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Effect of exogenous application of an aqueous quercetin solution on the physiological properties of *Andropogon gerardi* plants

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Abstract: The issues related to the deepening problem of soil salinity constitute an important aspect of the protection of the natural environment globally. Therefore, new plant species and innovative solutions supporting the efficient cultivation of plants on saline lands are sought. The research aimed to assess the effect of a quercetin water dilution used in various concentrations on the photosynthetic apparatus performance of *Andropogon gerardi* plants grown under salt stress. The foliar application of the aqueous quercetin solution significantly changed the relative chlorophyll content in the green part of leaves, the chlorophyll fluorescence parameters, and the gas exchange parameters.

Keywords: *Andropogon gerardi*; salt stress; quercetin; gas exchange; chlorophyll content; chlorophyll fluorescence

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1. Introduction

Due to the need to reduce greenhouse gas emissions, with particular emphasis on CO_2, plants produced for special energy purposes are increasingly important in the share of renewable biomass energy, and renewable fuels obtained from biomass can reduce our dependence on fossil fuel resources and reduce greenhouse gas emissions [1]. Big bluestem (*Andropogon gerardi*) is a perennial prairie grass with C_4 photosynthesis type. Big bluestem biomass is intended for direct combustion or processing into briquettes or pellets. It is also a valuable raw material suitable for fermentation and biogas production [2]. Energy crops should be characterized by efficient conversion of solar radiation energy into biomass, as well as a high dry matter content. Therefore, lignocellulosic biomass, including special energy crops such as big bluestem, can effectively supplement the production of biofuels because they require low production inputs and less competition with food production [3]. In addition, plantations of energy crops allow the management of areas excluded from typical agricultural production: wasteland, marginal land, or land degraded by salinity, which is one of the main threats to agricultural productivity [4,5]. It affects metabolic processes in plants, and their level of tolerance and the accommodation to stress varies depending on the species and cultivar. Crops treated by stress factors react by starting up their defense systems. Any visible symptoms are not observed on the first levels of stress, but the physiology of these plants may change significantly [6,7,8,9]. Genetic self-defense ability is not sufficient to protect plants at a sufficient level. Therefore, for protection and stimulation, various chemical compounds are used more and more often. Quercetin (Q) is one of the flavonoids found in plants in the form of glycosides. One of their most important function is to ensure communication with the environment and save plants from photosynthetic stress ROS, which can damage cell DNA, by protecting antioxidant activity [10, 11, 12]. There is little information about the use of Q in plant production, therefore an attempt was made to determine whether it can act as a biostimulator and positively affect the physiological characteristics and growth of plants, including energy plants. This study aimed to evaluate the result of the water solution of Q used in various concentrations (1%, 3%, and 5%) on the efficiency of the big bluestem photosynthetic apparatus cultivated under salt stress. The research hypothesis assumes that Q can be successfully used as a biostimulant and positively influence plant growth. Foliar spraying Q had a positive effect on the physiological parameters of big bluestem plants grown under salt stress and did not adversely affect the plant status while allowing for a higher yield of green mass, which could be used for energy purposes.

2. 4. Materials and Methods

The experiment was performed in vase experiments laboratory at the University of Rzeszów (Poland). Big bluestem seeds were sown in pots with a diameter of 15 cm, in a clay-sand particle size composition soil with a light-acidic pH (pH: 1M KCI=6.35; H_2O=6.52). The experiments were conducted in growth chambers (Model GC-300/1000, JEIO Tech Co., Ltd., Seoul, South Korea) at a temperature of 23±2° C, humidity 60±3% RH, photoperiod 16/8 h (L/ D), and the maximum light intensity of about 300 $\mu mol \cdot m^{-2} \cdot s^{-1}$. The substrate humidity was set as the substrate humidity level was set as 60% of the field water capacity. The experiment was carried out in four replications - 10 pots per variant (n=80), the positions of the pots in the experiment were randomized every 5 days. After emergence, the density of the experiment was set at 3 plants in one pot. In the two-leaf phase, the plants were watered with a 220mM water dilution of sodium chloride (NaCl). Plants not treated with NaCl were used as controls. 20 and 27 days after emergence, the plants were sprayed with an aqueous solution of derivative Q at concentrations of 1.0%, 3.0%, and 5.0% at 50 ml per pot by completely covering the plant's surface. On the controls sample, deionized water was used in the same volume.

Measurements of physiological processes: the net photosynthetic rate (P_N), transpiration rate (E), stomatal conductivity (g_s) and intercellular CO_2 concentration (C_i)), the relative chlorophyll (CCI) content, and chlorophyll fluorescence (the maximum quantum yield of photosystem II (PSII) (F_v/F_m), the maximum quantum yield of primary photochemistry (F_v/F_0) and the photosynthesis yield index (PI)) were performed four times on the first or second fully developed leaves: on the next day and seven days after each treatment following the methodology presented by Migut et al. [13].

Statistical analysis was made using TIBCO Statistica 13 (TIBCO Software Inc., Palo Alto, CA, USA). A repeated-measures ANOVA (with time assessment as a factor) was then performed. Tukey's post hoc test was performed with the significance level $p \leq 0.05$ to determine and verify the relationship.

3. Results and Discussion

3.1. Gas Exchange Measurement

The first plants' response to abiotic stress is the closing of the stomata [14]. Antioxidants, including quercetin, belong to the group of organic compounds which, through osmotic regulation, may play an important role in alleviating stress related to environmental factors, like salinity [15,16], and have a positive impact on the gas exchange process. In this research, it was found that the highest concentration of Q used (5%) had the most favorable effect on P_N, E, and g_s. Smaller differences in the values of the analyzed parameters were observed with the passage of time. The strongest plants response to the spraying application of Q was observed in the first and second measurement periods. A lower increase in the analyzed parameters was observed after the next application of Q. It may suggest that the first dose of the derivative has a strong stimulatory effect, and the subsequent dose may support the beneficial Q effect. The increase in g_s, seen by the quercetin derivative, lowered the intracellular CO_2 accumulation in the mesophyll and caused a reduction in C_i values. This phenomenon was associated with an increase in P_N intensity; therefore, it seems warranted to determine a single dose of quercetin in the environmental stress presence. The concentration of C_i increases with longer exposure to stress factors, which indicates a reduction in the ability to bind CO_2 in the Calvin-Benson cycle, and thus a significant reduction in photosynthesis efficiency may indicate degradation of the photosynthetic apparatus [17].

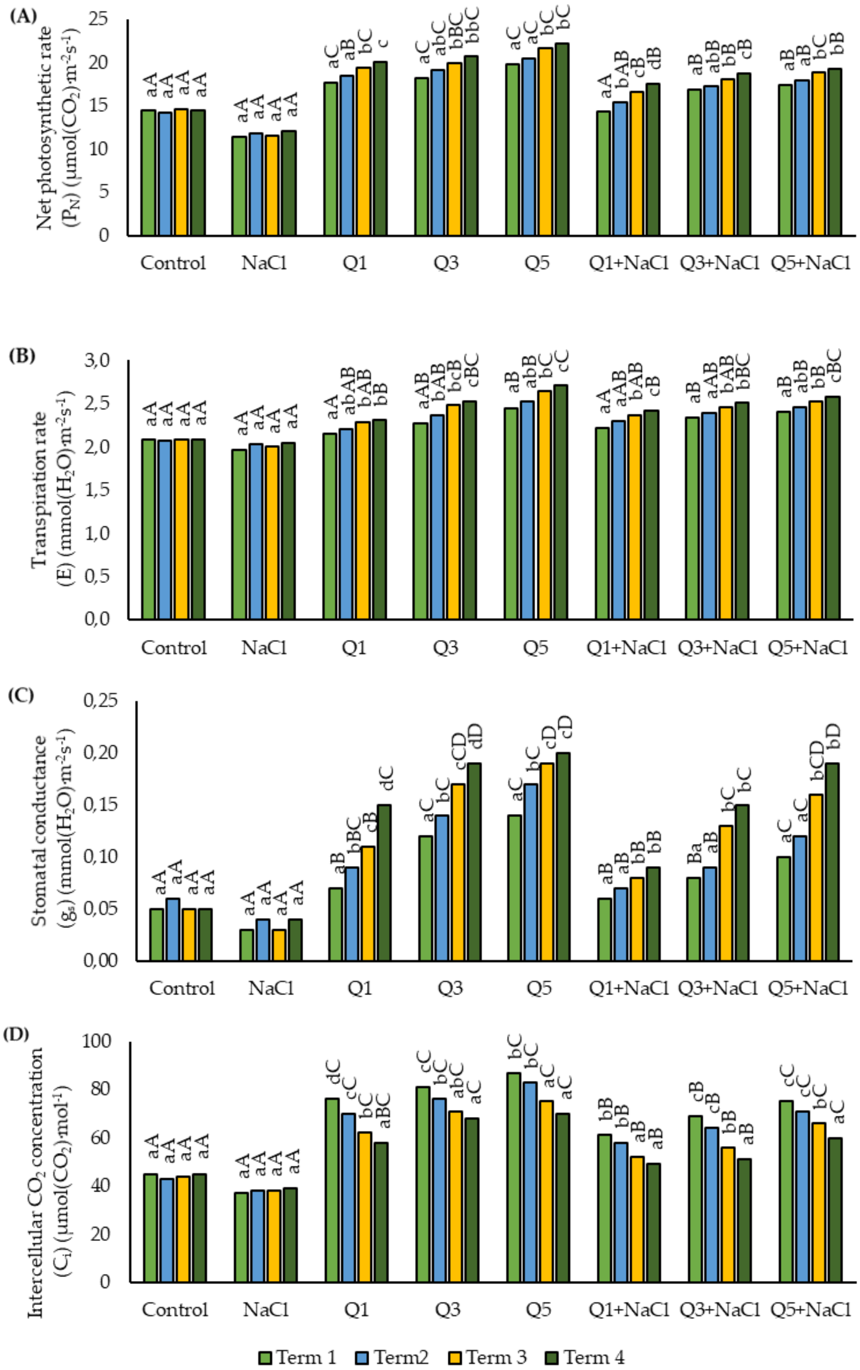

Figure 1. Effect of different aqueous concentrations of Q on big bluestem gas exchange parameters: (A) P_N, (B) E, (C) g_s, (D) C_i. Lowercase: significant differences between the averages of the respective

measurement times; Capital letters: Significant differences between the averages of the measurement dates for the concentrations (p <0.05).

3.2. Chlorophyll Fluorescence

Photosynthesis is related to all plant cell metabolic and physiological processes, and environmental changes modifying them will have an impact on the photosynthetic process. Nutrient deficiency and abiotic stresses occurring during plant vegetation directly affect the photosynthetic apparatus [18, 19]. The parameters of chlorophyll fluorescence in big bluestem plants were stimulated by the foliar application of the aqueous solution of Q. The increase in the value of these parameters was related to the increasing concentration of Q and the duration of the experiment.

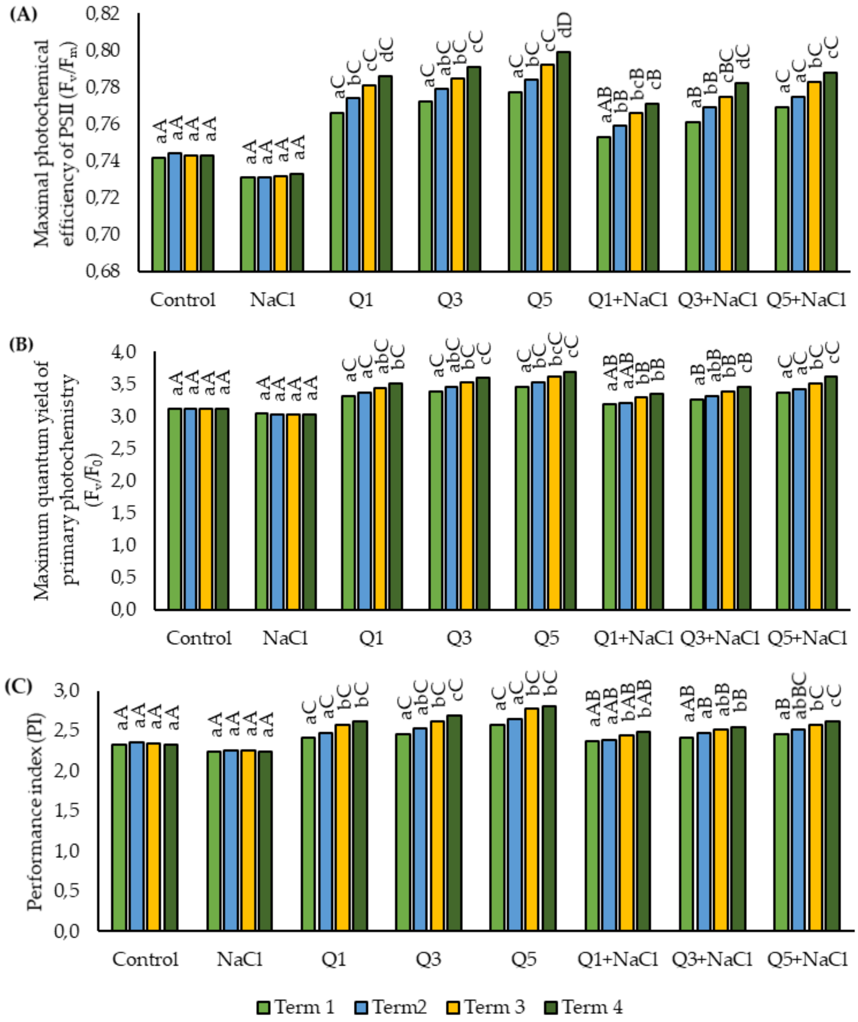

Figure 2. Effect of different aqueous concentrations of Q on Chl fluorescence parameters in the big bluestem leaves (A) F_v/F_m, (B) F_v/F_0, (C) PI. Lowercase: significant differences between the averages of the respective measurement times; Capital letters: Significant differences between the averages of the measurement dates for the concentrations (p <0.05).

3.3. Relative Chlorophyll Content

Chlorophyll, reflecting the health condition of plants is one of the most important biochemical features connected with the availability of water and the level of plant nutrition [20,21]. Reduction of it is content in plants subjected to abiotic stress may result from the breakdown of thylakoid membranes, which is more degraded than the synthesis of chlorophyll through the formation of proteolytic enzymes. The use of an aqueous solution of Q positively influenced the growth of the relative content of Chl in big bluestem leaves.

Aqueous Q solution can stimulate and improve plant tolerance to abiotic stresses by strengthening antioxidant enzymes and preserving photosynthetic activity, as well as preventing membrane peroxidation or strengthening the plant's defense system against oxidative damage.

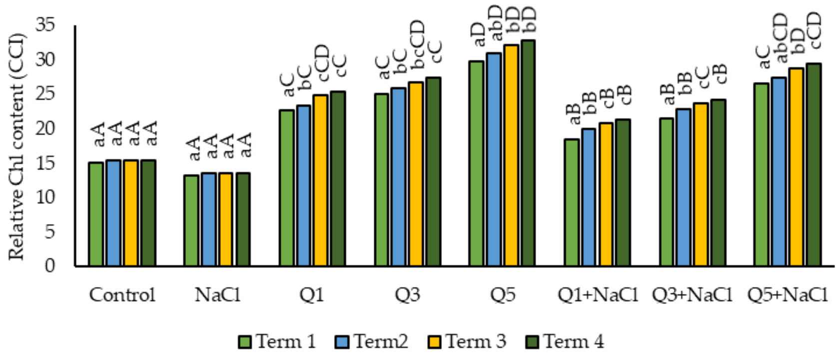

Figure 3. Effect of different aqueous concentrations Q on CCI in big bluestem leaves. Lowercase: significant differences between the averages of the respective measurement times; Capital letters: Significant differences between the averages of the measurement dates for the concentrations ($p < 0.05$).

4. Conclusions

An aqueous solution of Q used in the presented experiment positively affected the physiological properties of big bluestem plants and at the same time, no deterioration of their condition was observed. The most stimulating effect on the course of physiological processes had the 3% and 5% solutions. There was an increase in P_N, E, g_s, CCI, F_v/F_m, F_v/F_0, and PI values and a decrease in C_i values. The conducted research may contribute to increasing the yield of the above-ground mass of big bluestem plants, and thus increasing the profitability of establishing and running a plantation. In addition, these results can be used as a prime study for developing a strategy to reduce the negative impact of abiotic stresses on the productivity of agriculture, including crops intended for energy purposes. Foliar application of Q can be used as an effective and environmentally friendly way of limiting soil salinity impact on crops and initiating the development of resistance of big bluestem plants to stress, and lead to an increase in the potential and stability of its yield.

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