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RESEARCH ARTICLE

Assessment of salt tolerance in the cotton (*Gossypium hirsutum* L.) variety "Baraka" at the seedling stage

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Abstract

This study investigates the salt stress tolerance of the Uzbek cotton variety *Gossypium hirsutum* L. "Baraka", addressing the limited understanding of salinity responses in local cultivars. Seedlings were exposed to NaCl (sodium chloride) solutions at 50, 100, 150 and 200 mM for 21 days and fresh weight, shoot length, root length and total plant length were measured. Data were analyzed using one-way ANOVA (analysis of variance) with post-Bonferroni and Tukey tests. Significant differences were observed in seedling responses across salt concentrations. A comparative evaluation of germination-stage tolerance revealed that seedlings treated with 100 mM NaCl exhibited higher fresh weight and shoot length compared to other groups, indicating moderate salt tolerance at this concentration. For total length, seedlings grown under 150 mM NaCl showed greater resistance relative to other treatments. Growth inhibition followed a concentration-dependent pattern: fresh weight declined to 51 % of control at 200 mM, shoot length to 64.6 % and total length to 78.6 %. Root length displayed a non-linear response, increasing up to 108.3 % at 100 mM before declining at higher concentrations. The experimental results confirmed the inhibitory effects of salt on key morphological parameters. However, the "Baraka" variety demonstrated tolerance under low-to-moderate salinity, particularly at 100-150 mM NaCl. These findings provide valuable insights for breeding programs targeting salt-tolerant cotton varieties in Uzbekistan's saline agroecosystems.

Keywords: Baraka variety; cotton; one-way ANOVA; salt stress; tolerant genotypes

Introduction

Salinization is a serious global abiotic problem affecting agricultural productivity and natural ecosystems (1). Salt stress in plants, characterized by elevated levels of sodium (Na^+) and chloride (Cl^-) ions in the soil, negatively influences seed germination by increasing osmotic potential, reducing water uptake and toxic ion accumulation (2). Soil salinization is a global agricultural challenge that is intensified by decreasing arable land and rising sea levels, declining groundwater recharge and inefficient traditional irrigation methods with increased evaporation. High levels of soil salinity hinder the normal growth and development of plants, as well as affect crop quality, making it critically important to develop salt-tolerant genotypes that maintain high yields under saline conditions (3).

The accumulation of salts in potentially arable areas is a global issue, affecting about 340 million hectares worldwide (4). Moreover, areas affected by natural salinization occupy a significantly larger area than those salinized by irrigated agriculture (5-10).

According to numerous field surveys and mass assessments of farms located on saline soils, crop yield reduction has been established as follows: 0 - 33 % under mild salinity, ~50 % under moderate salinity, 67 - 83 % under severe salinity and nearly 100 % under very severe salinity (11).

Irrigation water serves both as a powerful source of salts for the soil, since about 80 % of it evaporates, leaving salts in the soil and as a means of transporting them to deeper subsoil layers with regular and timely watering (11, 12).

Excessive application of fertilizers and pesticides, after soil leaching, strongly mineralizes the water and progressively saturates it with toxic substances. Large amounts of this water are discharged into the Amu Darya and Syr Darya rivers and downstream, it is reused for irrigation (13).

The relevance of studying salt tolerance of crops is determined by the deterioration of soil conditions due to salinization, which poses a serious threat to the productivity of agroecosystems in arid regions, including Uzbekistan. The cotton variety *Gossypium hirsutum* L. "Baraka" has attracted the attention of researchers and agronomists due to its unique adaptive properties, allowing it to maintain relatively high yields under saline conditions. The cotton variety has a well-developed root system, exhibits resistance to soil salinity and combines high fiber quality with strong yield potential (14). As climate change leads to increased soil salinity and loss of fertility, the development of stress-tolerant varieties such as "Baraka" cotton has become a priority for the agricultural sector.

This study aims to comparatively analyze and determine the salt tolerance of cotton seedlings of the "Baraka" variety. Therefore, studies were conducted under irrigated conditions using various sodium chloride (NaCl) concentrations (0, 50, 100, 150 and 200 mM), using seedling fresh weight and growth parameters as key indicators for assessing salt tolerance under saline conditions. To achieve this goal, the following tasks were set: to conduct controlled laboratory experiments on growing cotton seedlings of the "Baraka" variety under different NaCl concentrations (0, 50, 100, 150, 200 mM); to assess seedling tolerance to salinity by measuring fresh weight and growth parameters, followed by comparative analysis using the one-way ANOVA (analysis of variance) method.

Materials and Methods

The cotton variety "Baraka" was developed using marker-assisted selection (MAS) with the BNL (Brookhaven National Laboratory)-1604 marker. The variety was derived from plants backcrossed five times to a recurrent parent and then self-pollinated for two generations (BC_5F_2 hybrids) through repeated individual selection. (14).

The experiments were carried out under controlled laboratory model conditions. Randomly selected and pre-soaked cotton seeds were planted, 10 seeds per pot, with 3 replications. Germination was conducted in a phytotron at a temperature of 28-30 °C under light conditions of 16 hr light/8 hr dark, lux 10000 for 21 days. Salt tolerance was assessed using a modified method (15). Irrigation was performed every second day with 100 mL of deionized water (0 mM, control) or NaCl solutions of varying concentrations (50 mM, 100 mM, 150 mM and 200 mM), to prevent oversaturation and avoid seedling decay. In this experiment, NaCl accumulation in the soil was minimal, since excess NaCl or water drained through the bottom of the pots and the soil remained moist for the next irrigation (16).

At the end of the experiment, measurements were taken of seedling height (up to the epicotyl) in centimeters (cm) and fresh plant weight in grams (g). Plant length measurements were performed using the Image J software for image analysis and processing, by analyzing photographs of the seedlings placed on a substrate with millimetre (mm) markings (17).

To assess statistically significant differences in the salt tolerance of cotton seedlings of the "Baraka" variety under different soil NaCl concentrations, a dataset was created containing of quantitative values of the following parameters for each seedling: weight (fresh biomass of the seedling), shoot length (height of the seedling), root length (root system length) and total length (combined shoot and root length).

Statistical analysis

Statistical data processing was carried out using the one-way ANOVA program ($\alpha = 0.01$) to evaluate the effect of NaCl on each parameter. The normality of parameter distribution was determined by the Kolmogorov-Smirnov and Shapiro-Wilk tests. Homogeneity of variances and equality of means were assessed using Levene's and Welch's tests, with $p > 0.05$ for most parameters. Multiple post-hoc comparisons were performed using Bonferroni and Tukey tests ($p < 0.001$). Statistical calculations were performed with the Statistical Package for the Social Sciences (SPSS) 21 software package (18-20).

Results and Discussion

In many studies devoted to investigating cotton tolerance to salt stress, the quantitative assessment of this tolerance has been carried out in different ways. For example, tolerance was determined as the ratio of the number or percentage of germinated plants in the experimental and control groups (21). In other studies, tolerance criteria included plant length or mass (22). Unlike these approaches, the work aimed at providing an objective assessment of salt tolerance using ANOVA, a robust parametric statistical method.

The data were first tested to determine whether they met the assumptions required for one-way ANOVA. A table of descriptive statistics for all salinity treatments was generated (Table 1). Table 1 summarizes the descriptive statistics (mean, variance, standard deviations, maximums and minimums) and mean plots for all parameters. At this stage, tests for the normality of data distribution were also carried out using the Kolmogorov-Smirnov and Shapiro-Wilk criteria.

Table 1 presents the descriptive statistics values calculated by the software. The columns show the experimental NaCl concentration values, the number of observations for each concentration and the program-calculated means, standard deviations, maximums and minimums corresponding to the 4 studied variables.

Data analysis showed that the trends in changes of parameter values across NaCl concentrations, as presented in Table 1, were nearly identical for all variables except root length. As salt concentration increased, the mean values of weight, shoot length and total length decreased, whereas for root length, the mean value at 50 mM was higher than in the control (9.72 cm vs 9.17 cm). Cotton seedlings of the "Baraka" variety exposed to 100 mM NaCl also demonstrated an increase in mean root length to 9.93 cm. However, in seedlings subjected to higher concentrations, namely 150 mM and 200 mM, there was a decline in the mean values to 9.81 cm and 9.37 cm, respectively. Nevertheless, these mean values remained higher than the average root length of control seedlings (i.e., at 0 salt concentration). Such an effect suggests that moderate

Table 1. Descriptive statistics for all salinity treatments

Parameters	NaCl (mM)	N	Mean	Standard deviation (SD)	Minimum	Maximum
Weight (g)	0	38	1.5921	0.24798	1.06	2.08
	50	35	1.4583	0.16977	1.17	1.86
	100	33	1.2979	0.12646	1.04	1.54
	150	33	0.9291	0.29123	0.26	1.40
	200	25	0.8124	0.21495	0.43	1.21
	Total	164	1.2521	0.36584	0.26	2.08
Shoot length (cm)	0	38	15.4339	1.68515	11.69	18.77
	50	35	14.8631	1.60269	12.09	18.12
	100	33	13.3348	0.92047	10.91	15.25
	150	33	11.1942	1.74353	6.14	14.04
	200	25	9.9696	1.18607	7.77	13.03
	Total	164	13.2037	2.51529	6.14	18.77
Root length (cm)	0	38	9.1666	2.96573	2.67	14.32
	50	35	9.7211	3.64970	1.49	18.01
	100	33	9.9279	2.87791	2.79	16.28
	150	33	9.8130	2.94841	3.51	16.89
	200	25	9.3616	2.15156	3.43	12.79
	Total	164	9.5979	2.97923	1.49	18.01
Total length (cm)	0	38	24.5987	3.89353	16.54	31.41
	50	35	24.5849	3.78522	15.80	31.82
	100	33	23.2624	3.04388	16.09	29.73
	150	33	21.0064	3.64562	12.27	29.65
	200	25	19.3300	2.63843	12.65	24.08
	Total	164	22.8009	3.98278	12.27	31.82

NaCl - sodium chloride; N - number of observations; g - gram; cm - centimeter; mM - millimolar.

salinity can trigger adaptive changes in root development, possibly enhancing root elongation as a compensatory response.

Evaluation of seedling growth under salinity stress: The analysis of fresh weight in 21-day-old cotton seedlings showed that salt stress reduced this parameter to 91.6 % of the control at 50 mM NaCl, 81.5 % at 100 mM, 58.4 % at 150 mM and 51.0 % at 200 mM (Fig. 1A). Fresh weight at 200 mM NaCl was reduced by nearly 50 % compared to the control.

When analyzing the next morphometric parameter of cotton seedlings, shoot length was significantly inhibited by all NaCl treatments (Fig. 1B). Salt stress suppressed seedling growth and as a result, this parameter amounted to 96.3 % of the control at 50 mM, 86.4 % at 100 mM, 72.5 % at 150 mM and 64.6 % at 200 mM NaCl. Similar to fresh weight, this analysis showed that the studied variety demonstrated the lowest shoot height at the highest NaCl concentration (200 mM), which represented a 35 % reduction compared to the control.

Root growth exhibited a contrasting trend compared to shoot length and fresh weight (Fig. 1C). In this case, there was no linear inhibition trend, as observed for fresh weight and shoot length; instead, the trend appeared nonlinear. The root length of cotton seedlings under salt stress reached 106.0 % of the control at 50 mM NaCl, 108.3 % at 100 mM, 107.1 % at 150 mM and 102.1 % at 200 mM. This finding indicates that the studied genotype exhibited nonlinear variation of root length growth at different NaCl concentrations compared to the control.

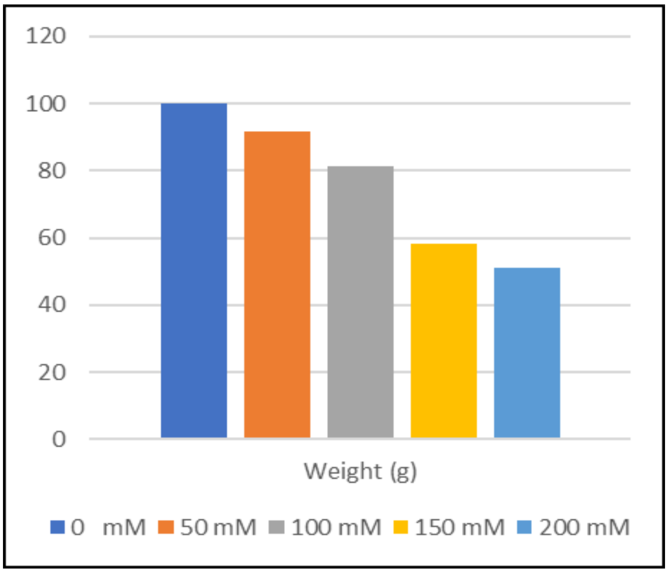
The analysis of total plant length showed that salt stress reduced this parameter to 99.9 % of the control at 50 mM NaCl, 94.6 % at 100 mM, 85.4 % at 150 mM and 78.6 % at 200 mM. For this parameter, a linear decrease was also observed with increasing salt concentration, compared with the control. This value was *a* 27 % reduction compared to the control, showing a linear trend (Fig. 1D).

Based on the obtained data, the Kolmogorov-Smirnov statistical test was conducted (Table 2) and determined that these morphological parameters of cotton seedlings under different NaCl concentration regimes followed a normal distribution law, except for the treatment where seedlings were irrigated with 150 mM NaCl solution. In this case, the distribution of the fresh weight parameter did not conform to normal distribution ($p < 0.019$), while the Shapiro-Wilk test indicated that this parameter under this NaCl concentration did follow a normal distribution ($p = 0.73$). The Shapiro-Wilk test confirmed normal distribution ($p > 0.05$) for all parameters across treatments, except fresh weight at 150 mM.

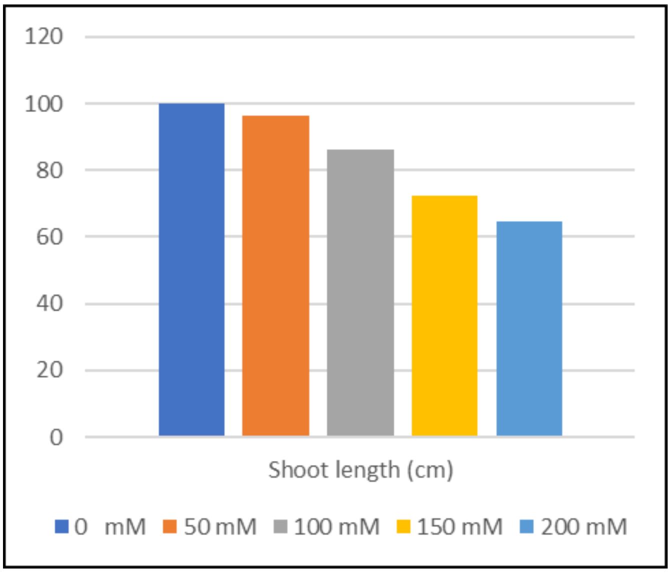
The obtained morphometric data were processed using Welch's robust test for equality of means and Levene's test for homogeneity of variances. The results of the statistical analysis indicated that the means and variances for all traits were homogeneous and reliable, except root length. Thus, one-way ANOVA was applicable for most traits, except root length.

Table 3 presents the results of the one-way ANOVA. The second column shows the between-group (between concentrations), within-group and total sums of squares of the deviations of trait values from the means (variability), with their values provided in the third column. The fourth column presents the number of degrees of freedom used to calculate the between-group and within-group variances, which are given in the fifth column. The ratio of the first variance to the second yields the *F*-value (Fisher's criteria). If the calculated *F*-value exceeds the critical *F*-value at the given degrees of freedom, a conclusion is made about the presence of significant intergroup differences between the means of the studied indicators. The sixth and seventh columns present the values of Fisher's criterion and their significance for all traits.

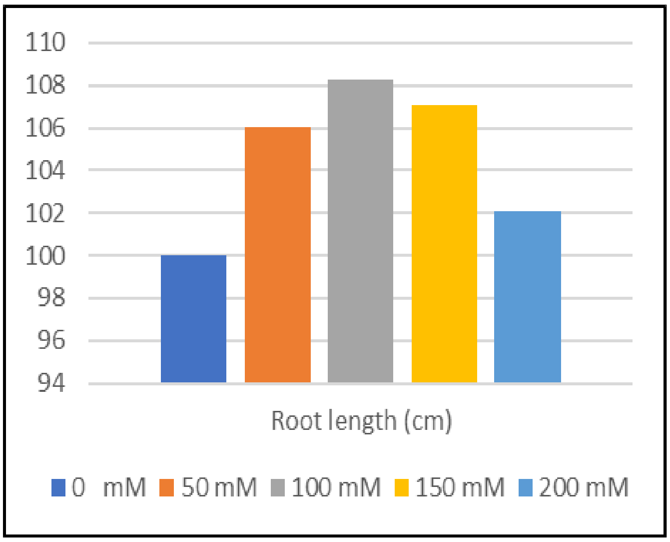
Based on the results of the one-way ANOVA program presented in this table, it was found that all traits - sample fresh weight, shoot height and total plant length, except for root length, showed relatively high values of Fisher's criterion *F*, defined as the mean square ratio of between-group to within-group variances. The *F-values* were 74.51, 77.18 and 13.31, respectively, with significance levels of $p < 0.0001$, confirming the presence of



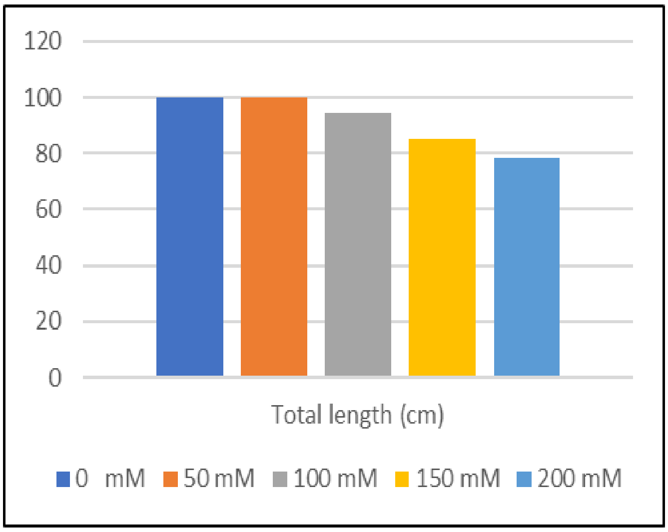
A. Fresh biomass of seedlings depending on NaCl concentration, expressed as % relative to control.



B. Seedling height depending on NaCl concentration, expressed as % relative to control.



C. Root length depending on NaCl concentration, expressed as % relative to control.



D. Total seedling length depending on NaCl concentration, expressed as % relative to control.

Fig. 1. Effects of different NaCl concentrations on fresh weight (A), shoot length (B), root length (C) and total seedling length (D) of “Baraka” cotton seedlings. Data are presented as mean ± SE, expressed as percentage relative to the control.

Table 2. Tests of the normality

Parameters	NaCl (mM)	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Weight (g)	0	0.054	38	0.200*	0.987	38	0.925
	50	0.079	35	0.200*	0.962	35	0.266
	100	0.106	33	0.200*	0.980	33	0.783
	150	0.168	33	0.019	0.941	33	0.073
	200	0.133	25	0.200*	0.964	25	0.503
Shoot length (cm)	0	0.059	38	0.200*	0.986	38	0.901
	50	0.062	35	0.200*	0.973	35	0.529
	100	0.095	33	0.200*	0.982	33	0.849
	150	0.088	33	0.200*	0.957	33	0.209
	200	0.104	25	0.200*	0.977	25	0.825
Root length (cm)	0	0.120	38	0.179	0.954	38	0.122
	50	0.139	35	0.083	0.971	35	0.465
	100	0.139	33	0.106	0.959	33	0.247
	150	0.111	33	0.200*	0.977	33	0.682
	200	0.132	25	0.200*	0.946	25	0.208
Total length (cm)	0	0.125	38	0.137	0.962	38	0.217
	50	0.098	35	0.200*	0.972	35	0.510
	100	0.113	33	0.200*	0.967	33	0.394
	150	0.118	33	0.200*	0.976	33	0.675
	200	0.095	25	0.200*	0.975	25	0.781

Indicates $p > 0.05$ (not significant), confirming normal distribution. NaCl - sodium chloride; g - gram; cm - centimeter; df - degrees of freedom; Sig. - significance; * - significance value reported as 0.200 by SPSS; Kolmogorov-Smirnov and Shapiro-Wilk - tests for normality.

Table 3. The results of the one-way ANOVA

Parameters	NaCl (mM)	Sum of squares	df	Mean square	*F*	Sig.
Weight (g)	Between groups	14.226	4	3.557	74.508	0.000
	Within groups	7.590	159	0.048		
	Total	21.816	163			
Shoot length (cm)	Between groups	680.697	4	170.174	77.185	0.000
	Within groups	350.555	159	2.205		
	Total	1031.253	163			
Root length (cm)	Between groups	14.118	4	3.529	0.392	0.814
	Within groups	1432.643	159	9.010		
	Total	1446.761	163			
Total length (cm)	Between groups	648.684	4	162.171	13.313	0.000

NaCl - sodium chloride; g - gram; cm - centimeter; df - degrees of freedom; *F* - *F*-value; Sig. - significance (*p*-value); Sum of squares - total variability; Mean square - average variability (sum of squares divided by df).

statistically significant differences between the mean values of NaCl concentration groups for these 3 traits.

For root length, the lower value of Fisher's criterion value ($F = 0.39$, $p = 0.81$) indicated that the tabulated critical value at $\alpha = 0.05$ exceeded the calculated one. Therefore, the null hypothesis of no differences between group means could not be rejected. This suggests that NaCl concentration had no statistically significant effect on the mean root length of 21-day-old seedlings of the variety "Baraka," and thus this trait was excluded from further calculations.

Since ANOVA only indicates the existence of differences between group means, but does not specify which groups differ from each other, the next step was to perform multiple post hoc comparisons using the Bonferroni test and Tukey's HSD (honestly significant difference) test (Table 4). Post hoc comparison represents pairwise comparisons of the studied groups to detect significant differences between them. Among the many criteria available in SPSS, the Bonferroni test is commonly used to control Type I error in multiple comparisons. In this method, the Type I error rate is divided by the number of comparisons to obtain a new critical level of significance, thus keeping the error within 5 % (23, 24). Tukey's HSD was used to confirm the results obtained with the Bonferroni test.

The results of both the Bonferroni and Tukey's HSD tests were identical. To avoid overcrowding, Table 4 presents only the Bonferroni test results. Pairwise comparisons of fresh weight, seedling height and total length across all NaCl concentrations provided mean differences, standard errors, significance levels and confidence intervals. Only pairs with $p < 0.05$ were included in the table.

Analysis of the results showed that, in the pairwise comparison of fresh weight between concentration groups, the most salt-tolerant samples were those grown under 100 mM NaCl. The difference between their weight mean and the control group (0 mM) was smaller than in other groups (difference = 0.29 g ± 0.05 g; $p < 0.0001$). A similar trend was observed for seedling height - only seedlings treated with 100 mM NaCl showed the smallest mean differences compared with the control, suggesting that this concentration reflects a point of relative tolerance for this trait (difference = 2.10 cm ± 0.35 cm; $p < 0.0001$).

For total plant length, the most salt-tolerant seedlings were observed at 150 mM NaCl. In this case, salt stress had a less pronounced effect on growth compared with 100 mM and 200 mM NaCl (difference = 3.59 cm ± 0.83 cm; $p < 0.0001$), data presented in Table 4. This indicates that, for different morphometric traits,

Table 4. Bonferroni multiple comparisons

Dependent variable	NaCl (mM)		Mean difference (I-J)	Std. error	Sig.	95 % Confidence interval	
	I	J				Lower bound	Upper bound
Weight (g)	0	100	0.29423*	0.05199	0.000	0.1508	0.4377
		150	0.66301*	0.05199	0.000	0.5196	0.8065
		200	0.77971*	0.05626	0.000	0.6245	0.9350
	50	100	0.16041*	0.05301	0.024	0.0141	0.3067
		150	0.52919*	0.05301	0.000	0.3829	0.6755
		200	0.64589*	0.05721	0.000	0.4880	0.8038
	100	150	0.36879*	0.05379	0.000	0.2204	0.5172
		200	0.48548*	0.05793	0.000	0.3256	0.6453
Shoot length (cm)	0	100	2.09910*	0.35331	0.000	1.1242	3.0740
		150	4.23970*	0.35331	0.000	3.2648	5.2146
		200	5.46435*	0.38237	0.000	4.4093	6.5194
	50	100	1.52829*	0.36028	0.000	0.5342	2.5224
		150	3.66890*	0.36028	0.000	2.6748	4.6630
		200	4.89354*	0.38882	0.000	3.8207	5.9664
	100	150	2.14061*	0.36554	0.000	1.1320	3.1493
		200	3.36525*	0.39370	0.000	2.2789	4.4516
	150	200	1.22464*	0.39370	0.019	0.1383	2.3110
Total length (cm)	0	150	3.59232*	0.83049	0.000	1.3007	5.8839
		200	5.26868*	0.89880	0.000	2.7886	7.7488
	50	150	3.57849*	0.84688	0.000	1.2417	5.9153
		200	5.25486*	0.91396	0.000	2.7329	7.7768
	100	200	3.93242*	0.92543	0.000	1.3789	6.4860

NaCl - sodium chloride; g - gram; cm - centimeter; Sig. - significance (p-value); Std. error - standard error of the mean difference; I, J - groups compared; 95 % confidence interval - lower and upper bounds of the mean difference; * - indicates a statistically significant difference between groups ($p < 0.05$).

tolerance thresholds may shift depending on the balance of osmotic adjustment and ion toxicity.

Plant growth inhibition under salinity stress can be explained by two complementary hypotheses. The first hypothesis attributes the effect to osmotic stress, where high salt concentrations reduce the water potential of the medium, limiting water uptake. The second hypothesis attributes the effect to ion toxicity, where excessive accumulation of Na^+ and Cl^- disrupts cellular metabolism and enzyme activity. Both osmotic and ionic factors interact, with their relative contributions determined by salinity level, salt's chemical composition and the plant's salt tolerance mechanisms.

The first attributes the effect to osmotic stress, where high salt concentrations reduce the water potential of the medium, limiting water uptake. The second point to ionic toxicity is that excessive accumulation of Na^+ and Cl^- disrupts cellular metabolism and enzyme activity. In reality, both osmotic and ionic factors act together and their relative impact is determined by the salinity level, its chemical composition and the plant's capacity to tolerate salt stress (25).

In this experiment, NaCl stress led to a significant reduction in fresh weight, shoot length and total length, reflecting osmotic and ionic constraints in cotton (26). For instance, the marked reduction in biomass (to 51 % of control at 200 mM NaCl) reflects Na^+ accumulation, which disrupts K^+ homeostasis and inhibits enzyme activity (27).

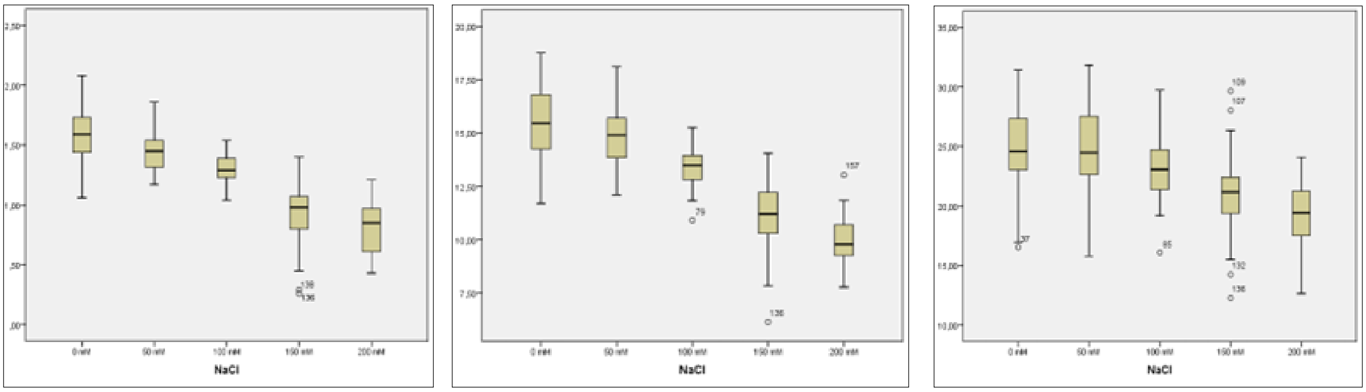
The non-linear increase in root length (108.3 % under 100 mM) may reflect auxin-mediated elongation or ion dilution strategies that enhance water uptake under moderate stress (27). This trend is consistent with MAS associated root traits reported for the "Baraka" variety (14). However, at 200 mM NaCl, root length decreased, indicating a toxicity threshold.

Fig. 2 showing the mean values with a standard error of 3 physiological traits of "Baraka" cotton samples grown under different artificially induced saline conditions with varying NaCl concentrations. The first graph, a box plot (Fig. 2), shows the relationship between key statistical characteristics of the studied physiological traits of seedlings and different NaCl concentrations.

In the first graph (Fig. 2), the distribution of the boxplots for fresh weight clearly demonstrates a downward trend, with fresh weight decreases as NaCl concentration in the irrigation solution increases. A similar trend is observed in the second graph, which shows the reduction in seedling height with increasing salt concentration. Additionally, in the first graph, 2 outliers were identified in the 150 mM treatment, whereas in the second graph, 1 outlier was observed for each of the three concentrations - 100, 150 and 200 mM.

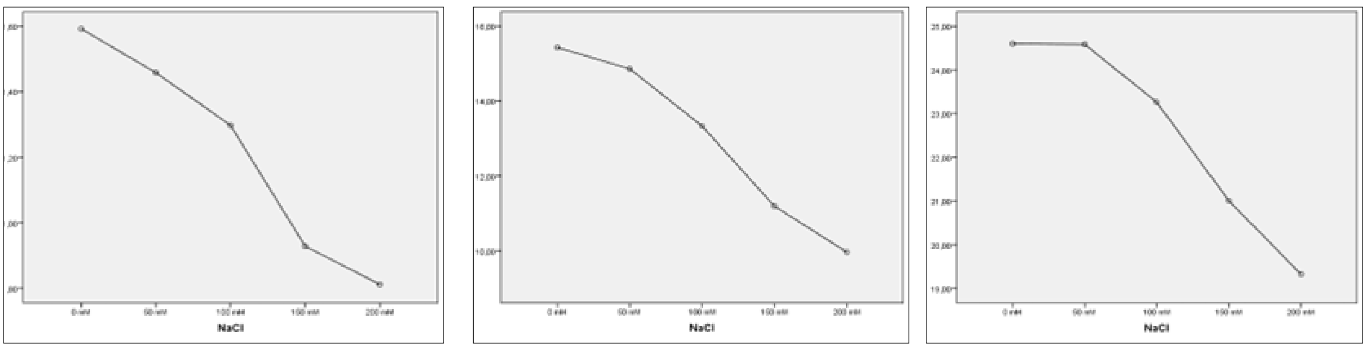
In the third graph, which analyses total length, all concentrations except 0 showed varying numbers of outliers, making it impossible to establish a clear trend in total plant length changes. This is most likely that the total length includes root length as one of its components, which turned out to be statistically insignificant and as shown above, the distribution of this trait does not follow the normal distribution.

The graphs illustrating the dependence of mean physiological traits on NaCl solution concentrations are presented in Fig. 3. In all 3 graphs, a downward trend in the values of the



A. Weight (g) **B. Shoot length (cm)** **C. Total length (cm)**

Fig. 2. Box plot of key physiological parameters of "Baraka" cotton seedlings under different NaCl concentrations: weight (A), shoot length (B) and total length (C). Data are shown as mean ± SE.



A. Mean of weight (g) **B. Mean of shoot length (cm)** **C. Mean of total length (cm)**

Fig. 3. Effect of NaCl concentration on mean physiological parameters of "Baraka" cotton seedlings: mean of weight (A), mean of shoot length (B) and mean of total length (C). Values represent mean ± SE.

studied traits was observed across all concentration groups relative to the control group.

Conclusion

Experiments with seedlings of the "Baraka" cotton variety revealed that saline solutions inhibited growth traits such as fresh weight, shoot height and total seedling length, with the strongest reduction observed at 200 mM NaCl. Root length exhibited a nonlinear response, increasing at 100 mM NaCl, likely as an adaptive mechanism to ion stress. Statistical analysis (one way ANOVA) indicated that seedlings exposed to 100-150 mM NaCl showed greater tolerance, particularly in shoot and total length traits. These findings suggest that Baraka possesses moderate salt tolerance compared to the "Tafakkur" variety-a valuable trait considering that about 50 % of Uzbekistan's irrigated lands are saline. This study provides a physiological basis for breeding salt-tolerant cotton lines, with future research focusing on molecular mechanisms such as *SOS* gene regulation using Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) and CRISPR-associated protein 9 (Cas9), which together constitute the CRISPR-Cas9 system.

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Authors' contributions

AAA wrote the manuscript and performed statistical analysis. ASI, IBS and VSK edited the manuscript. DEU, SSA, FSR, BMS, SRK, ATA, MRZ, KAU, SOK, DAM, RMA, ZZY, RAJ, NTK, NRI, NRR, AAS and BKR carried out the experiments, collected the data and participated in the preparation and revision of the manuscript. ZTB designed the research, edited and approved the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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