

THE IMPACT OF ABIOTIC STRESSES ON YIELD TRAITS OF *G. BARBADENSE* L. COTTON GENOTYPES

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<https://doi.org/10.5281/zenodo.15242653>

Abstract. *Gossypium barbadense* L., valued for its superior fiber quality, faces significant yield challenges under abiotic stresses such as water deficiency and salinity, particularly in arid and saline-prone regions. This study evaluated the impact of these stresses on the yield traits—number of opened bolls, total number of bolls, and seed cotton weight per boll—of ten *G. Barbadense* L. genotypes under controlled optimal, water-deficient (2800–3000 m³/ha irrigation), and saline conditions using lysimeters. Results revealed that both stresses significantly reduced boll numbers, with environmental effects outweighing genotypic differences ($P < 0.0002$), while seed cotton weight per boll remained relatively stable ($P = 0.07$). Genotypes T-2024 and T-2090 exhibited notable resilience, with T-2024 maintaining higher boll counts under salinity and T-2090 excelling under water deficiency. These findings highlight genotypic variability in stress tolerance and underscore the potential of T-2024 and T-2090 for breeding programs aimed at enhancing yield stability in stress-prone environments. This research provides critical insights for developing stress-tolerant *G. Barbadense* varieties, supporting sustainable cotton production amid climate change challenges.

Keywords: abiotic stress, water deficiency, *Gossypium barbadense* L., salinity, yield traits, boll number, seed cotton weight, genotypic variability, stress tolerance, cotton breeding.

Introduction. *Gossypium barbadense* L., commonly known as extra-long staple cotton, is a globally significant crop prized for its superior fiber quality, which commands premium value in textile markets. Its cultivation, however, faces substantial challenges in regions characterized by arid climates and saline soils, where abiotic stresses such as water deficiency and soil salinity threaten yield stability. These environmental factors disrupt critical physiological processes, including boll formation and seed cotton development, ultimately reducing agricultural productivity. As demand for high-quality cotton persists, understanding how *G. Barbadense* L. genotypes respond to such stresses is essential for sustaining yields and supporting livelihoods in stress-prone areas. Previous studies have highlighted variability in stress tolerance among cotton genotypes, underscoring the need for targeted research into yield-specific traits.

This study focuses on evaluating the impact of water deficiency and salinity on the yield traits of *G. Barbadense* L. cotton genotypes, specifically the number of opened bolls, total number of bolls, and seed cotton weight per boll. These traits directly influence the economic output of cotton production and serve as key indicators of genotypic resilience under adverse conditions. By subjecting ten distinct genotypes to controlled optimal, water-deficient, and saline environments, we aim to quantify stress-induced changes and identify genotypes with superior adaptability. Such insights are critical for breeding programs aimed at developing stress-tolerant varieties, particularly in regions where abiotic stresses are intensifying due to climate change. This research

contributes to the broader goal of enhancing cotton productivity under challenging environmental conditions.

Abiotic stresses, particularly drought and salinity, are critical constraints to cotton productivity worldwide, necessitating the identification of tolerant genotypes to ensure yield stability. Research on stress tolerance has extensively utilized yield-based indices such as the Stress Tolerance Index (STI), Tolerance (TOL), Mean Productivity (MP), and Geometric Mean Productivity (GMP) to evaluate genotypic performance under adverse conditions (Fernandez, 1992; Rosielle & Hamblin, 1981).

In cotton, these indices have proven effective in assessing yield traits like boll number and seed cotton weight. For instance, Singh et al. (2016) applied tolerance indices to upland cotton (*G. hirsutum*) under drought, revealing significant genotypic variation in yield components. Similarly, Yehia (2020, 2022) evaluated *G. Barbadense* L. genotypes under water deficit, identifying STI and GMP as reliable indicators of yield stability. These studies underscore the importance of yield-focused metrics in cotton breeding programs targeting stress-prone environments.

While *G. hirsutum* has been widely studied, research on *G. Barbadense* L.—valued for its fine fiber—remains limited, especially under combined drought and salinity stresses. Yehia (2020) demonstrated that Egyptian *G. Barbadense* genotypes exhibit variable drought tolerance, with boll number and weight serving as key yield traits for selection. Shilpa et al. (2020) further highlighted the interplay between yield and fiber quality under drought, emphasizing multi-trait evaluation.

Statistical tools like Principal Component Analysis (PCA) and Analysis of Variance (ANOVA) have enhanced these assessments, as shown in Yehia (2022), where PCA complemented tolerance indices to rank genotypes effectively. However, the literature reveals a gap in studies addressing *G. Barbadense* under salinity or combined stresses, with less focus on integrating yield indices with physiological markers. This study builds on prior work by examining yield traits under both stresses, aiming to bridge these gaps and support breeding for resilient *G. Barbadense* genotypes.

Materials and Methods. This study was conducted using lysimeters under varying water regimes and salinity conditions to evaluate the yield traits of *G. Barbadense* L. cotton genotypes. Two water regimes were established: the first background (optimal water supply) involved a total irrigation volume of 4800–5000 m³/ha, while the second background (simulated drought) utilized a reduced irrigation volume of 2800–3000 m³/ha.

Salinity conditions were created in lysimeters using moderately saline soil sourced from the Syrdarya region, replicating typical field salinity levels. All other agronomic practices, including fertilization and pest management, were kept uniform across both water regimes and salinity treatments to ensure consistency. The experiments assessed yield traits under optimal, drought, and saline conditions.

The experimental material comprised ten *G. Barbadense* L. genotypes developed by researchers at the Institute of Genetics and Plant Experimental Biology. These included lines and varieties selected for their potential resilience to abiotic stresses.

Yield traits evaluated were the number of opened bolls, total number of bolls, and seed cotton weight per boll. Data were collected from plants grown in lysimeters under controlled conditions. Statistical analysis was performed using Analysis of Variance (ANOVA) to determine the significance of environmental effects and genotypic differences, with a significance level set at $P < 0.05$. All measurements were replicated three times to ensure reliability of the results.

Results. The study evaluated the yield traits of ten *G. Barbadense* L. genotypes under optimal, water-deficient, and saline conditions, focusing on the number of opened bolls, total number of bolls, and seed cotton weight per boll. The results are presented in the following tables, accompanied by statistical analyses.

Table 1. Number of Opened Bolls in *G. Barbadense* L. Cotton Genotypes

№	Genotypes	Optimal conditions		Water deficiency conditions		Salinity conditions	
		X±SE	SD	X±SE	SD	X±SE	SD
1.	Angor (T-1981)	9,33±0,33	0,58	5,08±0,71	1,23	4,33±0,17	0,29
2.	T-479	10,92±1,54	2,67	7,17±0,44	0,76	4,90±0,21	0,36
3.	T-2025	11,67±1,30	2,25	7,00±0,76	1,32	4,75±0,38	0,66
4.	T-2024	9,83±0,93	1,61	7,00±1,04	1,80	6,08±0,55	0,95
5.	T-5570	10,83±1,67	2,89	6,42±1,04	1,81	4,33±0,60	1,04
6.	T-481	9,75±1,01	1,75	6,17±0,83	1,44	5,50±0,50	0,87
7.	T-563	9,38±1,35	2,34	6,25±1,14	0,25	5,75±0,80	1,39
8.	Buston (T-663)	9,17±0,73	1,26	6,50±1,26	2,18	5,08±0,71	1,23
9.	Duru-gavhar-4	8,50±1,04	1,80	6,83±0,83	1,44	5,33±0,33	0,58
10.	T-2090	8,50±0,76	1,32	7,67±0,60	1,04	5,29±0,61	1,06

This table presents the number of opened bolls for *G. Barbadense* L. genotypes under optimal, water-deficient, and saline conditions. Under optimal conditions, genotype T-2025 exhibited the highest number of opened bolls (11.67±1.30), while under water deficiency and salinity, this value decreased significantly (7.00±0.76 and 4.75±0.38, respectively).

T-2090 showed relative resilience in water-deficient conditions (7.67±0.60), outperforming most genotypes, whereas T-2024 maintained a higher number under salinity (6.08±0.55). Overall, water deficiency and salinity reduced the number of opened bolls across all genotypes, with varying degrees of tolerance observed, indicating genotypic differences in stress response.

Table 2. Multi-Factor ANOVA Analysis of Genotype and Environment Effects on Number of Opened Bolls

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Genotypes	5,59	9	0,62	0,94	0,5128
Environment	113,13	2	56,56	85,86	0,0001
Residual	11,85	18	0,65		
Total (corrected)	130,59	29			

The multi-factor ANOVA results indicate that environmental conditions (optimal, water deficiency, and salinity) had a highly significant effect on the number of opened bolls ($P = 0.0001$, $F = 85.86$), explaining a large portion of the variation ($SS = 113.13$). In contrast, genotypic effects were not statistically significant ($P = 0.5128$, $F = 0.94$), suggesting that differences among genotypes were less pronounced than the impact of environmental stress.

The interaction between genotype and environment ($SS = 11.85$) further highlights that certain genotypes may respond differently to specific stress conditions, though this interaction was not fully detailed in the analysis.

Table 3. Total Number of Bolls in *G. Barbadense* L. Cotton Genotypes

№	Genotypes	Optimal conditions		Water deficiency conditions		Salinity conditions	
		X±SE	SD	X±SE	SD	X±SE	SD
1.	Angor (T-1981)	12,13±0,51	0,88	7,83±1,30	2,25	7,05±0,12	0,20
2.	T-479	15,29±0,76	1,32	9,38±0,65	1,13	5,55±0,12	0,20
3.	T-2025	15,25±1,32	2,05	9,00±0,66	1,15	6,00±0,58	1,00
4.	T-2024	10,25±1,80	1,32	10,17±1,52	2,63	12,50±0,29	0,50
5.	T-5570	14,50±1,81	3,13	7,18±0,28	0,49	6,79±0,89	1,54
6.	T-481	10,38±1,44	1,38	5,50±1,01	1,75	7,30±0,17	0,30
7.	T-563	15,88±0,25	1,88	6,33±0,36	0,63	9,67±0,38	0,67
8.	Bo'ston (T-663)	11,92±2,18	3,50	7,50±1,44	2,50	7,17±0,10	0,17
9.	Duru-gavhar-4	8,75±1,44	0,50	10,50±1,98	3,44	7,63±0,22	0,38
10.	T-2090	11,25±1,04	3,50	8,83±0,55	0,95	7,75±0,14	0,25

This table displays the total number of bolls across the three environmental conditions. Under optimal conditions, T-563 recorded the highest value (15.88±0.25), followed closely by T-479 (15.29±0.76). Water deficiency significantly reduced boll numbers across all genotypes, with T-2024 showing notable stability (10.17±1.52). Under salinity, T-2024 again stood out with the highest total boll count (12.50±0.29), contrasting with the general trend of decline seen in other genotypes like T-479 (5.55±0.12). These results suggest that while stress generally diminishes total boll numbers, specific genotypes like T-2024 exhibit adaptability, particularly under saline conditions.

Table 4. Multi-Factor ANOVA Analysis of Genotype and Environment Effects on Total Number of Bolls

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Genotypes	24,74	9	2,74	0,54	0,8275
Environment	140,90	2	70,45	13,81	0,0002
Residual	91,81	18	5,10		
Total (corrected)	257,46	29			

The ANOVA analysis reveals that environmental factors significantly influenced the total number of bolls ($P = 0.0002$, $F = 13.81$, $SS = 140.90$), underscoring the dominant role of water deficiency and salinity in reducing boll formation. Genotypic effects were not significant ($P = 0.8275$, $F = 0.54$), indicating limited variation among genotypes under these conditions. The genotype-environment interaction ($SS = 91.81$) suggests some differential responses among genotypes to specific stresses, though the effect size appears moderate. This reinforces the idea that environmental stress is a stronger determinant of total boll number than inherent genotypic differences.

Table 5. Seed Cotton Weight per Boll in *G. Barbadense* L. Cotton Genotypes

№	Genotypes	Optimal conditions		Water deficiency conditions		Salinity conditions	
		X±SE	SD	X±SE	SD	X±SE	SD
1.	Angor (T-1981)	3,34±0,03	0,05	3,23±0,09	0,15	2,58±0,23	0,40
2.	T-479	3,07±0,03	0,05	3,06±0,23	0,40	2,33±0,08	0,14

3.	T-2025	3,45±0,20	0,35	2,69±0,28	0,48	2,53±0,06	0,11
4.	T-2024	2,60±0,12	0,20	2,12±0,17	0,29	2,71±0,22	0,37
5.	T-5570	3,09±0,06	0,10	2,58±0,20	0,34	2,36±0,20	0,35
6.	T-481	2,32±0,14	0,25	2,56±0,15	0,26	2,61±0,05	0,09
7.	T-563	2,89±0,16	0,28	2,71±0,08	0,13	2,53±0,07	0,12
8.	Bo'ston (T-663)	2,81±0,13	0,23	2,66±0,11	0,19	2,95±0,05	0,09
9.	Duru-gavhar-4	3,21±0,12	0,21	2,77±0,15	0,26	3,15±0,15	0,26
10.	T-2090	2,56±0,28	0,49	2,83±0,26	0,45	2,55±0,08	0,14

This table shows the seed cotton weight per boll across the three conditions. Under optimal conditions, T-2025 had the highest weight (3.45±0.20 g), while T-481 recorded the lowest (2.32±0.14 g). Water deficiency generally reduced weights, though T-2090 showed a slight increase (2.83±0.26 g vs. 2.56±0.28 g in optimal conditions). Under salinity, Duru-gavhar-4 (T-5560) maintained a relatively high weight (3.15±0.15 g), and Bo'ston (T-663) improved slightly (2.95±0.05 g). The data suggest that while stress impacts seed cotton weight, certain genotypes exhibit resilience or even slight improvements under specific conditions, reflecting variability in stress tolerance.

Table 6. Multi-Factor ANOVA Analysis of Genotype and Environment Effects on Seed Cotton Weight per Boll

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Genotypes	1,08	9	0,12	1,44	0,24
Environment	0,49	2	0,24	2,94	0,07
Residual	1,49	18	0,08		
Total (corrected)	3,05	29			

The ANOVA results indicate that neither genotypic effects ($P = 0.24$, $F = 1.44$) nor environmental conditions ($P = 0.07$, $F = 2.94$) reached statistical significance at $P < 0.05$ for seed cotton weight per boll, though the environmental effect approached significance. The relatively low sum of squares for environment ($SS = 0.49$) and genotype ($SS = 1.08$) suggests that seed cotton weight per boll is less sensitive to these factors compared to boll numbers. The genotype-environment interaction ($SS = 1.49$) implies some variability in how genotypes respond to stress, but overall, this trait appears more stable across conditions than boll-related traits.

Discussion. The results of this study demonstrate that abiotic stresses, specifically water deficiency and salinity, significantly impact the yield traits of *G. Barbadosense* L. cotton genotypes, with notable reductions in the number of opened bolls, total number of bolls, and, to a lesser extent, seed cotton weight per boll. These findings align with broader research on cotton, where drought and salinity are recognized as primary constraints to productivity, disrupting physiological processes such as boll development and seed cotton formation (Abdelraheem et al., 2019; Zhang et al., 2014; Shavkiev et al., 2019, 2020, 2021; Nabiev et al., 2020; Shukhrat et al., 2021; Matniyazova et al., 2022; Narimanov et al., 2023; Chorshanbiev et al., 2023; Azimov et al., 2024). The significant environmental effects observed in the ANOVA analyses underscore the dominant role of these stresses over genotypic differences, a pattern consistent with Yehia (2020), who reported that water deficit markedly reduced boll numbers in Egyptian *G. Barbadosense* genotypes.

Genotypic variability in stress response was evident, with certain genotypes like T-2024 and T-2090 showing relative resilience. T-2024 maintained a higher number of opened bolls under salinity (6.08 ± 0.55) and the highest total boll count (12.50 ± 0.29), suggesting an adaptive capacity to saline conditions. Similarly, T-2090 exhibited resilience in water-deficient conditions, with the highest number of opened bolls (7.67 ± 0.60) among tested genotypes. These findings echo those of Singh et al. (2016) and Shavkiev et al. (2017, 2023), who identified significant genotypic variation in *G. hirsutum* under drought, with some lines maintaining yield components better than others. The stability of T-2024 under salinity may be linked to physiological mechanisms such as ion homeostasis or osmotic adjustment, as reported in salt-tolerant cotton varieties by Liang et al. (2016), though further physiological studies are needed to confirm this in *G. Barbadense*.

In contrast, seed cotton weight per boll showed less sensitivity to environmental stress, with genotypes like Duru-gavhar-4 and Bo'ston (T-663) maintaining or slightly improving weights under salinity (3.15 ± 0.15 g and 2.95 ± 0.05 g, respectively). This relative stability aligns with Shilpa et al. (2020), who noted that drought affects boll number more severely than boll weight in cotton, possibly due to compensatory mechanisms in seed cotton development under stress. However, the lack of significant genotypic effects ($P = 0.24$) suggests that this trait may be less amenable to selection for stress tolerance compared to boll numbers, a finding that contrasts with Yehia (2022), where PCA identified boll weight as a selectable trait under water deficit.

The differential responses observed among genotypes highlight the potential for targeted breeding to enhance stress tolerance in *G. Barbadense*. For instance, T-2024's performance under salinity positions it as a promising candidate for breeding programs in saline-prone regions, such as those in Central Asia where soil salinization is increasing (Zhu et al., 2018; Chorshanbaev et al., 2022). Similarly, T-2090's resilience to water deficiency could be leveraged in arid environments, supporting the development of varieties suited to climate change-induced drought, as emphasized by Abdelraheem et al. (2021). These results build on the literature's call for multi-trait evaluation under combined stresses (Shilpa et al., 2020; Makamov et al., 2022a, 2022b; Azimov et al., 2023), though our study's focus on individual stresses reveals distinct genotypic strengths that may be masked in combined stress scenarios.

The non-significant genotypic effects across all traits suggest that while environmental stress exerts a strong influence, the tested genotypes may share a common genetic background limiting variability in stress response. This contrasts with broader germplasm studies, such as those by Zhang et al. (2014), which identified greater diversity in stress tolerance among *G. hirsutum* accessions. The limited genotypic variation in our study may reflect the specific selection history of these *G. Barbadense* lines, developed for fiber quality rather than stress tolerance, underscoring the need to incorporate wider genetic diversity in future evaluations.

These findings have practical implications for cotton breeding in stress-prone regions. The identification of resilient genotypes like T-2024 and T-2090 provides a foundation for integrating yield stability into breeding programs, potentially using tolerance indices like STI and GMP, as validated by Yehia (2020, 2022) and Shavkiev (2022). However, the gap in physiological data linking yield traits to stress adaptation mechanisms—such as water use efficiency or salt exclusion—limits our understanding of why certain genotypes outperform others. Future research should combine yield-based assessments with physiological and molecular analyses, as suggested by Liang et al. (2016), to elucidate the underlying basis of tolerance and enhance breeding precision.

In conclusion, this study confirms the detrimental effects of water deficiency and salinity on *G. Barbadense* yield traits while identifying genotypes with potential stress tolerance. These insights contribute to the growing body of evidence supporting genotype-specific breeding strategies to mitigate abiotic stress impacts, aligning with global efforts to sustain cotton productivity under changing climatic conditions.

Conclusion. This study investigated the effects of water deficiency and salinity on the yield traits of ten *G. Barbadense* L. cotton genotypes, revealing significant reductions in the number of opened bolls and total number of bolls under stress conditions, while seed cotton weight per boll exhibited greater stability. Environmental factors emerged as the primary drivers of yield variation, with water deficiency and salinity exerting a stronger influence than genotypic differences, as evidenced by the ANOVA analyses. Among the genotypes, T-2024 demonstrated notable adaptability to salinity, maintaining higher boll numbers, while T-2090 showed resilience under water-deficient conditions, suggesting their potential as valuable genetic resources for stress-tolerant breeding.

These findings underscore the vulnerability of *G. Barbadense* L. to abiotic stresses and highlight the importance of identifying resilient genotypes to sustain cotton productivity in arid and saline-prone regions. The observed genotypic variability, though limited, offers opportunities for targeted selection and breeding to enhance yield stability under adverse conditions. By providing insights into stress-specific responses, this research contributes to the development of improved *G. Barbadense* varieties, supporting agricultural resilience in the face of climate change. Future efforts should focus on integrating these yield-based evaluations with physiological and molecular studies to fully elucidate the mechanisms underlying stress tolerance, paving the way for more robust cotton cultivars.

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