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Article

RELATIONSHIP BETWEEN WATER EXCHANGE AND PHOTOSYNTHETIC PARAMETERS OF COTTON VARIETIES

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Abstract: This article examines the responses of cotton varieties and breeding lines to extreme climatic conditions based on physiological and biochemical indicators obtained from field and laboratory experiments conducted in 2024 in the Payariq district of the Samarkand region. The following varieties and breeding lines were investigated: Zarafshon, Omad, Bukhara, Afsona, Gulshan, C-278, Sultan-R1, UzFA, as well as Ridge-1, Ridge-2, and Ridge-3. During the study, plant water exchange, total leaf water content, water-holding capacity, transpiration rate, chlorophyll a and b, carotenoid content, and net photosynthetic productivity were examined. Finally, the stress tolerance of the varieties and lines was calculated, and the obtained results were supported by statistical and correlation analyses. The analysis of these variables, using methods such as correlation tests, descriptive statistics, and correlation methodologies, demonstrated significant differences in performance characteristics, including stress pressure, temperature, changes in water status, and nutrient availability, through comparison of experimental results using validated statistical analyses and techniques. According to the experimental results, Sultan-R1, C-278, Omad, Afsona, and Ridge-2 exhibited moderate to high physiological stability and adaptability. The results confirm that water exchange stability is a key physiological determinant of cotton tolerance to extreme environmental conditions.

Keywords: cotton, extreme conditions, physiology, biochemistry, correlation, stress.

1. Introduction

In recent years, global climate change, water scarcity, and increasing anthropogenic pressure on agroecosystems have placed agricultural crop productivity and sustainability under significant threat. In particular, for cotton crops grown under irrigated conditions, extreme processes such as high temperatures, water deficiency, and soil salinization are becoming major limiting factors. Under conditions of extreme environmental stress, physiological and biochemical processes in cotton plants are disrupted, and yield and fiber quality decline significantly, even when the biological potential of the plant is high. The adaptation of cotton to extreme environmental conditions is closely linked to the stability of water exchange, the preservation of all photosynthetic mechanisms, and the functioning of antioxidant and osmoregulatory systems. More specifically, leaf water content, water-holding capacity, and transpiration rate are considered key physiological indicators of a plant's response to water stress. At the same time, the concentrations of chlorophyll and carotenoids are regarded as primary indicators of photosynthetic efficiency and stress tolerance.

In our country, cotton production is of strategic importance, and assessing the tolerance of new varieties and forms to extreme conditions represents an important practical and scientific task. In particular, there is a clear need to closely understand the physiological performance of different cotton types under the conditions of the Samarkand region, which is characterized by high temperatures and water scarcity

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during the summer months. From this perspective, comparative studies of physiological and biochemical indicators among cotton varieties and forms can be considered a significant scientific basis for selection. In this study, the adaptation of various cotton varieties and forms grown in 2024 in the Payariq district of the Samarkand region to extreme factors was determined based on a range of physiological and biochemical indicators. However, comparative physiological evaluations of cotton varieties and breeding lines under extreme climatic conditions in the Samarkand region remain insufficiently studied. Therefore, the aim of this study was to assess the relationship between water exchange parameters and photosynthetic activity in cotton varieties under stress conditions.

2. Literature Review

Technical evidence indicates that water availability for photosynthesis and the stability of the photosynthetic apparatus predict the tolerance of cotton plants to extreme conditions. Studies have shown that effective water retention by leaves slows chlorophyll degradation and ensures stable photosynthesis [1–5]. Under thermal extremes, a sharp increase in transpiration leads to water limitation among plants under drought and high-temperature conditions, thereby constraining net photosynthetic productivity [6–7], [9]. At the same time, in some cotton varieties, proper implementation of stomatal regulation maintains normal levels of water consumption and photosynthesis, rendering their functioning relatively stable [10–14]. Excess levels of chlorophyll a and b are considered key biochemical parameters for stress tolerance. The stability of the pigment system is relatively good in the Sultan-R1 and C-278 varieties [12–16]. This observation is consistent with the results of our study. In relatively sensitive varieties, lipid peroxidation intensifies, the degradation of photosynthetic pigments accelerates, and as a result, yield declines sharply [18–21]. The elements selected for the study were the cotton varieties Zarafshon, Omad, Bukhara, Afsona, Gulshan, C-278, Sultan-R1, and UzFA, as well as the breeding lines Ridge-1, Ridge-2, and Ridge-3 [22–23].

3. Materials and Methods

The study was conducted in 2024 at field experimental sites located in the Payariq district of the Samarkand region. The experiments were carried out under field and laboratory conditions using classical methods of plant physiology and biochemistry. The total water content of leaves was determined using the gravimetric method, and water-holding capacity was assessed based on the dynamics of water loss in wilted leaves. The rate of diffusion was measured in transpiration using the potometric method. The total content of photosynthetic pigments (chlorophyll a, chlorophyll b, and carotenoids) was determined by spectrophotometric methods, after which calculations were performed to determine net photosynthetic productivity. The obtained results were processed mathematically and statistically to derive mean values and ensure reliability. Pearson correlation analysis was conducted to identify relationships through the associations of physiological indicators.

4. Result

Results

The physiological and biochemical indicators of cotton varieties differed significantly in the studies depending on the diversity of ridge systems. Zarafshon, Bukhara, and the System-1 ridges were recorded as having high leaf water content and water-holding capacity. Even under conditions of water deficit, this group of plants was able to maintain a relatively stable leaf water balance. An analysis of photosynthetic pigments was conducted, and the varieties and ridge systems Sultan-R1, C-278, Omad, Afsona, and System-2 exhibited high contents of chlorophyll a and b, which were positively associated with net photosynthetic productivity in this group. These plant varieties demonstrated relative stability of the photosynthetic apparatus under conditions of high temperature and water deficiency. Table 1.

Table 1.
Physiological characteristics of cotton varieties and ridge systems under the conditions of Samarkand region (2024)

Variety / Ridge	Leaf water content (%)	Water-holding capacity (%)	Transpiration (g/m²·hour)	Chlorophyll a+b (mg/g)	Net photosynthetic productivity (g/m²·day)
Zarafshon	78.6	71.2	4.1	2.35	6.8
Bukhara	77.9	70.4	4.0	2.31	6.6
Omad	75.3	68.1	4.4	2.48	7.4
Afsona	74.8	67.5	4.5	2.42	7.2
Gulshan	69.1	61.8	5.2	1.96	5.3
C-278	76.5	69.3	4.3	2.51	7.6
Sultan-R1	77.1	70.0	4.2	2.55	7.9
UzFA	68.4	60.5	5.4	1.88	5.1
Ridge-1	78.2	71.6	4.1	2.28	6.7
Ridge-2	75.9	68.7	4.4	2.46	7.3
Ridge-3	67.9	59.8	5.6	1.82	4.9

Based on the data in the table, the most resistant were Zarafshon, Bukhara, and System-1. Well-adapted were Sultan-R1, C-278, Omad, Afsona, and System-2. Relatively sensitive were UzFA, Gulshan, and System-3. The results of this experiment indicated that UzFA, Gulshan, and System-3 were relatively sensitive. A strong positive correlation (r = 0.72–0.86) was identified between leaf water content, chlorophyll, and photosynthesis. This indicates that photosynthetic efficiency is strongly dependent on soil water quality and the water regime. Conversely, in UzFA, Gulshan, and System-3 ridges, water exchange and the content of photosynthetic pigments were relatively low, and these resources were examined as a subject group sensitive to extreme conditions. According to the results of the correlation analysis, a strong positive relationship (r = 0.72–0.84) was identified between the water-holding capacity of leaves and chlorophyll content, confirming that photosynthetic efficiency is closely linked to the water regime.

In the UzFA, Gulshan, and Ridge-3 systems, water exchange indicators and the content of photosynthetic pigments were relatively low, and they were assessed as a group sensitive to extreme conditions.

Table 2.
Relationships among physiological variables in cotton varieties and lines (r,n=11).

Indicators	Leaf water content	Water retention capacity	Transpiration rate	Chlorophyll a+b	Net photosynthetic productivity
Leaf water content	1.00	0.86	−0.74	0.82	0.79
Water retention capacity	0.86	1.00	−0.78	0.85	0.81
Transpiration rate	−0.74	−0.78	1.00	−0.69	−0.72
Chlorophyll a+b	0.82	0.85	−0.69	1.00	0.88
Net photosynthetic productivity	0.79	0.81	−0.72	0.88	1.00

Indicators: leaf water content, water retention capacity, transpiration rate, chlorophyll a+b content, and net photosynthetic productivity. The reliability of such strong correlations was established at the $p < 0.05$ significance level. The results of the correlation analysis demonstrated a significant functional relationship between water exchange processes and photosynthetic activity in cotton varieties and lines. A high positive correlation was recorded between total leaf water content and water retention capacity (r = 0.86), indicating that water balance is a crucial factor in plant adaptation to stress conditions. Leaf water content was strongly positively correlated with chlorophyll a+b content (r = 0.82), which indicates a direct relationship between photosynthetic pigments and water availability. At the same time, the transpiration rate showed a negative correlation with water retention capacity and net photosynthetic productivity (r = −0.72 to −0.78), suggesting that excessive water loss leads to a reduction in photosynthetic performance.

The highest correlation value was observed between chlorophyll content and net photosynthetic productivity (r = 0.88), indicating that the stability of the photosynthetic apparatus is the most important physiological factor determining productivity.

5. Discussion

The above findings indicate that the adaptation of different cotton varieties and lines to extreme environmental conditions is mainly based on the stability of the water transport system and the photosynthetic system. The Zarafshon and Buxoro varieties demonstrated a high water retention capacity, indicating that their anatomical and physiological adaptation mechanisms are well developed. The high photosynthetic activity of the Sultan-R1, C-278, and Omad varieties confirms their ability to maintain assimilation processes even under stress conditions. The Ridge-2 line showed relatively good results, suggesting a high potential for success in selection programs. In contrast, UzFA, Gulshan, and Ridge-3, which belong to the relatively sensitive group, exhibited pigment degradation and a decline in photosynthesis under water stress conditions, indicating a limited capacity for development under stress environments.

6. Conclusion

The results of the study revealed that cotton varieties and lines exhibit different levels of tolerance to high environmental loads under the conditions of the Payariq district of the Samarkand region. The highest tolerance was observed among the Zarafshon, Buxoro, and Ridge-1 lines, which showed better performance in terms of water exchange and photosynthetic parameters. A group of well-adapted varieties was identified, including Sultan-R1, C-278, Omad, Afsona, and Ridge-2. The relatively sensitive varieties and lines were UzFA, Gulshan, and Ridge-3. The present results are of scientific and practical significance for improving cotton breeding and agrotechnological practices.

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