Prospects of quinoa cultivation in marginal lands of Egypt

Abd El-Hafeez ZOHRY

Crop Intensification Research Department, Field Crops Research Institute, Agricultural Research Center, Egypt

There is great opportunity in marginal lands of Egypt to be used in food production. However, these lands are characterized by low fertility and saline soil, scarce water resources and harsh weather conditions. One crop that proved to be able to grow under these unfavorable conditions is quinoa, classified by FAO in 2013 as a super food crop due to its high nutritional values. One of the most important benefits of quinoa flour is that it can be mixed with wheat flour in bread making, thus it can reduce the gap between flour production and consumption in Egypt. In this review, research carried out on quinoa, internationally and nationally, is highlighted in order to help researchers in Egypt to expand and improve their work with this important and promising crop.

Keywords: Super food, composite flour, sandy soil, salt-affected soil, water stress, salinity stress

Introduction

Cultivation of drought and salt tolerant crops has the potential to enhance farm-level productivity and livelihoods in drought and salt prone areas (Kaya and Yazar, 2016). Quinoa is one of these crops that is considered as a halophytic grain crop (Ruiz et al., 2016) grown in various climatic zones (Jacobsen et al., 2012) and it can be cultivated in low fertile soil (Vilche et al., 2003). It is adapted to adverse soil and climatic conditions in places where most agriculture is marginal (Garcia et al., 2015). The quinoa plants are reported to be tolerant to drought (Garcia et al., 2007) and can tolerate the stresses of soil and water salinity (Wu et al., 2016). At a global level, there are more than 6000 varieties of quinoa that are cultivated by farmers (Rojas et al., 2015). Those varieties can be classified into five main categories or ecotypes, according to their adaptation to specific agro-ecological conditions in major production areas (Bazile et al., 2015).

Quinoa seed has an extraordinary nutritional value for human, as it have an excellent balance of carbohydrates, lipids and protein for nutrition (Maradini-Filho et al., 2017). Quinoa protein has all essential amino acids found in wheat and in addition it contains lysine and sulfur amino acids (Escuredo et al., 2014) which meet and surpass the daily intake requirements that is recommended by the World Health Organization (Hirose et al., 2010). Quinoa has been selected by Food and Agriculture Organization of The United Nations (FAO, 2013) as one of the crops destined to contribute to food security in this century.

Quinoa is classified within the super foods for its high content in protein. It also has lysine, which is considered the first limiting essential amino acid in cereals (Arendt and Zannini, 2013). Quinoa seed, when properly handled to remove the bitter saponins in the pericarp, has a mild flavor and can be consumed the same ways as cereal grains (Fuentes-Bazan et al., 2012).

Marginal lands in Egypt are located on both east and west fringes of the Nile Delta and Valley. They are scattered over various areas in the country, where it covers 1.01 million hectares. Some of these lands are suitable to be cultivated with crops similar to the one cultivated in the Nile Delta and Valley. Other areas are unsuitable due to high soil salinity levels and/or have low quality groundwater for irrigation. These marginal lands are viewed as an opportunity for increasing agricultural production and ensuring food security in the country, if salinity tolerant crops were cultivated. Thus, introduction of salt-tolerant crops to these marginal areas, such as quinoa, is one strategic solution to cope with the high food demand of the growing population (Daoud et al., 2016).

Integrating quinoa as new crops in the Egyptian cropping pattern could play an important role in reducing wheat flour production-consumption gap. Because quinoa has a potential to grow as an alternative crop in marginal areas or with poor soil quality, it could contribute to increasing national agricultural production. It could be used to produce composite flour to partially replace wheat flour imports and encourage the use of locally grown crops for flour production (Jisha et al., 2008 and Hasmadi et al., 2014).

Although quinoa grains do not contain gluten, it can be mixed with wheat flour in the preparation of bread with high nutritional value (Morita et al., 2001). Abdellatif (2018) indicated that the chemical composition of quinoa seeds can be successfully used as a food ingredient to develop new products with high nutritional and organoleptic properties. Substituting wheat flour with 20% quinoa resulted in elevating protein, fat and fiber percentages than that of wheat flour (Soliman et al., 2019).

The objective of this review is to shed the light on the research done on quinoa internationally and nationally to help researchers in Egypt to expand and improve their work with this important and promising crop.

Effect of soil and water salinity on quinoa

In general, plants respond to salinity stress in two phases. In the first phase, a rapid response to the increase in external osmotic pressure which starts immediately after the salt concentration around the roots increases to threshold levels, which decreases new shoot growth. In the second phase, a slower response due to the accumulation of $Na+$ in leaves (salt accumulation to toxic concentrations) and increases senescence of older leaves (Munns and Tester, 2008). Quinoa’s salinity tolerance is a heritable trait with a polygenic character linked to a complex genetic basis that can be used as an efficient criterion for selection of salt resistant populations (Flowers and Colmer, 2008). Quinoa’s tolerance to high salinity at the primary stages of seed germination is based upon alterations in the levels of primary metabolites and enzyme activity (Adolf et al., 2013).

Algosaibi et al., (2015) cultivated quinoa in a greenhouse and irrigated it with four salinity levels (1.25, 4, 8 and 16 dS/m). They reported that the highest values of seed yield were recorded with 4 dS/m salinity level. Furthermore, 16 dS/m salinity level recorded the lowest seed yield of quinoa. Mahmoud (2017) conducted experiments in clay soil with salinity level equal to 3.37 dS/m. The plants were irrigated with three levels of saline water, namely 0.65, 10 and 20 dS/m. Her results indicated that quinoa seed yield was negatively influenced by increasing water salinity, where about 12 to 21% reductions in seed yield were recorded in the plots irrigated with water having 10 dS/m. Furthermore, 40 to 45% reductions in seed yield were recorded in the plots irrigated with water having 20 dS/m. Eisa et al., (2014) indicated that cultivation of quinoa under high saline soil conditions (ECe=27 dS/m) resulted in 30% yield reduction compared to soil with low salinity level (ECe=1.9 dS/m). On the other hand, Kaya and Yazar (2016) indicated that quinoa irrigated with saline water of 30 dS/m resulted in 18% reduction in the yield. The reduction was 7 and 14% with water salinity levels of 10 and 30 dS/m, respectively in comparison to irrigation with fresh water. Razzaghi et al., (2011) reported that the seed yield of quinoa cultivar Titicaca was reduced under salinity up to 20 dS/m of the irrigation water, but when exposed to salinity levels higher than 20 dS/m the plants adapted to it without yield components reduction. Eisa et al., (2017) reported that quinoa seed yield was reduced under EC value equal to 17.9 dS/m, however seed quality was not highly affected. Similarly, Riccardi et al., (2014) reported that irrigation of quinoa plants with saline water (ECe=22 dS/m) did not affect seeds quality.

From the above results, we can conclude that quinoa can be successfully grown and produce yield in salt-affected soils, where most of traditional crops cannot grow. Although the yield was reduced al high salinity levels, seed quality was not significantly affected.

Effect of water stress on quinoa

Water scarcity is a severe problem affecting plant growth and yield in the world. Under drought, many species respond by increasing the proportion of assimilates diverted to root growth with the concomitant root/shoot ratio increase (Sharp and Davies, 1989). A decrease in both transpiration and CO_2 assimilation rates were observed under water deficit as a result of low cell turgidity and stomatal closure of the leaves (Waseem et al., 2011). Water stress affects cell turgidity and stomatal aperture of leaves resulting in decreases in both transpiration rates and CO_2 assimilation (Waseem et al., 2011). Under reduced rate of CO_2 assimilation, leaf metabolism is impaired. Furthermore, Albert et al., (2011) reported that “the equilibrium between photochemical activity at photosystem II and electron requirement for photosynthesis is affected, generating an over excitation on photosynthetic system and photoinhibitory damages of photosystem II reaction centers”. Adaptation to water stress has been associated with cell osmotic adjustment, which is accomplished by accumulation of different compounds, such as soluble sugars, proline, glycine betaine, polyols, and other organic compounds (Chai et al., 2001).

Soil moisture plays an important role in determining the time and rate of quinoa seed germination and seedling growth (Gonzalez et al., 2009). Quinoa develops unique resistance mechanisms to water stress, allowing the plant to adapt to harsh conditions in arid and semi-arid regions (Jacobsen et al., 2003). Moreover, using deficit irrigation with fresh water to irrigate quinoa resulted in reduction in yield, where application of 50 and 75% of full irrigation resulted in 6 and 9% reduction in the yield of quinoa (Kaya and Yazar, 2016). Algosaibi et al., (2017) indicated that reduction of irrigation water by 50% reduced the quinoa seeds by only 14%. Geerts (2008) showed deficit irrigation is a valuable option for yield stabilization of quinoa plant in various areas of Bolivian Altiplano, where intra-seasonal dry periods are of great occurrence.

Razzaghi et al., (2012) attained no significant differences between yield of quinoa cultivar Titicaca under full and deficit irrigated treatments in a clay-loam soil. Pulvento et al., (2012) showed the ability of the same cultivar to preserve yield under drought and soil salinity at a level of 16 dS/m in an open-field experiment conducted in South Italy in clay-loam soil. Similarly, Cocozza et al., (2012) recorded good resistance of this cultivar to water and salt stress through stomatal responses and strict dependencies between relative water content and water potential components that caused osmotic adjustments, which is important for the maintenance of leaf turgor favorable to plant growth.

Uses of Quinoa internationally

In 2013, the United Nations declared the International Year of Quinoa. FAO organization defined quinoa to be the only plant food that provides all essential amino acids (Romero and Shahriari, 2011). Furthermore, it is cheap to produce due to its ability to adapt to different climate and soil conditions and its broad genetic variability (Molina-Montenegro, 2013). Processing of quinoa produces pearled quinoa, granules, flakes, flour, nodules, oil, pasta and starch (Francis et al., 2002).

Fresh quinoa leaves and harvest chaff are quite attractive for sheep, goats and fish (Arendt and Zannini, 2013) and quinoa leaves may be used for silage (Bazile et al., 2015). Residue from milling has a high nutritional content and can be used as animal feed. Low quality broken grains are used for poultry feed whereas stalks, bits of leaf, remains of the panicle, inflorescences, flowers and pedicels are used to feed sheep (Jacobsen et al., 2003).

Introduction of quinoa in Egypt

A series of studies were conducted on quinoa in Egypt to hopefully lead to its inclusion to innovate the cropping system of desert areas. Quinoa seemed to be very pertinent to grow in the Egyptian desert and new reclaimed sandy soil to combat degradation in these soils.

Shams (2011) reported that thirteen varieties and strains of quinoa (from Europe and Peru) were grown in sandy soils of North Sinai in Egypt under two land preparation treatments, namely with or without tillage. The results indicated that the European varieties out-yielded the Peruvian varieties (1.93 ton/ha versus 1.71 ton/ha, respectively). Furthermore, cultivation of quinoa under no tillage resulted in a higher yield, compared to cultivation with tillage (1.59 ton/ha versus 1.49 ton/ha, respectively).

Shams (2011) tested the effect of four sowing dates of quinoa seeds (15th of November, 15th of December, 1st of February and 15th of February) and two inter-row spacing, i.e. 15 and 20 cm apart in sandy soil. His results indicated that the highest yield was obtained when 15 cm inter-row spacing was used, where yield reduction was reduced by 18%. Moreover, the yield of quinoa was reduced when planting date was delayed to February, where yield reduction was 63%.

Abdel-Rheem et al., (2014) indicated that the suitable sowing date for quinoa in Middle Egypt is 25th of November, where the highest yield was obtained. Furthermore, irrigation application when 60% of soil moisture was depleted (irrigation every 40 days) resulted in the highest yield. They also reported that water consumptive use for quinoa was between 215 and 226 mm.

Shams (2012) also conducted field trials in Egypt north Delta sandy soils to determine the adequate nitrogen fertilizer rates for quinoa higher yields. The results showed that fertilizing quinoa with 360 kg N/ha increased plant height to reach 52.7 cm, increased grain yield per plant to reach 10.1 g/plant, increased grain yield to 1.20 kg/ha and increased biological yield to 2.79 kg/ha.

According to Gomaa (2013), the highest values of quinoa yield in calcareous soil in Egypt were recorded with application of 240 kg/ha ammonium nitrate in combination with bio-fertilizer (Nitrobin), in addition to application with 120 kg/ha calcium super phosphate in combination with bio-fertilizer (Phosphorin). She also indicated that the above treatment increased crude protein and mineral elements (phosphorus, potassium and calcium) in seeds.

Shams (2018) conducted field trials at Ismailia to evaluate nine quinoa genotypes under arid environment of sandy soil to determine its agronomic potential and chemical composition. The results showed that all the studied quinoa genotypes were successful in sandy soils with good grain yield under Egyptian conditions. Season length of the studied genotypes ranged between 115 to 160 days in the field. The highest yield was obtained from Amarilla Sacaca genotype with a season length of 160 days. The highest protein content in quinoa grains was recorded from QS17-2 accession, while the lowest value was recorded by Blanca de Junin variety. Moreover, Salcedo INIA variety had the lowest saponins content in quinoa grains while QS16 accession recorded the highest content.

Bazile et al., (2016) reported that “the FAO organization is actively involved in promoting and evaluating the cultivation of quinoa in 26 countries outside the Andean region with the aim to strengthen food and nutrition, where Egypt was one of these countries”. Field evaluations were conducted in two seasons and in two sites using 13 genotypes. A higher value than the weighted average yield for all countries was obtained with 1.89 ton/ha at the first site and 2.35 ton/ha at the second Egyptian site.

Eisa et al., (2017) tested the response of quinoa plants to high salinity under the Egyptian conditions. They concluded that quinoa seed yield was reduced as a result of increasing soil salinity up to 17.9 dS/m. Their results also indicated that there was a high ash content in seeds under saline conditions due to the increase of Na as well as K, P and Fe concentrations. By contrast, soil salinity led to significant decrease of Ca and Zn contents in seeds. Furthermore, Na was mainly accumulated in the pericarp followed by embryo tissues. They concluded that increasing most of essential minerals, especially Fe, in quinoa seeds produced under high saline conditions gave quinoa a distinctive value for human consumption.

Eisa et al., (2018) tested the effect of two planting densities for quinoa, namely 56,000 plants/ha as low density and 167,000 plants/ha as high density in marginal soil of El-Fayoum, where Ec was 5.3 dS/m in irrigation water and 3.8 dS/m in soil paste. Their results indicated that a higher yield was obtained when the higher planting density was used. However, this high plant density was associated with significant reduction in seed quality in terms of protein content.

According to Mahmoud (2017), sowing quinoa in North Egypt in the beginning of winter season (last quarter of November where maximum air temperature was 18.8 °C and minimum temperature was 8.2 °C) resulted in higher plant height, biomass and seed yields, compared to the sowing at second quarters of December and January. The optimum growth was associated with relative humidity of 68.8% and cumulative daylight hours of 1819 h and cumulative sunshine hours of 977 h. Symptoms of powdery mildew disease were observed on the quinoa leaves 53 days after sowing and progressed in appearance. The high percentages of relative humidity could be the major cause of spreading the disease in quinoa.

Conclusions

The productivity of traditional crops in the Egyptian cropping system is low when cultivated in marginal lands as a result of soil low fertility, soil high salinity and harsh weather conditions. In these environmental conditions, quinoa is considered as a good candidate to be cultivated there. According to research on quinoa in Egypt, it could be concluded that:

• Quinoa is a winter crop cultivated in both sandy and salt-affected soils;

• The suitable sowing date for quinoa is between 15th and 21st of November;

• Its season length is between 115 and 160 days, depending on the used genotype;

• The suitable inter-row spacing for quinoa is 15 cm in sandy soils;

• In sandy soils, nitrogen fertilizer requirement for quinoa is 360 kg N/ha. Application of 240 kg N/ha to quinoa, in addition to biofertilizer (Nitrobin) is sufficient to fulfill its requirements.

• Phosphorus fertilizer requirement for quinoa is about 30 kg P_2O_5/ha when applied with biofertilizer (phosphorin);

• Quinoa can be grown with no tillage in the sandy lands of Sinai;

• It can be grown under rainfed conditions and it gives a higher yield with supplementary irrigation;

• Some quinoa cultivars can tolerate salinity levels up to 17.9 dS/m;

• Under salt-affected soil, the suitable planting density of quinoa to obtain reasonable yield with high quality is 56,000 plants/ha;

• Quinoa can also be cultivated successfully under irrigation. Its water consumptive use is between

215 and 226 mm. Quinoa can produce its highest yield when irrigated every 40 days in clay soil;

• Livestock production can be implemented in marginal lands in Egypt, where quinoa can be cultivated. Fresh leaves and harvested branches could be used in feeding livestock.

• When quinoa seeds are processed to produce flour, it can be mixed with wheat flour to reduce flour production-consumption gap.

References

Abdellatif A.S.A. (2018). Chemical and technological evaluation of quinoa (Chenopodium Quinoa Willd) cultivated in Egypt. Acta Scientific Nutritional Health, 2:115-125.

Abdel-Rheem H.A., Abdrabbo A., Aboukheira A.A., Eisa N.M.A. (2014). Response of quinoa crop for water stress and planting date in the middle Egypt. J. Egypt. Acad. Soc. Environ. Develop., 15:49-66.

Adolf V.I., Jacobsen S.E., Shabala S. (2013) .Salt tolerance mechanisms in quinoa (Chenopodium quinoa Willd.). Environmental and Experimental Botany, 92:43-54.

Albert K.R., T.N. Mikkelsen, A. Michelsen, H. Ro-Poulsen, L. van der Linden (2011). Interactive effects of drought, elevated CO2 and warming on photosynthetic capacity and photosystem performance in temperate heath plants. Journal of Plant Physiology, 168:1550-1561.

Algosaibi A.M., Badran A.E., Almadini A.M., El-Garawany M.M. (2017). The effect of irrigation intervals on the growth and yield of quinoa crop and its components. Journal of Agricultural Science, 9:182-191.

Algosaibi A.M., El-Garawany M.M., Badran A.E., Almadini A.M. (2015). Effect of irrigation water salinity on the growth of quinoa plant seedlings. Journal of Agricultural Science, 8:208-2015

Arendt E.K., Zannini E. (2013). Cereal grains for the food and beverage industries. Woodhead Publishing Series in Food Science, Technology and Nutrition. 248:409-438.

Bazile D., Bertero H.D., Nieto C., (eds.) (2015). State of the art report on quinoa around the world in 2013. Rome: FAO; CIRAD. Available online at: http://www.fao.org/3/a-i4042e.pdf

Bazile D., Pulvento C. ,Verniau A., Al-Nusairi M.S., Ba D., Breidy J., Hassan L., Mohammed M.I., Mambetov O., Otambekova M., Sepahv, N.A., Shams A., Souici D., Miri Kand Padulosi S. (2016). Worldwide evaluations of quinoa: preliminary results from post international year of quinoa FAO Projects in Nine Countries. Front. Plant Sci., 7:850.

Chai C.L., Li S.H., Xu Y.C. (2001). Carbohydrate metabolism in peach leaves during water stress and after stress relief. Plant Physiol. Commun., 37: 495-498.

Cocozza C., Pulvento C., Lavini A., Riccardi M., d’Andria R., Tognetti R. (2013). Effects of increasing salinity stress and decreasing water availability on eco-physiological traits of quinoa grown in a Mediterranean-type agro-ecosystem. J. Agron. Crop Sci., 199: 229–240.

Daoud S., Elbrik Kh., Tachbibi N., Bouqbis L., Brakez M., Harrouni M.C. (2016). The Potential use of halophytes for the development of marginal dry areas in Morocco. In: M. A. Khan et al. (Ed.) “Halophytes for Food Security in Dry Lands”. pp: 141–156. Academic Press.

Eisa S., Abdel-Ati A., Ebrahim M., Eid M., Abd El-Samad E., Hussin S., El-Bordeny N., Ali S., El-

Naggar A. (2014). Chenopodium quinoa as a New Non-Traditional Crop in Egypt. Proceeding of “Bridging the gap between increasing knowledge and decreasing resources” conference. Tropentag, September 17-19, Prague, Czech Republic.

Eisa S.E., Eid M.A., Abd El-Samad E.H., Hussin S.A., Abdel-Ati A.A., El-Bordeny N.E., Ali S.H., Hanan M.A.A., Lotfy M.E., Masoud A.M., El-Naggar A.M., Ebrahim M. (2017). Chenopodium quinoa Willd. A new cash crop halophyte for saline regions of Egypt. Australian Journal of Crop Science, 1:343-351.

Eisa S.S., Abd El-Samad E.H., Hussin S.A., Ali E.A., Ebrahim M., González J.A., Ordano M., Erazzú L.E., El-Bordeny N.E., Abdel-Ati A.A. (2018). Quinoa in Egypt - plant density effects on seed yield and nutritional quality in marginal regions. Middle East Journal of Applied Sciences, 8:515-522.

Escuredo O., Martín M.I.G., Moncada G.W., Fischer S., Hierro J.M.H. (2014). Amino acid profile of the quinoa (Chenopodium quinoa Willd.) using near infrared spectroscopy and chemometric techniques. J. Cereal Sci., 60: 67-74.

FAO (2013). Launch of the international year of quinoa: UN celebrates Andean super food. http://www.fao.org/quinoa-2013/press room/news/detail/en/

Flowers T.J., Colmer T.D. (2008). Salinity tolerance in halophytes. New Phytol., 179: 945-963.

Francis G., Kerem Z., Makkar H.P., Becker K. (2002). The biological action of saponins in animal systems: a review. The British journal of nutrition, 88: 587-605.

Fuentes-Bazan S., Mansion G., Borsch T. (2012). Towards a species level tree of the globally diverse genus Chenopodium (Chenopodiaceae). Molecular Phylogenetics and Evolution, 62:359-374.

Garcia M., Condori B., Castillom C.D. (2015). Agro-ecological and Agronomic Cultural Practices of Quinoa in South America. In: K. Murphy and J. Matanguihan (Ed.) Quinoa: Improvement and Sustainable Production”, First Edition. John Wiley & Sons, Inc.

Garcia M., Raes D., Jacobsen S.E., Michel T. (2007). Agro-climatic constraints for rain fed in the Bolivian Altiplano. J. Arid Environ, 71:109-121.

Geerts S. (2008). Deficit irrigation strategies via crop water productivity modeling: field research of quinoa in the Bolivian Altiplano. Dissertationes de Agricultura. Faculty of Bio-Science Engineering, K.U. Leuven, Belgium.

Gomaa E.F. (2013). Effect of nitrogen, phosphorus and biofertilizers on quinoa plant (Chenopodium quinoa). Journal of Applied Sciences Research, 9: 5210-5222.

Gonzalez J.A., Gallardo M., Mirna Hilal M., Rosa M., Prado F.E. (2009). Physiological responses of quinoa (Chenopodium quinoa Willd.) to drought and waterlogging stresses: dry matter partitioning. Bot. Stud., 50: 35-42.

Hasmadi M., Faridah S., Salwa A., Matanjun I. P., Abdul Hamid M., Rameli, A.S. (2014). The effect of seaweed composite flour on the textural properties of dough and bread. Journal of Applied Phycology, 26:1057–1062.

Hirose Y., Fujita T., Ishii T., Ueno N. (2010). Antioxidative properties and flavonoid composition of Chenopodium quinoa seeds cultivated in Japan. Food Chem., 119: 1300-1306.

Jacobsen S.E., Mujica A., Jensen C.R. (2003). The resistance of quinoa (Chenopodium quinoa Willd) to adverse abiotic factors. Food Reviews International, 19:99–109.

Jacobsen, S.E., Jensen C.R., Liu F. (2012). Improving crop production in the arid Mediterranean climate. Field Crops Res., 128: 34–47.

Jisha S., Padmaja G., Moorthy S.N., Rajeshkumar K. (2008). Pre-treatment effect on the nutritional and functional properties of selected cassava-based composite flours. Innovative Food Science and Emerging Technologies, 9: 587–592.

Kaya C.I., Yazar A. (2016). Saltmed model performance for quinoa irrigated with fresh and saline water in a Mediterranean environment. Irrig. Drain., 65: 29–37.

Mahmoud A.H. (2017). Production of Quinoa (Chenopodium quinoa) in the Marginal Environments of South Mediterranean Region: Nile Delta, Egypt. Egypt. J. Soil Sci., 57:329 – 337.

Maradini-Filho A.M., Pirozi M.R., Borges J.T.S., Santana H.M.P., Chaves J.B.P., Reis-Coimbra J.S.D. (2017). Quinoa: nutritional, functional and anti-nutritional aspects. Crit. Rev. Food Sci. Nutr., 57: 1618-1630.

Molina-Montenegro M.A. (2013). Quinoa biodiversity and sustainability for food security under climate change. A review. Agronomy for Sustainable Development, 34:349-359

Morita N., Hirata C., Park S.H., Mitsunaga T. (2001). Quinoa flour as a new food stuff for improving dough and bread. J. Appl. Glyco. Sci., 48:263-270.

Munns R., Tester M. (2008). Mechanisms of salinity tolerance. Annual Review of Plant Biology, 59: 651–681.

Pulvento C., Riccardi M., Lavini A., Iafelice G., Marconi E., d'Andria R. (2012). Yield and quality characteristics of quinoa grown in open field under different saline and non-saline irrigation regimes. J. Agron. Crop Sci., 198: 254–263.

Razzaghi F., Ahmadi S.H., Adolf S.H., Jensen C.R., Jacobsen S.E., Andersen M.N. (2011). Water relations and transpiration of quinoa (Chenopodium quinoa Willd.) under salinity and soil drying. J. Agr. Crop Sci., 197:348-360.

Razzaghi F., Plauborg F., Jacobsen S.E., Jensen C.R., Andersen M.N. (2012). Effect of nitrogen and water availability of three soil types on yield, radiation use efficiency and evapotranspiration in field-grown quinoa. Agric. Water Manag., 109: 20–29.

Riccardi M., Pulvento C., Lavini A., d'Andria R., Jacobsen S.E. (2014). Growth and ionic content of quinoa under saline irrigation. J. Agro. Crop Sci., 200:246–260.

Rojas W., Pinto M., Alanoca C., Gomez Pando L., Leon-Lobos P., Alercia A. (2015). Quinoa genetic resources and ex situ conservation: In State of the Art Report on Quinoa Around the World in 2013, eds Bazile D., Bertero H. D., Nieto C., editors. (Roma: FAO & CIRAD), 56–82.

Romero S., Shahriari S. (2011). Quinoa's global success creates quandary at home. The New York Times, 19 March 2011. http://www.nytimes. com/2011/03/20/world/americas/20bolivia.html?_r=2&hp= &pag&.

Ruiz K.B., Aloisi I., Duca S.D., Canelo V., Torrigiani P., Silva H., Biondi S. (2016). Salares versus coastal ecotypes of quinoa: Salinity responses in Chilean landraces from contrasting habitats. Plant Physiol. and Biochem., 101:1–13.

Shams A.S .(2011). Combat degradation in rain fed areas by introducing new drought tolerant crops in Egypt. International Journal of Water Resources and Arid Environments, 1: 318-325.

Shams A.S. (2012). Response of quinoa to nitrogen fertilizer rates under sandy soil conditions. Proceeding of the 13th International Conference in Agronomy, Benha, Egypt, 9-10 September. 195-205.

Shams A.S. (2018). Preliminary evaluation of new quinoa genotypes under sandy soil conditions in Egypt. Agricultural Sciences, 9:1444-1456

Sharp R.E., Davies W.J. (1989). Regulation of growth and development of plants growing with a restricted supply of water. In Jones HG, Flowers TJ, Jones MB (eds.), Plants Under Stress. Cambridge University Press, England, pp. 71-93.

Soliman A.H., Abbas M.S., Abol-Ella M.F., Eassawy M.T., Mohamed R.H. (2019). Towards bridging wheat gap in Egypt by using cassava, quinoa and guar as supplements for the production of balady bread. Journal of Food Measurement and Characterization, 13:1873–1883.

Vilche C., Gely M., Santalla E. (2003). Physical properties of quinoa seeds. Biosys Eng., 86:59-65.

Waseem M., Ali A., Tahir M., Nadeem M., Ayub M., Tanveer A. (2011). Mechanisms of drought tolerance in plant and its management through different methods. Continental Journal of Agriculture Science, 5:10-25.

Wu G., Peterson A.J., Morris C.F., Murphy K.M. (2016). Quinoa seed quality response to sodium chloride and sodium sulfate salinity. Front. Plant Sci., 7: 1-8.

References