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Determination of Proline Content in Bread Wheat Varieties Under Iso-Cation Sodium Salinity Conditions

Abstract

The proline content was determined in 10-day-old seedlings of bread wheat varieties "Gobustan" and "Layagatli 80" grown under iso-cation sodium salinity conditions in both hydroponic and soil culture systems. The results showed that in both wheat varieties, the proline content in the roots and shoots of seedlings grown in hydroponic culture was higher compared to those grown in soil culture. Moreover, in both cultivation systems, the proline content in the root system of the seedlings was found to be higher than in the above-ground parts.

It was revealed that the effect of iso-cation sodium salts significantly increased the proline content in both shoots and roots of wheat seedlings grown in both hydroponic and soil cultures.

The increase in proline content due to the effect of salts was more pronounced in wheat seedlings grown in soil culture compared to those grown in hydroponic culture. At all salt concentrations, the proline content in "Layagatli 80" wheat seedlings was higher than in the "Gobustan" variety. It was revealed that proline content is one of the indicators of plant salt tolerance. The increase in proline levels under extreme salinity conditions may serve as a key parameter for selecting salt-tolerant genotypes.

Keywords: *proline, salt tolerance, hydroponic culture, soil culture, wheat seedlings*

Introduction

Soil salinization, as one of the most widespread abiotic factors, has a significant negative impact on the growth and development of agricultural crops (Sun et al., 2016), leading to oxidative stress. As a result, reactive oxygen species (ROS) are generated, photosynthetic efficiency declines, productivity decreases, and premature aging and death of plants occur (Singh et al., 2022; Mansour, Ali, 2021). Consequently, many countries around the world suffer from food shortages.

The relevance of the salinity tolerance problem lies in the fact that currently, more than 20% of the irrigated soils on Earth are affected by salinization, and this figure is predicted to rise to 50% by 2050 (Gadir et al., 2014; Ashraf Harris, 2014). Saline soils are widespread in the territory of Azerbaijan, and their extent continues to increase year by year (Mammadov, 2007).

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It should be noted that in Azerbaijan, chloride, sulfate, or sulfate-chloride types of salinization are the most widespread. There is evidence that the Na^+ and Cl^- ions have the most harmful effects on plants (Wang et al., 2007; Abdiyev, 2017). The accumulation of Na^+ cations in the soil severely degrades its physical properties. As a result, the soil structure deteriorates, its water and air regimes worsen (Mammadov et al., 2010), and ion homeostasis is disrupted in plants, leading to the accumulation of various toxic substances in the cells (Balnokin, 2005).

The negative effects of salts on plants are more pronounced during the early stages of ontogenesis, as plants are less tolerant to salinity at this phase. Therefore, studying the physiological and biochemical processes during the initial stages of seedling development is of great importance for understanding the mechanisms by which salts affect plant organisms. This is because the initial physicochemical processes occurring in plant cells significantly influence the subsequent changes in intracellular metabolism throughout the plant's development.

Research

It is known that a significant portion of the plant kingdom completes its life cycle under conditions of high salt concentration (Gasymov, 2012). Therefore, a comprehensive study of the issue of plant salt tolerance is of great theoretical and practical importance. It should be noted that various defense systems exist within plant organisms. One such defense component is proline, which possesses antioxidant properties. In addition to serving as a source of nitrogen, carbon dioxide, and reduced equivalents in plants, proline functions as an antioxidant, osmolyte, and energy substrate (Kuznetsov, Shevyakova, 1999; Kharitonova, Goncharova, 2010), and plays a role in protecting plants from superoxide stress (Shevyakova, Bakulina, 2008).

Taking the aforementioned points into account, the aim of the present study was to comparatively investigate the proline content in the shoots and roots of 10-day-old bread wheat cultivars grown under extreme salinity conditions in both hydroponic and soil cultures.

Materials and Methods

Taking the above into consideration, the aim of the present study was to comparatively investigate the proline content in the shoots and roots of 10-day-old bread wheat cultivars grown under extreme salinity conditions in both hydroponic and soil cultures.

As research subjects, 10-day-old seedlings of widely cultivated wheat varieties “Gobustan” and “Layagatli 80” (*Triticum aestivum* L.) were used. The seedlings were grown in Knop’s solution and in solutions containing 25–100 mM NaCl and Na_2SO_4 under normal aeration conditions (0.04 mg O_2/min) at a temperature of 20°C.

Besides, the plants were grown in saline dark gray-brown soils containing 0.2–1.0% (NaCl, Na_2SO_4) salts.

In the green plants cultivated under light and laboratory conditions, the level of illumination was measured with a luxmeter (420–480 lx) (Luxmeter Type 102; with a measurement error of 10%).

The amount of proline in the roots and shoots of the plants was determined using a modified spectrophotometric method proposed by Bates et al. (1973). Optical density was recorded at 520 nm. The proline concentration (0.01–0.02 mM) was calculated based on a calibration curve using the following formula:

$$y = 0.031x + 0.041$$

The experiments were conducted with 3–4 replications, and the obtained results were statistically processed (Kerdyashov, 2018). The experimental data showed a precision level of less than 5%, confirming the statistical reliability of the results.

Conclusion

Based on the obtained results, the amount of proline in the roots and shoots of wheat seedlings grown in hydroponic culture was higher compared to those grown in soil culture. It should be noted

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that, in general, physiological and biochemical processes in plants grown in hydroponic culture occur more rapidly than in those grown in soil culture (Abdiyev, 2017).

In both hydroponic and soil cultures, the amount of proline in the root system of wheat seedlings was higher than in the above-ground parts.

As shown in Figures 1 and 2, in the roots and shoots of 10-day-old "Gobustan" seedlings grown in hydroponic culture, the proline content increased with rising salt concentrations from 25 to 75 mM. Although it decreased with a subsequent increase in salt concentration (100 mM), it still remained higher than in the control.

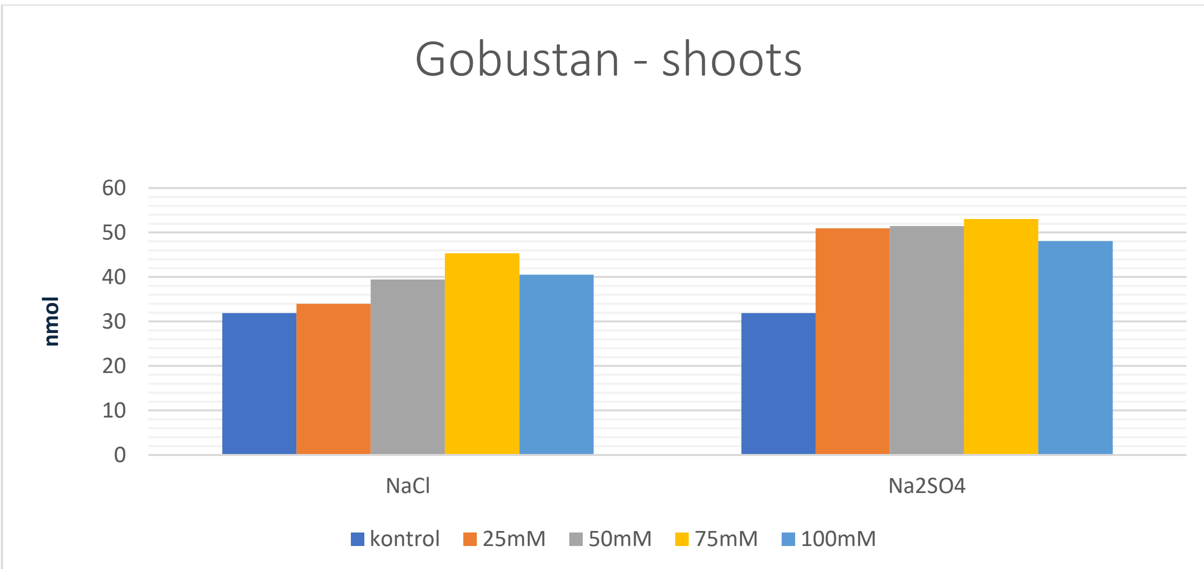

Figure 1. Effect of various NaCl and Na_2SO_4 concentrations on the amount of proline in the shoots of 10-day-old seedlings of the "Gobustan" variety grown in a hydroponic environment.

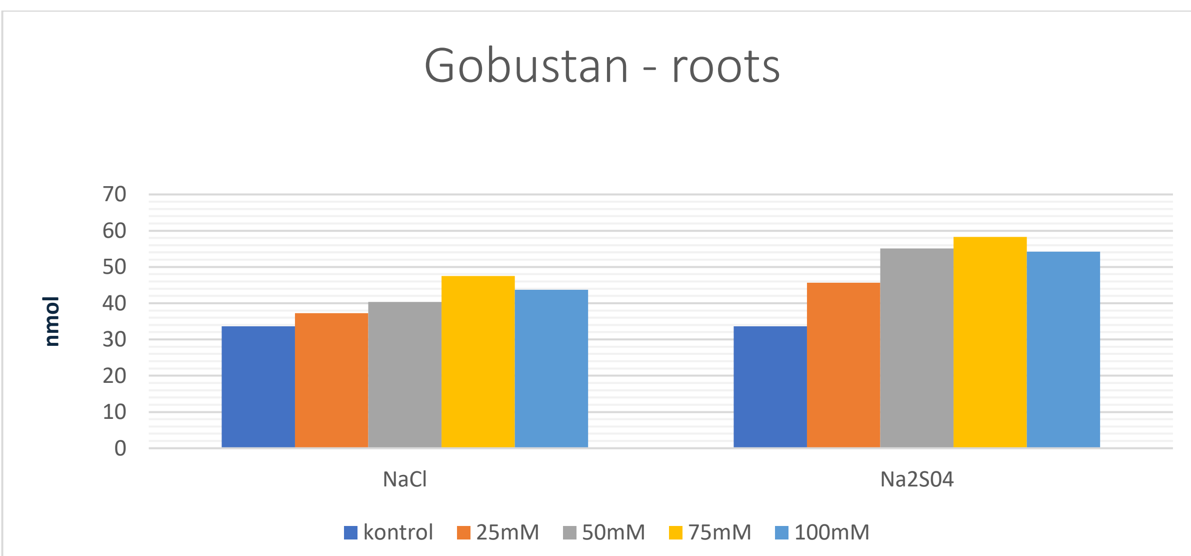

Figure 2. Effect of various NaCl and Na_2SO_4 concentrations on the amount of proline in the roots of 10-day-old seedlings of the "Gobustan" variety grown in a hydroponic environment.

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Under the influence of 75 mM NaCl, the proline content in the shoots and roots of wheat seedlings increased by 1.4 times. Exposure to 75 mM Na_2SO_4 led to a 1.7-fold increase in the shoots and a 1.73-fold increase in the roots. Similar results were observed in the “Layagatli” seedlings: 75 mM NaCl caused a 1.6-fold increase in proline content in the shoots and a 1.55-fold increase in the roots. Upon treatment with 75 mM Na_2SO_4, the proline content in both the shoots and roots of the “Layagatli” seedlings increased by 1.8 times.

A different pattern was observed in the shoots and roots of 10-day-old “Gobustan” seedlings grown in soil culture. When the salt concentration in the soil ranged from 0.2% to 0.6%, the proline content increased; however, at higher concentrations (0.8–1.0%), it decreased, though still remained above the control level. Thus, under the influence of 0.6% NaCl, the proline content in the shoots increased by 2.13 times and in the roots by 1.57 times. In response to 0.6% Na_2SO_4, the proline content in the shoots rose by 1.84 times and in the roots by 1.75 times.

A somewhat different result was observed in the 10-day-old “Layagatli” seedlings grown in soil culture. In both the roots and shoots of these seedlings, the proline content increased as the salt concentration rose from 0.2% to 0.8%. With a further increase to 1.0%, the proline level declined but remained higher than that of the control (Figures 3 and 4).

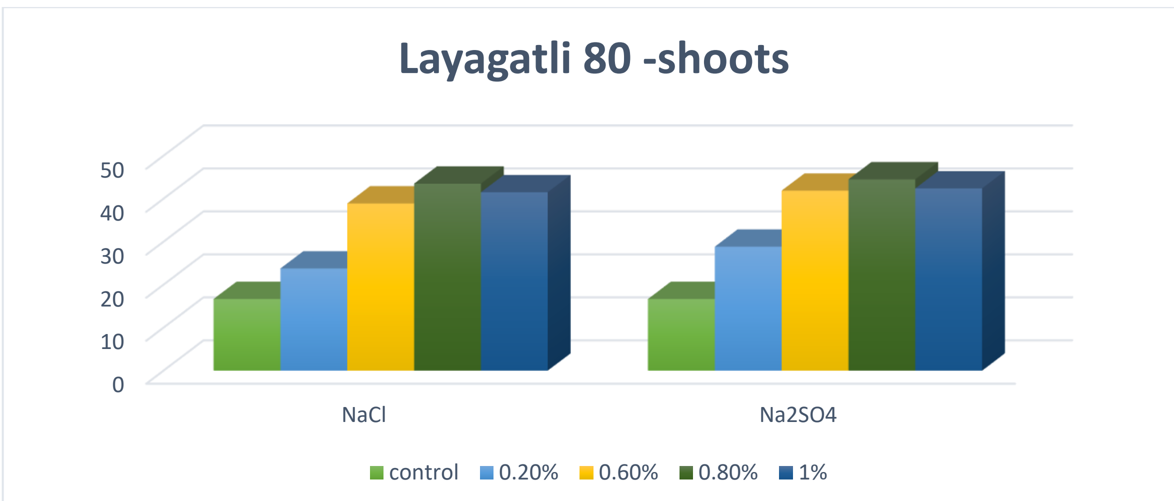

Figure 3. Effect of various NaCl and Na_2SO_4 concentrations on the amount of proline in the shoots of 10-day-old seedlings of the "Layagatli 80" variety grown in a soil culture.

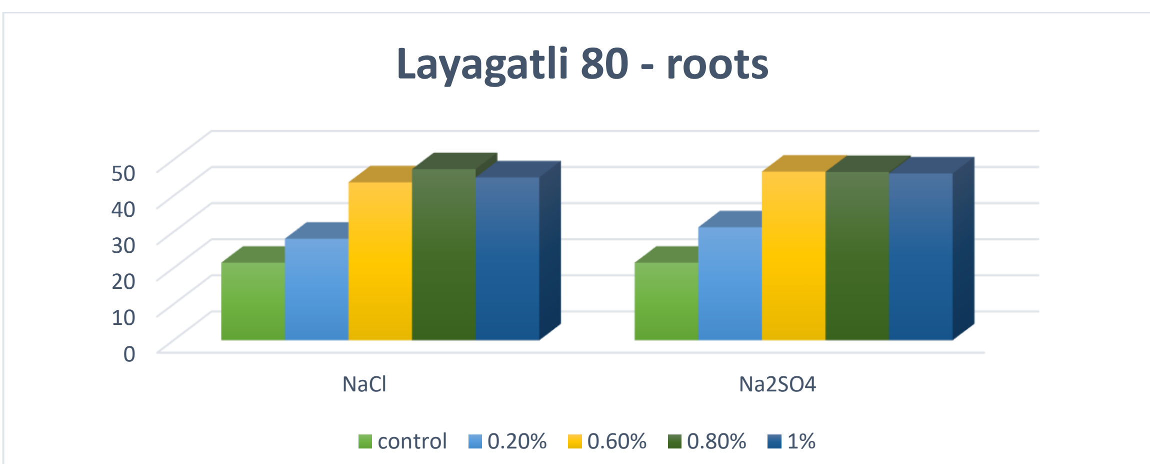

Figure 4. Effect of various NaCl and Na_2SO_4 concentrations on the amount of proline in the roots of 10-day-old seedlings of the "Layagatli 80" variety grown in a soil culture.

It should be noted that under the influence of 0.6% NaCl, the proline content in the shoots increased by 2.3 times and in the roots by 2.0 times. In response to 0.6% Na_2SO_4, the proline content rose by 2.5 times in the shoots and 2.1 times in the roots.

Although a decrease in proline content was observed in the roots and shoots of "Layagatli 80" wheat seedlings grown in soil culture with increasing salt concentration (1.0%), the levels still remained significantly above the control. Specifically, under the influence of 1.0% NaCl, the proline content in the shoots increased approximately 2.4 times, and under 1.0% Na_2SO_4, by 2.5 times. In the roots, proline levels increased 2.0 times with NaCl and 2.1 times with Na_2SO_4.

The research revealed that in wheat seedlings grown in soil culture, the proline content increased more significantly under the influence of salts compared to plants grown in hydroponic culture.

It should be noted that at all salt concentrations, the proline content in the seedlings of the "Layagatli 80" variety was found to be higher compared to the "Gobustan" variety. This suggests that proline accumulation may serve as one of the indicators of salt tolerance in plants.

Our findings are consistent with data reported in the literature. The increase in proline content under conditions of extreme salinity may be considered one of the key parameters for identifying salt-tolerant genotypes (Chondarzi, Pakniyat, 2021).

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