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THE IMPORTANCE OF QUINOA (*QUINOA CHENOPODIUM* WILLD.) CULTIVATION IN DEVELOPING COUNTRIES: A REVIEW

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ABSTRACT. Quinoa is a dicotyledonous species for seeds and, therefore, is not known as a cereal grain and is a pseudo-grain, which is introduced nowadays as a new crop in the world. Population growth and the need for more food put additional pressure on the environment, especially on water resources and agronomic ecosystems. This has led to more attention to plants that grow at different latitudes and altitudes. Climatic and environmental changes affect agricultural inputs, especially water resources. So, the best way of adapting to the current situation is the introduction of low-water, salt-resistant, and drought-tolerant plants to the recent climatic changes. Water scarcity has become a serious problem in many countries. This restriction has had a significant impact on the development of countries. The plants which grow in arid and semi-arid regions are often exposed to adverse environmental factors, such as drought or salinity. Salinity and drought stress, more than any other factor, decrease crop yields around the world. These two abiotic stresses are the main limiting factors for crop production, especially in arid and semi-arid regions of the world. Quinoa is an exceptional plant that can adapt to adverse conditions and can serve as a solution to the challenge of global food security. Recent droughts that occurred in the world have prompted governments to include plants in their development plans, which are adapted to the country's existing water and soil conditions and have high nutritional value. This way, quinoa cultivation can ensure their food security in the coming years.

Keywords: food security; food value; global needs; drought; salt; nitrogen.

INTRODUCTION

Global agriculture faces many challenges, such as increasing population growth and food demand. The world's population is likely to reach more than 10 billion by 2050,

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with the world's food demand for agricultural land increasing rapidly (Tilman *et al.,* 2011; Bouwman *et al.,* 2017; Bai and Tao, 2017). The impacts of global climate change and its effect on the growth and productivity of crops are predicted to have significant economic impact on population and the environment worldwide (Jaikishun *et al.,* 2019). A warm climate will be unsuitable for crop growth and yield since it reduces the soil's potential to capture and retain water and impound its fertility (González *et al.,* 2015). These impacts will not only be detrimental to the environment but will cause tremendous strain on the entire ecosystem due to the many-sided source and variable effects. One of the significant problems emanating from these scenarios is food security, which is poised to reinforce progressively (FAO, 2019).

Drought, particularly in developing countries, poses a significant challenge for farmers, and in some areas, it is so severe that scientists are concerned with other farmers' lack of adaptability and resilience loss (Altieri and Nicholls, 2017; Imbach *et al.,* 2017; Harvey *et al.,* 2014; Hannah *et al.,* 2017; Elum *et al.,* 2017; Khatri-Chhetri *et al.,* 2017). Therefore, the negative consequences of drought have become one of the main concerns of farmers in critical regions (Campell *et al.,* 2011). Especially in societies with subsistence economies, *i.e.* small-scale farmers' communities as they are entirely dependent on their nature and agriculture (Endfield *et al.,* 2004), drought stress reduces crop yields and depletes natural resources. Empowering farmers to cope with drought increases the security of nations to face the external threats and reduces the dependence of governments on other societies (Lipper *et al.,* 2014; Steenwerth *et al.,* 2014). In this regard, scholars and policymakers strongly emphasize the need for urgent action to prepare and adapt to the adverse effects of this phenomenon, especially in developing countries (IPCC, 2014). Because they understand the role of influencing factors on farmers' adaptation to ensure the development of appropriate policy measures and designing successful projects is vital for development (Gebrehiwot and Van der Veen, 2013). According to meet the growing needs of the increasing population, the introduction of plants with acceptable performance and resistance to stresses is necessary.

Quinoa is a pseudocereal and dicotyledonous seed belonging to the *Amaranthaceae* family, which in turn belongs to the *Chenopodiaceae* family. This family consists of economic species, such as spinach and beetroot (Jacobsen *et al.,* 2003; Vega-Gálvez *et al.,* 2010). Quinoa together with its wild relatives, including (*Chenopodium carnosolum, C. petiolare, C. pallidicaule, C. quinoa melanospermum* subsp., *C. ambrosoides incisum*) are a high diversity of species and applications (Fuentes *et al.,* 2009). These species have traditionally been planted over the years by farmers from the Andes in Colombia, Ecuador, Peru, Bolivia, Chile, and Argentina. Quinoa is a dwarf plant with about 93% self-immolation from the western Andean mountains of South America (Jacobsen *et al.,* 2005; Bazile *et al.,* 2014, 2015). To introduce the role and value of this plant in food security, the development of consumption and production, Food and Agriculture organization (FAO) named 2013 as the International Year of Quinoa (FAO, 2013). Quinoa is highly resistant against abiotic stresses, such as a wide range of cold, drought and salinity of the soli and also has an excellent ability to grow in marginal soils (Jacobsen *et al.,* 2009; Hernández-Ledesma, 2019). Quinoa is considered a climate-resistant, gluten-free, highly nutritious seed product with remarkable agronomic adaptation to adverse climatic conditions (Dallagnol *et al.,* 2013). The year 2013 was declared the year of quinoa by the United Nations, because these circumstances. Therefore, the goal of most countries in the world is to increase and evaluate the production of quinoa (Ruiz *et al.,* 2016). The procurement of sustainable food in noxious environmental conditions, resulting from climate change scenarios for its credentials in nutritional composition and relevance was selected by NASA (National Aeronautics and Space Administration) as a preferred food for its astronauts on board space missions (Schlick and Bubenheim, 1993; Jaikishun *et al.,* 2019).

This study shows that quinoa is of high nutritional value and is resistant to harsh environmental conditions (resistant to drought and salinity) to other crops. This plant has been introduced to the world since 2013 and requires extensive research in all regions of the world. Most of the developing countries have to cultivate plants that can meet their nutritional needs and grow properly in the climate of their areas.

Distribution

Worldwide, more than 6,000 varieties of plants have been grown by farmers (Rojas *et al.,* 2015). Quinoa plant, with high nutritional value and high growth potential and production, grows in unfavorable conditions for many cultivated plants. Quinoa is resistant to climatic changes, and its seeds have a high protein content (Schoenlechner *et al.,* 2010). In some parts of the world, quinoa is known as the "vegetable caviar" or the Inca rice. In the global distribution of quinoa production, Peru and Bolivia are the primary producers, in addition to USA, Ecuador, and Chile, Canada, Colombia, Argentina, and Mexico, which produce this plant mostly for local consumption (*Fig. 1*; FAO, 2011).

Quinoa has always been of great importance for many generations as an essential food for the people. In recent years, research and cultivation of this valuable plant have grown rapidly in the world. The reviews on the Google Scholar web site and the search for keywords, including quinoa, cultivation, agronomy, and agricultural research, during 1970 and 2013 (over 43 years) have shown that near 3040 scientific reports have been presented about quinoa. However, from 2013 to March 2020, more than 4050 studies have been reported (for seven years).

The high adaptability of quinoa to various agro-climatic habitats and edaphic conditions has increased the yields of different varieties in countries outside South America, such as Europe, USA, Canada, China, and India (Gonzalez *et al.,* 2012; Jacobsen, 2011). The trend of changes in the area under cultivation and production during the years 1961 to 2018 is shown in *Fig. 2*.

Hence, the world production of quinoa has augmented in the past years and was near to 160,000 tonnes in 2018 (FAO, 2020). The trend of changes in the area under cultivation of quinoa has increased from 52555 hectares in 1961 to 178313 hectares in 2018.

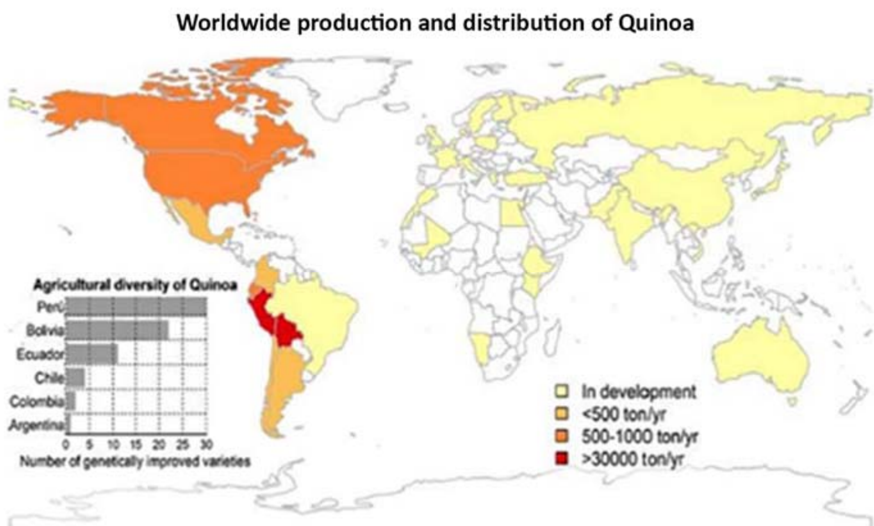

Figure 1 - Quinoa Production and Distribution Chart in the World (FAO, 2011)

Importance of quinoa cultivation

In recent years, rising food demand has led to population growth and the need for increased production, as well as broader use of agricultural lands (Xu *et al.,* 2014; Jahani and Fathi, 2017). One of the factors contributing to crop growth in developed countries is recognizing the potential climate and climatic needs of plants and using them to increase efficiency (Kamali *et al.,* 2010). Understanding the climatic parameters and their effects on plants are amongst the most critical factors in increasing yield and production (Kamali *et al.,* 2010). The major part of the arable land is under stress, sometimes associated with drought and salt stress, which leads to the yield reduction of many crops (Fathi *et al.*, 2017). Halophyte plants can grow in many areas, due to high adaptability to adverse environmental conditions (soil and water). Generally, environmental changes might reach critical levels in some areas and pose a severe threat to the quantitative and qualitative performance of agricultural products (Campbell *et al.*, 2011; Fathi and Tari, 2016). The development and promotion of quinoa cultivation diversifies food products in the human nutrition basket. However, determining the compatibility, production rate, areas prone to cultivation with economic production and selecting appropriate cultivars are essential that require further research in this area.

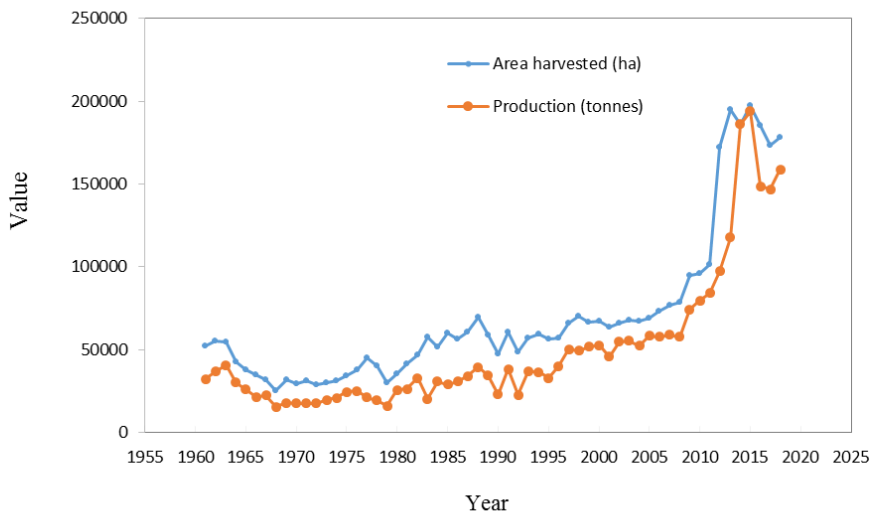

Figure 2 - Production and area harvested of Quinoa in World from 1961 to 2018 (FAO, 2020)

Importance and nutritional value of quinoa

Quinoa seeds are compact, digestible, and also a rich source of protein, iron, magnesium, fibers and vitamins. In comparison with standard grains, it has a higher protein content and more favorable amino acids (Zurita-Silva *et al.*, 2014). Quinoa, exceptionally, has a very accurate balance between fats (4-9%), protein (an average of 16% with high levels of essential amino acids) and carbohydrates (64%) (Bhargava *et al.* 2006; Vega-Gálvez *et al.*, 2010; Zurita-Silva *et al.*, 2014). Quinoa is a vibrant source of vitamins and fats (55-66% saturated fat), natural antioxidants, such as α- and γ- tocopherol and a wide range of minerals (Mastebroek *et al.*, 2000; Repo-Carrasco *et al.*, 2003; Bhargava *et al.*, 2006; Stikic *et al.*, 2012). Quinoa seeds and leaves can be used to produce alcohol and drugs (anti-inflammatory, analgesic and disinfectant) and as insect repellents (Vega-Gálvez *et al.,* 2010). In some countries, Quinoa is used as an alternative to meat and animal proteins (Jacobsen *et al.,* 2003). Quinoa can also be used to produce drinks and salad alternatives. Grains play a significant role in the human diet by meeting nearly half of an individual's need for energy and protein intake. Wheat, rice, barley, corn, rye, and bean are the most crucial foods in the world, in human and animal diets. Quinoa is an excellent nutrient that has higher nutritional content than those of other grains. Quinoa's advantage over other grains results from its richer lipid, protein and ash content. A comparison of the quinoa chemistry and several plants is shown in *Table 1*.

Table 1 - Comparison of the nutritional values of grains and quinoa (edible 100 g)

		Composition					
Plant	**Scientific name**	**Lipid (g)**	**Protein (g)**	**Ash (g)**	**Fiber (g)**	**Carbohydrate (g)**	**Energy (kcal/100g)**
Quinoa	*Chenopodium quinoa*	6.07	14.12	2.7	7	64.16	368
Rice	*Oryza sativa*	0.55	6.81	0.19	2.8	81.68	370
Wheat	*Triticum aestivum* L.	2.47	13.68	1.13	10.7	71.13	339
Barley	*Hordeum vulgare*	1.3	9.91	0.62	15.6	77.72	352
Maize	*Zea mays*	4.47	9.42	0.67	7.3	74.26	365
Rye	*Secale montanum*	1.63	10.34	0.98	15.1	75.86	368
Bean	*Phaseolus vulgaris*	1.1	28	4.7	5	61.2	399

Source: Navruz-Varli and Sanlier, 2016; Kozioł (1992)

Grain protein

The protein found in quinoa is more than that of the conventional cereals. But, its protein content is relatively lower than legumes protein. The protein content of quinoa seeds is variable in the range of 8% to 22%, depending on the variety and growth conditions, with a higher percentage than grains such as wheat, barley, and rice (Jancurová *et al.,* 2009). The protein content of quinoa is reported to be more than other cereals by Navruz-Varli and Sanlier (2016), as shown in *Table 1*. The exceptional characteristics of this plant have been made to be used as a portion of baby food for infants who do not use breast milk, especially in areas where there is a lack of nutrients (Matiacevich *et al.,* 2006). The majority of the stored proteins in quinoa is composed of globulins (37%) and albumins (35%), it contains low concentrations of prolamins, and these percentages may vary in different species (James, 2009). Quinoa, which provides a protein value similar to casein in milk, contains essential amino acids (Vega-Gálvez *et al.,* 2010). With its benefits close to those specified by FAO, its perfect amino acid balance and rich content with thionic amino acids and lysines. Quinoa is one of the plants that provide all the amino acids required for human life, and contrary to grain proteins that have negligible lysines, are accepted as high-quality proteins (Maradini Filho *et al.,* 2015). Comai (2007) reported that quinoa had not only rich protein content, but also had a sufficiently high concentration of amino acid composition and tryptophan, which is generally the second limiting amino acid. Also, it contains a high amount of non-protein tryptophan that can be absorbed more efficiently and help increment the usability of this amino acid in the brain, thus having an influence on serotonin neurotransmitter synthesis (Comai, 2007).

Carbohydrate

Carbohydrates, according to their degree of polymerization, can be classified into three main groups: 1 - sugars involving monosaccharides, disaccharides, and polysaccharides; 2 - oligosaccharides; 3 - polysaccharides containing starch and nonstarch (James, 2009). Quinoa is a deliberate part of carbohydrates, measured to 64% to 74% (dry basis) of dry matter (James *et al.,* 2009). Starch is the main carbohydrate of quinoa, which is about 32-69%. On the other hand, quinoa's nutritious fibers are similar to cereals and dissolve about 1.3-1.6% of fibers (James *et al.,* 2009). The role of food fibers is essential because of their specific characteristics, such as high water holding capacity, high capacity for ionic changes, the ability to absorb bile acids and toxic compounds and their effect on the growth of abundant intestinal microorganisms (Ruales and Nair, 1994). Useful and dissolved fibers of this seed have a positive impact on health, such as lowering blood cholesterol, improving digestion, and reducing blood glucose (Valencia-Chamorro, 2003).

Because of its complete freezing stability, low gelling point and low-temperature endurance, quinoa is an ideal thickener for soups, flours and sauces. Amylose content of quinoa starch varies between 3% and 22%, which is lower than that of corn and wheat, higher than that of some kinds of barley, and similar to that of basic rice types (Navruz-Varli and Sanlier, 2016). In comparison to wheat and barley starch, quinoa starch has maximum viscosity, a higher water absorption capacity, and bigger swelling capacity. Besides, it has wonderful stability even in freezing and retro gradation processes (Tang *et al.,* 2002). The following table shows carbohydrate compounds in quinoa, rice and barley *(Table 2)*.

Table 2 - Carbohydrate composition of quinoa, rice, and barley

Plant	Scientific name	Composition					
		Carbohydrate by difference	Starch	Fiber total dietary	Insoluble fiber	Soluble fiber	Sugar
Quinoa	*Chenopodium quinoa*	73.6[a] – 74[b]	52.2[a] – 69.2[c]	7[a] – 9.7[d]	6.8[c] – 8.4[d]	6.1[c] – 1.3[d]	2.9[d]
Rice	*Oryza sativa*	2.9[d]		2.8[e]			
Barley	*Hordeum vulgare*	77.7[e]		15.6[e]			0.8[e]

(% dry basis)
a - Data from USDA (2005); b - Data from Wright et al. (2002); c - Data from Mundigler (1998);
d - Data from Ranhotra et al. (1993) e - Data from James (2009)

Carbohydrates from quinoa can evaluate a nutraceutical food since they have useful hypoglycemic impacts and induce the decrease of free fatty acids (James, 2009). Berti and co-workers (2004) reported that in a person with celiac disease, the glycemic index of quinoa was slightly lower than that of gluten-free bread and pasta. Moreover, quinoa induced lower free fatty acid levels than gluten-free pasta and significantly lower triglyceride concentrations, compared to gluten-free bread (Berti *et al.,* 2004).

Saponins

Quinoa has an outer grain layer called saponin, which is toxic, has a bitter taste, and needs to be removed before the meal or during the food production process. Quinoa saponins are secondary metabolics that are distributed mostly in the crop and generally found in roots, leaves, seeds, stems, and fruits (Sparg *et al.,* 2004). These layers have protective characteristics, *i.e.,* they are produced for plant protection against harmful insects, microorganisms, and birds (Singh and Kaur, 2018). Saponins are divided into two main groups, steroid glycosides, and triterpenoid. Also, saponin varies by the position and numbers of sugar units linked to the xylose, hydrophobic aglycon, glucose, mainly arabinose, galactose, glucuronic acid, and rhamnose (Cheok *et al.,* 2014). Saponins are a large group of plant glycosides containing about 0.01-5% of a dry weight basis (Kuljanabhagavad *et al.,* 2008; Ando *et al.,* 2002). Medina-Meza *et al.* (2016) reported that quinoa contains 2 to 5% saponins in the form of oleanane-type triterpenoid glycosides or sapogenins found in the external layers of the seeds. Saponins is toxic to other organisms, but is commercially and industrially crucial for the preparation of soap and detergents. The bitter taste imparted by saponins could potentially be reduced by extrusion and roasting processes (Brady *et al.,* 2007).

Drought stress and quinoa

Breeding crops to withstand drought has always had its problems. Therefore, in the first step, cultivation of drought-tolerant plants, such as quinoa, is one of the best ways of preventing crop yield decline so that they have less yield loss under identical conditions (Oelke *et al.,* 1992; Vega-Gálvez *et al.,* 2010; Hinojosa *et al.,* 2018). The researchers showed that cultivation of different quinoa varieties in a wide range of climatic conditions, such as high or dry rainfall areas, cold or hot areas, areas 4000 m above sea level, US regions, Asia and Europe are highly adaptable (Jacobsen, 2003). Quinoa exhibits high resistance to a wide range of abiotic stresses, such as salinity and drought (Jacobsen *et al.,* 2009; Adolf *et al.,* 2013; Razzaghi *et al.,* 2011). Hinojosa *et al.* (2018) reported that quinoa is a drought-tolerant crop capable of growing and producing seed in the semi-desert conditions of Chile, the arid mountains of northwestern Argentina, Peru and the Altiplano, region of Bolivia. These environments are described as very dry, with less than 200 mm of annual rainfall (Aguilar and Jacobsen, 2003; Fuentes and Bhargava, 2011; Vacher, 1998).

However, the effects of drought stress vary depending on the type and moment of drought (Alandia *et al.,* 2016). For quinoa, in semi-arid environments, the flowering stage is one of the most important and critical stages of life in response to drought stress (Geerts *et al.,* 2008; He and Dijkstra, 2014; Jensen *et al.,* 2000).

On the other hand, if the drought is accompanied by heat stress, it can have a negative impact on quinoa. Researchers reported that quinoa is particularly sensitive to high temperatures during flowering because it can damage the flower and reduce pollen viability (Jacobsen, 2003; Peterson and Murphy, 2015; Hinojosa *et al.,* 2019). In a study by Hinojosa *et al.* (2018), it was found that the response of quinoa to elevated temperatures and other abiotic stresses varied depending on the variety and the combination of stressors. Many quinoa varieties show an increase in growth characteristics at higher temperatures but can suffer yield loss if combined with high temperatures with other stressors, such as low water availability or low relative humidity (Bazile *et al.,* 2016; Hinojosa *et al.,* 2018; Präger *et al.,* 2018).

Results of drought stress analysis on quinoa seed yield reported that quinoa yield with 208 mm of water (irrigation and rainfall) was 1439 kg/ha

(Oelke *et al.,* 1992). However, it has been reported that quinoa irrigation in arid regions has a higher yield (Martínez *et al.,* 2009). The quinoa plant protects osmotic potential from drought stress by increasing betaine and polyamines and, consequently, its yield is less affected (Ruiz-Carrasco *et al.,* 2011).

Pulvento *et al.* (2012) reported that grain yield of quinoa (Titicaca) ranged between 2300-2700 kg/ha^{-1}, during the growing season, whether under high irrigation (300-360 mm) or deficit irrigation (200-220 mm).

Al-Naggar *et al.* (2017), in Egypt, have evaluated five quinoa genotypes under three different growing season and water regimes, consisting of low (236 mm), moderate (500 mm) and high (820 mm) irrigation treatments (irrigation + rainfall). They showed high variability in morphological traits and yield among genotypes across the different water regimes. For example, sea-level variety 'QL-3' exhibited the most significant reduction in yield (56%) under severe stress; valley variety 'CICA-17' showed the smallest decrease (12%). Based on the survey, it can be concluded that: 1. Quinoa is resistant to drought; 2. During drought stress, if another stress occurs, it will cause severe yield loss; 3. The timing of drought stress is important in the growth stages of quinoa; 4. The response of cultivars to drought stress varies. It seems that due to the different reactions of quinoa cultivars to drought stress, this plant can be used in areas with water scarcity, and since quinoa has shown good resistance to drought stress, more research is needed to determine the resistance of quinoa to drought stress.

Salt stress and quinoa

After drought stress in plants, salinity is one of the major agricultural problems in arid and semi-arid regions. High salinity is considered as one of the substantial abiotic stresses that limit crop production because it causes reduced respiration, photosynthesis and protein synthesis (Hinojosa *et al.,* 2018).

Photosynthesis reduction, nutrient imbalance, membrane denaturalization, stomatal closure, and a dramatic increase in reactive oxygen species (ROS) production are the basic physiological changes in crop under salt stress (Gupta *et al.,* 2014; Munns *et al.,* 2015). High accumulations of ROS cause severe crop toxicity, including the oxidative damage in lipids proteins, proteins, and DNA; but, low concentrations of ROS act as signaling molecules (Miller *et al.,* 2010; Sharma *et al.,* 2012; Hinojosa *et al.,* 2018). However, many members of the Chenopodiaceae family are classified as salt-tolerant (Wilson *et al.,* 2002). In the halophytes plant, the seedling and germination stages are the most sensitive stages to the salinity (Debez et *al.,* 2004; Gul *et al.,* 2013). In fact, after passing through the emergence stage, quinoa has a high tolerance to salinity stress. Studies have shown that quinoa can withstand these conditions and grow in poor soils (Wilson *et al.,* 2002).

The researchers reported that the optimal salinity conditions for quinoa growth are between 100 to 200 mM of NaCl (Sun *et al.,* 2017; Eisa *et al.,* 2017; Hariadi *et al.,* 2011). Quinoa is an optional plant that is able to withstand sea surface salinity (40 dS/m^{-1}) (Adolf *et al.,* 2013). A study has shown that with saline irrigation water as high as 40 dS/m, a yield reduction of only 50% will occur (Razzaghi *et al.,* 2011). Studies have shown that some quinoa cultivars are able to complete their lifespan at 50 dS/m. The presence of salt bags on the surface and under the quinoa leaves and their excretion of salt is one of the plant's strategies for combating salinity (Koyro *et al.,* 2008).

Nitrogen (N) fertilizer and quinoa

The tendency of the international community towards sustainable agriculture is to reduce the use of various inputs, especially chemical feedstocks, with the ultimate goal of achieving sustainable performance and reducing adverse environmental impacts. N is the main limiting factor for crop production, especially in arid and semi-arid regions, and therefore is widely used as a chemical fertilizer (Semenov *et al.,* 2007; Ichie *et al.,* 2002). N plays an essential role in achieving high quantitative and qualitative yields in crops (Zhao *et al.,* 2003; Cassman *et al.,* 2003) and is involved in the formation of amino acids, vitamins, and chlorophyll. If sufficient N is available to the plant, it will increase the growth rate of the plant and store the protein content of the seed (Zeidali *et al.,* 2018; Karami *et al.,* 2018; Khan *et al.,* 2011).

N is one of the most important elements for plant growth. Researchers reported that quinoa reacts strongly to the N fertilizer (Schulte auf'm Erley *et al.,* 2005). However, it should be noted that N fertilizer should not be over-consumed. Research has shown that excessive application of N fertilizer increases the length of the vegetative period and delays the reproductive phase (Marschner, 2011). It seems that split and optimum use of N fertilizer can have an impact on increasing crop yield. In an experiment in Europe, the yield of quinoa was obtained by consuming 120 N kg/ha^{-1} at 3500 kg/ha^{-1} (Schulte auf'm Erley *et al.*, 2005). Berti *et al.* (2000) reported the highest grain yield of quinoa with the highest N utilization (225 kg/ha^{-1}). Excessive amounts of N decrease grain yield, as it slows down maturity and increases vegetative growth. N fertilizer application increases grain yield and its protein content (Williams and Brenner, 1995). Gomaa (2013) reported that N fertilizer increased vegetative growth and metabolic process in quinoa, as well as the accumulation of the plant dry matter.

The results of an experiment conducted at Izmir University in Turkey, for the effect of different levels of N fertilizer on grain yield in

Mediterranean climates, showed that the best amount of N for maximum grain yield, harvest index, and 1000-grain weight, was 150 kg/ ha^{-1} (Geren, 2015). In another experiment, it was reported that the best N level for quinoa was 120 kg/ha^{-1} (Mosseddaq *et al.,* 2016). Generally, the N consumption rate is different for each climate and region. Nevertheless, according to the studies, it can be stated that the recommended N fertilizer for quinoa is about 100 to 200 kg/ha^{-1}. However, this may increase in some areas.

CONCLUSIONS

Population growth and the need for more food put additional pressure on the environment, especially on water resources and agronomic ecosystems. This has led to more attention to plants that grow at different latitudes and altitudes. Climatic and environmental changes affect agricultural inputs, especially water resources. So, the best way of adapting to the current situation is the introduction of low-water, salt-resistant, and drought-tolerant plants to the recent climatic changes.

Quinoa has recently been considered as a food source due to its resistance to drought, salinity, and high nutritive value in terms of protein, essential amino acids, vitamins, and essential elements. The amount of required amino acids in quinoa seed protein is high, and the main application of using quinoa is a food supplement, due to its response to the growing international demand for gluten-free products. The seeds of this plant are abundant in preparing sweets, biscuits, salads, all kinds of food, as well as cereal flour enrichment. Quinoa is a resistant plant that can be grown in poor soil. This plant is an excellent economic alternative for the agricultural sectors. The superior adaptability of quinoa under different climatic and terrestrial conditions has led to cultivating such plants in many parts of the world to address the problems of malnutrition and starvation.

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