EURASIAN JOURNAL OF ACADEMIC RESEARCH
Innovative Academy Research Support Center
IF = 7.899 www.in-academy.uz

THE EFFECT OF ABIOTIC STRESSES ON PLANT PRODUCTIVITY TRAITS IN PIMA COTTON GENOTYPES

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https://doi.org/10.5281/zenodo.15210299

ARTICLE INFO

Received: 08th April 2025
Accepted: 13th April 2025
Online: 14th April 2025

KEYWORDS

Gossypium barbadense L., productivity, drought, genotyp, ANOVA, breeding.

ABSTRACT

The study evaluated the productivity of Gossypium barbadense L. genotypes under drought and salinity. ANOVA was used to analyze yield parameters of 10 genotypes under optimal, water-deficient, and saline conditions. Genotypes T-479 (23.01 g) and T-2090 (21.72 g) showed high drought tolerance, while Duru-gavhar-4 (15.98 g) and T-2024 (15.54 g) exhibited salinity resilience. Environmental factors accounted for 79% of yield variability. Stress-tolerant genotypes are recommended for breeding programs to develop adaptive cotton varieties.

Introduction

Pima cotton (*Gossypium barbadense* L.) holds a significant position in global agriculture due to its high-quality fiber and considerable economic value (Shavkiev et al., 2022; Chorshanbiev et al., 2023; Narimanov et al., 2023; Azimov et al., 2024). In regions like Uzbekistan, where abiotic stress factors such as drought and salinity are widespread, enhancing the productivity and ensuring yield stability of this crop remains a key objective in the fields of genetics and plant breeding (Shukhrat et al., 2021; Chorshanbiev et al., 2022; Azimov et al., 2023). In recent years, studying plant adaptability to stress conditions has become increasingly relevant due to climate change and increasing scarcity of water resources. In particular, identifying genotypes with tolerance to adverse conditions such as drought and salinity, and evaluating their yield potential, serves as a crucial foundation for the development of stress-resistant cultivars in the future. In this study, the yield performance of fine-fibered *Gossypium barbadense* L. genotypes was evaluated under optimal, water-deficit, and saline conditions (Nabiev et al., 2020; Makamov et al., 2022a, 2022b; Matniyazova, 2022). The primary objective of the research was to assess the genotypes' tolerance to abiotic stress factors, compare their yield potential, and identify genotypes adapted to drought and salinity. The results not only reveal the role of genetic diversity and environmental influence on plant productivity but also provide practical recommendations for future breeding of cotton cultivars tolerant to adverse environmental conditions.

Literature Review

Stress tolerance indices are widely used to assess genotype performance under water-deficient and saline conditions. Fernandez (1992) proposed effective selection criteria for breeding under stress conditions, emphasizing the importance of distinguishing between yield potential under optimal conditions and stability under stress. Rosielle and Hamblin (1981) developed the theoretical framework for selecting genotypes based on yield differences in both stressed and non-stressed environments—an approach that has been successfully applied in cotton research (Singh et al., 2016; Yehia, 2020).

Studies on cotton (*Gossypium spp.*) have explored drought and salinity tolerance concerning yield traits and fiber quality. Singh et al. (2016) evaluated *G. hirsutum* genotypes under drought conditions using stress indices and found significant genetic diversity in yield components such as boll number and boll weight. Yehia (2020, 2022) assessed Egyptian fine-fiber cotton (*G. barbadense*) genotypes under water-deficit conditions using the Stress Tolerance Index (STI) and Principal Component Analysis (PCA), identifying genotypes with high drought tolerance. Shilpa et al. (2020) highlighted the relationship between fiber quality and yield under drought stress, underscoring the necessity of multi-trait selection in cotton breeding programs.

Statistical methods such as analysis of variance (ANOVA), PCA, and correlation analysis have enhanced the reliability of stress tolerance studies. Yehia (2022) proposed a comprehensive evaluation approach that combines PCA and stress tolerance indices for cotton genotypes. However, the literature tends to focus more on single-stress studies (e.g., only drought or only salinity), with fewer investigations on their combined effects. Moreover, while *G. hirsutum* has been extensively studied, there is a lack of data on the physiological responses of *G. barbadense* genotypes under salinity stress.

This study aims to fill these gaps by evaluating the yield performance of *G. barbadense* genotypes under both water-deficit and saline conditions using statistical analyses such as ANOVA. This integrative approach provides a comprehensive understanding of stress tolerance and facilitates the identification of genotypes suitable for drought- and salinity-prone environments.

Materials and Methods

This study was conducted under lysimetric conditions using different water regime treatments. The first treatment (well-watered control) involved optimal irrigation, with a total water application of 4800–5000 m^3/ha. The second treatment simulated drought stress, with a total irrigation volume of 2800–3000 m^3/ha (Shavkiev et al., 2019; Shavkiev et al., 2021; Makamov et al., 2023). Salinity stress conditions were modeled using moderately saline soil collected from the Syrdarya region, applied in lysimeter settings. All other agrotechnical practices were kept uniform across the different treatments.

Yield-related traits of *Gossypium barbadense* L. genotypes were evaluated under both optimal and stress-induced (drought and salinity) conditions. The plant material consisted of breeding lines and cultivars developed by researchers at the Institute of Genetics and Experimental Biology of Plants, Academy of Sciences of Uzbekistan. Data were collected from plants grown in lysimeter conditions.

To determine the significance of environmental effects and genotypic differences, the collected data were analyzed using multifactor analysis of variance (ANOVA). The significance level was set at $P < 0.05$.

Results

Under optimal conditions, plant yield varied among genotypes, ranging from 24.60 g to 41.57 g, demonstrating a high yield potential. The highest yield was recorded in the "T-2025" genotype (41.57±1.57 g), confirming its excellent growth and yield potential when fully supplied with water and nutrients. The lowest yield was observed in the "T-2090" genotype (24.60±0.87 g), indicating its stable but relatively low productivity. Among other genotypes, "T-479" (36.96±0.86 g) and "T-5570" (37.37±1.63 g) also showed high yields. Overall, most genotypes exhibited a moderate, stable yield ranging from 25 g to 37 g.

Under water-deficit conditions, yield significantly decreased, varying between 14.41 g and 23.01 g. The highest yield under drought stress was recorded in the "T-479" genotype (23.01±1.54 g), indicating its high tolerance to water stress, with minimal difference compared to its optimal yield (36.96 g). The lowest yield was observed in the "T-2024" genotype (14.41±1.13 g), showing a significant reduction (over 11 g) from its optimal yield (25.64 g), indicating its low adaptability to drought stress. Meanwhile, the "T-2090" (21.72±0.59 g) and "Duru-gavhar-4" (17.98±1.80 g) genotypes performed relatively better under drought conditions, with "T-2090" maintaining stability with low standard deviation. As a general trend, water-deficit conditions reduced yield by an average of 10–15 g compared to optimal conditions, confirming the negative impact of this stress factor on productivity.

Table 1. Yield performance (g/plant) of pima cotton genotypes

Genotypes	Yield under Optimal Conditions (g/plant)		Yield under Water-Deficit Conditions (g/plant)		Yield under Salinity Conditions (g/plant)	
	X±SE	SD	X±SE	SD	X±SE	SD
Angor (T-1981)	31,19±1,38	2,40	16,27±1,62	2,80	11,15±0,53	0,92
T-479	36,96±0,86	1,49	23,01±1,54	2,66	11,02±0,70	1,22
T-2025	41,57±1,57	2,72	18,48±0,63	1,10	12,54±1,04	1,81
T-2024	25,64±1,07	1,85	14,41±1,13	1,95	15,54±0,79	1,36
T-5570	37,37±1,63	2,83	16,17±1,37	2,37	10,28±0,78	1,36
T-481	24,71±1,35	2,33	15,61±1,32	2,29	14,28±0,40	0,69
T-563	27,44±0,83	1,43	16,92±0,94	1,62	14,42±0,47	0,81
Bo'ston (T-663)	28,97±0,87	1,50	17,89±0,69	1,20	14,93±1,05	1,81
Duru-gavhar-4	28,81±1,32	2,28	17,98±1,80	3,13	15,98±0,59	1,02
T-2090	24,60±0,87	1,50	21,72±0,59	1,02	13,51±0,61	1,06

Under salinity stress conditions, yield further decreased, ranging from 10.28 g to 15.98 g. The highest yield was recorded in the "Duru-gavhar-4" genotype (15.98±0.59 g), indicating its high adaptability to salinity stress, with a smaller reduction (13 g) compared to its optimal yield (28.81 g). The lowest yield was observed in the "T-5570" genotype (10.28±0.78 g, SD = 1.36), which showed a sharp decline of approximately 27 g from its optimal yield (37.37 g), confirming its low tolerance to salinity stress. Among other genotypes, "T-2024" (15.54±0.79 g) and "Bo'ston (T-663)" (14.93±1.05 g) showed relatively stable performance under salinity, indicating their moderate adaptability to stress conditions. Overall, salinity stress reduced yield by an average of 10–25 g compared to optimal conditions, but genotypes like "Duru-gavhar-4" and "T-2024" maintained stability.

A multifactorial ANOVA analysis was conducted to determine the effect of genotype and environment on plant yield traits. The differences in yield traits among genotypes were statistically insignificant (P-Value = 0.7176 > 0.05), with an F-Ratio value of 0.68. This indicates that the genotypes studied in the experiment ("T-2025", "T-479", "Duru-gavhar-4", etc.) are genetically similar in terms of yield, and the observed differences between them are more related to external environmental factors than genetic influences.

On the other hand, the environmental effect was statistically highly significant (P-Value = 0.0001 < 0.05), with an F-Ratio value of 46.69, showing a strong impact of environmental conditions (optimal, water-deficit, and salinity) on yield performance. For instance, the "T-2025" genotype yielded 41.57 g under optimal conditions, but this dropped to 12.54 g under salinity stress, highlighting the significant role of the environment in trait variability.

The interaction between genotypes and environment was also significant (SS = 313.17, MS = 17.3981). These values indicate that different genotypes responded differently to environmental conditions. For example, the "T-2024" genotype had a yield of 25.64 g under optimal conditions, but it dropped to 15.54 g under salinity, yet it maintained stability compared to other genotypes. In contrast, "T-5570" showed a sharp decrease from 37.37 g under optimal conditions to 10.28 g under salinity, indicating low adaptability to stress. Additionally, "T-2090" genotype showed strong performance with 21.72 g under water-deficit stress, indicating its good adaptability to such conditions.

In terms of total variation (Total SS = 2044.19), the environmental effect (SS = 1624.59) accounted for approximately 79% of the total variation, while the effect of genotype (SS = 106.43) and the interaction (SS = 313.17) contributed to a smaller proportion.

Table 2. Multifactorial ANOVA analysis of the effects of genotype and environment (optimal, water deficit, salinity) on plant yield traits

Source of Variation	Sum of Squares (SS)	Mean Square (MS)	F-Ratio	P-Value
Genotype	106.43	53.215	0.68	0.7176
Environment	1624.59	540.353	46.69	0.0001
Genotype × Environment	313.17	17.3981	-	-
Total	2044.19	-	-	-

Analysis of plant productivity shows that, under optimal conditions, the genotypes have high productivity (24.60–41.57 g), with genotypes such as “T-2025” and “T-479” showing the best results in these conditions. While water scarcity reduced productivity by an average of 10–15 g, genotypes like “T-479” (23.01 g) and “T-2090” (21.72 g) demonstrated tolerance to this stress. Under salinity conditions, productivity further decreased (10.28–15.98 g), but genotypes “Duru-gavhar-4” (15.98 g) and “T-2024” (15.54 g) maintained stability. ANOVA analysis confirmed that the primary reason for the differences in productivity is the environment, not the genotypes (P-Value = 0.0001). Although the genotypes have similar characteristics, their adaptability to the environment was different.

Conclusion

From a selection perspective, genotypes that showed high performance under stress conditions are particularly noteworthy. For drought tolerance, the genotypes “T-2090” and “T-479” are recommended, while for salinity adaptability, “Duru-gavhar-4” and “T-2024” are suggested. Since these genotypes have maintained relatively high productivity under stress conditions, they could serve as an important source for developing drought and salinity-tolerant varieties in the future.

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