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PHYSIOLOGICAL STRATEGIES OF PLANT SPECIES FROM POACEAE FAMILY UNDER CHANGING BIOTIC AND ABIOTIC FACTORS

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Summary. Global climate changes have caused significant challenges for plants adaptation, such as irregular precipitation and sharp temperature contrasts. Modern molecular, genetic, physiological and biochemical approaches and environmentally friendly technologies can help expand the pool of climate change-resistant plant species. The results of current research highlight the need to understand the molecular and genetic mechanisms of plant adaptation to abiotic stresses, including drought, high temperature and salinity. This is especially important for ensuring food security and maintaining ecological balance in the face of global change. The Department of Cultivated Flora of the M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine has achieved significant results in acclimatization, selection and introduction of new species and varieties of plants from *Poaceae* family in Ukraine.

Keywords: *Poaceae* family, extreme climatic conditions, abiotic stress, physiological strategies, biologically active compounds.

Introduction

Global climate change has caused a number of consequences, such as irregular precipitation and various stress factors negatively affecting various organisms, including plants, adapting to new harsh conditions. The urbanized environment aggravates the situation by reducing the number of climate- and urbanization-resistant plant species. However, new approaches to plant acclimatization, breeding, selection and genetics, as well as some environmentally friendly growing technologies, can expand the pool of well-adapted plant species and varieties. Vegetation helps to mitigate the effects of heat in the urban environment, improves the psychological health of residents and preserves biodiversity. Therefore, special attention should be paid to ornamental plants for urban landscapes with stress-resistant properties. Integration of such plants can improve the ecological balance and overall quality of the urban environment both for people and natural habitats (KISVARGA, Szilvia, et al. 2023).

Studies of plant responses to abiotic stresses, which began with model species and gradually expanded to important crops, have shown insufficient stress tolerance of the genotypes developed in traditional breeding programmes. Today, breeding programmes include new strategies to study the physiological, biochemical and molecular responses of plants to environmental changes, which is key to ensuring food security. The impact of water shortage, high temperatures and salinity on plant species is also taken into account (Dos Santos, et al. 2022).

Environmental factors, such as climate and soil properties, affect plant growth, physiological processes and metabolic profile. Also the effects of precipitation, temperature and soil conditions (soil texture, pH, electrical conductivity, organic matter, calcium carbonate content and overall soil fertility) on nutrient levels, antioxidant compounds and peroxidase activity in crops were analyzed. Research has demonstrated a positive correlation between the content of phosphorus, sodium, potassium, calcium, antioxidants, enzymatic activity on one hand and temperature and precipitation

on the other hand. It was found that in regions with lower temperatures and precipitation levels, plants showed greater adaptation to mountain and alpine weather conditions, accompanied by a decrease in antioxidant compounds and oxidative enzyme activity (Khademian Amiri, Setareh, et al., 2022).

Secondary plant metabolites are biologically active compounds that play an important role in the pharmaceutical, food, cosmetic and agricultural industries due to their unique properties. They are divided into three main groups: phenolic compounds, terpenoids and nitrogen compounds. Secondary metabolism is a mechanism of plant adaptation to stress environmental conditions. Stress can be in the form of distress, causing negative impact on plant, leading to damage, or eustress — positive and "productive" form of stress, activating plant metabolism. Environmental factors are generally divided into biotic and abiotic ones, which can be artificially induced to stimulate the production of secondary metabolites. Recently, several approaches to plant metabolic activation, generally known as elicitation, have been developed using various metabolic inducers or "elicitors" (Aguirre-Becerra, Humberto, et al. 2021).

Currently, the latest scientific advances in molecular genetic approaches were used to improve heat tolerance in plants. Also scientists study the potential role of biochemical and molecular markers in screening of genetic material for high temperature resistance genes, and use next-generation genetic sequencing to identify new genes associated with defence mechanisms and protective metabolic pathways (Wani, Shabir H.; Kumar, Vinay (eds.). 2020).

Drought stress has a negative impact on plant growth, photosynthetic pigments, gas exchange, stomatal functions and ion absorption by various parts of plants, including roots and shoots. Reduced plant growth rates are the result of oxidative stress, which is neutralized by antioxidant compounds, the concentration of which increases in response to dehydration. The provision of clean water in sufficient quantities is critical for the population, various industries and ecosystems, as water is essential for drinking, agriculture, sanitation and energy production. However, the world's water resources are under significant threat. According to UNESCO (World Water Assessment Programme, 2012), about 700 million people in 43 countries already suffer from water shortages, and it is projected that 'by 2025, 1.8 billion people will live in countries or regions with absolute water scarcity, and two-thirds of the world`s population may be under water stress.

Many researchers have concluded that certain types of antioxidants increase metabolic activity in cells. Progress in the development of drought tolerant varieties is significantly hampered by limited genetic resources and physiological, biochemical and genetic traits. Therefore, the identification of multiple genetic, metabolic pathways and strategies inducing tolerance to water stress and increasing drought tolerance are particularly important (Alharbi, Khadiga, et al., 2022).

Plants use photosynthesis to convert light energy into chemical energy. However, the efficiency of photosynthesis can vary significantly under the influence of abiotic factors, such as temperature, light intensity and water availability. After analyzing the impact of changes in abiotic conditions on the photosynthetic adaptation of plants, it can be underlined that plants have developed various adaptive mechanisms to optimize photosynthesis under different types abiotic stress. For example, under high light intensity, plants can regulate their photosynthetic apparatus by reducing or increasing photorespiration activity. In case of insufficient water uptake, plants can close stomata to reduce water loss and photosynthetic activity or activate various molecular pathways to increase drought tolerance. Understanding these molecular adaptation mechanisms is key to developing strategies to improve crop productivity and resilience in a changing environment.

Despite the advances in understanding the impact of abiotic conditions on photosynthetic adaptation of plants, there are still many unresolved problems. The complex interactions between plants and the environment, as well as the effects of various stresses, need to be further investigated. In addition, sustainable agricultural practices need to be developed to mitigate the negative effects of climate change on crop productivity (Ahmad, Noman, et al., 2023).

Plants have evolved complex mechanisms to adapt to cold stress at the physiological and molecular levels. Research on plant cold tolerance has been conducted over the past 10 years and it is especially important for expanding the areas of adaptation of perennial grasses. As a result, there have been significant advances in improving plant cold tolerance from a molecular and physiological perspective. Cold stress response, such as stimulation of the genes expression encoding osmoregulatory elements and strategies for improving cold tolerance have been identified (Ahad, Arzoo, et al. 2023).

Intensive agricultural practices have a global impact on environment causing issues related to food security and public health. Agricultural ecosystems cause significant loss of biodiversity and natural habitats, high levels of agrochemical pollution, extensive use of resources, and changes in soil composition. This, in turn, causes human health issues and causes loss of plant nutritional quality (Arenas-Salazar, Ana Patricia, et al., 2024).

Identification of the genes and metabolic pathways, plants use to respond to high temperature and drought will be very useful for the development of new crops, resistant to different stress conditions (Martin, Ruth C. et al., 2021).

Plants of the *Poaceae* family, such as rod millet *Panicum virgatum* L., finger millet or Himalayan finger millet *Eleusine coracana*, foxtail millet *Panicum italicum* L., are of great agricultural importance worldwide (Bhinda, Mahender Singh, et al., 2022; Rakhmetov, 2018).

Based on the results of long-term research, the Department of Cultivated Flora of M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine has accumulated considerable experience in the introduction, acclimatisation and selection of new, non-traditional species and cultivars of plants of the *Poaceae* family. The collection of energy and industrial crops includes about 240 taxa of this family. Significant progress has been made in the introduction of representatives of such genera as *Miscanthus*, *Sorghum*, *Panicum* and *Eleusine* (Collection Fund..., 2020). According to EU legislation, energy crops must be grown on marginal lands (BURY, Marek, et al., 2021).

Panicum virgatum L. is a promising perennial energy crop which can become one of the most important crops not only in the bio-energy sector, but also in the area of phytoremediation - restoration of various contaminated areas affected by anthropic factors (D.B. Rakhmetov, O.M. Vergun, S.M. Kovtun-Vodyanitska et al. 2020).

It has been proven that rod millet plants can actively absorb heavy metals from the soil and accumulate them in the aboveground and underground parts, which prevents these pollutants from entering wastewater (Guo et al., 2019; Hou et al., 2020).

The results of our research indicate that *Panicum virgatum* plants have been successfully introduced, fully acclimatised and there is a possibility of their naturalisation within climatic conditions of Ukraine. As plants with a C_4 photosynthetic pathway, they use solar energy efficiently, are drought-, cold-, frost-resistant winter-hardy and are resistant to flooding.

The Department of Cultivated Flora of M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine has created a valuable gene pool of *Panicum virgatum*, which includes about 40 samples, as a result of many years of introduction, breeding and biotechnological selection work. Over the years, comprehensive research has been conducted to study the biological, morphological and ecological characteristics, biochemical composition of *P. virgatum* plants, productivity of its aboveground phytomass and seeds, yield of the key valuable substances, and to determine the energy value of these millet plants. Our research team has created a number of highly productive strains with specified and stabilized parameters of yield, phytomass sugars content, as well as total energy and biofuel raw materials yield.

The study of plants` biochemical characteristics, metabolic processes and overall productivity of mentioned crops is of great importance today. Evaluation of the biological and ecological role of plants in phytoremediation, improvement of carbon balance in phytocoenoses,

identification of prospects for introduction, use of plants in green energy, soil improvement, ornamental horticulture and bioeconomy – all these areas are considered very promising.

Materials and methods

This study involved comprehensive search and analysis of available printed and electronic scientific papers and key scientific literature aggregators (Scopus, Web of Science, Pubmed, Researchgate, Science Direct, Google Scholar etc.). The methods of comparative analysis, systematization and generalisation of scientific data were used in the current study.

Conclusions

Global climate change poses serious challenges for agriculture, which, in turn, heavily depends on climatic conditions. Modern plant breeding and selection programmes focus on studying of physiological and molecular responses of plants to environmental changes, which is important for global food security.

Environmental factors, such as climate and soil conditions, have significant impact on plant growth and development, physiological processes and metabolic profile. Research on the effects of precipitation, temperature and soil conditions on nutrient and antioxidant levels can help develop new strategies to improve plant adaptation.

Drought stress negatively affects the process of photosynthesis and ion absorption, leads to significant decrease in plant growth and productivity. In order to combat the negative effects of climate change, it is important to introduce new sustainable agricultural practices and use modern technologies such as biostimulants and various environmentally friendly approaches.

Recent advances in the understanding of the molecular mechanisms of plant stress adaptation may contribute to the development of new strategies to improve their resilience, which will have a positive impact on food security and the preservation of ecological balance. Secondary metabolites of plants, in particular phenolic compounds, terpenoids and nitrogen compounds, are important in various fields, due to their beneficial properties and as one of the mechanisms of plant adaptation to stress conditions.

The Department of Cultivated Flora of M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine has made significant progress in the introduction of *Poaceae* family representatives (overall about 240 taxa) into agriculture. Significant achievements have been made in the acclimatization, breeding, physiology and biochemistry of plants of *Miscanthus, Sorghum, Panicum, Eleusine* and other genera. Among the novel crops in Ukraine, the plant *Panicum virgatum* having a C4 photosynthetic pathway deserves special scientific attention.

As a promising highly adaptive perennial plant, it can become one of the leading and strategically important target crops for use in Ukrainian bioeconomy.

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