al*., 2024).

Create Robust Extension System

Success in agricultural development is not achieved without the adoption of improved technologies by a vast number of farmers including indigenous crops that have cultural and knowledge attachments to the society. Establishment of a strong extension system links the research community to the farming community. The transfer of new technologies to farmers is facilitated if the studies are made towards solving the major constraints and also by involving farmers from an early stage of technology development as it enhances the ultimate acceptance of the technology. Since farmer-to-farmer extension is more efficient in expanding the new technologies than the formal system, involving farmers in seed production and distribution is important. A transdisciplinary approach to mainstreaming indigenous and underutilized crops into the production, marketing and food system, which offers real opportunities for developing a sustainable and healthy food system, while, at the same time, achieving societal goals such as employment creation, wellbeing, and environmental sustainability. This process can be initiated by researchers translating existing evidence for informing policy-makers to pay attention for their development through research and utilization (Tafadzwanashe *et al*., 2018). Similarly, policy-makers need to acknowledge the divergence in the existing policies, and bring about policy convergence in pursuit of a food system which includes smallholder famers, and where indigenous and underutilized crops are mainstreamed into the Ethiopian food system, where anchote is the showcase in western Ethiopia (Desta *et al*., 2021).

Establish Partnership with Relevant Stakeholders

Establishing a genuine partnership with national, regional and international institutions is important for the success of any intended project. Nowadays, public-private partnership (PPP) is considered as an effective system to bring together the public and the private sectors towards enhancing agricultural sustainability in the developing world. Spielman *et al*. (Blum, 2011) investigated 75 PPP projects carried out by the International Agricultural Research Centers considering three criteria: (i) the contribution towards reducing the cost of research; (ii) added value to research by facilitating innovation; and (iii) impact of research on smallholders and other marginalized groups in developing countries' agriculture. Thus, indigenous food crops could benefit from this initiative of research and development. Enhance a Regional Network of partners to share knowledge, information and research findings using existing networks. It is necessary to promote public and private partnership for promoting underutilized foods, support better networking and linkages using Internet and web-based tools (ICT) and an online platform for exchange of information, encourage exchange visits, collaboration among countries for research and collaboration, promote conservation and collection of genetic resources and promote germplasm exchange, exchange of scientists, technicians, researchers and others between academe/ universities (Patrick and Nomindelger , 2014.

New Institutional Arrangements

For major crops, such as wheat and rice, much of the linking of research with farmers has been performed by Centers of the CGIAR (Rosamond *et al*., 2002), but there are large numbers of indigenous and orphan crops where virtually nothing has been done. It is on this point that the new African Agricultural Technology Foundation (AATF) instituted by the Rockefeller Foundation holds considerable promise. Its mission is to help design the relevant templates, protocols, and procedures that will lower the transaction costs of applying biotechnology to major and orphan and indigenous crops in Africa. By doing so, it will provide a model for other regions. The McKnight Foundation's Collaborative Crop Research Program is also aimed at enhancing the transfer of science from major to orphan crops and training scientists from poor countries in advanced genetics and genomics methods. Finally, the biotechnology programs being developed and promoted in Dutch, Swiss, and US aid agencies are contributing to progress in orphan crops. Special programs and new incentives within the scientific and development communities should be further encouraged to achieve widespread spillover benefits for poor farmers. Embracing indigenous knowledge and local institutions in climate change adaptation projects can enhance adoption and scaling success of climate-smart agriculture innovations in smallholder farming through promoting indigenous and underutilized crops. Such efforts will improve: establishment of useful networks with relevant stakeholders, capacity building to farmers on production and utilization and provision improved livelihoods through food and nutritional security attainment (Clifton, 2020).

Conclusion and Recommendations

Indigenous and underutilized crops (IUCs) provide food and income for resource-poor farmers and consumers and grow under extreme environmental conditions, where many of which are poorly suited to major crops. A number of these indigenous crops are extensively grown in many parts of Ethiopia with scanty information of production and utilization due to no attention from research and development. The production of IUCs in Africa could realize an expected impact in lowering food prices by 20%–40% for consumers and 10%–20% for producers, which also contributes to a significant increase in farm income and 6.5% increase in annual agricultural growth.

Crop production could be increased by either expanding the arable area, inclusion of orphan and indigenous crops or by intensification. According to the Food and Agriculture Organization (FAO), agricultural intensification represents about 80% of future increases in crop production in developing countries. Based on this goal, crop breeders and scientists are focusing on achieving improved cultivars that produce higher yields and at the same time tolerate the sub-optimal soil and climatic conditions prevailing in the target areas through improving indigenous crops.

Since the Green Revolution did not occur in Africa, the continent did not benefit from it that boosted the productivity of food crops in other parts of the world. However, due to the lack of genetic improvement, orphan and indigenous crops produce inferior yields in terms of both quality and quantity. Modern improvement techniques are not yet employed in African crops. Breeders of these crops are mostly dependent on conventional techniques such as selection and hybridization. Only limited numbers of breeders implement modern techniques such as marker-assisted breeding, transgenics, and other non-transgenic genomics tools. Yield potential studies on these understudied crops of Africa have indicated that the productivity of these crops could be increased several folds by using improved genotypes and/or management practices (Nin-Pratt *et al*., 2011; Fermont *et al*., 2009; PROMISO, 2012; Teklu and Tefera, 2005).

Hence, an agricultural revolution is required to increase food production for under-researched crops such as anchote in order to feed the ever-increasing population of Ethiopia. The next Green Revolution for Africa needs to also include these locally adapted crops in the production, research and development that are mostly known as indigenous and orphan crops. Although these crops are largely unimproved, the implementation of modern improvement techniques on these crops has many advantages. There is an increasing interest both from private and public institutions in developed countries to support African agriculture. Hence, African institutions need to devise strategies and approaches, which also focus on establishing partnerships that have to be implemented to tackle the challenges, especially in the face of climate change through inclusion of indigenous and underutilized food crops in all systems of agriculture as they ensure sustainable foods systems in countries like Ethiopia due to their potential to promote resilience in food systems and enhance food and nutrition security. Indigenous and underutilized food crops are prime connectors between people and their environment, and have an important role to play in the achievement of the global objectives of the Sustainable Development Goals (SDGs), thus ensuring social, economic, and environmental sustainability due to their;

1. richness in terms of provision of healthy, nutrient dense foods, that meet nutritional requirements and promote healthy diets; SDGs 2 and 3, which are ensuring zero hunger; good health and wellbeing;

2. capacity to enhance resilience in the ecosystem by promoting genetic diversity and enhancing environmental preservation in view of climate change. This is in line with SDGs 13 and 15, which deal with combatting climate change and its impacts and protecting, restoring, and promoting terrestrial ecosystems;

3. aid in income generation to improve livelihoods for individuals and potential for profits for economic growth. This adheres to the SDG 8 themes; sustainable economic growth, decent and productive employment for all;

4. social value, reduced inequality, as it relates to self-worth and dignity, including a sense of belonging and connecting to one’s roots. This follows closely SDGs 10 and 12: reducing inequality. The review proposes a transdisciplinary approach to mainstreaming underutilized indigenous crops into the food system, which offers real opportunities for developing a sustainable and healthy food system, while, at the same time, achieving societal goals such as employment creation, wellbeing, and environmental sustainability. This process can be initiated by researchers translating existing evidences of food and nutritional security status of Ethiopia, the genetic diversity degradation of indigenous and underutilized crops, and the ever-increasing population visa viz farm land degradation due to deforestation, soil salinity, acidity, and erosion; the major crops becoming at risk due to climate change(diseases and pests pressure) and the shift in food and feed habit of the society due to health factors which directly encourages the promotion of indigenous and underutilized food crops to be developed through science and technology for further production and utilization for informing policy-makers. Similarly, policy-makers need to acknowledge the divergence in the existing policies, and bring about policy convergence in pursuit of a food system which includes smallholder famers, and where indigenous and underutilized crops are need to be mainstreamed into the Ethiopian food system before it is too late to lose their genetic diversity.

This review argues that indigenous crops such as anchote are not underutilized, but undervalued despite of their far-ranging benefits as food, feed, medicinal and cultural crops. By preserving biodiversity and indigenous knowledge on production and utilization of indigenous food crops, providing improved varieties and developing improved cultivation practices, it is possible to contribute to the well-being of thousands of poor farmers by enabling them to participate in growing markets around the metropolitan cities and the climate dependent vast majority farmers of Ethiopia.There must be a regular annual meeting on promotion of underutilized foods with different themes based on increasing challenges and or needs focusing on laying out of the following major outlets;

Policies and Strategies

- Promote better documentation and validation,
- Disseminate sustainable management plans for indigenous and underutilized foods,
- Develop a system for documentation of traditional knowledge and practices on indigenous and underutilized crops and foods,
- Engage policy-makers in promoting indigenous foods by integrating food diversity in government policies and programs,
- Examine legal instruments to come up with a legal framework on wild indigenous foods,
- Develop/revise standards for underutilized foods,
- Promote sustainable conservation use: domesticating and introducing to farming systems,
- Support with incentives for those who are maintaining indigenous and underutilized plant species in situ and on farm,
- Promote processing and post-harvest technologies to promote into the food system,
- Link with educators and influence curriculum development at schools and universities to integrate indigenous and underutilized food resources,
- Support policies for seed systems for both the public and private sectors,
- Provide legal frameworks to mainstream and provide necessary supports,
- Develop joint programmes through MOUs/MOAs among government, private sectors and NGOs to promote indigenous and underutilized foods,
- Support recognition of indigenous people who depend on production of indigenous foods.

Research

- Research on ecological implications on overharvesting of wild species and deforestation,
- Need to identify plants based on their status (e.g. endangered, abundantly available, etc.), Validation and screening of indigenous foods (linking science with traditional knowledge),
- Better propagation techniques/technologies for

domestication and popularization of wild plants,

- Set up databases for different food species (using images, scientific names and their availability in different agro-ecological zones),
- Investigate the nutritional contents of varieties and species,
- Research on allergic agents of different indigenous and underutilized foods.

Advocacy

- Link to the media via providing stories from the indigenous knowledge of the producers and consumers and from science (nutritional contents and adaptability) perspectives,
- Marketing strategies for indigenous and underutilized foods and consumer awareness of their values,
- Public awareness on the value of indigenous and underutilized foods and information sharing platforms via school curriculums,
- Promoting food festivals, diversity fairs, food competitions, food tasting using indigenous foods,
- Multisectoral policy advocacy (e.g. agriculture with health sector and different NGOs, etc.),

Partnerships and Networks

- Enhance a Regional Network of partners to share knowledge, information and research findings using existing and special platforms,
- Promote public and private partnership for promoting indigenous and underutilized foods,
- Encourage exchange visits among countries for research and collaboration,
- Promote conservation and collection, use, enhancement, marketing and commercialization of genetic resources and promote germplasm exchange,
- Exchange of scientists, technicians, researchers and others between research institutes and universities. Therefore, in combination with a steadily rising increase in urbanization in conjunction with climate change, the way forward to secure food and nutritional security lies in alternative food pathways focusing on indigenous and underutilized food crops. Policy makers should be involved because they have an important contribution to make in institutionalizing the works on underutilized species and in helping to protect local communities trying to realize benefits from local agrobiodiversity.

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