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Quinoa nutritional profile, health benefits, production challenges, and breeding strategies

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Quinoa (*Chenopodium quinoa Willd.*) belongs to the amaranthaceous family and is a pseudocereal plant that has a greater genetic diversity, which enables its production in diverse climatic conditions. South America is its origin; it has gained global importance due to its nutritional value and health benefits, including essential minerals and a balanced amino acid profile. Despite its increasing importance, challenges such as diseases, pest resistance, agronomic constraints, and changing climatic conditions affect quinoa production. Recently, quinoa cultivation has been introduced in Pakistan, and improved breeding strategies, including modern techniques like marker-assisted breeding, offer solutions to better quality and enhanced yield. Improving growing practices and postharvest technologies is beneficial for sustainable quinoa production globally.

Keywords: Genetic diversity, Climate resilience, Marker-assisted breeding, and Postharvest technologies

INTRODUCTION

Quinoa (*Chenopodium quinoa Willd.*) belongs to the amaranthaceous family and is a dicotyledonous plant. It is also a pseudocereal plant with some nutritional benefits (1). Quinoa is a plant that grows once a year, has upright stems, leaves on both sides, and clusters of flowers called panicles, which are between 15 and 70 cm in length. Quinoa is an allotetraploid species with a total of 2n = 4x = 36 chromosomes, despite having a natural chromosome number of x = 9. The plant's structure enables self-pollination while minimizing inbreeding depression (2). This crop is cultivated throughout South America, from Colombia to southern Chile (1).

Quinoa seeds are small and flat, about 2.5mm in length and 1mm in diameter. They are available in different colors like white, yellow, red, and brown. They have brown seed coat covers, which help them protect themselves. The deep and well-drenched root system of quinoa helps them survive in dry and poor soil. They have reduced water loss ability due to the presence of calcium oxalate in their leaves. They adapt to different climatic zones and can survive temperatures ranging from 4°C to 38°C. They grow well at high altitudes and in low-rainfall areas. Its tolerance to drought, salinity, and extreme weather makes it a suitable crop for climate-changing areas. Farmers cultivate six thousand varieties of quinoa, showcasing its extensive genetic diversity (1).

South America is the origin of quinoa, and the Andean people started domestication 7000 years ago. It was a staple food crop for native people (3). The ancient farmers selected and domesticated the best plants; as a result, there is now a high level of genetic diversity in plants (4). When the Spanish explorers came, they rejected the quinoa. The indigenous people continued to grow quinoa. In the 1900s, its health advantages were discovered, making it a valuable crop all over the world (3). The United Nations marked 2013 as the International Year of Quinoa to highlight its genetic diversity, health benefits, and role in world food (4).

The basic purpose of this review is to get familiarized with the quinoa crop and its long journey from being neglected to being of valuable agricultural importance. We will discuss its world importance and also highlight its status in Pakistan. We will then examine its difficulties, and the breeding techniques required to resolve them. We also give a touch to molecular marker studies that can be very beneficial in its improvement.

Top Quinoa-Producing Countries

The world's top producer of quinoa is Peru, which is followed by Bolivia, Ecuador, and Bhutan (5). Below is their production shown in Figure 1:

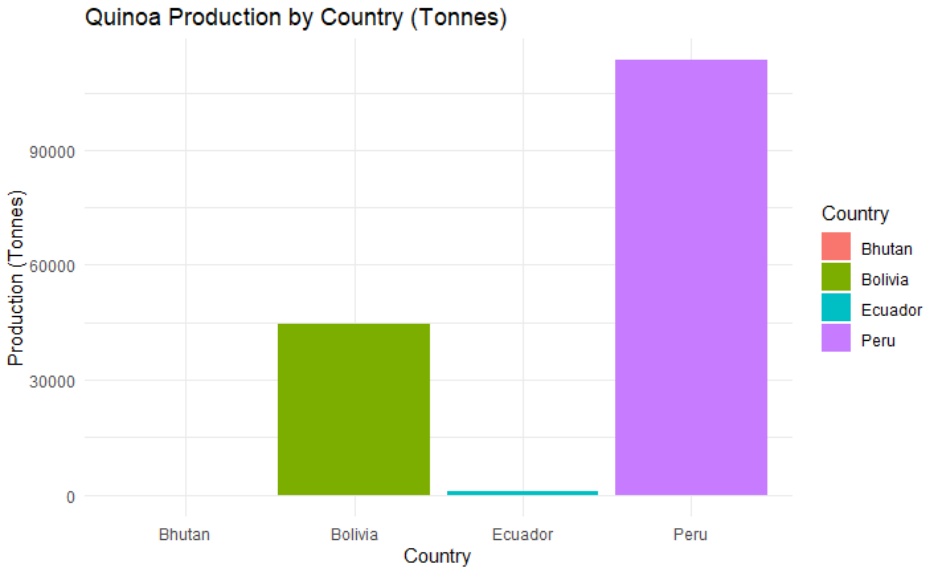

Figure:1 Top Quinoa producing countries

Quinoa production in Pakistan

Pakistan is advancing towards quinoa cultivation gradually, but still, it is a new crop for Pakistan. Quinoa was introduced in 2009 for the first time in Pakistan, and the scientists developed the first variety for cultivation in 2019. Pakistan is still among the early stages Quinoa adoption countries, but good market structure, better mechanization, and improved breeding methods help it to become a significant quinoa producer (6).

Nutritional Profile and Health Benefits of Quinoa

Quinoa's nutritional profile is very high. It has protein (12.1-16%), contains all essential amino acids, carbohydrates (56.2–77.0%) with low glycemic index starch, dietary fibers (7.0-13.9), and lipids (5.5-8.5%). It also contains minerals (Ca, Fe, Mg, P) and vitamins (B1, B3, C, E). It has various health benefits, like being helpful for heart health, improving digestion, regulating blood sugar, and strengthening muscles and bones. It is a gluten-free grain, which makes it ideal for celiac patients (7).

Quinoa Production Challenges

Quinoa production has several challenges, including high weed infestation, disease and pest attacks, stand establishment issues, saponin-free quinoa, seed longevity after harvest, photoperiod sensitivity, stem resistance, heat stress at the reproductive stage, and agronomic and socio-economic constraints points to its cultivation (8). But the changing climatic conditions in the different areas of the world are the biggest issues among all (3).

Quinoa Breeding Strategies

The main objective of quinoa breeding is the development of cultivars that can perform well in changing climatic conditions with high yield and good-quality grains for industrial use. In order to improve its nutritional value, breeding programs can make use of the diverse germplasm of quinoa. To improve quinoa, a variety of breeding techniques are employed, such as introduction, hybridization, backcrossing, mutation, and selection (both individual and mass selection) (9). To further improve quinoa, modern approaches have also been introduced, including double haploid breeding, in vitro callus production, male sterile line development for hybrid production, and molecular marker development (8).

CONCLUSION

Quinoa has a diverse germplasm that is resistant to drought, salinity, and extreme climates, making it a valuable crop for sustainable agriculture in food-insecure areas. Its nutritional profile is also high and has numerous health benefits. The number of quinoa-cultivating countries is 120 now, which is increasing day by day. In the future, there is a need to optimize quinoa's growing practices, improve soil-plant relations, and strengthen postharvest technologies. Utilization of marker-assisted breeding is beneficial for better-performing variety development and saves time.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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