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REVIEW

A Review of Amaranth Crop as a Potential Solution to Ethiopia's Nutritional Crisis

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Abstract: Amaranths have an immense nutrition potential to alleviate malnutrition problems. However, since amaranth cultivation and production in Ethiopia is highly scarce, its impact to lessen the malnutrition problem has not been explored to its maximum potential. This review assesses the potential role of amaranth crops for nutrition security in Ethiopia. Worldwide yield of amaranth is about 35–40 tons/ha while in Ethiopia it is still 2.25 tons/ha which is 17 times lower than the world average. Amaranth is described by its nutritious and gluten-free grain that contains a significant amount of protein, which ranges between 14% and 17%, fat (5–9%) and starch (62%). However, the highest biological value of amaranth protein was reported to be 75–79%. It can also be used in savory dishes as well as sweet breakfast, porridge, salads, and baked breads in different countries. However, amaranth is not extensively cultivated in Africa and merely South Africa is conducting large researches and grand projects in a wider scope. It is a neglected crop especially in Ethiopia. Amaranth production is still at the beginning or low stage. The government also losses its focus of attention on amaranth to solve nutrition insecurity in Ethiopia. Thus, to produce amaranth crop in a broader range and use it as a key solution for malnutrition problems in Ethiopia, comprehensive varietal adaptation, continuous training, and strong market linkage should be given attention by the concerned bodies such as research institutes, industries, non-governmental organizations and ministerial bureaus.

Keywords: amaranth dynamics, elemental analysis, health benefits, malnutrition, nutritional composition

Introduction

The genus *Amaranth* (L.) belongs to the order Caryophyllales, which includes quinoa, spinach, and beetroot.[1] Dicotyledonous mesophyte amaranth uses a unique C4 carbon-fixation mechanism.[2] Amaranth is a fast-growing, pseudo cereal that can grow in arid environments and on depleted soils, where conventional cereals cannot.[3] Amaranth has a strong capacity for efficient water utilization in addition to its environmental hardiness, and it is also an international annual or transient perennial plant.[4] The amaranth vegetable types are thought to have originated in Southeast Asia, whereas the amaranth grain is said to have come from Central and South America.[5] Globally, China, Russia, Bolivia, Ecuador, and Peru are the top producers of amaranth.[6] Although Amaranth *cruentus*, A. *blitum*, and A. *dubius* are cultivated in Africa, the productivity is very low.[7]

There are reports of considerable mineral and bioactive chemical concentrations in amaranth species.[8] Therefore, it is said that diversifying underutilized crops offers untapped potential for Africa and can help with sustainability, food security, combating poverty, and hunger.[9] Consuming amaranth is said to promote strong teeth because it contains about 16% calcium in terms of minerals and vitamins.[10] Similarly, amaranth grains contain a significant quantity of protein, which ranges between 14% and 17%, fat (5–9%) and starch (62%). However, the highest biological value of amaranth protein reported to be 75–79%.[11] Amaranth grain (cooked) contains 251 calories per 246 g serving, and this serving contains 3.9 g of fat, 9.4 g of protein, and 46 g of carbohydrate.[12] Medicinal treatments against atherosclerosis, stomach ulcers, as well as antiseptic, antifungal, and anti-inflammatory preparations are also made from amaranth in the pharmaceutical sector.[12]

Amaranth is a crop with the ability to address a variety of malnutrition-related issues; however, it is not utilized or explored to its full potential in Ethiopia. The small-scale farmers in Ethiopia are not experienced in amaranth production.[2] In

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Ethiopia, amaranth production is still at beginning or low stage.[13] On their farms close to their homes, several farmers have started to cultivate and intercrop amaranth. It is therefore not widely grown in Ethiopia. Furthermore, the poor cultivation and production of the amaranth crop in Ethiopia can be attributed to a number of factors, including a lack of improved varieties, soil depletion issues, disease and pest issues, and lack of postharvest facilities.[14] Hence, this review is initiated to assess the potential of amaranth crop for food and nutrition security in Ethiopia.

Methodology

The authors used different methods to conduct a literature search for this assessment, and indexed papers from the Scopus, Web of Science, as well as PubMed sets were employed during the investigation or study.

Amaranth Production Dynamics in Ethiopia

A critical analysis of the underutilized grain amaranth (*Amaranth spp*.) along the food and nutrition security value chain in Germany described the state of the current understanding of the inherent potential of grain amaranth, its current use in the food industry, and proposes a framework for actions and partnerships necessary to scale up and improve amaranth value chain.[15]

According to a field trial conducted to examine the performance of amaranth varieties during the rainy season at the Fruits and vegetables teaching and research farm of the Usmanu Danfodiyo University, Nigeria, amaranth varieties called *NHAC3 and NHAC 2019* performed better in the study area.[16]

According to a review study on the potential for using the seed crop amaranth (*Amaranth spp*.) in East Africa as a substitute crop to support food security and climate change mitigation, improving amaranth production in East Africa holds substantial potential for helping small-holder farmers in Africa by giving them a reliable source of food and income while also reducing the effects of climate change.[17]

According to a study on the consumption of noodles and use of the herb done at the University of Zululand in South Africa to boost nutritional content and maximize the consumption of vegetable an intervention can be used to concentrate noodles using amaranth as a supplement.[18]

Consequently, a study stating the nutritional composition and growth parameters of two consumed amaranth species in South Africa—red (Amaranth *cruentus L*.) and green (Amaranth *Graecizans L*) grown in an open field versus a greenhouse reported that A. *Cruentus* and A. *Graecizansn* had imminent mineral composition than the greenhouse cultivation system.[19]

According to a study titled "amaranth production and consumption in South Africa: the challenges of sustainability for food and nutrition security" deliberate efforts should be made to integrate amaranth into traditional agricultural value chains through increased research attention and awareness of its nutritional benefits, and this will ensure sustainable production to keep up with the anticipated rise in utilization.[20]

According to a study conducted in Ethiopia to estimate the genetic diversity, heritability, and genetic advance for yield and yield-contributing traits of amaranth genotypes based on agro morphological traits, genotypes are chosen due to their high yield potential and good yield-related traits and future selection efforts for amaranth should therefore continue to evaluate the genotypes under various environmental conditions.[2]

The genotypes Mandiira-II and AC-NL were found to be superior in leaf yield and leaf characteristics and were therefore identified for release to be used as a substitute vegetable source in Ethiopia, according to an experiment conducted to assess vegetable amaranth genotypes for adaptation, leaf yield and quality at Melkassa, Holleta and Assosa Agricultural Research Centers in 2015 and 2016 under rainfed and irrigated conditions.[21]

Another study that looked at the physicochemical properties of three different amaranth species, Amaranth *caudatus*, which has red seeds, Amaranth *hypochondriacus*, which has white seeds, and Amaranth *cruentus*, which has black seeds that were grown in the country's east found that the amaranth grains can be a significant source of Na, Cu, Fe, K, Mg, and Zn for human nutrition.[22]

Increased nutritional awareness, production, and consumption of grain amaranth products may be a way to address iron deficiency in the study area, according to a study that was conducted to prepare iron-rich complementary food using amaranth and chickpea grains in rural Kebeles in Hawassa City, South Nations Nationalities and Peoples of Ethiopia.[23]

According to an experiment on the protein quality of amaranth grains grown in Ethiopia as affected by popping and fermentation, using amaranth instead of wheat or maize when preparing complementary foods could significantly help meet young children's daily needs for essential amino acids.[15,24]

Each mega-environment may serve as an initial selection site for its respective target environment, and targeting a specific season may give a bet, according to research done to compare the performance of amaranth entries for vegetable yield across locations and seasons, evaluate the relative contributions of genetic vs environmental sources of variation to yield, and cluster locations into mega-environments (MEs) to suggest future test sites (2016 and 2017).[25]

According to a 2010 study on the production of bread and malt flour in Ethiopia using mixtures of amaranth and cereals (wheat, maize, and rice), up to 10% of amaranth can be added to wheat flour to produce bread, and a malted amaranth and rice mixture is a good source of calcium.[15]

The highest rates of compost (15 tons/ha) and urea (150 kg/ha) significantly increased the growth parameters and yield when compared to the control and had the highest mean values for all parameters measured, according to a field experiment carried out in Ethiopia in 2013 to assess the effect of different levels of urea (0, 50, 100, and 150 kg/ha) and compost (0, 5, 10, and 15 tons/ha) on the growth and yield of Amaranth *cruentus*.[26] Therefore, using urea and compost is crucial for boosting Amaranth *cruentus* productivity.

Amaranth has a variety of health benefits and medicinal properties, including those that are important in preventing bleeding tendencies, very useful in preventing a child's growth, being stunted, increasing the flow of breast milk, and valuable in preventing premature old age.

The scholars also stated to organize the available information and identify knowledge gaps on the taxonomic and use diversity of the family Amaranthaceous in Ethiopia.[13]

Factors Affecting Amaranth Production in Ethiopia

Ethiopia is endowed with an abundance of natural resources, including a sufficient amount of landmass, fertile soil, a pleasant climate, water, animals, and others.[27] As a result, the nation has enormous potential for the cultivation of amaranth. Loamy or silty loam soil with strong water-holding capacity is ideal for amaranth growth.[28] The loamy soil percentage is one of the main soils in Ethiopian agriculture and covers more than 80% of the nation, according to the GIS-based hydrological zones and soil geo-database of Ethiopia.[29] Similarly, the amount of water is crucial for the best amaranth production. Due to its poor capacity for water intake, the crop is said to be unable to tolerate conditions of waterlogging.[30] Furthermore, amaranth has been known to flower early and stop producing leaves when exposed to severe dryness.[31] Ethiopia therefore has a lot of water that is perfect for growing amaranth all year long. Amaranth is known for its excellent tolerance for dry conditions, and according to reports, the crop seeds require soil temperatures between 18°C and 25°C for germination and air temperatures over 25 °C for optimum growth.[32] An important factor in determining the growth of amaranth plants is the number of increasing degree days throughout the growing season.[20] Lower temperatures and shorter days will cause flowering, which will then cause the yield of leaves to decrease.[20] Likewise, Ethiopia has enough labour to support the growth and production of amaranth crops, which require at least 194 mandays per hectare every season.[31] In the nation, there is also a market demand that is accessible.

Ethiopia has a great potential for amaranth crop cultivation and production, however the actual output and productivity are still very low.[15] Although amaranth production levels are unknown, a new study suggests that under cultivation, amaranth can provide up to 35–40 tons/ha of fresh leaf material.[33] In contrast, the grain yields of amaranth recorded in the literature show a high degree of variation depending on elements including the soil's physical and chemical characteristics, climate, planting density, planting time, variety, and fertilization level.[34] As a result, Ethiopia still produces 2.25 tons of seeds per hectare on average, which is 17 times less than the global average.[35] Lack of improved varieties, low crop awareness, soil fertility challenges, insect and disease issues, lack of postharvest facilities, and lack of government commitment are some of the main factors limiting amaranth yield.[36]

For instance, cultural practices including sparse fertilizer application and the removal of vegetative cover contribute to Ethiopia's high rate of soil nutrient loss.[15] There is no prospective Amaranth crop variation used for different purposes because the Amaranth *cruentus* variety predominates in Ethiopia.[37] Amaranth is particularly susceptible to numerous pests and diseases, including viruses, because Ethiopia lacks a sustainable approach of managing pest and disease

outbreaks.[38] The three most common and often reported diseases of the amaranth crop in the nation are anthracnose, damping-off, and wet rot.[39]

Similarly, postharvest losses of amaranth continue to be a major issue for the security of food and nutrition in sub-Saharan Africa, particularly Ethiopia.[40] Therefore, it is projected that 15.5 to 27.2% of the amaranth crop is wasted each year as a result of inadequate postharvest facilities in the nation.[41] So, there is still a larger disparity in Ethiopia when we compare the annual lost amaranth yield to the country's malnutrition issue.

Malnutrition Rate in Ethiopia

At the end of December, 2022, out of 3.2 million children under the age of five in Ethiopia who had been screened for acute malnutrition, more than 31,500 had severe malnutrition and more than 217,300 had moderate malnutrition.[42] The high rates of malnutrition were caused by a lack of food, nutritional supplies, and services. Along with natural disasters and internal conflicts, Ethiopia's high malnutrition rate is mostly caused by a lack of knowledge about and access to nutrient-rich agricultural products like amaranth.[43]

Research findings indicated that amaranth is well known for its great nutritional value around the world.[40] For instance, it is claimed to be abundant in antioxidants like gallic and vanillic acids. The antioxidants work to combat free radicals, which are harmful consequences of regular cellular activity and assist to prevent everything from heart disease to the telltale symptoms of ageing.[44] According to reports, the seeds are also used to make oil, flakes, flour, and muesli.[37] The high content of micronutrients found in amaranth, including calcium, magnesium, iron, vitamins, and other necessary nutrients, are also emphasized.[45] As a result, amaranth is valued for all the aforementioned benefits to nutrition security, especially in industrialized countries.[30]

Agronomy of Amaranth Crop

According to research, amaranth is grown throughout the world at various times of the year under irrigation and rain-fed circumstances.[46] For instance, the crop is sown in North India from the middle of March until the end of June, whereas it is sown in South India virtually all year long.[47] The optimal time, according to many authors, is from mid-spring to early summer, when seeds are sown in straight rows, covered with dirt; keeping the soil moist is crucial for early sprouting.[48] It is advised to plough the land with fine tilth and pulverize it to remove any clods before planting amaranth.[49] At the time of the final ploughing, it is also advised to apply well-decomposed farmyard manure at a rate of 25 tons per ha.[50]

The researchers' findings indicate that amaranth develops naturally but can also be grown from seed.[37] Since the seedlings of amaranth are delicate, it is crucial to have a fine soil and a firm seedbed.

According to reports, commercial fertilizers with a high nitrogen concentration and 6 tons/ha of cow manure are used to fertilize amaranth.[51] However, regions fertilized with composted chicken manure also produce larger harvests.[52] Similar to this, the nitrogen level reported by experts might be ranged from 50 to 200 kg per hectare and this can be vary based on the species.[53] The soil should be thoroughly prepared, free of clods and crusts, and should be spaced 25 to 30 cm apart within rows and 50 cm apart between rows because amaranth seeds are so tiny.[54]

Researchers have identified three different planting methods for amaranth, including direct seeding from the ground, shallow row planting, and tray planting.[55] Amaranth is reported to take between 30 and 55 days after seeding to be ready for harvest due to the nature of the crop.[55] The biggest obstacle in the cultivation of amaranth is manual harvesting.[56] Systematic planning for the handling, grading, packing, and storage of the products is reported as a crucial step in the post-harvest handling process.[57]

Economic and Health Benefits of Amaranths

Amaranthus spinosus leaves and young plants are harvested for domestic consumption during droughts in tropical Africa and other regions, with occasional leaves available for sale on markets.[58] It is a popular underutilized plant with potential economic worth that has recently gained recognition.[37] With the help of crops like amaranth, farmers have the option to diversify their cropping operations and protect themselves from the price swings of a single commodity market.[59]

According to reports, amaranth can feed everyone and can stop food shortages.[60] It is generally regarded as a wholesome grain that is gluten-free and rich in fibre, protein, and minerals.[61,62] Amaranth is typically described as

having a variety of uses, including adding flavour to savory foods and sweet breakfast cereal, sprinkling it over salads, blending it into soups, baking it into breads and pastries, and eating it as a snack.[63] The flour can be used in baked items like bread and pizza dough, indicating the authors.

In addition, studies have shown that amaranth is a highly nutritious plant that offers a variety of advantages, reducing the impact of nutrition on a range of body processes and aspects of health.[64] The plant's leaves and seeds are both said to be edible, and most of the nutrients found in the seeds are also found in the leaves.[65,66] Amaranth leaves should be grown in households around the world as a vegetable due to its resilience under many climatic conditions, and amaranth grain cultivation may be expanded worldwide since the gluten problem (from wheat, rye, and barley) has become better known.[67]

According to a review done to suggest amaranth green as a suitable home garden vegetable for peoples worldwide to encourage more consumption of vegetables.[68] Amaranth has additionally been associated with a range of health advantages, including reduced cholesterol, less inflammation, and faster weight loss.[69,70] The entire plant component of amaranth that is used for producing medication is its greatest asset. Moreover, amaranth is used to cure ulcers, diarrhea, mouth or throat edema, and high cholesterol, and some of the benefits are listed below (Figure 1).

Amaranth is also reported as a good source of vitamins and important minerals (Figure 2). According to a review report on the nutritional value and utilization of amaranth (Amaranth *spp*.) in Nigeria, amaranth exhibits anthelmintic, immunomodulatory, anti-inflammatory, and anti-androgenic characteristics.[71–73]

Based on studies conducted in African countries, amaranth is a critically nourishing diet for the treatment of HIV/AIDS patients.[74] The antiretroviral medications perform ineffectively or not at all when eating badly, and the drug frequently turns into a poison on its own. As a result, a combination of amaranth grain porridge (1 cup) and Moringa leaf powder (1 tablespoon) from Moringa leaves (Moringa *oleifera*) offers AIDS patients excellent nutrition as well as the freedom to take antiretroviral medications without experiencing any negative side effects.[75]

Amaranth can be used as a cereal supplement since it has a fair amount of high-quality protein, improving the diet's overall nutrient quality.[76–78] Since it is known to have more than 17 amino acids, it is a good and extremely nutrient-rich pseudocereal (Figure 3).

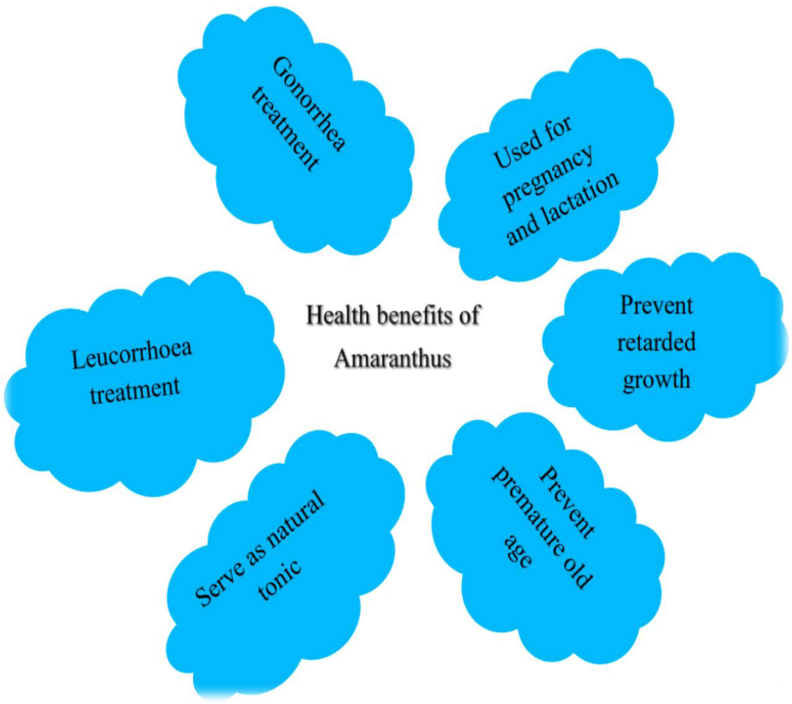

Figure 1 Some of the health benefits of amaranth.

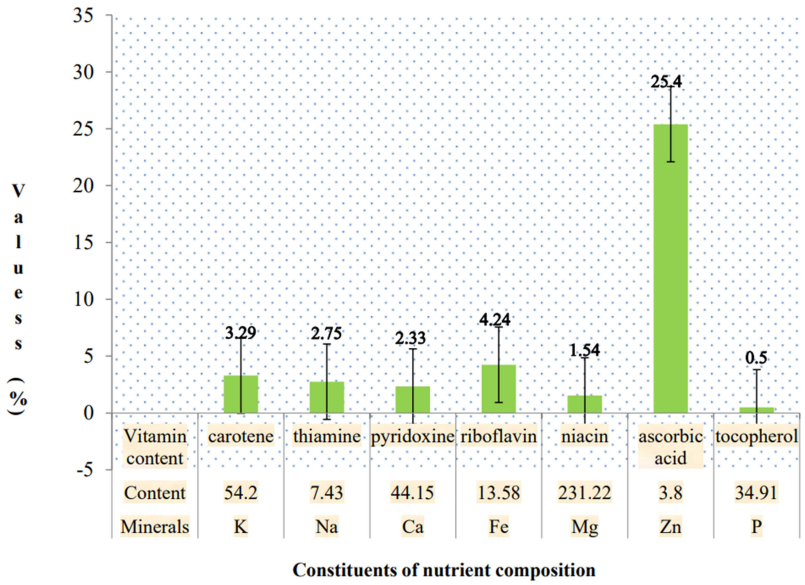

Figure 2 Nutritional composition and associated roles of amaranth leaves (mg/100 g (dry weight)).

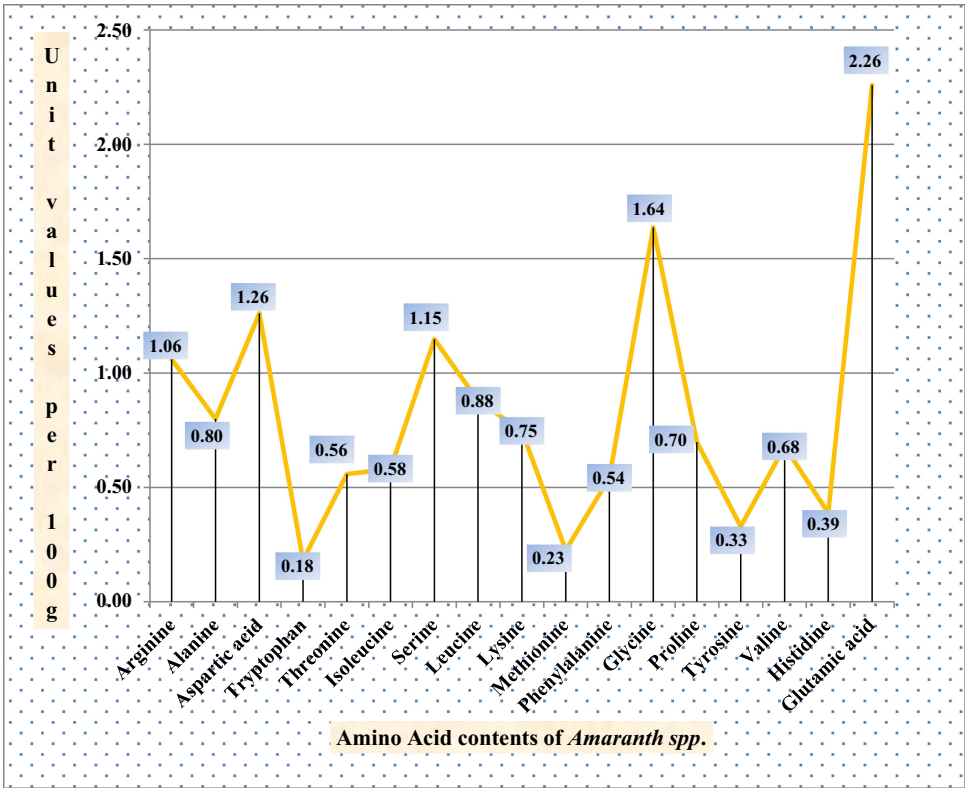

Figure 3 Amino Acid content of *Amaranth spp*.

Ecological Benefits of Amaranths

According to reports, amaranth is the best type of crop for reducing soil, water, and environmental pollution as well as for bio-cycling urban trash.[79] The plant is renowned for responding to soils with sufficient mineral reserve and high organic content.[80] This in turn encourages the plant's growth so that it can quickly reach market value.[81]

Challenges of Amaranth Production in Ethiopia

It is well known that domestic amaranth cultivation is either extremely restricted or nonexistent in Ethiopia.[82] The current problems in Ethiopia are believed to be agronomic flaws (plant population, fertilizer, crop combinations, postharvest losses, storage, and marketing) in the amaranth production processes.[15] Ethiopia also lacks effective postharvest methods and facilities to address amaranth challenges, which is one of the primary barriers hindering the availability of amaranth in other nations.[83] It is common to take amaranth as a food source for poor people in Ethiopia and the information on the nutritional importance of the crop is not well understood.

Review Gaps

There is no sufficient research on amaranth crops (leaves and grains) in Ethiopia. The societal perceptions, variety improvements, and development are not understood in Ethiopia. Moreover, models for production and nutrition components are not developed. It is also important to study into how climate change may affect amaranth cultivation and production in Ethiopia. Since amaranth grain harvesting is a serious challenge worldwide, it is vital to design and develop an appropriate postharvest technology.

Conclusions

Amaranth is a prominent food and nutritious crop grown for its economic, nutrition, and health benefits. Globally, it is also known for its gluten-free grain that contains a significant amount of protein, which ranges between 14% and 17%, fat (5–9%) and starch (62%). The global yield of amaranth is about 35–40 tons/ha while in Ethiopia it is still 2.25 tons/ha which is 17 times lower than the world average. Amaranth is also limited in Africa continent and only South Africa is investing more on large researches and grand projects. However, amaranth is a neglected crop especially in Ethiopia, and the production is still at the beginning or low stage. The government also loses its focus of devotion to amaranth to elucidate nutrition insecurity in Ethiopia. Therefore, to produce amaranth crop in a larger scale and employed as a fundamental solution for malnutrition in Ethiopia, variety improvement, sustainable and continual training, and solid market linkage should be given attention by the concerned bodies including research and higher education institutions, industries and other ministerial departments.

Data Sharing Statement

The dataset that supports the findings of this review is included in the article.

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