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A Brief Study of Quinoa Role and Its Adaptation towards Salinity and Drought Stress

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ABSTRACT

In light of declining freshwater supplies and soil salinization, it is critical to evaluate the ability of halophytic plant species to grow in semi-arid and arid environments, where crop plant production is significantly reduced. Soil salinity is a major agricultural issue in Pakistan, with alt-affected soils alone covering over six million hectares and more than 70% of tube-wells in saline areas pumping out salty water. Quinoa is a crop with seeds having a variety of nutrients in it as well as it's seed are gluten-free with good agronomic, morphologic and biochemical characteristics and has a great potential to grow under combative climatic conditions; this property of quinoa makes it an excellent crop especially in the countries where adverse climatic conditions exist. It is a pseudo-cereal and is adaptable to different environmental needs, and has a great potential to deal with various abiotic stresses. Quinoa grows well under arid to semi-arid conditions where salinity and drought are common problems. Several studies have been carried out to elucidate the mechanisms used by quinoa to cope with high salt levels in the soil at various stages of plant development, but further research is still needed. Despite several recent researches on quinoa abiotic tension, much detail remains undisclosed. The present review discusses the quinoa adaptation towards salinity and drought stress.

Keywords: *Drought stress, Salinity stress, Quinoa seed, Nutritional value, Plant growth, Yield.*

INTRODUCTION

Soil salinity is the chief agricultural problem in Pakistan. Salt-affected soils alone cover more than six million hectares, and more than 70% of tube-wells in saline areas inject brackish water. The situation is worse in Sindh and Southern Punjab than in the rest of the region.

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The nation is located in a semiarid and arid environment with a subtropical continental climate that is undergoing salinization and sodification (Husnain et al., 2021; Ch et al., 2021; Haroon et al., 2020). Excessive salt levels have a negative impact on the biological, chemical, and physical soil properties. These have an influence on behavior of soil biota and root of plants, which, in turn, has an impact on crop growth and production (Syed et al., 2021). Furthermore, salinity also contributes variation in pH, mobility of micro (Fe, Zn) and macronutrients that significantly affect the crop growth and production (Gondal et al., 2020a; 2021b; 2021c; & 2021d).

These issues are disrupting the entire supply structure of the third world arid and semi-arid areas. These habitats have now become severely degraded and desertified. Attempts have been created to learn to cope with salinity and benefit from salty land and water supplies. The world has also been experiencing extreme water shortages in recent years, so there is an urgent need to save and use water effectively. As a result, bringing these saline fields into productive agricultural lands for the rapidly expanding population is critical from food security standpoint. Work is being done to develop and test water-saving technology, less water consumed crops can be grown, genetically modified crops that can grow in salinity and find and develop plants with high water-use potential (NIAB, 2021).

Among all solutions quinoa adaptation towards salinity stress is a promising technique that has gain interest. Quinoa is a halophyte that has evolved to thrive in harsh conditions with saline soil. Quinoa grown in salinized soil had a protein content of 13.1 to 16.7%, which was equivalent to non-saline conditions (Wu et al., 2016). Quinoa is gaining popularity around the world as a result of its high nutritional quality and resistance to salt stress (Stikic et al., 2012). When compared to glycol-phytes, halo-phytes are better at dealing with high salt levels during cotyledon emergence (Debez et al., 2004). Through numerous research studies, it has been observed that certain halophytic crops are relatively intolerant to salinity during the early growth stages; the most critical phase for the quinoa crop is the establishment period (Malcolm et al., 2003). A lot of work done by scientists on quinoa adaptation towards salinity, but still more working is needed to attain maximum benefits.

History and role of quinoa

Chenopodium quino is a grain that originated in the Andes and has been their staple food (Martinez et al., 2015). It is a pseudo-cereal and is adaptable to different environmental conditions, and has a great potential to deal with other abiotic stresses and to meet the growing food demand of the world's population; thus, quinoa alleviates poverty worldwide. It is native to the Andean region and is considered a climatically tolerant crop. The Incas and Tiwankans have been cultivating and using it for centuries. Even it was used in place of wheat for food purpose has good nutritional value. Quinoa is a crop with seeds having a variety of nutrients in it as well as gluten-free seed crop with good agronomic, morphologic and biochemical characteristics and has a great potential to grow under aggressive climatic conditions; this property of quinoa makes it an excellent crop especially in the countries where adverse climatic conditions exist. Quinoa grows well under arid to semi-arid conditions where salinity and drought are common problems. It is also highly adapted to frost (Ruiz et al., 20014, & 2016).

Worldwide Importance of quinoa

Quinoa is a seed crop that has been traditionally used as a source of food and for survival of Andean cultures in the Andean region for decades. Quinoa is grown in Bolivia, Peru, Ecuador, Chile, Argentina, and Colombia, but it was introduced to Europe, North America, and Africa for the first time in recent years, with excellent yields and yield attributes (Abugoch, 2009). However, the utilization of quinoa in developing countries is high and is increasing every single day, but is still lower than the countries which are the prime producer of quinoa. So, annual quinoa consumption in Bolivia and Peru ranges between 2.37 kg per person and 1.15 kg per person, while quinoa consumption in the United States was 0.03 kg per person (FAO, 2013).

Jacobsen and Mujica, (2003) stated that, within the southern Andean boundary, four Chenopodium species are considered its precursors, and are modified into current day quinoa. Molecular, phylogenetic, and cytogenetic techniques showed the allopolyploid basis of C. quinoa from the hybridization of diploid predecessors. Quinoa is not a Gramineae plant, but it does produce seeds, which can be crushed into dredge as well as being a cereal crop; referred as pseudo-cereal. Quinoa flour is mainly used to make toasted and baked products like bread, noodles, cookies, biscuits, portions of pasta, and pancakes (Bhargava et al., 2006). Also its seeds are used to produce beer or 'chicha', a traditional South American ceremonial alcoholic beverage. (FAO, 2011).

Dietary and economic role of Quinoa

Quinoa seeds have too much nutritional value and can be used like cereal grains; that’s why they gained people's attention throughout the world. Quinoa has a good and balanced amount of necessary amino acids, fatty acids, micronutrients, vitamins, and antioxidants that positioned it on the top of the cereal list (James, 2009). Leaves of quinoa are consumed just like spinach .The amount of nutrients in quinoa is so enough that it is globally deliberated as the vital foods in nutrition of both human and animal. Quinoa has a significant preference over wheat, rice and other such grains as it is a rich source of lipids and proteins. Content of protein (g 100g^{-1} eatable stuff) in quinoa seeds varies between 13.1% - 16.7%, as compared to other crops like rice, barley, corn, and rye; these values are more remarkable in quinoa and nearer to that of wheat to some extent (USDA, 2015).

The central storage proteins in quinoa are albumin and globulins with 35% and 37% percentages, correspondingly. Nevertheless, prolamins are present in lower concentration (Abugoch, 2009). Additionally, quinoa proteins are in higher concentration, they are also regarded as high-quality proteins because of the presence of balanced amino acids. In quinoa protein, all vital amino acids are present. Lipids contains about 5.5 to 7.4 g 100 g^{-1} eatable stuff, greater than wheat (1.7 g 100 g^{-1} edible matter) and rice (0.7 g 100 g^{-1} eatable stuff), that makes the quinoa to be considered a substitute to oilseed crop (Navruz-Varli & Sanlier, 2016). Palmitic acid is the most abundant saturated fatty acid in quinoa, accounting for about 10 percent fatty acids in total; on the other hand, unsaturated fatty acids, such as oleic, range from 19.7–29.5 %, linoleic from 49.0–56.4 %, and alpha-linolenic from 8.7–11.7 %, acids account for total 88 % of fatty acid in quinoa seeds, similar to soybean lipids (Repo-Carrasco et al., 2003).

Quinoa contains higher concentration of vitamin E than wheat, which means that fatty acids are better protected from free radical damage (Alvarez-Jubete et al., 2010). Quinoa has higher contents of pyridoxine (B6) and folic acid compared to other cereals. The pyridoxine and folic acid amount in 100 g of quinoa are said to be sufficient for an adult's daily food requirements. Still, for children, riboflavin fulfills 80% of food demand and 40% of adults’ requirement (Abugoch James, 2009). Levels of vitamin C are also high in quinoa that ranged from 4.0 to 16.4 mg 100 g^{-1} dry stock. Though, the thiamin concentration in quinoa is minimal compared to that of oat and barley (Navruz-Varli & Sanlier, 2016). The mineral content in quinoa has remarkable significance. The quinoa seed contains essential nutrients in more amount than those found in normal grains. In addition, quinoa contains available forms of calcium, magnesium, and potassium; therefore, sufficient for balanced nutrition (Vega-Ga´lvez et al., 2010). Besides, it is adapted towards drought stress by following mechanisms.

Drought and its mechanisms of adaptation

Drought condition referred to as the continuing lack of precipitation for one season or more (Trenberth et al., 2014). Plant physiochemical and morphological characteristics are badly affected under drought conditions. Water is a necessary component for plant growth and productivity. Drought can occur anyplace in the world or any type of environment like arid, semi-arid, or humid. Immediately in the upcoming eras, lack will become more and more common and unembellished. Water deficit conditions have severe and long-term adverse effects on nature and ecosystems (Rahmat et al., 2016). In Pakistan, the province of Sindh and Baluchistan have gone through severe water deficit conditions many times in the previous history.

Arid climatic conditions constitute high temperature and low precipitation, and a significant area of Pakistan lies under dry to semi-arid climatic conditions (Kazmi et al., 2015). In drought conditions, reactive oxidants cause oxidative damage to plants, thereby decreasing the stomata closure and photosynthesis. The production of reactive oxidants is regarded as a menace to cells because it may harm nucleic acids, proteins, lipids, peroxidation, and consequent membrane devastation (Maksup et al., 2014).

Quinoa has potential to overcome abiotic stresses like drought (Aziz et al., 2018; & Iqbal et al., 2018), salinity (Shabala et al., 2012; & Waqas et al., 2017), frost and show positive response on marginal lands (Bazile et al., 2016), as a result, it's developing into a stress-tolerant crop. Plants have variety of physiological, biochemical, and molecular pathways for reducing negative effects of water stress. Quinoa has a unique capacity to stand with water-deficient conditions because it has naturally less water requirement and has the potential to continue photosynthesis and uphold its leaf area even after a long-term drought period. Drought can occur randomly, with sporadic and fatal episodes, in the Andean region, that can ultimately cause injury to the initial seed germination stages, crop loss, and postponed harvest (Jacobsen et al., 2009). Quinoa has three different adaptations to drought stress, i.e. escape, tolerance, and avoidance from drought (Garcia et al., 2007; & Jacobsen & Mujica, 2003). Some other protective mechanisms used by qui noa are tissue elasticity, low osmotic ability, reduced leaf area via dehiscence, and the presence of vesicular calcium oxalate. Quinoa can also survive drought due to its small and thick-walled cells (Abugoch et al., 2009).

Osmotic adjustment is an essential physiological mechanism, adapted to drought stress (Blum, 2017). Chemical solutes such as soluble sugars, proline material, and glycine betaine are organic solutes, whereas inorganic ions such as K+, Cl-, and Na+ are crucial osmolytes. Previously, numerous works have been described that evident the accumulation of osmolytes improve the quinoa tolerance to drought (Iqbal et al., 2018; & Aziz et al., 2018), but inorganic ions role in the osmotic adjustment under water deficit condition is still unnoticed. Because of the increased level of reactive oxygen species (ROS) in many plants, drought stress normally induces oxidative harm (Farooq et al., 2017; & Ashraf et al., 2015).

ROS such as H_2O_2, O_2, and OH are cytotoxic and disrupt natural metabolism by damaging nucleic acids, oxidizing proteins, and inducing lipid peroxidation (Foyer & Noctor, 2005). For overcoming the oxidative damage caused by ROS, plants developed anti-oxidative protection schemes to generate a equilibrium among the creation and foraging of these sorts (Alscher et al., 2002). Enzymatic POD, SOD, GPX, APX, and CAT antioxidants, as well as non-enzymatic GSH and ASA antioxidants, function together in the plant's defensive mechanism to fight ROS (Cavalcanti et al., 2007). Antioxidants are the first line of defense against deadly ROS, and low levels of ROS in quinoa can reduce oxidative damage and improve drought resistance (Aziz et al., 2018; & Iqbal et al., 2018).

Numerous mechanisms are associated with drought resistance in quinoa, naming: deficiency emission, drought lenience, and drought evasion, with wide varietal alterations (Jensen et al., 2000). Drought escape happens mainly because of early maturity and thus an essential feature in zones with the hazard of drought at either the start or the termination of the period of growth. Quinoa also has adaptations to tolerate drought through plasticity in evolution, elasticity in tissues, and stumpy osmotic latent. Plant also escapes to the drought adverse possessions through thick root system and it deep penetration; through dropping off leaves; reducing leaf area, thick-walled cells and forming special vesicular glands; small that can withstand large water losses without losing turgor; and stomatal behaviour (Jensen et al., 2000).

Table 1: The effect of water stress on several biological, physiological and other morphological processes of plants

Crop	Results	Reference
Wheat	Rate of photosynthesis, dry weight, the conductance of stomata, the content of photosynthetic pigment, transpiration, and mesophyll, leaf area and relative water content decreased.	Allahverdiyev, 2016
Coffea canephora	A parameter comparison was made between a drought-susceptible variety and drought-resistant multiplicity. Resistant diversities presented the probable to maintain xylem pressure, increasing elasticity of tissue and efficiency of water use. Tissue stiffness, osmotic adjustment and conductance of stomata are reduced.	DaMatta et al., 2003
Coffea canephora	Increased the rigidity of the cell wall, reduce carbon assimilation by 60-80%, reduce the conductance of stomata by 35% and rate of transpiration.	DaMatta et al., 2002
Jatropha curcas	Buildup of proline, total soluble sugars, and amino acids, and increased catalase activity during dehydration.	Dos Santos et al., 2013
Wheat	The improved water conditions increased root length and dry mass, root length and aerial biomass. Water stress studies have shown a negative correlation between source, air biomass, root weight density and source dry biomass.	Elazab et al., 2016
C_3 plants	Stomatal conductance parameters were used to compare the metabolic processes in dissimilar lessons of C_3 plants. When water stress was encountered, the reduction of ATP and RuBP was reanalyzed, and the stomatal closure was induced.	Flexas et al., 2006
Triticale, field bean, maize and amaranth	Compared with triticale and amaranth, field beans and corn are effective in adapting to the environment. This is because the synthesis of phenolic compound acts as a photoprotective agent, thereby avoiding the destruction of PSII	Hura et al., 2007

Salinity and halophytic plant species

Quinoa is a member of the Amaranthaceae family, which contains the most halophytic plant species (44 %) (Flowers et al., 1986). It may withstand up to 19 dS m^{-1} EC (Wilson et al., 2002). Quinoa is halophytic plant that can withstand salinities as those found in seawater (EC) of 40 dS m^{-1} (Koyro & Eisa, 2008). However, all crops vary in their tolerance to soil salinity; mostly, crops cannot survive at high salts, mostly as high as seawater (Flowers, 2004). Salinity disturbs all of the growth and development stages of quinoa and alters its physiology; but, tolerant varieties of quinoa can persist in these conditions (Jacobsen, 1999). Sodium chloride at an EC of 15dSm^{-1} or above affects plant growth and yield adversely. This shows that the threshold level of salinity, after which the quinoa yield began to decrease, lies between 8 to 16 dS m^{-1} NaCl. This finding shows distinctions with other results, where two cultivars of quinoa show an increment in yield at EC of 15 dS m^{-1} compared to control after that yield of the crop began to decrease (Jacobsen et al., 1999).

The attention on quinoa around the globe is increasing every day because of its high nutritional consistency and resistance to salt stress (Stikic et al., 2012). When compared to glycophytes, halophytes are better at dealing with high salt levels during cotyledon emergence (Debez et al., 2004). Though it been observed in numerous researches that sometimes halophytic crops are relatively intolerant to salt stress during the early growth stages, the most critical period for quinoa crop is the establishment time (Malcolm et al., 2003). The growth and yield of a crop, the number of sources, seed and weight yield per plant were expressively declined at salinity stress. At an elevated level of salt stress, the NaCl channel into the seed was stuck. There is a association between these possessions, the plant's salinity tolerance, and a potential pre-adjustment of the crop to the salt stress of the seed formed.

Salt tolerance is a multigenic trait with heterosis, domination, and other implications (Flowers, 2004). Approximately 25% of the controlled genes are unique to salinity stress (Ma et al., 2006). However, salt tolerance in different plants is enhanced by pile and stack by key physiological character that deliberates the vital features (Shabala & Mackay, 2011). Quinoa possesses critical characteristics such as efficient regulation of xylem Na+ loading and repossession in vacuoles, resistance to reactive oxygen species, improved K+ retention, and effective control. Quinoa is a good source of genes for salt tolerance in other plants. The development of a genetic linkage map was a first step toward genetic characterization and marker-assisted selection of beneficial agronomic traits in quinoa (Maughan et al., 2004), and it now serves as the foundation for fine mapping of quantitative trait loci. The significant genetic inconsistency of quinoa to salinity is a rich source for selecting and breeding for improved tolerance. The availability of cultivars adapted to a variety of altitudes and climates allows for cultivar selection, adaptation, and breeding for the operation under additional environmental controls (Christiansen et al., 2010) and aids in the generation of a double haploid population, which is required for marker-assisted selection.

Mechanisms involved in salt stress

Quinoa is thought to grow and survive in saline soils through a variety of unusual, yet unknown mechanisms. It's an intriguing model crop for figuring out how complex ion transport processes under saline conditions are caught up in mechanisms (Wilson et al., 2002). It has been stated that the physiology and anatomy of halophytes and glycophytes plants are very similar (Shabala & Mackay, 2011). On the other hand, halophytes have the specialized potential to use common tolerance mechanisms of salts (Bohnert et al., 1995). Though halophytes have distinctive property of having salt glands, specialized epidermal cells isolate and expel surplus solutes from active tissues (Liphschitz & Waisel, 1982).

Epidermal Bladder Cells

The unique anatomical character of quinoa is salt bladders presences, on both the sides of leaf surfaces. Bladder Cells is one of the storage sites for extra Cl^-, Na^+, and K^+ (Agarie et al., 2007). But, secretion through repossession into EBCs is < 20% in quinoa than other halophytes (Orsini et al., 2011). These bladder cells can store water and variety of other metabolic compounds (Jou et al., 2007). To lessen water loss and restrict excessive damage by UV, salt bladders play a vital role as a secondary epidermis in plants. New leaves had the highest density of EBC, which protect PSII against UV damage. In UV-visible leaves, EBC removal by moderate scrubbing did not show significant improvements in photochemical efficiency (Shabala et al., 2012). When compared to the leaf lamina's physical defense against light, the EBC defensive function is fairly known to organic osmolytes accumulation with ROS-searching or governess strength. Some quinoa genotypes were found to have distinct colored (reddish) salt bladders, which are highly salt. It can be assumed that this type of coloration in quinoa is because of the accumulation of betalaine pigments, also found in *Mesembryanthemum crystallinum* (Adams et al., 1998). Under stress conditions, some genotypes have a competitive advantage over the others because of their capacity to store a good amount of EBC; as a result, the manufacture of these pigments comes at a high cost and takes a long time (Gershenzon, 1994).

Osmotic adjustment

When quinoa plants were treated with NaCl concentrations ranging from 0-500mM (0–50 dS m-1), it was discovered that the buildup of inorganic ions such as Na^+, Cl^- and K^+ resulted in 95 % osmotic adjustment in older leaves and 80-85 % in younger leaves (Hariadi et al., 2011). A concurrent increase can supplement rise in the vacuolar Na+ content, which is needed to maintain cell turgor in cytosolic osmolality. This objective can be attained in this section by either improving the cytosolic potassium or storing organic osmolytes compatible solutes, actually, in quinoa proline, soluble sugars, and glycine betaine increase (Ruffino et al., 2010). At germination and seedling establishment, osmotic adjustment plays a key role. In the event of a decrease in osmotic capacity, the seed's water content must be preserved. Dehydration can be countered by lowering the seed matric potential. Based on various researches' conducted on seeds descendants from plants treated with salts, researchers hypothesized that an increase in protein content in pre-adjusted seeds contributes to a decrease in matric capacity. Salinity can decrease water potential in the plant ovary while also promoting water absorption, which they contribute to an accumulation of Na+ and Cl in the seed pericarp and a synthesis of organic solutes in the seed (Koyro & Eisa, 2008).

Osmo-protection and construction of different reactive oxygen species (ROS)

Osmotically-induced stomatal closure and deposition of Na+ toxic level in the cytosol of a cell under salt stress decrease the capacity of the chlorophyll pigment of plant to absorb light completely and hence promote the development of several ROS (Tavakkoli et al., 2010). These ROS have foraged to prevent them from causing detrimental effects on metabolism of plants such as peroxidation of lipids, DNA destruction, protein destruction, carbohydrate oxidation, pigment degradation, and diminishing enzyme activity (Noctor & Foyer, 1998). Plants have two main antioxidant systems: enzymatic and non-enzymatic antioxidants. The capacity of ROS to search for various well-suited solutes such as Protein, mannitol and Myo-inositol, are present in quinoa tissues, has been identified in non-enzymatic antioxidants (; Ruffino et al., 2010; & Aguilar et al., 2003). The Ruiz-Carrasco et al. (2011) revealed that 30 dSm^{-1} EC cause proline deposition. The less salt-tolerant genotypes improved moderately, while the more salt-loving genotypes increased 3–5-fold.

Furthermore, the extra resistant genotypes had the highest ratio of polyamines under salt-stress and play a significant role, which explains retention of these compounds than the reduction in putrescine. The ultraviolet radiation (λ 315–280 nm) can cause minor injury to the photosynthetic machinery in younger leaves as compare to older leaves, evidenced by differences in organic osmolytes pool size (Shabala et al., 2012). Remarkably, foliar of glycine betaine, recently it has been shown that it is ineffective in ROS rummaging in vitro (Smirnoff & Cumbes, 1989), considerably decrease injurious UV light effects onto quinoa leaf photochemistry (Shabala et al., 2012). The chemical chaperon action that protects PSII from oxidative stress was credited with this effect (Halliwell & Gutteridge, 1990).

Sodium elimination and xylem loading

In glycophytes, sodium removal is a very useful trait (Munns & Tester, 2008). The tonoplast Na+/H+ exchanger, transfers sodium into vacuole, when deposited in the cytosol (Apse & Blumwald, 2007). Transgenic plants overexpressing the HvHKT2;1 transporter had higher Na+ concentrations in the xylem, better Na+ leaves translocation, and better salt resistance than wild nature, according to previous studies on halophytic barley crops. The tendency of barley to transfer Na+ to the shoot rather than depositing it in leaf tissues is one of the most significant factors restricting salt tolerance (Mian et al., 2011). This adds to the proof that Na+ removal has a secondary role. SOS1 transporters regulate Na+ transport over long distances, normalize Na+ loading into the xylem, and influence Na+ recovery from the xylem (Shi et al., 2002: & Shabala Y Macky 2011). They propose that in halophytic plants, xylem Na+ loading is a complex process requiring improved SOS1 Na+/H+ antiporter feature at the xylem parenchyma interface. Different researchers carried out pharmacological experiments that revealed the function of the high-affinity potassium transporter in sodium uptake in Suaeda Maritima, a Chenopodiaceous family member (Wang et al., 2007). Furthermore, research on glycophytes indicates that non-selective cation channels are needed for sodium ion absorption through the cell membrane in plants (Demidchik et al., 2002). It's still a mystery how sodium ion absorption in quinoa is controlled by transport systems.

Retention of Potassium

In cells, K+ retention and K+ homeostasis in cytosol are important for plant tolerance (Shabala & Cuin, 2007). Under stressful conditions, excessive potassium leakage from cytosol occurs frequently in both leaf and root tissues. A reduction in the cytosolic K+ pool may result in the production of enzymes involved in protein catabolism, as well as an increase in plant tissue programmed cell death (Shabala, 2009). Quinoa's significant salinity tolerance is due to its highly effective K+ preservation. Quinoa is thought to hold K+ concentrations in the cotyledons relatively high during the seedling stage of the plant (Ruffino et al., 2010), and better K+ amounts in xylem and leaf sap at later stages of development (Adolf et al., 2012). Sodium is used as a cheap osmoticum because it has a good K+/Na+ ratio. Improved sodium absorption should be accompanied by improved potassium transfer to the stem (Cuin et al., 2009).

According to studies on other primates, K+ transport into the xylem is a passive process supported by externally rectifying pathways such as NORC or SKOR at the xylem parenchyma (Wegner & de Boer, 1997). However, further research is needed to see whether the same transporters are involved in this phase in quinoa. It's essential that K+ stays in the roots. According to pharmacological studies, TEA+, a potassium-selective voltage-gated channel blocker, can suppress NaCl-induced K+ fluxes from quinoa roots. Tonoplast-localized NHX proteins were discovered to promote K+ sorting in the vacuole in Arabidopsis, and they were also found to be involved in the regulation of cell turgor, including in stomatal guard cells, thus regulating the role of stomata and water connections in plants (Barragán et al., 2012).

Exchange of gases, stomata control and water use efficiency (WUE)

Gas exchange and transpiration have declined in quinoa under salt stress (Bosque Sanchez et al., 2003). Increased salinity decreases soil water potential and, as a result, leaves water potential and stomata conductance in both completely irrigated and drought-stricken plants. When potential of leaf water falls below −1.75 MPa threshold level, stomatal conductance adversely affected. They used the precarious values of relative available soil water to the plant as a benchmark for an extreme drop in leaf water capacity, resulting in plant loss (Razzaghi et al., 2011). Improvement in ABA concentration and decrease water capacity in soil and leaf under saline conditions has been attributed to osmotic stress caused by water deficit rather than a particular ion-toxicity (Zhang et al., 2006). In quinoa, salinity cause decline in stomatal density that can express a central mechanism to improve water use efficiency (Orsini et al., 2011). Ion fluxes of guard cells are progressively controlling stomatal conductance, which is a complex operation (Blatt, 2000). Cuticular transpiration is almost entirely reliant on the leaf's surface's passive hydraulic permeability and thus is unable to respond quickly to changing conditions. As a result, reducing stomata density and abundant cuticular pores associated with them would support osmotically stressed plants even at high rates of cuticular transpiration (Shabala et al., 2012).

CONCLUSION

Salinity is the chief problem of Pakistan and the population of Pakistan is increasing day by day. The current sources are unable to meet the population requirement due to less growth and other problems. Therefore, the most important feature of quinoa is its high salt resistance, which distinguishes it from wheat, corn, barley, and maize. Every year, arable land is destroyed due to salinization, rise in temperature, and heavy drought, both of which are becoming more common. As a result, farmers have started to seek out plants able to grow in saline soils and can tolerate other abiotic stress such as quinoa. Another distinguishing characteristic of quinoa is its extraordinary nutritional content, which includes essential amino acids and mineral amounts that remain stable in the face of abiotic stress. Quinoa is also a multipurpose plant, as it can be used as fruit, biomass can be used to feed animals or a cover crop, and plantings can be used for phytoremediation.

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