QUINOA (*CHENOPODIUM QUINOA*, WILLD.), NEEDFUL GENETIC RESOURCE UNDER THE CONDITIONS OF CLIMATE CHANGE

QUINOA (*CHENOPODIUM QUINOA*, WILLD), RESURSĂ GENETICĂ ESENȚIALĂ ÎN CONDIȚIILE SCHIMBĂRILOR CLIMATICE

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Abstract. *The negative effects of climate change are a real challenge for modern agriculture today, as agriculture, in general, is severely affected. By increasing the land areas affected by drought and salinity and, consequently, reducing their fertility, as well as due to demographic growth and urbanization (migration), there is an ever-increasing demand for food for the global population. These negative effects of climate change have made the strategy of the EU and the member states to be designed in such a way as to anticipate the effects of climate change; whereas this support should address both short-term effects, such as natural disasters, and long-term effects, such as land loss due to sea-level rise or drought. In these circumstances, it is of great interest to find sustainable cultures/solutions, species with vegetable value, with a sufficiently high ecological plasticity to promote sustainable and productive agricultural ecosystems through the use of "climate-ready" model species that have the ability to respond to severe environmental conditions. A species with a similar genetic background is Chenopodium quinoa, sp., a species of South American origin, unique in the world for its potential to respond to adverse environmental conditions, such as: drought, alternating temperatures, frost, salty soils, etc.*

Key words: quinoa, climate change, sustainable crops

Rezumat. *Efectele negative ale schimbărilor climatice sunt o adevărată provocare pentru agricultura modernă actuală, întrucât agricultura, în general, este grav afectată. Prin creşterea suprafeţelor de teren afectate de secetă şi salinitate şi, în consecinţă, reducerea fertilităţii acestora, precum și din cauza creşterii demografice și a urbanizarii (migrării), se înregistrează o cerință tot mai crescândă de hrană a populației la nivel global. Aceste efecte negative ale schimbărilor climatice au făcut ca, strategia UE și a statelor membre să fie concepută, astfel încât, să anticipeze efectele schimbărilor climatice; întrucât acest sprijin ar trebui să abordeze atât efectele pe termen scurt, cum ar fi dezastrele naturale, cât și efectele pe termen lung, cum ar fi pierderea de teritorii din cauza creșterii nivelului mării sau a secetei. În aceste circumstanţe este de mare interes găsirea unor culturi/soluții sustenabile, specii cu*

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valoare legumicolă, cu o plasticitate ecologică suficient de ridicată, care să promoveze ecosistemele agricole durabile și productive prin utilizarea unor specii- model, „climate-ready”, care au abilitatea de a răspunde condițiilor de mediu severe. O specie cu un asemnea fond genetic este Chenopodium quinoa, sp., o specie de origine sud-americană, unică în lume prin potențialul de a răspunde condițiilor nefavorabile de mediu, precum: seceta, temperaturi alternante, îngheț, soluri sărăturate etc.
Cuvinte cheie: quinoa, schimbări climatice, culturi sustenabile

CIRCUMSTANCES

In recent decades, climate change is rapidly deteriorating crop production conditions. The phenomena of salinization and drought are constantly increasing in all areas of the world, as well as in Romania.

On the other hand, there is a constant population growth worldwide, which means that new species and genotypes tolerant to these factors can be identified and used for modern-future agriculture. The species tolerant to stress and salinity exist, they have an ecological plasticity and a very high value of biodiversity, due to the different climatic conditions in their area of origin, but at the moment they are unused and neglected.

One such species is quinoa *Chenopodium quinoa*, Willd., which we have focused on in this paper, in particular emphasis is placed on the ecological plasticity of the plant, respectively resistance to drought and salinity.

The cultivation of the species was largely abandoned with the arrival of the Spanish conquerors, who replaced the quinoa plant with cereals brought from Europe (wheat and barley), much more productive at that time. The quinoa plant is currently grown throughout the Andean region, in the USA, in Europe, Asia and Africa (Bazile *et al.,* 2016; Mazoyer *et al.,* 2006).

Quinoa is a plant grown mainly for its edible seeds, with a high degree of digestibility (Asao et al., 2010). Also, the leaves can be eaten as a substitute for spinach, in various dishes, well known in the area of origin (Stoleru *et al*., 2021; Vitanescu, 2020).

The nutritional value of quinoa leaves is special, quinoa is a very interesting food, being a precious source of protein, vitamins and minerals (FAO, 1992).

According to the Food and Agriculture Organization of the United Nations (FAO), quinoa can assure the global food security due to its high nutritional qualities as well as tolerance to various abiotic stresses including salinity (FAO, 2013).

The cultivation of the quinoa plant is very important for modern agriculture, because this species is unique in the world in its potential to respond to adverse environmental conditions, such as: drought, alternating temperatures, frost, saline soils, etc. With sufficiently high ecological plasticity (due to a rich genetic background), the quinoa species promotes sustainable and productive agricultural ecosystems by using "climate-ready" models. The sustainability of agricultural ecosystems is a major concern (Mujica *et al*, 2001).

Also, a sustainable diet should provide quality food at affordable costs, with a low impact on the environment. Therefore, increased market demand for food coexists with the need to allocate arable land for agriculture and genetic diversity to protect ecosystem resilience (Jacobsen *et al*, 2013).

GENETIC PERSPECTIVES

Adapting agriculture to climate change and dietary needs involves the use of sustainable crops, such as species or genotypes resistant to abiotic stress. Utilizing tolerant species or genotypes can reduce costs for rehabilitating saline soils and cleaning up polluted sites.

Although genetic variability within a species often leads to the identification of genotypes tolerant to abiotic stress, salinity tolerance is generally low in crops, except for some species such as quinoa, which are extremely tolerant. While all quinoa genotypes exhibit salinity tolerance, some are more resilient than others (Adolf *et al*., 2012), highlighting the need to research and conserve the biodiversity of this species.

Introducing measures aimed at promoting agrobiodiversity is crucial to ensure food security and provide balanced nutrition for rural populations in developing countries. Diversification is considered a means to achieve food production security. Neglected and underutilized species are an important component of agrobiodiversity. These include a wide variety of cultivated and wild crops in different countries, traditionally used and with potential for adaptation to climate change, medicinal properties, as well as resistance genes to diseases and pests. These are some of the reasons why neglected and underutilized species can contribute to the diversification of diets and agricultural systems, reducing inputs, providing higher quality food, and preserving cultural diversity (Mazoyer *et al.,* 2006). Many neglected and underutilized species are traditionally grown by local farmers, as is the case with quinoa.

Key characteristics of quinoa, such as its excellent nutritional properties, high tolerance to salinity and drought, biodiversity, and its cultural contribution to the Andean region, make it promoted as a globally scalable crop in a sustainable manner if a connection is maintained between past, present, and future knowledge.

ECOTYPES OF THE SPECIES

The evolutionary dynamics of quinoa species' spread are primarily due to the vast number of existing species, over 3000 species, wild or cultivated. The domestication process resulted in significant changes such as increased stem, inflorescence, and seed size, inflorescence positioning at the end of the stem, loss of seed dispersal mechanisms at maturity, and varying levels of pigmentation. Quinoa is an allotetraploid with a chromosome count of 2n= 36.

Table 1

Classification of ecotypes on the quinoa species according to D. Bazile
(https://www.researchgate.net/publication/258796109_Quinoa_biodiversity_and_sustainability_for_food_security_under_climate_change_A_review)

Ecotip	Altitudine (m)	Zona	Caracteristici
Quinoa de vale	2.500 - 3.600	Columbia, Ecuador, Peru, Bolivia	The plants are tall, some reaching up to 3.5 meters, they are adapted to temperatures between 10 and 18°C and are not resistant to frost.
Altiplano	>3800	Lacul Titicaca, la granița dintre Bolivia și Peru	Low rainfall (400 to 800 mm/year) and favorable temperatures (6 to 17 °C), 0.5 to 1.5 meters, with white berries.
Salares	<3000	Bolivia, Chile	Tolerance to salty soils, annual precipitation is below 200 mm, winter temperatures drop below -20 ° C
Quinoa from sea level areas	<1500	Sud-Centru Chile	Height from 1 to 1.4 m, the species are unbranched; The seeds are small, flat, yellow, translucent, rich in saponins, bitter.
Yungas	1.500 - 2.000	Bolivia	Moisture tolerance and resistance to higher temperatures, seeds are small, white or orange, includes late flowering genotypes

The high degree of diversity of quinoa populations native to Chile has been investigated by molecular methods (Fuentes *et al*., 2009). This study showed a good compatibility between the ecological constraints and the biodiversity of the quinoa species. In addition, the analyzes carried out the differences between the cultures of the central Andes and the southern latitude (tab.1).

The natural geographic distribution of the plant ranging from southern Colombia (2ºN) to south-central Chile (43ºS), including a branch in northwestern Argentina and some subtropical lowlands in Bolivia, makes the species highly tolerant to abiotic stress factors (Hinojosa *et al*., 2018; Mazoyer, 2002)(fig.1).

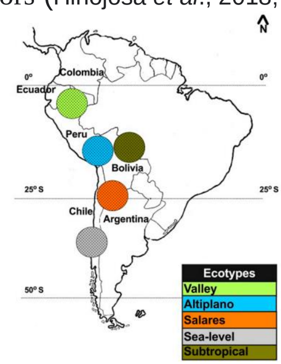

Fig. 1. Geographic distribution of the five quinoa ecotypes (Hinojosa *et al.,* 2018) (https://www.researchgate.net/publication/258796109_Quinoa_biodiversity_and_sustainability_for_food_security_under_climate_change_A_review

Fig. 2. Varieties of quinoa, sp.
(https://www.notulaebotanicae.ro/index.php/nbha/article/view/9733)

- 1. Bibio: native to Chile, has a short growing season; the plant is red with white and smaller seeds, early ripening and high yield (fig.2).
- 2. Bright: edible variety, also used as an ornamental plant, 1.5 m, with different colors from orange, red, bordeaux, white and yellow.
- 3. Buffy: high yield and a high stem resistance (fig.2)
- 4. Puno: height of 0,95-1,70 m, with a vegetation of 165-170 days; the variety is intended for cultivation for seeds, the saponin content is lower than in the Titicaca variety.
- 5. Titicaca: the first improved variety in Denmark, being also a bitter tasting variety; the vegetation is 160-165 days, with a height that varies depending on the density; between 0.90-1.60 m.
- 6. Vanilla Cherry: as the name suggests, this variety produces clusters of cream and red flowers; height of 1.5 m, used as a decorative plant for borders.

- 7. Vanilla franceză: 2 m in height, the seeds are white and glossy; very good yield.
- 8. Vikinga: 1-1,75 m in heigh; is considered the first sweet variety with a low content of saponin in the seeds; the vegetation is 155-160 days.

OVERALL

Today, we have molecular tools that can generate data sequences from any species much more efficiently, allowing for comparisons between neglected/underutilized species and staple crops or between stressed and unstressed plants of the same genotype. The identification of genes with salinity tolerance is ongoing.

Drought- and salt-tolerant crops can be developed through two approaches:

1. Firstly, staple crops can be improved by introducing genes from tolerant plants (e.g., many staple crops have wild relatives that are more tolerant to drought and high salinity). Once deciphered, resistance mechanisms could be genetically manipulated to produce crops with improved tolerance.
2. Secondly, some secondary crops grown in marginal areas are already drought- and salt-tolerant. Improving the agronomic performance of these crops can be an efficient way to increase crop diversity and can be an engineering tool used for staple crops. Quinoa is a candidate for both approaches.

Recent research investments aim to enrich quinoa varieties, focusing on high productivity, reduced maturity periods, and promoting sweet varieties.

Quinoa's exceptional tolerance to hostile environmental conditions makes it a good candidate for ensuring food security in the face of inevitable changes.

CONCLUSIONS

Physiological, biochemical, and morphological responses of different quinoa varieties to various abiotic stress factors show that quinoa has high ecological plasticity and tolerance to these stressors. This tolerance and ecological plasticity appear to be genetically controlled.

Recent exploration of crosses between quinoa and its wild relatives provides new genetic combinations with production yields in extreme conditions.

Since the reference genome of the quinoa species has been known, new genetic transcription studies on the salinity and drought resistance of the species have been conducted (Hinojosa *et al.*, 2018).

To protect the genetic variability of the quinoa species in the Andean region, 59 gene banks have been established in several countries since the 1960s. A total of 16,422 genotypes have been conserved, the majority of which are concentrated in Bolivia and Peru.

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