Amaranth as Nutrition-Rich and Climatic Resilient Crop: A Review

Samreen NAZEER[1]
Muhammad ZUBAIR AKRAM[2] (✉)
Madad ALI[3]

Summary

Malnutrition and climatic changes are the most significant issues nowadays. The present form of food is not acceptable and balanced nutrition. Besides, much food can be destroyed by climatic changes. There must be some crops that we can consider for future food security. There is a need to explore crops rich in nutrition that can survive in such climatic conditions. Some crops have such qualities that are considered super and functional foods. These foods have higher nutrition and are also rich in some phenolic compounds that are medicinally proven against a specific disease; that is the reason we call them super and functional food. *Amaranthus* is one of them. It has higher protein quality and quantity than our staple food, wheat, barley and maize. Some of the lines of amaranth report a protein content of more than 21%. It contains higher minerals and vitamins in it. The plant makes a beautiful landscape; because of this, it is mostly used for landscaping, but now many scientists are working on it considering this crop good not for beautification but for high nutrition and high tolerance against global climate changes. *Amaranthus* has the potential to survive in changing climatic conditions. It is resistant to drought, salinity and heavy metals as some studies confirm. This review comprises morphology, nutrition and climatic resilient properties of amaranth.

Key words

Amaranthus, high nutrition, nutritional profile, climate resilience, future crops

[1] Department of Agricultural Genetic Engineering, Faculty of Agricultural Sciences and Technologies, Nigde Omer Halisdemir University, Nigde, 51240, Turkey

[2] School of Agricultural, Forest, Food and Environmental Sciences, University of Basilicata, Potenza, 85100, Italy

[3] Department of Plant Breeding and Genetics, Faculty of Agriculture, University of Agriculture Faisalabad, 38040, Pakistan

✉ Corresponding author: muhammadzubair.akram@unibas.it

Received: August 15, 2020 | Accepted: June 23, 2022

History of Amaranth

The genus *Amaranthus* is a part of the family Amaranthaceae and has 50 to 70 species (Costea and Demason, 2001). Most species are locally present in America, while some (15) are in Asia, Africa, and Europe (Das, 2016). *Amaranthus* class is highly important because of phenotypic variation and characteristics of inflorescence (Stetter and Schmid, 2017).

Grain Amaranth was firstly cultivated in America (Arreguez et al., 2013). The oldest seeds of *Amaranthus hypochondriacus* L. were dated 1500 years old and *Amaranthus cruentus* L. was 6000 years old and both were found in Tehuacana (an area in Mexico). History shows that amaranth was widely cultivated in Aztec civilization and was an important part of that civilization in Mexico during the 1400s. When the Spanish arrived, there was a drastic reduction in the production of amaranth. It was suggested that the introduction of wild and domesticated amaranth from Asian regions was carried out in Latin America (Sauer, 1993) around the 1700s.

In recent 50 years, a few theories have recommended the species of grain amaranth. Sauer (1993) suggested some models in which the said grain amaranth was domesticated from *Amaranthus hybridus* L. He also indicated that the domestication of these species was from different ancestors. In the past, some studies were also carried out to prove that DNA polymorphism, meiotic behaviour and allozyme analysis of hybrid chromosomes favour this hypothesis. These studies said all three-grain amaranth species have the same *A. hybridus* ancestor (Kietlinski et al., 2014). Ancestral population genetic investigation shows a precise geographic classification of *A. hybridus* from South America (Stetter et al., 2017). In the earlier time, botanists and explorers thought grain amaranth was indigenous to Asia because of its wide distribution. Grain Amaranth, like *A. cruentus* distributed in the Burma area. Based on its geographical, morphological, physiological and archaeological data, it seems that its domestication was started in America (Stetter and Schmid et al., 2017).

Plant Morphology

Amaranthus plant is herbaceous; dicot has a beautiful large inflorescence and contains a turgid stem. Amaranth belongs to the C4 family of the plant. This plant has greater efficiency in utilizing more CO_2 under temperature extremes (25 to 40°C) and nutrient stress due to its anatomical features and C4 photosynthesis pathway. Due to this feature, it has wide adaptability to many stress conditions (Topwal, 2019).

Roots

Amaranthus has a quick developing root framework that helps absorb water and substances without any trouble from the soil. Its roots can spread up to 1.4 to 1.9 m and attain a length of 2 to 2.5 m. This fast-growing framework was observed in both amaranth species, i.e., vegetable and grain. The root architecture makes the amaranth plant compete with other crops (Topwal, 2019).

Stem

Amaranthus plant can attain a height of 0.5 to 3.5 m. Its stem may be simple or branched, but it depends upon cultivar and environmental conditions. In the breeding program of amaranth the first breeding goal of the researcher is to obtain those lines that have a stem length of 1.5 m with less branching (Topwal, 2019).

Leaves

Amaranthus leaves are of different shapes, including elliptical, praise and lanceolate. Leaves tips are uncaring, taper, and intense, in different colours like green, silver, purple and pink. Silver and ruddy spots also exist on leaves due to the presence of anthocyanin (Topwal, 2019).

Inflorescence

Amaranthus is monoecious. Its inflorescence is unisexual. The inflorescence is of the different colours: purple, orange and blood red etc., in bunch form on the branch known as the glomerulus. Except for the first flower, male (staminate), all are female (pistillate). This crop is 90% self-pollinated and 10% cross-pollinated; mostly, pollination is done by wind (anemophilous). Pollination also depends upon genotype; in some species, the cross-pollination rate can be increased up to 30%. In a bunch, the male flower opens before the female flower, so pollens pollinate that female part from other bunches. Different types of inflorescences (large or small-sized) have been observed in grain *Amaranthus*. Erect type inflorescence was observed in *A. hypochondriacus* and *Amaranthus caudatus*, while *A. cruentus* shows semi-erect inflorescence. The inflorescence has diverse colours: pink, purple, green, yellow, orange, violet, brown and in some cases, two colours on the same inflorescence.

Seed

Amaranthus seeds are produced in the utricle and characterized as dehiscent, semi-dehiscent and indehiscent. The type of utricle influences shattering losses. Seeds are of different colours: white, gold, black, brown and red. Seeds are 0.9 to 1.7 mm in diameter and grains are lenticular in shape. Its 1000 seed weight ranges from 0.6 to 1.1 g (Caselato-Sousa and Amaya-Farfan, 2012).

Phenology of *Amaranthus*

Brainard et al. (2005) prove that photoperiodism affects the *Amaranthus* plant before anthesis; this fact makes *Amaranthus* a short-day plant. According to this study, when the plant is exposed to a temperature of 20°C and a 12 h photoperiod, this plant takes 70 days to be mature. Bavec and Mlaker (2002) show that to obtain a high yield, this must be sown during optimum temperature, ensuring its maximum yield, germination, and emergence (Brainard et al., 2005). In the USA, this plant is cultivated in a wide area by maintaining a plant population of 3 00,000 plants per hectare by carefully managing row-to-row and plant-to-plant distances that give maximum yield (Pospisil et al., 2006). As *Amaranthus* is a climate-proof crop, it can be grown on poor soils. Some studies suggest no increment in yield when N is applied to more than 100 kg/ha (Pospisil et al., 2006). There is also evidence that yield may be increased by more application of N (Escudero et al., 2004), but it is still confusing.

Climatic Requirement for Phenology

Amaranthus plants are C4 in nature. They can perform well under extreme temperatures and other stress conditions due to their superior photosynthetic pathway to C3 plants (Stallknecht and Schulz-Schaeffer, 1993). From tropical marshes (3500 m) to the Himalayan regions, the grain *Amaranthus* species are widely distributed and develop well in many geographic territories. *Amaranthus* plants can reach up to 300 cm in height (Joshi and Rana, 1991). The species of grain *Amaranthus* have a diverse form of inflorescence and morphological traits. Its inflorescence can identify it because every plant species has a different inflorescence shape. Under field conditions, the crop takes 4 to 5 months to mature from sowing to harvesting (Sooby et al., 1998). Production technologies and other *Amaranthus* crop requirements are the same as for maize. That is why farmers have observed the intercropping trend of this crop with Quinoa and Maize in the Andean region (Das, 2016).

Temperature is considered a limiting factor in plant germination and early growth. The optimum temperature recommended for germination and early growth of *Amaranthus* is 20 to 30°C (ISTA, 2010). A temperature lower than 18°C seems to limit the plant's growth and affects its development (Das, 2016). After sowing, seeds germinate after 4 to 5 days of sowing. Proper management of row-to-row and plant-to-plant distances aids formal strand establishment and maximizes production potential (Bhatia, 2005). All three grain *Amaranthus* species differ in their response to daylight and day length. Of these *Amaranthus*, *A. hypochondriacus* is a day-neutral plant and the rest two (*A. caudatus* and *A. cruentus*) are short-day plants (i.e., produce inflorescence and seeds when days have a duration of < 12 h) (Mbwambo, 2013). On the *Amaranthus* plant, flowering arises 4 to 9 weeks after sowing (Gimplinger et al., 2008), but it depends upon the cultivar and its response to photoperiodism. It produces seeds 5 to 7 weeks after flowering. This plant has the property of staying green even after seeds are produced on the plant (Das et al., 2016). It is recommended that seeds must be harvested before plant colour changes to brown, otherwise it causes a substantial yield reduction due to shattering losses. In general, this is a low input requiring plant that can be cultivated by low fertilizer demand, but proper care during crop and timely harvesting are important for attaining maximum yield.

Genetic Resources

Amaranthus species has a wide range of diversity, so efforts are needed to preserve its genetic resources across the globe. Recently, 61 diverse *Amaranthus* genetic resources have been maintained in almost 11 countries (Das, 2016). The first step to preserve *Amaranthus* genetic resource was taken in the 1970s by Rodale Research Centre (RRC), Pennsylvania, USA. A total of 1400 accession from different countries belonging to various species has been preserved in this center (Kauffman and Weber, 1990). This system is now a part of the National Plant Germplasm System in USDA (United States Department of Agriculture) (Brenner et al., 2000). Recently, USDA has played a leading role in the *Amaranthus* germplasm collection, with almost 3300 accessions from 40 countries (Trucco and Tranel, 2011). These 3300 accessions belong to 42 different species. While the main spots of *Amaranthus* diversity are well documented, gaps in these collections exist for wild species and landraces from regions where *Amaranthus* is not the main crop. There is a need to investigate and fill these gaps to make collections more efficient and conserve them before they are lost. Some taxonomic keys and descriptors have been developed to characterize *Amaranthus* germplasm (Grubben and van Sloten, 1981). Phenotypic characterization of *Amaranthus* germplasm on a larger scale has been well documented in India, USA, Peru, and Mexico. It shows a higher variation in important morphological and agronomic characters in the indigenous and exotic germplasm of *Amaranthus* (Joshi, 1986; Das, 2016). Variation frequency was maximum in *A. cruentus* and *A. hypochondriacus* accessions from Mexico and Guatemala (Espitia, 1992; Kietlinski et al., 2014). So, germplasm collected from a wide distribution gives a higher diversification that can be inserted in modern breeding programs for improvement and adaptation of this grain to different regions (Stetter et al., 2017; Wu and Blair, 2017).

Species

Amaranthaceae are commonly viewed as the family of *Amaranthus*. The word *Amaranthus* was obtained from the Greek word “Anthos,” which means “un-wilting” and “everlasting” (Rastogi and Shukla, 2013). According to its taxonomical investigations, this family is categorized into two classes (i.e., Blitopsis dumort and *A. saucer*) (Allen, 1961). The segment Blitopsis dumort has x = 17, while *A. saucer* is dibasic with x = 16 and 17 accept polyploidy, i.e., *Amaranthus dubius* Mart. ex Thell. (Madhusoodanan and Pal, 1981). Two main species of *Amaranthus* are mainly considered vegetable *Amaranthus* (*Amaranthus lividus* L. and *Amaranthus tricolor* L.). From this, *A. tricolor* contains ornamental plants. Across the globe, about four hundred *Amaranthus* species are distributed in the tropical, mild and subtropical atmospheric regions (Suma, 2002). Around 20 species of *Amaranthus* are found in India (Grubben and Stolen, 1981). Three species from the *Amaranthus* genus are termed grain *Amaranthus* and these generally belong to South America. *A. hypocondriacus*, *A. cruentus* and *A. caudatus* L. are included in this category. *A. hypochondriacus* is commonly known as prince *Amaranthus*, *A. cruentus* red *Amaranthus*. In contrast, *A. caudatus* is love-lie bleeding and Inca wheat. There are some other species of *Amaranthus* whose leaves can be used for edible purposes, like *A. tricolor* and *Amaranthus blitum* L.

Vegetable Amaranth

Many species of *Amaranthus* have its reasonable utilization in the form of leaves (*A. blitum* L., *A. lividus* L., *A. viridis* L., *A. gracilis* L., *A. tricolor* L. and *A. gangeticus* L.). These are now commonly used as potherbs (bubbled greens). It has emerged as a popular leafy vegetable in Africa’s humid regions due to its spinach-like flavour, high production, climatic resilience, and nutritional value of the grain.

Grain Amaranth

Amaranthus is a pseudo-cereals crop. *A. hypochondriacus* (ruler's plume), *A. cruentus* L. (sub *A. paniculatus* L. bramble greens), *A. caudatus* L. (purple *Amaranthus*, love-lie bleeding) are considered as grain *Amaranthus*.

Crop with High Nutrition and Functional Properties

In *Amaranthus*, the amount of calcium, phosphorus and potassium is larger than in oat grain. The grains and leaves of *Amaranthus* contain a higher amount of minerals, lipids, and a well-balanced protein profile (Barca et al., 2010). It is found that *Amaranthus* seeds contain amino acids (particularly lysine, phenylalanine, and threonine) and minerals (particularly calcium, iron, and zinc) two times more than wheat (Nascimento et al., 2014). In an underdeveloped country, *Amaranthus* gives all the essential supplements for fulfilling the daily body requirements like development, improvement, and anticipation of the healthful issue (Kachiguma et al., 2015). Unlike other nourishment sources like maize and wheat grain, *Amaranthus* has high-quality proteins with all essential amino acids (Venskutonis and Kraujalis, 2013). Most of the essential amino acids like lysine, valine, isoleucine, and abundance of leucine are insufficient in grains of oat (Mlakar et al., 2009), while they are rich in *Amaranthus*. Its grains have 5.2 to 6.1 g 100 g^{-1} of lysine in it. The sulfur-containing amino acid is higher (2.6 to 5.5 g 100 g^{-1}) in *Amaranthus* than in another majority of vegetable species, that is 1.4 g 100 g^{-1}; (Juan et al., 2007). In *Amaranthus*, entire ranges of an amino acid are from 31.22 to 44.88 g 100 g^{-1}, making it a nutritive rich source for development (Akin-Idown et al., 2013). The grain of *Amaranthus* contains 13 to 20 % of the protein. Albumins and globulins are the most abundant proteins (50 to 60 %) (Kaur et al., 2010).

In *Amaranthus*, the amount of protein differs from species to species (Kaur et al., 2010). Different supplements, amino acids and protein are at maximum in wild species rather than in developed ones (Andini et al., 2013). In the USA and Europe, for celiac disease patients and weight control plans, the *Amaranthus* is particularly favoured as a substitute for wheat (Huerta-Ocampo and Rosa, 2011) because of its gluten-free property (Alvarez-Jubete et al., 2009). The seeds of *Amaranthus* can be exposed to a few medicines, for example, toasting, pounding, and puffing to be expended as moment and drinks with milk and water or to be added into bread tortillas, treats, or different arrangements (Bhat et al., 2015). Using gluten-free *Amaranthus* seed flour can enhance the health benefits and reduce the edibility of other cereals. Its usage upgrades the quality of protein, fat substance and corrosive amino acid profile (Bressani et al.,1992). In *Amaranthus*, a generally realized medical advantage is that *Amaranthus* grains are free from gluten and contain some bioactive compounds like quercetin that are medicinally proven to cure specific diseases. *Amaranthus* oil has restorative properties and is rich in tocopherols, squalene (4 to 6 %), phytosterols (0.3 to 0.4 %), bioactive compounds and flavonoids (Rastogi and Shukla, 2013; Khamar and Jasrai, 2014). The oil of *Amaranthus* is the best because squalene has a preventing agent of cancer. Oil also shields the skin from then untimely maturity by forestalling cell harm (Khamar and Jasrai, 2014). Different compounds of *Amaranthus*, for example, tannins, flavonoids, cardiovascular glycoside, steroids and triterpenoids, have been recognized as anti-inflammatory and anti-cancerous properties (Reyad-ul-Ferdous et al., 2015). *Amaranthus* is generally used in traditional medicines (Kumar et al., 2012). In *A. hypochondriacus*, the seeds protein has a similar property to the lunasin compound, which is an anti-cancer compound present in soybean (Silva-Sanchez et al.,2008).

Nutrition Properties of *Amaranthus*

Regarding essential substances, grain *Amaranthus* has adequate quality protein from 17 to 19% (Gamel et al., 2007). The grains of *Amaranthus* have double the amount of the essential amino acids in their protein (particularly lysine and threonine etc.) and higher mineral levels (calcium, iron, magnesium, and zinc) in their grains than cereals (Espitia, 1992). As simple to cook, *Amaranthus* shows a guarantee for enhancing nutritional quality in the form of enhanced mineral substance (Fe, Zn) and quality protein (Dodok et al., 1997). *Amaranthus* can be ordinarily popped. Its processing or blending with other flours gives novel nutrition properties, tastes, and flavours. Chemical composition analysis of *Amaranthus* affirms their high potential for nutraceutical utilizes (Das et al., 2016). Seeds and oil are both high in vitamins and squalene, which are helpful for hypertension or cardiovascular disease (Anjali et al., 2013). Regular utilization of grain *Amaranthus* can lower blood pressure and cholesterol level. It also enhances immunity by enhancing antioxidant status (Gonor et al., 2005). In the current malnutrition scenario, this food can be important for underdeveloped countries. (Brenner et al., 2000).

Carbohydrates

Carbohydrates are the main component of *Amaranthus* grain (Wu and Corke, 1999). Different species of *Amaranthus* have different starch contents, like *A. cruentus* species contains 48% and *A. hypocondriacus* has 62 % starch in it (Saunders and Becker, 1984). Starch granules have different shapes depending on species to species. *A. hypocondriacus* is angular and polygonal in shape with a diameter of 1 to 3 πm (Stone and Lorenz, 1984). *A. cruentus* has spherical, angular, and polygonal shapes ranging from 0.76 to 1.6 nm (Qian and Kuhn, 1999). *A. hypochondriacus* species has glutinous and non-glutinous starch that contains 100 % pure amylopectin (Tomita et al., 1981), while *A. caudatus* has only non-glutinous (Okumo and Sakaguchi, 1982). Starch contents in *A. cruentus* and *A. hypochondriacus* have more swelling power and absorbance capacity than wheat and maize (Reiso et al., 1999). They also have less solubility and less susceptibility to amylases as well as low amylose content (4.7 to 12 %) in it (Kong et al., 2009).

According to a study by Sarker and Oba (2019a), maximum carbohydrate content was observed as 98.54 g kg^{-1} FW, while minimum carbohydrate content was 15.48 g kg^{-1} FW. In another study by the same authors, Sarker, and Oba (2019b), carbohydrates ranged from 9.30 to 2.33 g $100g^{-1}$ FW.

Fat/Oil

Another vital substance obtained from grain *Amaranthus* is fat, which is in higher quantity than in the oat. This fat is a high quantity of unsaturation with little saturated fats. Linoleic acid is considered a significant component of unsaturated fat and is over half in the seed of *Amaranthus* and 47 % in leaves. The higher contents are oleic acid, over 20 %, and palmitic acid, near 20 %. Of the primarily saturated fats, 43 % linolenic acid is found in the green leaves and palmitic acid, about 17 to 24 % in stems and seeds (Fernando and Bean, 1984). Oil mostly has unsaturation in it (more than 75 %). β-sitosterol is present in the lush green leaves of *A. caudatus* (Dixit and Verma, 1971). α-spinasterols and hentricontanein are present in the leaves and stem of *A. spinosus*

(Banerji and Chakravarti, 1973). The below-ground part of *A. spinosus* has ester linkages of octacosanoic acid with α-spinasterol. Massimo et al. (2004) reveal that the β sitosterols and the three different noteworthy phytosterols (sitosterols, campesterol and stigmasterol) are found in other species of *Amaranthus*.

Oil extracted from *A. cruentus* and *A. hypochondriacus* ranges from 5 to 9 % (Gamel et al., 2007). This oil has more solubility than sunflower oil, as confirmed by the hyper oxide stability test (Gamel et al., 2007). This oil melts at −27°C. The oil is clear, pourable, and medium to light in colour (He and Corke, 2003). It is highly unsaturated with an elegant aroma and good taste. *Amaranthus* oil mostly has non-polar compounds in it like triglycerides (81 to 83 %) and a significantly lower quantity of phospholipids (10 to 11 %) (Games et al., 2007). Omega (ω9, ω6, ω3) fatty acids are rich in this fat. Its digestibility is almost like cotton, but *A. cruentus* species oil has less digestibility. Tocols are also in oil (1450.01 to 1465.15 mg kg^{-1}) (Grazdiene, 2007). *Amaranthus* oil has a higher quantity of squalene (6 to 7 %) (generally utilized in the cosmetic industry) than wheat which only has 0.1 to 1.7 %. Different species have different quantities of squalene; *A. hypochondriacus* has 6 to 6.5 %, *A. cruentus* has 4.5 to 9.5 % (Gamel et al., 2007), and *Amaranthus edulis* has 6.5 to 7 % squalene (He and Corke, 2003). The *Amaranthus* oil is composed of myristic acid (0.5 to 1 %), palmitic acid (17 to 19 %), stearic acid (4 to 6 %), anarchidic acid (1 to 2 %), behenic acid (2 to 3 %), oleic acid (27 to 31 %), linolenic acid (60 to 65 %) and linoleic acid (40 to 43 %) (He and Corke, 2003). Its oil can increase HDL cholesterol levels and remarkably reduce non-HDL cholesterol, ultimately lowering low-density lipoprotein cholesterol levels by 20-52 % (Chaturvedi et al., 2007). *A. tricolor* seeds give up to 4.3 % oil containing 23% saturated and 78% unsaturated fatty acids (Chidambaram and Iyer, 1941). Saturated acids have myristic acid, 25 % palmitic acid, 39 % stearic acid, and 33 % anarchidic acid, 2.5 %. Unsaturated acid has linoleic acid at 56 % and oleic acid at 45 %. An inhibitory growth steroid masterol was also reported in *Amaranthus* roots (Roy et al., 1982). In a study by Sarker and Oba (2019a), the highest fat content observed was 4.35 g kg^{-1} FW, while the minimum was observed as 1.42 g kg^{-1} FW.

According to Sarker and Oba (2019b), in leafy vegetable *Amaranthus* species, *A. viridis* and *A. spinosus* genotypes show low-fat content and are recommended as cholesterol-free food. Their study reveals the fat content ranged from 0.28 to 0.63 g^{-1} FW. As per literature, fat is helpful in the transport of vitamins A, D, E and K, aids in digestion and absorption of these vitamins, and is additionally a good source of omega three and omega six fatty acids.

Proteins

Protein contents present in grains of the *Amaranthus* crop are more than in maize and other cereal grains (Bejosano and Corke, 1998). Amino acids are limited in maize, wheat, and other cereals by lysine. EAAI esteem (up to 90.4 %) demonstrate that the protein present in *Amaranthus* is practically identical to the protein in the egg and can be utilized as a superfood (Pisarikova et al., 2005a). Sulphur-containing amino acids (up to 4.5 %) are found in high protein concentrations (Senft, 1980), typically in different bean crops. The protein in the *Amaranthus* crop is closely related to the dimension prescribed by the international organizations, i.e., FAO or WHO, for a well-balanced diet (Gorinstein et al., 2002). The protein contents of *Amaranthus* grains are from 14.51 to 15.11 % (Rodas and Bressani, 2009). The leaf protein contents of the *Amaranthus* crop range from 15 to 18 g kg^{-1}, with an average capacity of 12 g kg^{-1} (Shukla et al., 2006). The protein present in leaves of *Amaranthus* spp. is relatively higher than in leafy vegetables like spinach and some other plants. Lysine contents in this protein are about 40 to 50 g kg^{-1} (Pisarikova et al., 2005b). The amino acids quantity *Amaranthus* grain is revealed of the presence of imperative amino acids, in particular, leucine, alanine, pralines, methionines, isoleucine and serine, etc., which proposes that *Amaranthus* is a pseudo-cereal that can be utilized as a replacement to cereal grains (Jaun et al., 2007). Juan et al. (2007) outline that more balanced amino acid contents are observed in the wild adopted species that can be introduced into cultivated lines by hybridization to improve nutrition.

Stem amaranth leaves are rich in dietary fiber, moisture, carbohydrate and protein. They can be a potential source of dietary fiber, moisture, carbohydrate content, protein content, mineral concentration, phenolic compounds, flavonoids, almost all kinds of vitamins, phytopigments to our daily nutritional requirements and antioxidants abundance in our body. *Amaranthus* is the best source of protein for vegetarians and people in low-income countries. In a study by Sarker et al. (2020a), stem amaranth has higher protein content, i.e., 3.46 g 100 g^{-1} FW, than *A. tricolor* (i.e., 1.26 %). According to them, in low-income countries, people mainly depend upon *Amaranthus* for their protein needs. In line with observations of Sarker and Oba (2019a), red morph *Amaranthus* has protein content ranging between 11.38 to 62.26 g kg^{-1}. From the results of Sarker et al. (2020b), green morph *Amaranthus* species show more protein content (38.73 g kg^{-1}) as compared to red morph *Amaranthus* (1.26 %). In the investigation of Sarker et al. (2015b), protein content ranged from 1.01 to 1.88 %.

Minerals

Many mineral elements have been outlined in the *Amaranthus* species. The lush green *Amaranthus* crop contains potassium (K) from 6.5 to 6.8 g kg^{-1} with a normal range of 3.8 g kg^{-1}. It has calcium (Ca) (0.74 to 2 g kg^{-1}) with a mean average 1.8 g kg^{-1}. Magnesium (Mg) is present from 2.9 to 3.2 g kg^{-1} with a normal range of 3 g kg^{-1}. Zinc (Zn) from 435.7 to 1235 mg kg^{-1} with a normal range of 792.7 mg kg^{-1}. Iron (Fe) from 785 to 2310 mg kg^{-1} with an average of 1235 mg kg^{-1}. Manganese (Mn) with a normal range of 110 mg kg^{-1}, nickel (Ni) with a normal range of 223 mg kg^{-1} (Shukla et al., 2006).

Amaranthus crop used for grain purposes has a mineral content higher than cereals. 66 % of minerals stay present in the brans and the germ portions (Saunders and Becker, 1984). Bran and germ coverings have higher ash contents in comparison with perisperm. The grains likewise have a higher substance of different nutrients like Fe, Ca, K, Mg and Zn. In a study by Chakrabarty et al. (2018), results reveal that mineral components showed an insignificant correlation with the biological yield except for a few listed as zinc versus copper, magnesium versus calcium and manganese versus iron. They have recommended a genotype with coding SA8 that exhibited maximum yield and suitable concentrations of zinc, calcium, manganese, potassium, iron, and magnesium. They also recommended two genotypes with coding SA6 and SA11 that have low biological productivity. Still, their mineral concentrations were significantly higher, and they proposed these genotypes as potential donor parents for incorporating potential genes for higher mineral content into other genotypes via breeding purposes.

According to observations of Sarker et al. (2020a), the leaf of stem amaranth contains a significant amount of potassium (K), calcium (Ca), and magnesium (Mg), i.e., 9.61 mg g^{-1}, 24.40 mg g^{-1} and 29.77 mg g^{-1} respectively based on the dry weight. Additionally, they also show that leaf also contains a considerable amount of iron (Fe), i.e., 1131.98 μg g^{-1}, manganese (Mn), i.e., 269.89 μg g^{-1}, copper (Cu), i.e., 25.03 μg g^{-1}, and zinc (Zn), i.e., 1006.53 μg g^{-1} based on the dry weight.

Based on Sarker et al.'s (2020b) investigation, potassium content ranged from 4.19 to 5.17 mg g^{-1} FW. The calcium ranged from 1.89 to 3.09 mg g^{-1} FW. The iron content ranged from 9.25 to 17.83 μg g^{-1} FW. The manganese content ranged from 5.82 to 15.89 μg g^{-1} FW. A more significant difference has been observed in zinc concentration, ranging between 8.81 to 17.03 μg g^{-1} FW. In contrast, they did not find any significant difference between magnesium content genotypes between 2.84 to 3.01 mg g^{-1} FW. The authors also discovered that mineral concentrations in *Amaranthus* were much higher than in spinach, spider flower, kale, and black nightshade.

The study led by Sarker and Oba (2020a) in the leaf of *A. blitum* showed a considerable amount of K (10.24 mg g^{-1}), magnesium (30.42 mg g^{-1}) and calcium (24.74 mg g^{-1}) based on their dry weight. They also checked Fe content, i.e., 1153.83 μg g^{-1}, Mn, i.e., 207.50 μg g^{-1}, Cu, i.e., 26.13 μg g^{-1} and Zn, i.e., 878.98 μg g^{-1} based on the dry weight. They also concluded that mineral contents in *A. blitum* leaf were much higher than in the spinach, kale, and black nightshade.

Sarker et al. (2015a) showed a tremendous variation in Zn concentrations ranging between 449.68 to 1235.01 mg kg^{-1}. The Mn concentration ranged between 62.70 to 155.70 mg kg^{-1}. They studied nine traits in their research and observed high variations in Fe concentration ranging from 1750.12 to 2324.94 mg kg^{-1}. The Mg concentration varied from 2.32 to 3.10 g 100 g^{-1}. The K content ranged from 1.70 to 6.50 g 100 g^{-1}. According to Sarker et al.'s (2015b) study, K concentration varied from 0.84 to 1.60 %. On the other hand, Ca and Mg ranged from 1.49 to 3.47 %, 2.84 to 3.53 %, respectively.

Considering the results of Sarker and Oba (2019a), mineral concentrations of K, Ca, and Mg ranged between 6.55 to 16.28 mg g^{-1} DW, 16.02 to 34.82 mg g^{-1} DW and 35.43 to 24.51 mg g^{-1} DW respectively. They also observed remarkably significant results in Fe concentration ranging between 195.12 to 2057.02 μg g^{-1} DW. On the other hand, Mn, Cu and Zn contents varied from 132.65 to 356.84 μg g^{-1} DW, 12.09 to 45.12 μg g^{-1} DW and 601.37 to 1525.92 μg g^{-1} DW respectively.

In the study of Sarker and Oba (2019b) on two amaranth species, i.e., *A. viridis* and *A. spinosus*, K varied from 6.45 to 7.22 mg g^{-1} FW, while no significant variations were observed in terms of Ca, Mg and P that ranged between 2.44 to 2.84 mg g^{-1}, 2.88 to 3.78 mg g^{-1} FW, 0.68 to 0.94 mg g^{-1} FW respectively. They recorded Fe content between 8.66 to 10.23 μg g^{-1} FW. They also recorded Cu, Zn and Na contents and found a range from 1.37 to 3.02 μg g^{-1} FW and 10.9 to 14.72 μg g^{-1} FW and 24.56 to 25.56 μg g^{-1} FW respectively.

Vitamins

For daily required vitamins level, *Amaranthus* is a diverse food that has a good quantity of vitamins in it (Graebner et al., 2004). In the lush green leaves of *A. tricolor*, carotenoids (vitamin A) are present ranging from 0.8 to 0.9 mg kg^{-1}. Ascorbic acid (vitamin C) is present in a range from 110 to 115 mg kg^{-1} (Shukla et al., 2006). *Amaranthus* crop has a higher extent of riboflavin, commonly called vitamin B2 nutrient and vitamin C nutrient as compared with cereals. It is likewise a decent source of vitamin E that has extraordinary antioxidant property. A naturally occurring compound named quercetin and vitamin K are additionally revealed in *A. blitum* (Ganju and Puri, 1959).

In a study conducted by Sarker et al. (2020a), significant amount of vitamin C has been found in stem amaranth (1355.14 μg g^{-1}) as compared to *A. tricolor*. According to Sarker and Oba (2019a) vitamin c contents ranged between 103.53 to 190.58 μg g^{-1}. In another investigation of Sarker and Oba (2019c) vitamin C and phenolic compounds concentration were from 94.51 to 122.43 μg g^{-1} DW and 71.62 to 220.04 GAE μg g^{-1} DW respectively.

Fiber

Fiber is additionally a usual element of the whole *Amaranthus*. Lush green leaves of the vegetable amaranth contain a fiber range between 6.96 to 9.66%, with an average of 8.40% (Shukla et al., 2006). In *Amaranthus*, fiber is somewhat lower than in wheat, and is present in bran rather than in perisperm. The fiber content is present in a range of 20 to 28% in *A. cruentus*, 36 to 50% in *A. hypocondriacus* and 34 to 45% in *A. caudatus* (Pedersen et al., 1990).

Rather than these essential, healthfully vital aggravates, some secondary metabolites obtained from metabolic and synthetic pathways are also present in the *Amaranthus* crop that are additionally assumed as essential nutrients for the human diet.

As per Sarker et al. (2015b), dietary fiber ranged between 5.97 % and 9.75 %. In light of Sarker and Oba (2019a), dietary fiber concentrations ranged from 59.96 to 91.94 μg g^{-1} FW in 25 different red morph genotypes. As specified by the results of Sarker and Oba (2019b), *A. spinosus* had a significantly higher dietary fiber content than *A. viridis*. According to their results, dietary fiber ranged between 9.17 to 11.24 g 100 g^{-1} FW.

Phytic Acid

The contents of phosphorus found in different *Amaranthus* spp. are created by the availability of phytic acid. It ranges from 0.4 to 0.7% in *Amaranthus*, similarly distributed in the *Amaranthus* seeds (Stintzing et al., 2004). It is diminished by dehulling action or by extensive water extraction. It can bring down the level of cholesterol in different humans (Shukla et al., 2003).

Pigments and Chlorophyll

The lovely shade of the *Amaranthus* is the result of the existence of betacyanin, which belongs to the beta line group. In different *Amaranthus* spp., betacyanin is distinguished as amaranthine and iso-amaranthine (Repo-Carrasco-Valencia et al., 2010). *Amaranthus* is an intermediate compound engaged in altering N compounds in the cell (Gins et al., 2002). Leaves of lush green vegetable amaranth crop have a chlorophyll content ranging from 489 to 655 mg kg^{-1} and chlorophyll b contents range from 405 to 555 mg kg^{-1} accordingly (Ivete et al., 2004). The enormous biosynthesis of different pigments like amaranthine, phenylalanine and tyrosine is the main reason for declining quantities of varying lignin compounds, protein contents and cellulose concentrations in the foliage (Gins et al., 2002).

In an investigation by Sarker et al. (2015a), twenty-five different genotypes of amaranth showed a significant variation in beta-carotene content and ascorbic acid concentrations in the range between 0.62 to 1.09 mg g^{-1} and 60.25 to 177.20 mg 100 g^{-1}. In the results of Sarker et al. (2020a), stem amaranth has a significant amount of betacyanin, betaxanthin, betalain, and total carotenoids as 31.12 μg 100 g^{-1}, 31.81 μg 100 g^{-1}, 62.92 μg 100 g^{-1} and 1675.38 μg 100 g^{-1} respectively. They reveal that stem amaranth contains a significant range of chlorophyll a, b and total chlorophyll content, which are 126.47 to 429.62 μg g^{-1} FW, 50.72 to 239.09 μg g^{-1} and 179.94 to 669.72 μg g^{-1} FW) respectively. According to Sarker et al. (2020b), betacyanin, betaxanthin and betalain vary from 69.15 to 241.17 ng g^{-1} FW, 70.76 to 164.29 ng g^{-1} FW and 139.91 to 392.82 ng g^{-1} FW respectively.

As stated by Sarker et al. (2018a), amaranth genotypes have variations in terms of chlorophyll a, b and total chlorophyll as they are in the range of 127.26 to 636.87 μg g–1, 51.67 to 292.19 μg g–1 and 179.94 to 906.23 μg g–1 respectively. They also observed a significant difference in beta-cyanins, beta-xanthins, betalains, total carotene and ascorbic acid concentrations as they were between 185.52 to 538.51 ng g–1, 181.90 to 584.71 ng g–1, 367.35 to 1121.85 ng g–1, 32.77 to 105.08 mg 100 g–1 and 11.97 to 184.77 mg 100 g–1.

According to Sarker et al. (2018b), chlorophyll a, b, total chlorophyll, beta-cyanins, beta-xanthins, betalains, total carotene and carotene and ascorbic acid have significantly differed among genotypes. They ranged between 126.47 to 380.80 μg g^{-1}, 49.63 to 211.93 μg g^{-1}, 193.31 to 538.49 μg g^{-1}, 106.37 to 352.26 ng g^{-1}, 99.94 to 370.76 ng g^{-1}, 206.23 to 719.84 ng g^{-1}, 62.2 to 132.32 mg 100 g^{-1} and 18.87 to 185.87 mg 100 g^{-1} respectively.

In under observations of Sarker and Oba (2019a), chlorophyll a, b, total chlorophyll, beta-cyanins, beta-xanthins, betalains and total carotenoids concentrations have remarkably differed among genotypes. They were ranged from 15.30 to 65.82 mg 100 g^{-1}, 7.32 to 29.73 mg 100 g^{-1}, 24.17 to 95.04 mg 100 g^{-1}, 13.96 to 56.78 μg 100 g^{-1}, 12.57 to 58.12 μg 100 g^{-1}, 26.52 to 114.89 μg 100 g^{-1} and 564.66 to 1677.26 μg g^{-1} respectively.

Prominent variations have been observed in Sarker et al.'s (2019b) findings. The results show good variations in chlorophyll a, b, total chlorophyll, beta-cyanins, beta-xanthins, betalains and carotenoids as they were ranged between 267.85 to 302.56 μg g^{-1} FW, 135.26 to 152.42 μg g^{-1} FW, 413 to 445.22 μg g^{-1} FW, 185.52 to 538.51 ng g^{-1} FW, 532.12 to 561.42 ng g^{-1} FW, 68.52 to 92.87 mg 100 g^{-1} respectively.

In the finding of Sarker and Oba (2019c), betalains, beta-xanthin, beta-cyanin and carotenoids varied significantly and remarkably among genotypes. They observed the range between 384.39 to 1122.47 ng g^{-1} FW, 144.11 to 585.22 ng g^{-1} FW, 240.28 to 624.75 ng g^{-1}, FW, 23.02 to 55.55 mg 100 g^{-1} FW. They also observed 2 to 3 folds of carotenoids in red colour genotypes compared to green colour genotypes.

Oxalates and Nitrates

Besides its superior nutritional properties, it has two antinutritional compounds, i.e., oxalates and nitrates. Oxalates range from 5 to 20 g kg^{-1} in vegetable amaranth while 3 to 17 g kg^{-1} in grain *Amaranthus* (Siener et al., 2006). Nitrates range from 0.9 to 1 mg kg^{-1} in vegetable amaranth and 0.8 to 1 mg kg^{-1} in grain types (Gelinas and Seguin, 2007). These two compounds have the feature of reducing the absorption of Ca and Zn, which later results in the formation of stones in the kidney (Radek and Savage, 2008). These compounds can easily be removed by boiling the seeds from 5 to 7 minutes before using.

Celiac Disease

Wheat, barley and some other cereals contain gluten protein that couldn't be used by a person that has gluten sensitivity disease named celiac disease (Catassi and Fasano, 2008). Because of the presence of gluten, the intestinal mucosal can be harmed, and its functions may be lost (Fasano and Catassi, 2001; Pagano, 2006). It has been noticed that by utilization of a gluten-free diet one can prevent celiac sickness (Thompson et al., 2009). *Amaranthus*, quinoa and buckwheat can be used for this purpose because of their superior quality nutritional profiles and gluten-free properties (Kupper, 2005).

Stress Resistant Crop

Due to current stress conditions, including biotic and abiotic stress, there is a need to develop some climatic resilient crops. These crops must have the ability to survive in stressful conditions. Climatic resilient crops are such crops that can survive in stressful situations and must be necessary for future food security. Some pseudo-cereals can likewise be utilized from a similar request Caryophyllales, for example, amaranth and quinoa etc. (Clouse, 2016).

Tolerance against Drought Stress

Vegetable amaranth was cultivated around 2000 years ago by early civilization and has remained to date. Recently its utilizations all over the world has grown. Vegetable amaranth leaves contain high nutrients, minerals, and protein content (Makus and Davis, 1984). *Amaranthus* can stand under high-stress conditions like high temperature, low soil supplements, drought and change in photoperiod day length to dry spell (Myers, 1996). However, to ensure the extension of vegetable amaranth cultivation in drought-prone regions, a deeper understanding of the strategies employed by different *Amaranthus* genotypes in adaptation to drought stress is required. Because of water deficit, from the morphological point of view and physiological angle reaction of the plant to different responses, a wider variety of dry spell resilience systems have been built up (Blum, 1996). In the genotypical and physiological study, Liu and Stutzel (2002 a, b) demonstrate that the vegetable crop amaranth shows a very high potential against dry seasons condition and a high limit of osmotic alteration from 1.08 to 1.24 MPa and guarantees that *Amaranthus* keeps on working in dry seasons condition (Liu and Stutzel, 2002a). More advanced studies indicate that the *Amaranthus* plant leaves can overcome the stomatal closure and lessening of leaf extension to control water transpiration rate (Liu and Stutzel, 2002b). The proper study on *Amaranthus* plant adaptation under drought stress has not been identified yet and is under investigation.

Studies have demonstrated that dry season pressure can unexpectedly influence the development of plant organs (Spollen et al., 1993), resulting in the change of the internal highlights of the whole plant body (French and Turner, 1991). The adjustment in root-shoot dry matter ratio has been well developed as one of the mechanisms for adjusting plants to dry spell pressure (Turner, 1997). Dry spell pressure decreases during both root as well as shoot development. However, the growth of roots appears to be the least affected. Sharp and Davies (1979) initiated that solute be gathered in the tip of the root under submerged restricting conditions and subsequently, water be pulled through this region which kept up root turgidity and caused development. In this manner, an expanded root-to-shoot proportion is often seen in droughty plants (Finn and Brun, 1980; Chartzoulakis et al., 1993).

Similarly, dry season pressure regularly promotes an abatement in leaf dry mass proportion (leaf dry mass/plant all-out dry mass) in many yield species (Van Den Boogaard et al., 1996). In the soil-plant-environment-continuum (SPEC), water is taken from the roots and transported to the leaves and unfolded into the air. The relationship between leaf territory and root dry mass mirrors the harmony between plant organs over seawater misfortune and take-up. Changes in this relationship under dry season and pressure may assume a job in controlling plant water status (James and William, 1998). The study on this aspect of drought is less common (Van Den Boogaard et al., 1996; James and William, 1998). Explicit leaf zone (SLA), a marker of leaf thickness, has been frequently decreased under dry spell conditions (Marcelis et al., 1998). Diminishing SLA in droughty plants might be because of the distinctive affectability of photosynthesis and leaf region extension to soil drying. Dry spell pressure influences leaf development sooner than photosynthesis (Jensen et al., 1996; Tardieu et al., 1999). A decrease in SLA is an approach to improving water use proficiency (WUE) (Wright et al., 1994; Craufurd et al., 1999). The reason is that thicker leaves generally have a greater thickness of chlorophyll contents and proteins or units of leaf territory and subsequently have a more prominent photosynthetic limit than more slender leaves.

A very comprehensive study on the response of *Amaranthus* to drought stress has been conducted by Sarker and Oba (2018b). In this study, the researcher used four different genotypes of *A. tricolor* and reported the response of these genotypes to drought stress in terms of ROS marker and physiological and biochemical attributes. They reported substantial effects of drought on genotypes response in observed parameters and these genotypes to behave differently. Although the response depends upon the drought duration, ROS marker and physiological and biochemical attributes were observed during the study. They recommend two genotypes coding VA14 and VA16 as drought-tolerant varieties with tolerance in terms of ROS marker and physiological and biochemical attributes recorded during the experiment. They observed a significant correlation among ROS marker, MDA content, H_2O_2, compatible osmolytes, proline content, total phenolic content, total flavonoid content and total antioxidant capacity, demonstrating that compatible osmolytes and non-enzymatic antioxidant systems (proline, glutathione etc.) illustrated significant role in quenching of ROS in *A. tricolor* genotypes. However, this phenomenon should be confirmed for a broader range of water deficit stress as well as over a broader range of abiotic and biotic stresses. As a result, more ascorbic acid concentration suggests that it has a crucial role in the ascorbic acid-glutathione cycle ASC-GSH for quenching ROS. There is a need to study a comprehensive study of ASC-GSH under water deficit stress in *A. tricolor* cultivars.

Tolerance against Salinity Stress

The problem of salt stress on different plants is the most critical issue of agriculture in both regions, i.e., arid and semi-arid worldwide. Saltiness and water pressure extensively diminish the development of roots and shoots. For adjustment to this kind of burden, natural solutes, for example, amino or sugars compounds, have been speculated to assume a critical job as osmoprotectants counteracting checking the poisonous impact of sodium and Chlorine ions in shoot part of different species of plants (Storey et al., 1977; Hanson and Nelson, 1978; Ahmad et al., 1979; Hanson and Scott, 1980; Cheeseman, 1988; Csonka and Hanson, 1991; Wang et al., 1999). Past examinations have demonstrated that glycine betaine, a compound in *Amaranthus*, gathers in *Hypochondriacus* spp., *A. caudatus* and *A. tricolor* (Valenzuela-Soto and Munoz-Clares, 1994; Russell et al., 1998; Wang et al., 1999). Whenever *A. tricolor* was developed under salt pressure (300 mM NaCl), leaf GB content customarily increased. Nonetheless, there is little data on the time-course of GB amassing after salt pressure or after alleviation from saltiness.

According to Sarker and Oba (2020b), salt-sensitive and tolerant genotypes of *A. tricolor* behave differently under salinity conditions in terms of growth response, anatomical response, physiological activities, ROS accumulation, antioxidant activity, and antioxidant defence system. These genotypes also show different attitudes towards biochemical attributes related to oxidative stress tolerance. According to findings, tolerant genotypes have significantly higher relative water content, photosynthetic pigment concentrations, lower electrolyte leakage, more leaf thickness, lower vessel lumen, more vessel frequency and more thickness of plastids. Additionally, they are more adapted to saline conditions than salt-sensitive genotypes. Authors recommend that, in tolerant genotypes, ROS accumulation be lower because of more enzymatic solid and non-enzymatic antioxidant systems in the cells. According to the results, it seems that *A. tricolor* does not need to induce the total capacity of the non-enzymatic and enzymatic antioxidant system for tolerance against salinity. However, it is believed according to the results, that in tolerant genotype, total phenolic contents, total flavonoids contents, ascorbate, carotenoids, superoxide dismutase, ascorbate peroxidase are seen to be significant detoxifiers of hydrogen peroxide H_2O_2 ROS.

In contrast, glutathione peroxidase and catalase activity are significantly higher in sensitive genotypes as they have more concentration of H_2O_2. The superoxide dismutase aids in the detoxification of reactive oxygen species in both tolerant and sensitive genotypes. Additionally, it contributes to detoxifying ROS in tolerant genotypes; this system is more robust in tolerant genotypes than in sensitive genotypes. According to results, increment in SOD, AsA-GSH cycle (glutathione cycle) concentration denoted as significant contributor for detoxification of reactive oxygen species more specifically H_2O_2.

Augmentation of Functional Components Imposing Abiotic Stress

Recently, a study has been conducted under water deficit conditions and increased total antioxidants content (TAC), TPC, total flavonoid contents (TFC), and minerals and vitamins contents (Sarker and Oba, 2018c). Another study under salinity has revealed that under salinity conditions, *A. tricolor* shows an enhanced tolerance by showing an increment in TAC, TFC, β-carotene level and TPC. It also shows that *A. tricolor* nutritional quality is enhanced under salinity conditions. They also show increased protein contents, dietary fiber contents and carbohydrates under salinity conditions (Sarker et al., 2018).

Another study also follows the same results under saline conditions. They concluded that *Amaranthus* could tolerate saline stress without affecting the quality of its final product. This study observes a remarkable increment in β-cyanin, β-xanthin and betalain contents (Sarker and Oba et al., 2019). *Amaranthus* leaves are a rich source of bioactive pigments that can aid in conferring abiotic stresses. In another study, they first identified a novel phenolic compound called trans-cinnamic acid in *A. tricolor* under salinity. They also studied salicylic acid, isoquercetin, m-comaric acid and gallic acid in *A. tricolor*, which increase the severity of stress (Sarker and Oba, 2018d). According to all these studies, there is a need to promote this crop as an alternative crop under water deficit conditions and in salinity-prone areas. There is a need to urge the farmers to use this crop because of its climate-proof behaviour and nutrition-rich qualities.

Uses of *Amaranthus*

Amaranthus crop is a profoundly nutritious superfood. All parts of this crop, including shoots, leaves and delicate stems, are used for eating in sauces, soups, or cooking with different vegetables. The grains are mainly consumed for eating purposes. Its plants can be used as a high-quality forage in livestock. In addition, its blooms make lovely ornamentals in fresh and dry forms. *Amaranthus* plant does not belong to the cereal's family; that is why it is considered pseudo-cereal because it is utilized in the same way as other cereal grains. Likewise, with other small grains, the grains of *Amaranthus* might be prepared in popped, chipped, expelled and ground flour frames. In Mexico, Alegria is the most common and popular dish that is made up of popped *Amaranthus*. The flour of its grains is mixed with other flours to make cereals, cookies, bread, and other baked items.

Initially, it was prescribed that grain of *Amaranthus* should only make 12 to 20 % of the flour mix; however, it has been shown that mixing 50 to 75 % remains in functional properties and taste. Well-ground *Amaranthus* makes a delicious and nutritious porridge cooked with only *Amaranthus* or with any other cereal like wheat or other pseudo-cereal.

Future Prospects

Amaranthus possesses versatility in its use and nature. The availability of genetic diversity among different species of grains and vegetable amaranth has opened new avenues for breeders to develop new, improved and developed lines that are nutritionally rich and are well-adopted to a specific area as the seed embryo of the *Amaranthus* crop contains a large number of amino acids so we can develop a particular nutrient-rich variety (Tomoskozi et al., 2009). The lines with the tolerance to drought and capacity to grow in sodicity can be considered for cultivation on non-cultivable land. Oil contents of *Amaranthus* seed mainly comprise non-polar lipids. They have a high degree of unsaturation that should be distinguished and trailed by the foundation of exact oil refining forms. There has been a considerable need to develop varieties with very low/no oxalates and nitrate contents that need extensive research. Teutonico and Knorr (1984) demonstrated a reduction in oxalate and nitrate by using tissue culture strategies that open new avenues for producing new varieties using tissue culture techniques with low oxalates and nitrate contents. Demko (1997) assesses the utilization of *Amaranthus* spp. *retroflexus* as another option of the sustainable power source and shows that it came to a range of 70 to 90% of the calorific intensity of wood. So, there is a need to explore other species for renewable energy. Because of accessible data on the remedy of *Amaranthus* crop for pharmaceutical ventures, scientists should concentrate on separating compounds with medicinal value. So, *Amaranthus* can be used for the current malnutrition scenario and future food security.

Conclusion

Amaranthus is a high-nutrition crop that can be an alternative to already consumable, low-nutrition crops. It has the potential to contribute to the current malnutrition scenario. Further studies can be conducted to explore its potential against stressful conditions. *Amaranthus* has all properties that can be considered a super and functional food.

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