ABSTRACT

dissertation for the degree of Doctor of Philosophy (PhD) in the specialty "8D05101 - Biology"

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General characteristics of the work. The dissertation work is devoted to the study of adaptation mechanisms of immature plants *Chenopodium quinoa* Willd under the influence of abiotic stressors.

The relevance of the work. Statistical projections show that by 2050, the world's population will increase to 9.7 billion people, so there are now growing concerns about whether agriculture will be able to produce enough food for a growing population. Major crops such as wheat, rice, barley and maize have limited resources to resist the worsening processes of land desertification: soil salinization and water scarcity, especially in marginal regions that are most vulnerable to climate change (Jarvis et al. 2015; Hamdy 2016; Jacobsen 2016; Hunter et al. 2017).

Consequently, there is an urgent need to find alternative solutions to maintain and possibly increase agricultural productivity in areas where growing traditional crops is becoming increasingly difficult and uneconomical. Therefore, it is important to shift the focus to new highly nutritious and sustainable crops.

For cultivation on saline soils in order to subsequently reduce the level of salinity, attention can be paid to plants belonging to the Amaranthaceae family, which are relatively recent additions to modern agriculture originating from the New World. Many members of the family are classified as pseudophyllales (Caryophyllales: Amaranthaceae), which in recent years have attracted the attention of farmers in the world because of their highly nutritious grains and green mass, especially because of their valuable amino acid composition (rich in lysine, arginine and histidine). Amaranth crops also contain medical bioactive substances such as squalene and antioxidants, which contribute to disease prevention. And the significant content of iron (Fe) in seeds makes them potentially effective in combating iron deficiency anemia. Moreover, the protein of amaranth seeds does not contain gluten, which makes it an excellent source of protein for people with celiac disease. Unlike traditional crops, amaranths not only withstand harsh conditions such as drought or soil salinization, but also show an increase in the content of proteins, vitamins, phenolic acids, flavonoids and natural antioxidants. Therefore, amaranths can be considered a promising choice for farmers, especially on marginal soils.

One of the representatives of this family, actively introduced into agricultural production in many regions of the world, is Chenopodium quinoa Willd, a facultative halophytic plant species capable of adapting to a wide range of marginal environments, including soils with high salinity and areas prone to drought. The most tolerant quinoa varieties are able to cope with salinity levels as high as in seawater (Razzaghi et al., 2015), (Kramer P.J., Boyer J.S. (1996). In addition, quinoa has great nutritional value − the seeds of this crop are well

balanced in carbohydrates, lipids, amino acids and proteins, which are useful for human nutrition. Therefore, this species seems promising for introduction into agricultural production in arid regions.

Nevertheless, despite the growing global recognition of the need and potential of alternative crops, despite the positive research from pilot studies, there are still many unresolved issues that need to be explored before these crops are recognized where other agricultural plant species have so far prevailed.

Among the numerous abiotic stresses, drought and salinization of the soil are probably among the most widespread and detrimental to vegetation both in the world and in Kazakhstan. Although halophytes have a wide range of salt tolerance, they also, to a greater or lesser extent, suffer from excessive salt concentration in the soil. In addition, in the field, plants often experience both drought and salt stress, which leads to serious growth disruption. Both drought and salt stress have a detrimental effect on plants throughout the growing season, preventing seed germination, growth and development, flowering and fruiting. Both single and, moreover, combined abiotic stress factors cause a number of morpho-anatomical, physiological and biochemical changes in plants, negatively affect growth and development and can lead to a sharp decrease in economic productivity. When drought and salt stressors occur simultaneously, the morphophysiological processes of plant control against them, being non-specific, are largely similar. But, compared with individual stressors, combined stresses can sometimes cause opposite, even antagonistic reactions at different levels of plant organization. В целом, currently, there is a great lack of scientific information regarding the effects of combined effects of stressors on crops.

Stress resistance often increases as plants mature. However, even in halophytes, the most damaging effects of osmotic and salt stress on plant development are characteristic of young plants when their growth rate and sensitivity are at their peak. Therefore, it is extremely important to assess the impact of both single and combined stresses on young plants.

To date, the salt tolerance of the species has been relatively well studied for quinoa, drought tolerance has been less studied and the effect of the combined action of stress factors, which are very characteristic of the arid climate of Kazakhstan with a large number of saline and degraded lands, has practically not been considered at all.

Therefore, the proposed research topic is certainly relevant.

The object of the study: *Chenopodium quinoa* Willd.

Subject of research: Drought resistance, salt resistance, combined stresses, adaptive mechanisms of immature plants *Chenopodium quinoa* Willd.

Research methods: botanical, anatomical, physiological, biochemical

The purpose of the work: To study the adaptive mechanisms of immature Chenopodium quinoa Willd plants under the influence of single and combined abiotic stress factors to determine the possibilities and risks of the prospect of introducing this crop into marginal agricultural regions of the country.

To achieve the goal, the following tasks were set:

1. To study the anatomical and morphophysiological parameters of Chenopodium quinoa Willd. when exposed to osmotic, salt and combined stresses;

2. To study photosynthetic activity of photosystem II in Chenopodium quinoa Willd. when exposed to osmotic, salt and combined stresses;

3.To determine changes in the synthesis of secondary antioxidant metabolites in Chenopodium quinoa Willd. when exposed to osmotic, salt and combined stresses.

Theoretical and methodological basis of the research:

In this study, the quinoa variety "Vakhdat" from Tajikistan was used; the seeds were provided by the Center for Genetic Resources of the Tajik Academy of Agricultural Sciences (TSGR TAAS).

Morpho-anatomical, physiological and biochemical studies of plants were carried out according to generally accepted methods.

The ions were measured using an FPA-2-01 flame photometer. The parameters of photosynthetic activity were evaluated using a Junior-PAM fluorimeter.

The analysis of organic compounds was carried out by gas chromatography with mass spectrometric detection (Agilent 6890N/5973N) and liquid chromatography (Milichrom-A-02 liquid chromatograph “EcoNova" JSC).

The author's personal contribution to scientific results: the definition of the purpose and objectives of the dissertation work, literary review, conducting experiments, presentation of the main results in the dissertation were carried out personally by the author; preparation of abstracts and articles for publication, processing of research results, statistical analysis of the data obtained were carried out with the participation of joint authors.

Scientific novelty and significance of the dissertation work.

The novelty of the research lies in the fact that for the first time a comprehensive analysis of the effect of salt, osmotic and combined stress factors on morphophysiological parameters, ion balance and photosynthetic activity of immature Chenopodium quinoa Willd plants was carried out. and the level of stress exposure was revealed, which is transitional from eustress to distress.

For the first time, the metabolic profile of Chenopodium quinoa Willd plants subjected to salt, osmotic and combined stresses was studied using chromatomass spectrometry and information was obtained on the effect of abiotic stresses on the antioxidant system, valuable in the context of the possibility of using induced stress to increase the synthesis of BAS for the needs of the food and medical industry.

The theoretical significance of the research work. It consists in the fact that important morpho-physiological, photosynthetic and biochemical patterns of the response of young Chenopodium quinoa Willd plants to the effects of single and combined stresses have been identified, It has also been shown that the antioxidant

system in plant tissues is multicomponent and includes not only antioxidant enzymes, but also secondary metabolites of pharmaceutical value; the functional interaction of antioxidant components is due to adaptive stress reactions of the body. These results can be used both to understand the mechanisms of quinoa protection from adverse conditions, and for approaches to the targeted synthesis of valuable BAS.

The practical significance lies in the fact that levels of abiotic factors have been identified that cause both eustress, stimulating plant development, and distress leading to the death of young quinoa plants, which is important for determining the possibilities of introducing this crop into marginal agricultural regions of the country.

The main provisions submitted for protection:

1. The salt concentration in the substrate plays a key role in maintaining quinoa growth, with values from 100 mM to 200mm NaCl providing the best conditions for the development of young plants. The combined stress caused by the level of 200 mM NaCl+ PEG-6000 is a transition from eustress to distress for immature quinoa plants.

2. The identified mechanisms of resistance to osmotic, salt and combined stresses, such as water balance, morphometric parameters of the leaf and stem, activity of the photosynthetic apparatus, the work of enzymatic and non-enzymatic antioxidants, indicate the relationship of anatomical-morphological, physiological, biochemical indicators, as a result of which these indicators can be considered integral and used in testing plants for resistance to abiotic stresses.

3. The revealed increase in the concentration of enzymatic and non-enzymatic antioxidants under the action of abiotic stresses can become the basis for the method of directed synthesis of valuable BAS for the food and medical industry.

The doctoral student's personal contribution to the preparation of each publication consisted in collecting data on the subject of research, performing all laboratory studies, including analysis, interpretation and design of the results obtained, and preparing manuscripts of publications.

Review and approval of the results of the work. The results of the dissertation work were reported and published in the collections of Materials of international scientific and practical conferences: Proceedings of the international scientific conference "Formation and development of experimental biology in Tajikistan", Dushanbe: Donish, 2022, – p.56 ; Materials of the X Congress of the Society of Plant Physiologists of Russia "Plant Biology in the era of global climate change" September 18-23, 2023, Ufa, − p. 422; Materials of the international conference of students and young scientists "Farabi Alemi" April 6-8, 2023,-from 38; Materials of the international conference of students and young scientists "Farabi Alemi" April 4-5 2024,-p.32;

The main results of the dissertation were annually heard at the Scientific and Technical Council of the Faculty of Biology and Biotechnology, at meetings of the Department of Biodiversity and Bioresources of Al-Farabi Kazakh National

University and the Scientific Council of the RSE at the Institute of Genetics and Physiology.

Publication of the research results. The main content of the dissertation has been published in 9 publications, including 2 articles in international peer-reviewed journals with an impact factor included in the Scopus and Web of Science databases (Q1, %67 and Q3, %44); 3 articles in journals from the list of publications recommended by the Committee for Quality Assurance in the field of Science and Higher Education of the Ministry of Education and Science of the Republic of Kazakhstan for the publication of the main results of scientific activity, 4 abstracts in collections of materials of international and republican conferences, of which 2 are foreign. The author's h-index is 2 (https://www.scopus.com/authid/detail.uri?authorId=57219198742).

The structure and scope of the work. The dissertation consists of 92 pages of text: introduction, literature review, materials and methods, results and discussion, conclusions, 211 sources of bibliography, 4 tables, 25 figures.