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Research Article

Morpho-biochemical Changes of Chili (*Capsicum annuum* L) Genotypes under Different Salt Stress Conditions

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ABSTRACT

Salinity is a devastating abiotic stress worldwide; seriously hamper crop production through altering growth and biochemical constituents of plants at the coastal ecosystem. Growing salt tolerant genotypes is the most effective strategy to improve crop production in the ecosystem. Objective of the experiment was to investigate the saline induced changes in growth and biochemical constituents of different chili genotypes, and identify salt tolerant chili genotype. The study evaluated three chili genotypes—Anal 1701, Black Kobra, and Traditional variety—grown under varying salinity levels (0, 3, 6, 9, and 12 dSm^{-1} at the germination stage; and 0, 3, and 6 dSm^{-1} at the vegetative stage) using a two-factorial completely randomized design with three replications during Rabi season of 2024. Salinity stress had a significant impact on plant height, proline, and chlorophyll content during the vegetative stage ($P < 0.001$). Anal 1701 showed the greatest proline concentration (38.54 mg 100 g^{-1} fresh leaf) and chlorophyll-a content (4.75 mg g^{-1} fresh leaf). Traditional variety and Black Kobra came in second and third, respectively; while Black Kobra showed lowest chlorophyll-a concentration (1.05 mg g^{-1} fresh leaf). During germination stage up to 6 dSm^{-1} salinity level the root and shoot growth was increased; thereafter increasing salt concentration drastically reduced the parameters. The germination and vegetative stage experiment suggested that the Anal 1701 chili cultivar be cultivated in the soils influenced by coastal salt with an alternative of traditional variety. The study's conclusions will help to choose chili genotypes for upcoming breeding initiatives that try to increase salinity tolerance and reduce production loss.

Introduction

Among abiotic stresses soil salinity is the most severe factor limiting the crop production across the coastal ecosystem (Kumar et al., 2018; Sultana et al., 2021; Haque, 2020a). In Bangladesh salinity affects around 1.01 million hectares of land. However, there is a vast difference of salinity among locations (Khanam et al., 2020; Haque, 2018; Rukaia et al., 2021). Soil salinity creates many adverse impacts on plant growth, ion effects, osmotic stress, and imbalance in plant nutrition, disrupting the plant growth and development (Shila et al., 2016; Sikder et al., 2016; Haque, 2020b). Due to excessive salinity vast lands remain fallow during *Rabi* season which ultimately reduces the intensity of cropping in the coastal ecosystem especially in Bangladesh (Jodder et al., 2016; Haque et al., 2025). Excessive salinity makes imbalances on availability and uptake of plant nutrients (Haque et al., 2023a; 2023b; 2024a; Haque and Hoque, 2023).

Osmotic adaptations, including proline accumulation, help plants to cope with salt and guard against oxidative and osmotic stress (Jharna et al., 2017a; Jharna and Samanta, 2021). Furthermore, under salinity stress, responses to free amino acids, chlorophyll and glucose accumulation differ by cultivar and growth stage (Jharna et al., 2001; Jharna et al., 2014).

Chili (*Capsicum annuum L.*) is one of the most important vegetables and spice crops from the Solanaceae family were widely cultivated across the Bangladesh. Chili has many benefits. It contains fiber, capsaicinoids, steam-volatile oils, protein, fatty oils, carotenoids, vitamins (A and C), and mineral nutrient elements (Marin et al., 2004). Chili is a good source of vitamin B6. It supplies huge amount of iron, magnesium and potassium. Chili could be used to produce color, texture, oleoresin and

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aroma which are the essential ingredient in food industries, and in pharmaceuticals (Osuna-Garcia et al., 1998). The capsaicinoid present in chili act as medicine in anticancer, antioxidant, and antiarthritic diseases (Akbar et al., 2010). So, chili is an integral part of the life of the peoples of Bangladesh. The current production is far below to the total annual requirement of the country. There is a scope to cultivate chili in the vast fallow lands of the coastal ecosystem of Bangladesh if a suitable salt tolerant variety could be identified.

Salinity inhibits the growth of chili by causing nutritional imbalances, ion toxicity, and osmotic stress (Ashraf and Harris, 2004). Therefore, the key biochemical and morpho-physiological mechanism responsible for salt resistance in chili plants is lacking behind in Bangladesh. The objective of the study was to evaluate the accumulation of biochemical constituents and photosynthetic pigments in the leaves of chili genotypes in salt-stressed conditions and to examine the growth parameters of chili genotypes in salt-stressed conditions to identify a suitable salt tolerant genotype.

Materials and Methods

Duration and location

Two experiments; one at germination stage and another at growth stage were conducted during *Rabi* season 2024 at Patuakhali Science and Technology University, Bangladesh. The university located at coastal ecosystem of Bangladesh. The germination stage experiment was conducted in the petridish at the laboratory of the Department of Biochemistry and Molecular Biology, and the growth stage experiment was conducted at pot culture condition in the net house of the university. The detailed description of both germination and pot culture experiment is given in the following sub-heads.

Effects of salt stress on chili genotypes at germination stage

The germination stage experiment was conducted using two factorial completely randomized design with three replications. Three chili genotypes including Anal 1701, Black Kobra and Traditional variety were the first factor, and second factor were five levels of salinity (0, 3, 6, 9, and 12 dSm^{-1}). Therefore, treatment combinations were Anal 1701 × 0 dSm^{-1}, Anal 1701 × 3 dSm^{-1}, Anal 1701 × 6 dSm^{-1}, Anal 1701 × 9 dSm^{-1}, Anal 1701 × 12 dSm^{-1}, Black Kobra × 0 dSm^{-1}, Black Kobra × 3 dSm^{-1}, Black Kobra × 6 dSm^{-1}, Black Kobra × 9 dSm^{-1}, Black Kobra × 12 dSm^{-1}, Traditional variety × 0 dSm^{-1}, Traditional variety × 3 dSm^{-1}, Traditional variety × 6 dSm^{-1}, Traditional variety × 9 dSm^{-1}, Traditional variety × 12 dSm^{-1}, The Anal 1701 is a hybrid chili variety and is marketed by ACI seed company. Black Kobra variety is marketed by Bankim seed. The traditional variety was collected from the local farmers. The levels of salinity were prepared by dissolving crude salt in distilled water and measuring EC with an EC meter. The control (0 dSm^{-1}) was maintained using distilled water only.

For germination test, total 25 healthy seeds were placed on two layers of filter paper in 15 cm diameter petri dishes on 5 February 2024. The 20 ml of treatment solutions were poured in each Petri dish. The Petri dishes were fixed on a table inside the laboratory. Adequate lighting was fixed on the table. The seeds were allowed to germinate at room temperature (25±2°C). Distilled water was added whenever necessary to the Petri dish to keep the filter paper moist.

Data collection

Data on percent germination was recorded at 6 days after seed placement whereas observations on other parameters were recorded on the 12th days.

The Germination percentage was calculated using the following formula:

$$Germination\ percentage = \frac{Total\ number\ of\ germnated\ seeds}{Total\ number\ of\ seeds\ placed} \times 100$$

Shoot length was measured in centimeter (cm) from the base to the tip of the leaf blade of five randomly selected seedlings. Root length was measured in cm from the seedling base to the tip of the root of five randomly selected seedlings. Dry biomass weight was measured in grams by weighing the mass of ten randomly selected seedlings from each Petri dish after oven-drying at 65^{0}C for 48 hours using a sensitive balance. The vigor index (VI) was worked out according to the following formula:

VI= Germination% × (Root length in cm + Shoot length in cm)

Effects of salt stress on chili genotypes at vegetative stage

Salinity tolerance of the same set of chili varieties was also evaluated at the vegetative stage in a net house with ambient conditions using a randomized complete block design model with three replications. Total twenty seven plastic buckets were used in the experiment. Each bucket was filled with 3 kg soil. Soils were collected from Patuakhali Science and Technology University research farm. Soils were air dried and ground before filling the bucket.

The treatments were similar with germination stage experiment but only three rates of continuous salinity using crude NaCl (0, 3 and 6 dSm^{-1}) were maintained. The treatment combinations used in the vegetative stage experiment were Anal 1701 × 0 dSm^{-1}, Anal 1701 × 3 dSm^{-1}, Anal 1701 × 6 dSm^{-1}, Black Kobra × 0 dSm^{-1}, Black Kobra × 3 dSm^{-1}, Black Kobra × 6 dSm^{-1}, Traditional variety × 0 dSm^{-1}, Traditional variety × 3 dSm^{-1}, Traditional variety × 6 dSm^{-1}. Basal fertilizers (100 mg N kg^{-1} soil as urea, 60 mg P kg^{-1} soil as triple superphosphate and 80 mg K kg^{-1} soil as muriate of potash) were applied to the pot. Eight chili seeds were sown in each pot. After proper emergence of seedlings extra seedlings were thinned out keeping four seedlings per pot. Proper irrigation and other management practices were done for healthy crop growth. After 40 days, plants were harvested, and leaves were collected for chemical analysis and growth parameter assessment.

Chlorophyll content of leaf

Chlorophyll content of leaf was determined according to the analytical technique developed by Coombs et al. (1985). Leaf chlorophyll were extracted using 80% acetone Spectrophotometer reading was taken at 645 and 663 nm wavelengths, and the result was expressed as mg g^{-1} fresh weight of leaf. The formulas for computing chlorophyll 'a' and chlorophyll 'b' were as follows:

Chlorophyll a = (13.19 A_{663}- 2.57 A_{645}) x DF
Chlorophyll b = (22.10 A_{645}- 5.26 A_{663}) x DF

Where,
A_{663}=Absorbance at 663 nm wavelength
A_{645}= Absorbance at 645 nm wavelength 7.93, 19.53, 13.19, 2.57, 22.10 and 5.26 are absorption co-efficient
DF= Dilution Factor = (10/1000)×0.05= 0.2

Total sugar content

Total sugar content was determined by the anthrone method (Dubois et al., 1956). 200 milligrams of fresh leaves were ground with 5 mL of 80% ethanol, then filtered through Whatman no. 1 filter paper, and the residue remaining in the filter paper was washed with 5 mL of 80% ethanol. The colour was developed using anthrone reagent. Absorbance was measured at 620 nm wavelengths in a spectrophotometer.

Proline content

Proline content of leaf was determined following the method described by Bates et al. (1973). 200 milligrams of fresh leaf sample were homogenized in 10 mL of 3% sulfosalicylic acid, centrifuged, and then filtered through Whatman no. 1 filter paper. The colour was developed using toluene. The absorbance was measured at 520 nm.

Statistical analysis

Data analysis was done using STAR (Statistical Tool for Agricultural Research) software. Significant effects of the treatments were tested by analysis of variance (ANOVA) technique, and treatment means were separated at 5% level of significance by Duncan's Multiple Range Test.

Results and Discussion

Salinity induced changes in chili genotypes at germination stage

Effects on germination percentage

The germination percentage of chili genotypes was significantly ($P < 0.001$) influenced by salinity levels, variety and their interaction. Based on the single effect increasing salt concentration the germination percentage gradually decreased (Table 1). Among the tested varieties traditional variety (94.1 %) had the best performance followed by Anal 1701 (91.7 %) and Black Kobra (86.9 %). Based on the interaction effect traditional chili genotype recorded the highest (96.6%) germination in the 3 and 6 dSm^{-1} salinity level. Up to 12 dSm^{-1} salinity level this genotype recorded 90.6% germination. In the same case the Anal 1701 and Black Kobra recorded germination percentage of 89.3 and 81.3 %, respectively. So, on the basis of germination percentage, the traditional variety was significantly more salt tolerant than other varieties.

Table 1. Single and interaction effect of salinity and variety on germination percentage of chili genotypes at germination stage

Salt concentration	Chili genotypes			Salt concentration mean
	Anal 1701	Black Kobra	Traditional	
0 dSm^{-1}	93.3 Aab	90.6 Ab	95.3 Aa	93.1
3 dSm^{-1}	92.0 ABb	88.6 ABc	96.6 Aa	92.4
6 dSm^{-1}	92.0 ABb	88.0 ABc	96.6 Aa	92.2
9 dSm^{-1}	92.0 ABa	86.0 Bb	91.3 Ba	89.7
12 dSm^{-1}	89.3 Ba	81.3 Cb	90.6 Ba	87.1
Variety mean	91.7	86.9	94.1	
Significance level: Variety-***, Salinity-*** and interaction-**, %CV- 1.83				
Standard error of means: Genotype- 0.61, Salinity-0.78, Genotype×Salinity- 1.36				

Similar small letters in a row, or similar capital letters in a column are not significantly different at 5% level by DMRT
CV= Co-efficient of variation, **= Significant at 1% level, ***=Significant at 0.1% level

Effects on root length

The root length of chili seedlings affected significantly ($P < 0.001$) due to the single effect of salinity, different varieties and the interaction between salinity and variety (Table 2). Over the mean salinity treatments the root length ranged from 1.01 cm to 4.34 cm, the highest being in the 3 dSm^{-1} saline condition and the lowest in the 12 dSm^{-1} salinity. In the experiment control treatment had lower root length than 3 and 6 dSm^{-1} salinity treatment; which indicates that slightly saline condition is good for increasing root length. However, higher salt concentration like 9 and 12 dSm^{-1} salinity drastically reduced the root length of chili. This result was consistent over the varieties. The beneficial role of sodium in low concentration was also described by some other researchers (Jharna et al., 2017a). Actually there are seventeen elements considered essential for plants. In addition sodium, cobalt, vanadium and silicon have been established as essential micronutrients in some plants (Haque et al., 2023c; 2024b). Therefore, in lower concentration sodium application was found growth promoting element; whereas excess dose is highly toxic to plants (Akter et al., 2021). Among the varieties Anal 1701 chili genotype showed the highest mean root length of 4.345 cm, while the traditional variety had the lowest root length of 1.82 cm. Under various salinity levels, the Anal 1701 variety with 0, 3, 6, 9, and 12 dSm^{-1} salinity recorded significantly ($P < 0.001$) higher root length (4.40, 6.65, 5.60, 3.01, and 2.05 cm, respectively) than other two varieties (Table 2).

Effects on shoot length

The shoot length of chili genotypes was significantly affected ($P < 0.001$) by salinity, variety and their interaction. Based on the interaction effect the Anal 1701 variety recorded shoot length of 3.27 cm under control condition, and it progressively increased up to 6 dSm^{-1}; thereafter it falls drastically and lowest was obviously found in 12 dSm^{-1} salinity treatment (Table 2). Completely similar trend was found in Black Kobra variety. However, in traditional variety highest shoot length was found in control treatment and was gradually decreased with the increase of salt concentration in the growth medium. Interestingly at every salinity level the Anal 1701 variety exhibits the longest shoots, suggesting that it is the most resilient to salinity stress. Shoot lengths for Black Kobra and Traditional were comparable, with Black Kobra doing marginally better at lower salinity levels. Since the Anal 1701 variety performs better under salinity stress, it may be suggested for cultivation in saline-prone locations.

Table 2. Single and interaction effect of salinity and variety on root and shoot length (cm) of chili genotypes at germination stage

Salt concentration	Chili genotypes			Salt concentration mean
	Anal 1701	Black Kobra	Traditional	
Root length (cm)				
0 dSm^{-1}	4.41 Ca	2.13 Db	2.19 Bb	2.91
3 dSm^{-1}	6.65 Aa	3.88 Ab	2.48 Ac	4.33
6 dSm^{-1}	5.61 Ba	2.70 Bb	2.55 Ac	3.62
9 dSm^{-1}	3.01 Da	2.50 Cb	1.08 Cc	2.19
12 dSm^{-1}	2.05 Ea	0.19 Ec	0.79 Db	1.01
Variety mean	4.34	2.28	1.82	
Significance level: Variety-***, Salinity-*** and interaction-***; %CV- 2.14				
Standard error of means: Genotype- 0.022, Salinity-0.028, Genotype×Salinity- 0.092				
Shoot length (cm)				
0 dSm^{-1}	3.27 Ba	1.23 Bc	2.46 Ab	2.33
3 dSm^{-1}	3.58 Aa	2.10 Ac	2.27 Bb	2.65
6 dSm^{-1}	3.66 Ba	2.10 Ac	2.25 Bb	2.67
9 dSm^{-1}	2.70 Ca	1.30 Bb	1.36 Cb	1.79
12 dSm^{-1}	1.35 Da	1.00 Cc	1.16 Db	1.17
Variety mean	2.91	1.54	1.90	
Significance level: Variety-***, Salinity-*** and interaction-***; %CV- 3.60				
Standard error of means: Genotype- 0.027, Salinity-0.035, Genotype×Salinity- 0.061				

Similar small letters in a row or similar capital letters in a column are not significantly different at 5% level by DMRT
CV= Co-efficient of variation, ***=Significant at 0.1% level

Effects on vigor index

Salinity alone caused a significant ($P < 0.001$) fall in the vigor index at the germination stage, with a minor increase in salt content followed by a sharp decline (Fig. 1). At 12 dSm^{-1} the vigor index was 192.9, and at 3 dSm^{-1} it was 643.84. The Anal 1701 variety with the greatest vigor index (662.8) was followed by the conventional (353.9) and Black Kobra (336.3) variety.

According to the interaction effect, the Anal 1701 variety had the highest vigor index (717.1, 941.7, 825.5, 525.3, and 304.3 in 0, 3, 6, 9, and 12 dSm^{-1} salinity, respectively) when compared to other varieties at varying salinity levels (Fig. 1). Jharna et al. (2017b) studied vigor index under salt stress condition and grouped salt tolerant rice genotypes, and reported that the tolerant varieties had higher vigor index.

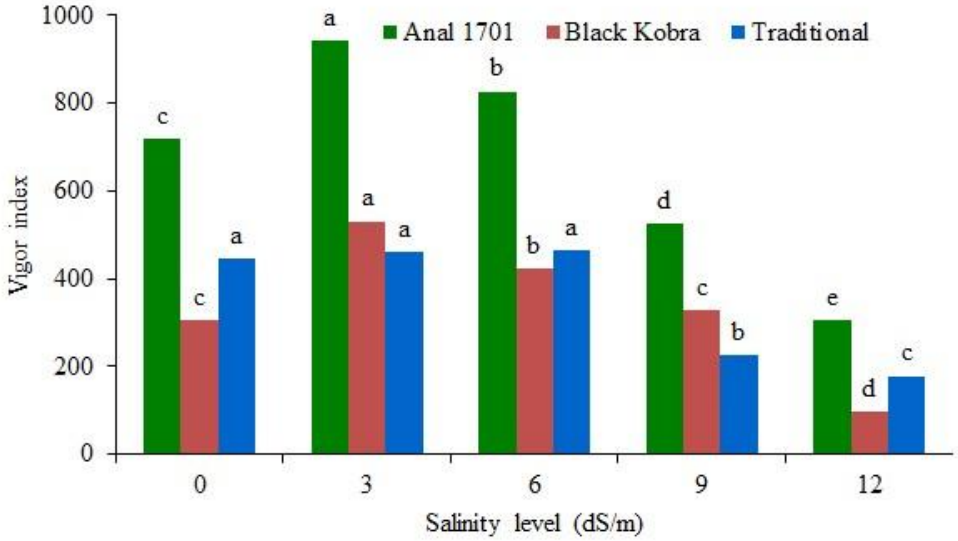

Fig 1. The interaction effect of salinity and variety on vigor index of chili genotypes at germination stage

*Similar small letters in a same color column are not significantly difference at 5% level of DMRT, Significance level: Variety-***, Salinity-*** and interaction-***, %CV-3.17*

Effects on biomass dry weight

Biomass dry weight of chili during the germination stage was greatly impacted by salinity, variety, and their interactions (Table 3). Based on the single effect biomass dry weight ranged from 0.008 g10-seedlings^{-1} at 12 dSm^{-1} salinity to 0.035 g10-seedlings^{-1} at 3 dSm^{-1}. Among the varieties Anal 1701 had the highest total dry biomass weight; the Traditional variety and the Black Kobra had very closer total biomass dry weight.

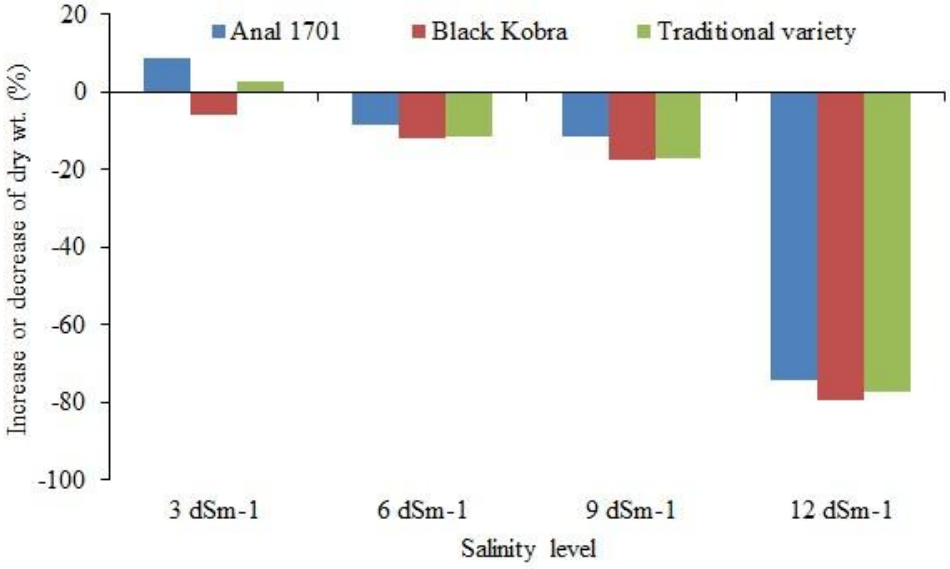

Fig 2. Percent increase or decrease of dry biomass weight due to salinity stress in different rice genotypes at germination stage

Considering interaction effect under control condition the variety Anal 1701 recorded total dry biomass of 0.035 g, which increased to 0.38 g at 3 dSm^{-1} salt concentration; thereafter increasing salt concentration gradually decreased the biomass weight of chili. Similar trend was also found in Traditional variety. The genotype Black Kobra had highest biomass weight at control treatment, which gradually decreased with the increase of the salt concentration. However, the decreasing trend up to 9 dSm^{-1} was gradual, but at 12 dSm^{-1} it reduced drastically (Fig. 2). The drastic reduction of biomass weight in high saline condition was also found by Jharna et al. (2014). Since it retains some biomass even at 12 dSm^{-1}, albeit at a low level, Anal 1701 seems to be the most resilient to high saline environment. Among the varieties, the Anal 1701 variety had the better performance compared to all other varieties across salinity levels.

Table 3. Single and interaction effect of salinity and variety on dry biomass weight/10 seedlings (g) of chili genotypes at germination stage

Salt concentration	Chili genotypes			Salt concentration mean
	Anal 1701	Black Kobra	Traditional	
0 dSm^{-1}	0.035 Ba	0.034 Ab	0.035 Bab	0.034
3 dSm^{-1}	0.038 Aa	0.032 Bc	0.036 Ab	0.035
6 dSm^{-1}	0.032 Ca	0.030 Ca	0.031 Ca	0.031
9 dSm^{-1}	0.031 Ca	0.028 Db	0.029 Db	0.029
12 dSm^{-1}	0.009 Da	0.007 Eb	0.008 Eab	0.008
Variety mean	0.029	0.026	0.027	
Significance level: Variety-***, Salinity-*** and interaction-***; %CV- 2.41				
Standard error of means: Genotype- 0.0002, Salinity-0.0003, Genotype×Salinity- 0.0005				

Similar small letters in a row or similar capital letters in a column are not significantly different at 5% level by DMRT
CV= Co-efficient of variation, ***=Significant at 0.1% level

Salinity induced changes in chili genotypes at vegetative stage

Effects on plant height

Table 4 shows that salinity, variety, and their interaction during the vegetative stage significantly ($P < 0.001$) affected the plant height of chili genotypes. With the control having the maximum height and the 6 dSm^{-1} salinity having the lowest, the plant height varied between 80.71 cm and 87.77 cm. The Black Kobra variety had the tallest plant among the genotypes, measuring 90.30 cm, while the Traditional variety was the shortest one. Anal 1701 and Black Kobra variety had the highest plant height at 6 dSm^{-1} salinity according to the interaction effect.

Table 4. Single and interaction effect of salinity and variety on plant height (cm) of chili genotypes at vegetative stage

Salt concentration	Chili genotypes			Salt concentration mean
	Anal 1701	Black Kobra	Traditional	
0 dSm^{-1}	87.20Ab	98.21Aa	77.89Ac	87.77
3 dSm^{-1}	82.97Bb	89.74Ba	77.89Ac	83.53
6 dSm^{-1}	82.12Ba	82.97Ca	77.04Ac	80.71
Variety mean	84.09	90.30	77.60	
Significance level: Variety-***, Salinity-*** and interaction-***; %CV- 1.75				
Standard error of means: Genotype- 0.69, Salinity-0.69, Genotype×Salinity- 1.20				

Similar small letters in a row or similar capital letters in a column are not significantly different at 5% level by DMRT
CV= Co-efficient of variation, ***=Significant at 0.1% level

Effects on proline content

Table 5 shows that all chili genotypes had higher levels of proline content when exposed to salinity; the increase was significant ($P < 0.001$) and ranged from 16.44 to 37.35 mg 100 g^{-1} fresh leaf. Up to 6 dSm^{-1} salinity the proline concentration progressively increased with increasing salinity, having the lowest content occurring at 0 dSm^{-1} salinity level. The maximum proline concentration (38.54 mg 100 g^{-1} fresh leaf) was found in the Anal 1701 cultivar. The genotypes Traditional variety and Black Kobra were ranked the second and third, respectively. Proline content was also significantly impacted by salinity and variety ($P < 0.001$). Under 6 dSm^{-1} salinity, the conventional variety had the highest proline content (50.62 mg 100 g^{-1}), while the lowest was 8.10 mg 100 g^{-1} observed in the same variety at 0 dSm^{-1} salinity. The higher proline accumulation in stress condition was also reported by Jharna et al. (2001).

Table 5. Single and interaction effect of salinity and variety on proline and total sugar content of chili genotypes at vegetative stage

Salt concentration	Chili genotypes			Salt concentration mean
	Anal 1701	Black Kobra	Traditional	
Proline content (mg 100 g^{-1} fresh leaf)				
0 dSm^{-1}	30.09Ca	11.14Cb	8.10Cc	16.44
3 dSm^{-1}	39.62Ba	14.07Bc	29.97Bb	27.89
6 dSm^{-1}	45.90Ab	15.54Ac	50.62Aa	37.35
Variety mean	38.54	13.58	29.56	
Significance level: Variety-***, Salinity-*** and interaction-***, %CV- 1.62				
Standard error of means: Genotype- 0.208, Salinity-0.208, Genotype×Salinity- 0.361				
Total sugar content (g 100 g^{-1} fresh leaf)				
0 dSm^{-1}	1.09	1.08	1.07	1.08 C
3 dSm^{-1}	1.43	1.43	1.43	1.43 B
6 dSm^{-1}	1.49	1.49	1.48	1.49 A
Variety mean	1.33	1.33	1.32	
Significance level: Variety-NS, Salinity-** and interaction NS, %CV- 18.59				
Standard error of means: Genotype- 0.117, Salinity-0.117, Genotype×Salinity- 0.203				

Similar small letters in a row or similar capital letters in a column are not significantly different at 5% level by DMRT
CV= Co-efficient of variation, **=Significant at 1% level, ***=Significant at 0.1% level, NS= Not significant

Effects on total sugar content

Total sugar content was significantly ($P < 0.01$) increased due to salinity, but was not significant in chili variety and the interaction between salinity and variety (Table 5). Total sugar content was 1.08 g 100 g^{-1} fresh leaf under non-saline conditions (0 dSm^{-1}), 1.43 g 100 g^{-1} at 3 $dSm^{-1}$and 1.49 g 100 g^{-1} fresh leaf at 6 dSm^{-1} salinity. Therefore, significantly lowest total sugar content was found in control treatment, which progressively increased with increasing salinity level and the highest total sugar content was recorded in 6 dSm^{-1} salinity condition. Similar increasing trend due to increasing salt concentration also observed in rice by Jharna et al. (2013).

Table 6. Single and interaction effect of salinity and variety on Chlorophyll-a and Chlorophyll-b content of chili genotypes at vegetative stage

Salt concentration	Chili genotypes			Salt concentration mean
	Anal 1701	Black Kobra	Traditional	
Chlorophyll-a (mg g^{-1})				
0 dSm^{-1}	1.967 Ab	1.078 Ac	2.620 Aa	1.888
3 dSm^{-1}	1.726 Ba	1.075 Ac	1.247 Bb	1.349
6 dSm^{-1}	1.566 Ca	1.047 Bc	1.159 Cb	1.243
Variety mean	1.753	1.053	1.675	
Significance level: Variety-***, Salinity-*** and interaction-***; %CV- 2.20				
Standard error of means: Genotype- 0.015, Salinity-0.015, Genotype×Salinity- 0.026				
Chlorophyll-b (mg g^{-1})				
0 dSm^{-1}	0.557 Ab	0.323 Ac	0.655 Aa	0.512
3 dSm^{-1}	0.461 Ba	0.262 Bb	0.191 Cc	0.305
6 dSm^{-1}	0.393 Ca	0.307 Ab	0.266 Bc	0.322
Variety mean	0.470	0.297	0.371	
Significance level: Variety-***, Salinity-*** and interaction-***; %CV- 4.30				
Standard error of means: Genotype- 0.007, Salinity-0.007, Genotype×Salinity- 0.013				

Similar small letters in a row or similar capital letters in a column are not significantly different at 5% level by DMRT
CV= Co-efficient of variation, ***=Significant at 0.1% level

Effects on leaf Chlorophyll- a content

The individual impact of salinity, variety, and their combination had a substantial ($P < 0.001$) impact on the chlorophyll-a content of fresh leaves at the vegetative stage (Table 6). As salinity increased the amount of chlorophyll-a dropped from 1.88 mg g^{-1} in non-saline circumstances to 1.34 mg g^{-1} at 3 dSm^{-1} and 1.2 mg g^{-1} at 6 dSm^{-1}. Black Kobra contained the lowest amount of chlorophyll-a (1.05 mg g^{-1}), while the most was found in the Anal 1701 variety (1.75 mg g^{-1}). At every salinity level, Anal 1701 gave the best results. In agreement of the current findings the varietal

difference of chlorophyll accumulation was also reported by Sume et al. (2023).

Effects on leaf Chlorophyll- b content

Table 6 demonstrates that the investigated treatments had a substantial ($P < 0.001$) impact on the amount of chlorophyll-b in chili leaves. As salinity increased, the amount of chlorophyll-b dropped from 0.512 mg g^{-1} in non-saline circumstance to 0.305 mg g^{-1} at 3 dSm^{-1} and 0.322 mg/g at 6 dSm^{-1}. Anal 1701 had the greatest chlorophyll-b concentration of any variety (0.47 mg g^{-1}), followed by Black Kobra (0.29 mg g^{-1}) and Traditional (0.37 mg g^{-1}). The Anal 1701 variety showed the best performance under salt stress, with the maximum chlorophyll-b content (0.39 mg g^{-1}) at 6 dSm^{-1} salinity.

Conclusion

Salinity is the most subversive agent in the coastal ecosystem that seriously restricts the production of field crops. The use of salt-tolerant crop varieties is the most profitable approach to improving crop production in this fragile ecosystem. In the experiment, three chili genotypes were tested under varying salt concentrations. Salinity dramatically lowered physiological parameters, development, and germination; the negative impacts increased with stress level rises. Anal 1701 variety was found the most tolerant to salt stress, maintaining better growth and physiological activity. However, a traditional variety exhibited moderate salt tolerance and also could be recommended to be grown in the coastal salt-affected soils, while Black Kobra showed the highest sensitivity, highlighting its unsuitability for saline environments. These findings emphasize the importance of choosing genotypes for saline-prone areas for future best breeding programs. Further studies should be done on breeding for genetic improvement of salinity tolerance in chili plants.

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Conflict of interest

The author has declared no conflict of interest.

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