American Journal of Biochemistry and Biotechnology

Original Research Paper

Stress Resistance Physiological Traits in Maize Under High-Concentration Salt Stress

Mingxia Wang

School of Hydraulic Engineering, Yellow River Conservancy Technical Institute, Kaifeng, China

Article history
Received: 28-9-2023
Revised: 21-12-2023
Accepted: 29-12-2023

Email: wangmingxia2023620@163.com

Abstract: To quantitatively analyze the stress-resistant physiological characteristics of maize under high-concentration salt stress, a combination of statistical analysis and quantitative recursive analysis is selected to conduct salt stress experiments on maize seedlings. 20 treatments are set up, with each treatment consisting of 5 pots and 3 plants per pot. The experiment is conducted without the involvement of any animals. Physiological characteristics data of maize seedlings under various salt stresses are collected and subsequently processed and analyzed using SPSS software. A big data distribution model for salt stress is set up, relevant rules are mined through recursive graphs, stress-resistant physiological traits are evaluated, random distribution characteristics of salt alkali-resistant maize stress physiological sequences are calculated and the adverse physiological morphology of salt alkali-resistant maize is assessed. Overall, valuable insights into the physiological responses of maize seedlings to different salt stresses are obtained through this research, which can contribute to future studies on stress-resistant crops. The findings indicated that stress caused by high concentrations of salt would affect the levels of Malondialdehyde, proline, and soluble sugar, as well as the functionality of antioxidant enzymes in maize. Among them, under $NaHCO_3$ salt stress, the content of MDA, proline, and soluble sugars in maize seedlings showed a trend of first decreasing, then increasing, and then decreasing again, while the content of SOD in maize seedlings showed an upward trend. Under the stress of $NaHCO_3$ and NaCl, the SOD activity in the leaves of Changfeng 1 and Demeiya 1 exhibited a rising trend as the stress time was extended. The activity of SOD in the two varieties that were treated with $NaHCO_3$ reached its maximum value after 36 h of stress. Under salt stress, the direct participation of the increase in δ-OAT activity in the clearance of MDA is observed. P5CS and δ-OAT can enhance the compressive strength of corn by interacting with various other indicators. Research methods are capable of effectively analyzing the stress-resistant physiological traits of maize when subjected to high-concentration salt stress. Compared to previous studies, the study extends the duration of stress and analyzes the physiological changes of maize in resisting salt stress. Not only that but also multiple comparisons of salt stress have been added to gain a clearer understanding of the physiological changes of maize under different salt stresses.

Keywords: High Concentration, Corn, Physiology, Quantitative Analysis, Salt Stress, Technology

Introduction

Under abiotic stresses such as drought, elevated temperature, and salinization, plants may not be able to grow and develop normally and the development of their roots, stems and leaves may be inhibited, leading to a decrease in the efficiency of photosynthesis within the plant and damage to cell membranes. Drought or excessive salt can affect plant water absorption and nutrient use, thereby reducing crop yield. Soil salinization is becoming an increasingly prominent issue, given the deteriorating ecological environment on Earth, and the rapid increase in industrial and agricultural production and population. Furthermore, due to non-scientific irrigation and irrational fertilization methods, the extent of secondary salinization in land has significantly increased and the resulting soil salinization, caused by human factors, has become a grave concern for China's food security (Sousa *et al*., 2021). Corn is the primary grain crop in China and it also holds the distinction of being the crop with the largest planting area in dry fields throughout the country. Under extreme temperature stress, the synthesis of volatile substances in sweet corn seedlings will be affected, as some scholars have pointed out. When subjected to stress due to low temperatures, there will be a decrease in auxin and jasmonic acid (Xiang *et al*., 2021). The experimental results conducted by certain scholars have demonstrated that the photosynthesis of maize is influenced by salt and cadmium stress, resulting in the inhibition of biomass synthesis and subsequently impacting the growth of maize (Sujatha *et al*., 2019). Hence, it is imperative to examine the stress-resistant physiological characteristics of maize that are associated with its yield. Although traditional methods for evaluating maize stress resistance physiological traits under stress are commonly used, they are manual evaluations that possess a certain degree of subjectivity. Consequently, they do not facilitate a profound understanding of these traits. The objective analysis method, which is based on the reverse physiological sequence of corn and possesses stronger objectivity, is achieved through the combination of biological analysis and big data models. Therefore, applying this method to research to compensate for the shortcomings of previous manual evaluation methods. To enhance the stress resistance of maize under high-concentration salt stress, a method that incorporates statistical analysis and quantitative recursive analysis has been proposed. This method aims to provide a theoretical basis for future research on crop salt tolerance mechanisms and the breeding of salt-alkali-tolerant maize varieties, to promote the continuous improvement of salt-alkali-tolerant maize quality. The proposed method offers the capability to assess the physiological traits of salt alkali-resistant maize in response to high-concentration salt stress, thereby enhancing the precision of such maize under similar conditions. It holds significant application value in the analysis of salt alkali-resistant corn under high-concentration salt stress, particularly in antibiotic analysis. Currently, most research on salt stress focuses on measuring the changes in plants after 6 days or more of stress, analyzing the harm and degree of salt stress to plants. The research experiment sets the time of salt stress at different periods such as 12 and 24 h, mainly analyzing the physiological changes of plants in resisting salt stress in the early stage of salt stress, aiming to reveal the maximum and longest time that plants can resist salt stress in the early stage. This can provide a basis for how plants can effectively alleviate the damage caused by salt stress.

Materials and Methods

Test Materials and Instruments

The corn varieties evaluated are "Demeiya 1" and "Changfeng 1". Among them, "Demeiya 1" is a salt alkali-tolerant corn; Changfeng 1 is a salt alkali-sensitive corn. Both corn materials were provided by an agricultural research institute. These two corn varieties are selected and 10% $NaClO_4$, distilled water, and 1/2 concentration Hoagland nutrient solution are prepared. Among them, the conductivity of the hydroponic solution is 1.3 mS/cm. Prepare sulfosalicylic acid solution, acidic ninhydrin reagent, toluene, trichloroacetic acid, thiobarbituric acid solution, quartz sand, and select anthrone reagent and concentrated H_2SO_4 solution. The instruments include a centrifuge, spectrophotometer, electronic analytical balance, constant temperature water bath, mortar, test tube, pipette (1, 5 mL), water bath pot, stoppered test tube, and constant temperature water tank.

Cultivate Corn Seedlings

In an agricultural research institute in Daqing, the plump seeds of corn varieties are manually selected. These seeds are of the same size. They are then disinfected with 10% $NaClO_4$ for 10 min, thoroughly rinsed with tap water, and subsequently rinsed multiple times with distilled water. The selected seeds are germinated at a temperature of 28°C and seeds showing consistent germination are chosen for cultivation. 20 treatments are set up, each with 5 pots and 3 plants per pot. After reaching the stage of one leaf and one heart through hydroponics, they are cultured using a Hoagland nutrient solution diluted to half its concentration. The lighting schedule consists of 16 h of light per day and 8 h of darkness, with temperatures during the day and night maintained at 28 and 20°C, respectively. The nutrient solution is changed every 3 days to ensure the necessary nutrients for the growth of corn seedlings, maintain their growth and development, and continuously ventilate 24 h a day to create a good ventilation environment for the growth of corn seedlings and eliminate the impact of poor ventilation on the experiment.

Salt Stress Treatment

When the seedlings grow to three leaves and one heart, the following treatments are carried out: NaCl and $NaHCO_3$ are set with concentration gradients of 0, 25, 50, 75, and 100 mmoL•L^{-1}, respectively; Na_2SO_4 and Na_2CO_3 are set to 0 mmoL•L^{-1} and 12, respectively 5, 25, 37.5, 50 mmoL•L^{-1} concentration gradients, starting from the addition of salt and sampling and measurement every 12, 24, 36 and 48 h. The control group consists of NaCl solution, $NaHCO_3$ solution, Na_2SO_4 solution, and Na_2CO_3 solution with concentrations of 0 mmoL-L^{-1}. Each treatment is repeated three times.

Measurement Items and Methods

Sulfosalicylic acid determines the proline content (Duan *et al*., 2020; Mishra and Chundawat, 2019; Ganie *et al*., 2019; Singh and Senger, 2020). During the measurement process, standard curves are drawn and 0.1 g of corn leaves under different treatments are accurately weighed and placed in large tubes. Then, 5 mL of 3% sulfosalicylic acid solution is added to each tube and extracted in a boiling water bath for 10 min. The extraction process should be shaken frequently, cooled, and filtered into a clean test tube. The filtrate is the extract of proline. Take 2 mL of the extraction solution into another clean glass stoppered test tube, add 2 mL of acetic acid and 2 mL of acidic ninhydrin reagent, and heat in a boiling water bath for 30 min. The solution turns red. Then add 4 mL of toluene, shake for 30 sec, let it stand for a moment, take the upper liquid into a 10 mL centrifuge tube, and centrifuge at 3000 rpm for 5 min. Gently pipette the upper layer of proline red toluene solution into a colorimetric cup, using toluene as the blank control, and compare the color at a wavelength of 520 nm on a spectrophotometer to obtain the absorbance value. According to the standard curve, determine the content of proline in 2 mL of the measuring solution and calculate the percentage of proline content in the sample. The content of soluble sugars is determined by the anthrone colorimetric method (Liu *et al*., 2019). In the process of measuring soluble sugars, a glucose standard curve is created, followed by weighing 1 g of corn leaves, cutting them into small pieces, placing them in a mortar, adding a small amount of distilled water, grinding them into a homogenate and adding them to a 20 mL graduated test tube. Wash the mortar with 10 mL of distilled water and transfer the washing solution into a graduated test tube. Boil for 10 min, cool, and filter. Collect the filtrate in a 100 mL volumetric flask, dilute to volume with distilled water, shake well, and set aside. Use a pipette to absorb 1 mL of the extraction solution and transfer it to a 20 mL stoppered graduated test tube. Add 1 mL of water and 0.5 mL of anthrone reagent. Slowly add 5 mL of concentrated H_2SO_4 solution. After covering the test tube stopper, gently shake well and boil for 10 min. The colorimetric blank group was mixed with 2 mL distilled water and 0.5 mL anthrone reagent and both were kept in a boiling water bath for 10 min. After cooling to room temperature, compare the color at a wavelength of 620 nm and record the optical density value. Check the standard curve to obtain the corresponding glucose content.

Malondialdehyde (MDA) content is determined by colorimetric assay with thiobarbituric acid. In the process of measuring MDA, first, weigh 1 g of corn leaves, add a small amount of quartz sand and 2 mL of 10% trichloroacetic acid, grind to a homogenate, then add 8 mL of 10% trichloroacetic acid for further grinding. Centrifuge the homogenate at 4000 r/min for 10 min and the supernatant is malondialdehyde extract. Take 4 clean test tubes, number them, and 3 sample tubes (three replicates). Add 2 mL of extraction solution to each tube, 2 mL of distilled water to the control tube, and then add 2 mL of 0.6% thiobarbituric acid solution to each tube. Shake well, react the mixture in a boiling water bath for 15 min, cool quickly, and then centrifuge. Measure the absorbance values of the supernatant at wavelengths of 532, 600, and 450 nm, respectively. On this basis, calculate the MDA content. Î±$^{-1}$-Pyrroline^{-5}-Carboxylic acid Synthetase (P5CS) activity assay is defined as a hydroxylamine hydrochloride colorimetric assay. The units of enzyme activity are U-g^{-1}-min^{-1} and one unit of enzyme activity (1U) is defined as the amount of enzyme required to form 1 of γ-glutamine (wet sample) per minute. Ornithine δ-Aminotransferase (δ-OAT) activity is determined and Ornithine δ-Aminotransferase-like (δ-OATS) activity is determined, with one unit of enzyme activity (1U) defined as the amount of enzyme required to produce 1 mmol of δ^{-1}-pyrrolidine^{-5}-carboxylic acid (wet sample) in 1 h, i.e., U-g^{-1}-h^{-1}. Superoxide Dismutase (SOD) activity is determined using a total SOD activity assay kit (product number: A001^{-1} hydroxylamine method, produced by Nanjing Jianjian Bioengineering research institute in August 2016), according to the instructions.

Information Sampling of Antibiotic Forms in Salt Alkali-Resistant Maize Under Salt Stress

To achieve an intelligent evaluation of maize reverse physiological morphology under high-concentration salt stress, a corresponding intelligent evaluation model is constructed. The statistical pool of the reverse physiological sequence of salt alkali-resistant corn under high concentration salt stress is composed of *N* statistical sensor nodes. *N* represents the number of statistical sensor nodes:

$$C_{N,m}(r) = \frac{2}{N(N-1)} \sum_{i=1}^{N} \sum_{j=i+1}^{N} H\left(r - \left\| \boldsymbol{x}_i - \boldsymbol{x}_j \right\|\right) \tag{1}$$

Equation 1, *r* represents a variable, *m* represents the variable, *i*, *j* represents the sequence number, *x* represents the variable, and $H(\cdot)$ represents the Heavy side function, as shown in Eq. 2:

$$H(x) = \begin{cases} 0, & x \le 0 \\ 1, & x > 0 \end{cases} \tag{2}$$

The spatial reconstruction of the sequence mapping relationship of salt alkali tolerant maize is then conducted in Eq. 3:

$$X = [s_1, s_2, \cdots s_K]_n = (x_n, x_{n-\tau}, \cdots, x_{n-(m-1)\tau}) \tag{3}$$

Equation 3, s represents the corn sequence, k represents the quantity of s, $K = N\text{-}(m\text{-}1)\ \tau$. τ is the relative time delay in evaluating the sequence of salt alkali-resistant corn anti-inverse physiological statistics under high concentrations of salt stress:

$$D = \lim_{r \to 0} \frac{\lg C_m(r)}{\lg r} \tag{4}$$

D represents time, $C_m(r)$ is the correlation integral of the salt alkali-resistant corn anti-inverse physiological statistics sample sequence under high-concentration salt stress under the relative sampling delay. When the phase spatial distribution trajectory Euclidean distance r is small enough, the independent random distribution variables of the salt alkali-resistant corn anti-inverse physiological statistics sequence under high-concentration salt stress are calculated to realize the information sampling of salt alkali-resistant corn anti-informative conditions under high-concentration salt stress.

Analysis of Physiological Characteristics of Salt Alkali-Resistant Maize Under Salt Stress

Statistical analysis and sample monitoring are used to sample the sequence of the reverse physiological statistics of the salt alkali-resistant corn under high-concentration salt stress (Nedeljković *et al*., 2019). The large data distribution model of the sequence of the reverse physiological statistics of the salt alkali-resistant corn under high-concentration salt stress is constructed by using the high-concentration salt stress method:

$$Q(a, b_i) = \sum_i \sum_j \left[y_{ij} - \left(\hat{a} x_{ij} + \hat{b}_i \right) \right]^2 \tag{5}$$

$Q(.)$represents the big data distribution model. The results show that the characteristic of the anti-inverse physiological characteristic of salt alkali-resistant corn under high-concentration salt stress satisfies the minimum extremum:

$$\begin{cases} \dfrac{\partial Q}{\partial \hat{a}} = -\sum_i \sum_j 2\left[y_{ij} - \left(\hat{a} x_{ij} + \hat{b}_i \right) \right] x_{ij} = 0 \\ \dfrac{\partial Q}{\partial \hat{b}_i} = -\sum_i \sum_j 2\left[y_{ij} - \left(\hat{a} x_{ij} + \hat{b}_i \right) \right] = 0 \end{cases} \tag{6}$$

When Q reaches the minimum, the best correlation rule characteristic of the sample sequence of salt alkali-resistant corn under high-concentration salt stress is obtained and the correlation rule mining method is used to obtain the statistical characteristic of salt alkali-resistant corn anti-backward physiological evaluation under high-concentration salt stress as follows:

$$\begin{cases} \hat{a} = \dfrac{\sum_i \sum_j \left(x_{ij} - \bar{x}_i \right)\left(y_{ij} - \bar{y} \right)_i}{\sum_i \sum_j \left(x_{ij} - \bar{x}_i \right)^2} \\ \hat{b}_i = y_i - a\bar{x}_i \end{cases} \tag{7}$$

where, $\bar{x}_i = \frac{1}{j}\sum_j x_{ij}$ $\bar{y}_i = \frac{1}{j}\sum_j y_{ij}$ j is a scalar coordinate sequence of the sample sequence collected by the salt alkali-resistant corn anti-biological statistics under high-concentration salt stress. With m as the embedded dimension, $s_i = (x_i, x_{i+\tau}, \cdots, x_{i+(m-1)\tau})^T$ represents a subset of the anti-biological evaluation of salt alkali-resistant corn under high-concentration salt stress, and the eigenvector model of the anti-biological statistics of salt alkali-resistant corn under high-concentration salt stress is expressed as:

$$x_n = (x_n, x_{n\text{-}\tau}, L, x_{n\text{-}(m\text{-}1)\tau}) \tag{8}$$

The correlation rule mining of constructing a recursive graph $R(i, j)$ for evaluation of stress-resistant physiological traits is followed:

$$R(i, j) = H\left(\varepsilon_i - d_{ij} \right), \quad i, j = 1, 2, ..., N \tag{9}$$

Using a quantitative recursive analysis model, the characteristic quantity of the anti-inverse physiological evaluation of point x_i and point x_j is quantified and the sample sequence cost function of the anti-inverse physiological statistics of salt alkali-resistant corn under high-concentration of salt stress is obtained as follows:

$$G(U \left| \mu_k, \sum_k \right.) = (2\pi)^{-d/2} \left| \sum_k \right|^{-1/2} \times \exp\left[-\frac{1}{2}(U - u_k)^T \sum_k^{-1} (U - u_k) \right] \tag{10}$$

The above formula $G(U|\mu_k, \sum_k)$ constrains the characteristic quantity of stress-resistant physiological traits, and the quantitative tracking recognition of stress-resistant physiological traits is conducted (Zhu *et al*., 2017).

Analysis and Optimization of Stress-Resistant Physiological Traits in Maize Under Salt Stress

Based on statistical analysis and sample monitoring methods, the intelligent evaluation system is perfected and designed (Indriani *et al*., 2021). Under high concentrations of salt stress, the amount of mutual information of the anti-biological statistical samples of salt alkali-resistant corn is as follows:

$$I(\tau) = -\sum_{ij} p_{ij}(\tau) \ln \frac{p_{ij}(\tau)}{p_i p_j} \quad (11)$$

Time points $x(t)$ and $x(t + \tau)$ are not correlated, indicating that the salt alkali-resistant corn anti-reversal statistical sample sequences are fully predictable under high-concentration of salt stress (De Sá-Martins *et al*., 2019). Using least squares fitting, the optimal estimate of K for the correlation of the sequence bit sequence of the salt alkali-resistant corn anti-inverse physiological statistics under high-concentration salt stress is obtained. The formula is as follows:

$$D'_{t+1} = 1 - (1-\lambda)\sum_{n=0}^{\infty} \Omega_{m+n+1}((n+1)b - t) \quad (12)$$

$$L'_{t+1} = (1-\lambda)\sum_{n=0}^{\infty} \Omega_{k+n}(n+1)b \quad (13)$$

In the above formula, Ω denotes the entropy function, and the characteristic of the anti-inverse physiological distribution of salt alkali-resistant corn under high-concentration of salt stress is followed as:

$$x_k = f\{x_{k-1}, u_{k-1}, w_{k-1}\} \quad (14)$$

Using the quantitative regression analysis method for big data feature extraction and information regression analysis, a feature extraction model for the statistical analysis of the inverse physiological state of salt alkali-resistant corn under high-concentration salt stress is constructed:

$$\begin{cases} x(k+1) = \left(\begin{bmatrix} 1 & 0.6 \\ -0.4 & 0.5 \end{bmatrix} + \begin{bmatrix} 0.02 & 0.01 \\ -0.02 & 0.12 \end{bmatrix} \right) x(k) \\ \qquad + \begin{bmatrix} 1 \\ 1 \end{bmatrix} kx(k-\tau_k) + \begin{bmatrix} 0.1 \\ 0.1 \end{bmatrix} w(k) \\ z(k) = \begin{bmatrix} 1 & 1 \end{bmatrix} x(k) + 0.1u(k) + 0.1w(k) \end{cases} \quad (15)$$

Based on the feature extraction model, the physiological status of salt-alkali-resistant maize under stress can be understood. On this basis, the adverse physiological morphology of salt-alkali-resistant corn is analyzed and evaluated. If the probability random variable of the time series $x(t)$ appears in the distribution interval i. Under high-concentration salt stress scatisfies $a_k \geq 0$, $\sum_{k=1}^{K} \alpha_k = 1$. The statistical mathematical method is used to calculate the random distribution characteristics of the inverse physiological sequence of salt alkali-resistant corn under high-concentration salt stress (Liang *et al*., 2021; Ali *et al*., 2021; Shafique *et al*., 2021) and the regression value of salt alkali-resistant corn's anti-biotic index under high-concentration salt stress is obtained as follows:

$$|s(f)| = A\sqrt{\frac{1}{2k}\{[c(v_1) + c(v_2)]^2 + [s(v_1) + s(v_2)]^2\}} \quad (16)$$

$F\sigma = 1$ is the standard α-stable distribution, then the adaptive evaluation and accurate prediction of the adverse physiological shape of salt alkali-resistant corn under high-concentration of salt stress can be realized.

Results

Using maize varieties "Demeiya 1" and "Changfeng 1" as materials, five salt stress gradients were set up. Eight physiological and biochemical indicators during the seedling stage were measured through hydroponic experiments and the relationship between related enzymes and salt tolerance was explored, revealing the synthesis and regulatory mechanism of proline in maize.

Salt Stress Effects on Malondialdehyde Content and Membrane Permeability of Salt Alkali-Resistant Corn

MDA is the product of membrane lipid peroxidation and its concentration can reflect the extent of plant damage under stress. Figure 1 shows the changes in MDA content in the leaves of two maize varieties under increasing salt stress. When subjected to $NaHCO_3$ and Na_2CO_3 stress, the MDA content initially decreased and then increased with prolonged stress time, reaching its minimum value after 24 h of stress for both varieties. Under Na_2SO_4 stress, the MDA content in the leaves of both maize genotypes initially decreased and then increased with prolonged stress time. After 24 h of stress, the MDA content of Changfeng 1 was lower than that of other periods, while Demeiya 1 had a lower MDA content than other periods after 36 h of stress. Similarly, under NaCl stress, the MDA content in the leaves of both maize genotypes initially decreased and then increased with prolonged stress time. Changfeng 1 reached its lowest MDA level after 36 h of stress, while Demeiya 1 reached its lowest point after 24 h of stress. With the prolongation of salt stress time, the content of MDA in maize seedlings first decreased and then increased with the prolongation of stress time. The plant's protective mechanism could not resist external stress, so the content of MDA began to increase again.

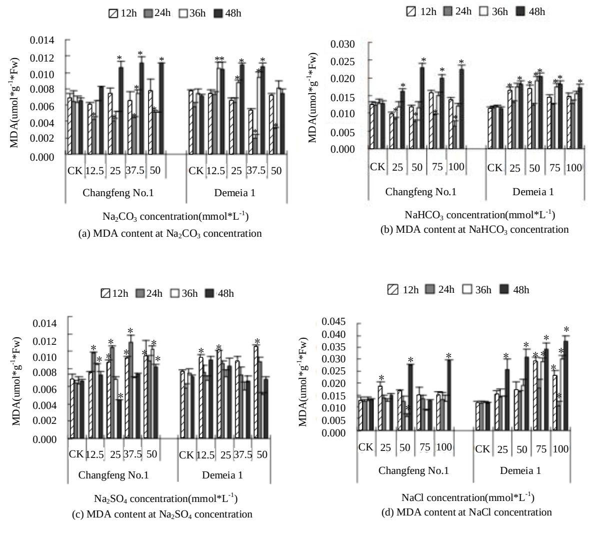

Fig. 1: Malondialdehyde (MDA) content in maize under different salt stress; Note: Compared with the control group, "*" indicates a significant difference (p<0.05)

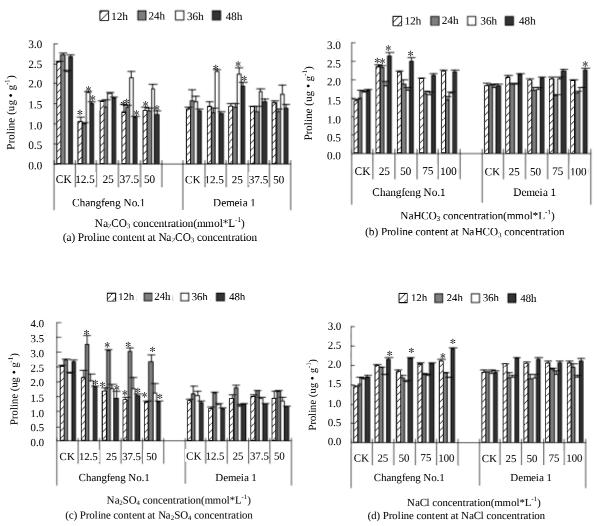

Fig. 2: Proline content under different salt stresses; Note: Compared with the control group, "*" indicates a significant difference (p<0.05)

Maize Salt Stress Effect on Proline Content

As soil salinity increased, the proline content in two maize varieties' leaves underwent changes, as depicted in Fig. 2. Under $NaHCO_3$ stress treatment, the proline content in the leaves of both maize genotypes initially decreased and then increased with the prolongation of stress time. After 48 h of stress, the proline content reached its maximum. When the $NaHCO_3$ concentration was 25, 50, 75, and 100 mmoL•L^{-1}, the proline content in Changfeng 1 seedlings leaves was 1.56, 1.48, 1.24, and 1.30 times higher than that of the control, respectively. The proline content in Demeiya 1 leaves was 1.18, 1.12, 1.23, and 1.26 times higher than that of the control, respectively. Under Na_2CO_3 stress, the proline content in both maize genotypes' leaves reached its highest value after 36 h of stress. For the same stress concentration, the proline content in Changfeng 1 leaves first increased and then decreased with prolonged stress time, while the proline content in Demeiya 1 leaves initially decreased, then increased, and finally decreased again. Under Na_2SO_4 stress treatment, the proline content in both maize genotypes' leaves increased initially and then decreased with prolonged stress time. The maximum content of proline in the leaves was reached after 24 h of stress. When the Na_2SO_4 concentration was 12.5, 25, 37.5, and 50 mmoL•L^{-1}, the proline content in Changfeng 1 leaves was 1.19, 1.12, 1.11, and 0.98 times higher than that of the control, respectively. The proline content in Demeiya 1 leaves was 1.02, 1.13, 1.08, and 1.05 times higher than that of the control, respectively. The trend in proline content in both maize genotypes leaves under NaCl stress treatment was consistent with that under $NaHCO_3$ stress treatment and both reached their highest values after 48 h of stress. The increase in proline in salt-alkali sensitive maize was greater than that in salt-alkali-tolerant maize, indicating a positive correlation between the accumulation of proline under salt-alkali stress and the degree of plant damage and indicating that it was a product of stress. However, there was no evidence in this experiment to suggest a negative correlation between proline and plant salt tolerance.

Salt Stress Effects on Soluble Sugar Content of Salt Alkali-Resistant Corn

With increasing stress duration, the soluble sugar content in two maize varieties leaves exhibited changes as depicted in Fig. 3. Under $NaHCO_3$, the soluble sugar content in the leaves of Changfeng 1 maize seedlings initially decreased and then increased as the stress time extended, reaching its peak at 36 h of stress. On the other hand, Demeiya 1 showed an initial increase followed by a decrease in soluble sugar content with prolonged stress time and reached its maximum value at 24 h of stress. At $NaHCO_3$ concentrations of 25, 50, 75, and 100 mmoL•L^{-1}, the soluble sugar content in the leaves of Changfeng 1 was 1.64, 1.30, 2.03, and 1.59 times higher than that of the control. In comparison, the soluble sugar content in Demeiya 1 leaves was 1.89, 1.21, 2.00, and 2.24 times higher. Under Na_2CO_3, both varieties reached their maximum soluble sugar content after 12 h of stress. The soluble sugar content in Changfeng 1 leaves showed a decreasing trend, while Demeiya 1 showed an increasing trend followed by a decrease. Under Na_2SO_4, both varieties displayed a decreasing trend in soluble sugar content. The maximum content of soluble sugar in both maize varieties' leaves was observed after 12 h of stress. At Na_2SO_4 concentrations of 12.5, 25, 37.5, and 50 mmoL•L^{-1}, the soluble sugar content in Changfeng 1 leaves was 1.99, 1.14, 1.86 and 1.47 times higher. Similarly, the soluble sugar content in Demeiya 1 leaves was 2.70, 2.56, 2.20, and 2.07 times higher than that of the control. Under NaCl stress treatment, the soluble sugar content in both maize varieties' leaves initially increased and then decreased. The soluble sugar content in Changfeng 1 leaves reached its maximum value at 36 h of stress, while Demeiya 1 reached its maximum value at 24 h of stress. With the prolongation of stress time, the changes in soluble sugar content in the leaves and roots of two genotypes of maize seedlings both showed varying degrees of decrease and some even showed a bimodal growth phenomenon. This may be due to the stress time of the experiment being within 48 h and the alleviating effect of the plant itself was lost.

Salt Stress Effect on Antioxidant Enzyme Activity of Salt Alkali-Resistant Corn

As stress time extended, the soluble sugar content in two maize varieties of seedling leaves showed changes as shown in Fig. 4. Under the stress of NaHCO3 and NaC, SOD activity in Changfeng 1 and Demeiya 1 leaves showed an upward trend. SOD activity in the two varieties treated with NaHCO3 reached its maximum value at 36 h of stress. At NaHCO3 concentrations of 25, 50, 75, and 100 mmol•L-1, respectively, the SOD activity in Changfeng 1 leaves was 0.96, 0.99, 0.93, and 0.86 times that of the control, SOD activity in Demeia 1 leaves was 1.19, 1.14, 1.10 and 0.95 times higher. The two genotypes of maize varieties treated with NaCl reached their maximum values at 48 h of stress. At NaCl concentrations of 25, 50, 75, and 100 mmoL•L-1, the SOD activity in Changfeng 1 leaves was 1.01, 1.07, 0.99, and 0.78 times higher and SOD activity in leaves of Demeiya 1 was 0.95, 0.93, 0.92 and 0.95 times higher. Changes in SOD activity in the leaves of two genotypes of maize seedlings treated with Na2SO4 were highest under low concentration (12.5-25 mmoL•L-1) stress for 24 h and not significant under high concentration (37.5-50 mmoL•L-1) sodium ion stress. Under different concentrations of stress, the SOD activity in the leaves of two genotypes of maize seedlings treated with Na2CO3 showed different trends with the prolongation of stress time and different salt and alkaline-tolerant maize varieties showed different trends. SOD can protect the structure of membranes under stress, thereby enabling plants to tolerate and resist stress to a certain extent. Due to the stress that maize undergoes, it undergoes a brief period of adaptation to the adverse environment. At this time, the plant's protective ability will decrease and the plant itself will have a direct destructive effect on the antioxidant system. As the salt alkali concentration increases, the ability to clear reactive oxygen species will decrease.

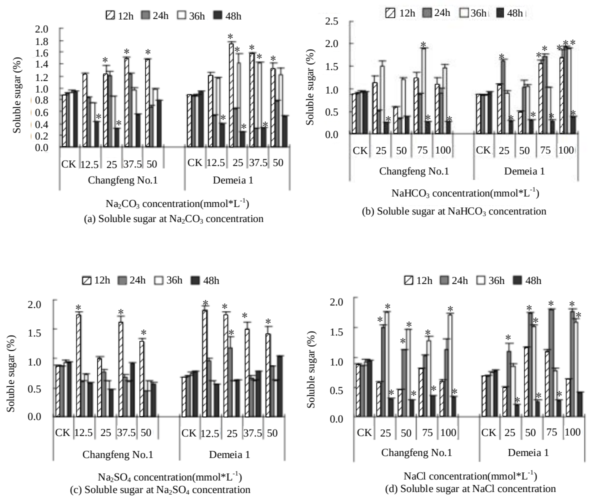

Fig. 3: Contents of soluble sugar of salt alkali-resistant corn under different salt stresses; Note: Compared with the control group, "*" indicates a significant difference ($p<0.05$)

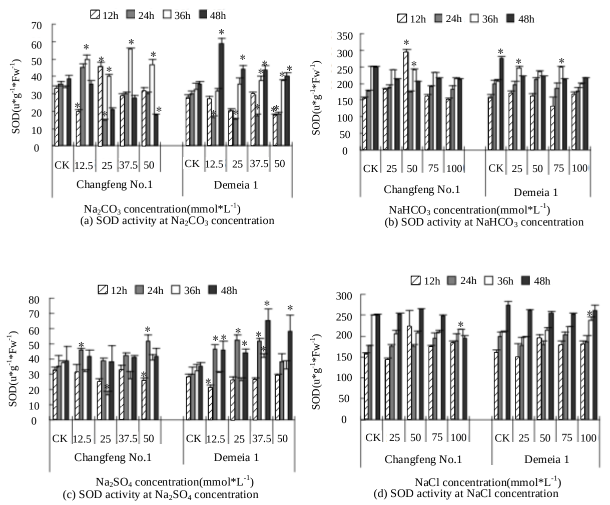

Fig. 4: Salt stress effect on SOD activity of salt alkali resistant corn; Note: Compared with the control group, "*" indicates a significant difference ($p<0.05$)

Correlation Between Physiological and Biochemical Indexes of Salt Alkali-Resistant Corn Under Salt Stress

Physiological indicators of corn under salt stress did not play an independent role here, but there was a certain correlation between each indicator (Table 1). Chl: Chlorophyll content; Pro: Proline content; SS: Soluble sugar content; MDA: Malondialdehyde content; CMP: Cell membrane permeability; P5CS: δ^{-1}-neneneba pyrroline-5-carboxylic acid synthase activity; δ- OAT: Ornithine- δ- Aminotransferase activity; SOD: Superoxide dismutase activity. Simple correlation coefficients were 0.547 and 0.815, while partial correlation coefficients were 0.626 and 0.888. To exclude the comprehensive influence of various variables, some correlation analyses indicate that the activity of soluble sugars and P5CS was closely related to the content of proline, playing a positive role. The partial correlation between MDA content and soluble sugar content was positive, reaching a significant level. However, their correlation was significant. The partial correlation between δ-OAT activity was negative and there was no significant positive correlation between MDA and SOD, but between the two indicators. Salt stress impact on maize δ-OAT activity was closely related to MDA content, but it had a negative impact. The results indicated that under salt stress, the increase in δ-OAT activity directly participates in the clearance of MDA. The SOD and P5CS δ-OAT activity was positively correlated and reached a significant level, which was consistent with some correlation analysis results, indicating that under salt stress, there was a positive synergistic effect between SOD and P5CS δ-OAT activities. The activity of P5CS and δ-OAT showed a simple negative correlation and reached a significant level, but some correlations were not significant, indicating that under salt stress, P5CS and δ- OAT can improve the compressive strength of corn by interacting with other indicators. By analyzing the correlation between different physiological and biochemical indicators, there was a certain correlation between physiological and biochemical indicators. Through their mutual influence, the growth of corn was regulated. In the actual cultivation process, the purpose of regulating other related indicators was achieved by controlling certain physiological and biochemical indicators.

Regression Analysis

Using Eqs. 14-17, regression analysis was conducted on the above data to construct a testing environment for the intelligent evaluation system of maize stress resistance physiological characteristics. The dynamic range of feature sampling was 50 dB to +50 dB. When detecting stress resistance physiological characteristics, a DSP core control method was used. The data length of human-machine information sampling was 1024 and the information conversion frequency was 1.23 KHz. Based on the simulation environment and parameter settings mentioned above, an intelligent evaluation was conducted. The evaluation probability distribution of maize stress resistance physiological characteristics was obtained, in Fig. 5. From Fig. 5, the stability and accuracy of the research method in evaluating the stress resistance physiological status of salt alkali-resistant corn are relatively high.

Table 1: Correlation matrix among physiology indexes

	Pro	SS	MDA	P5CS	δ-OAT	SOD
Pro	1.000	0.626**	0.294*	0.888**	0.109	0.373**
SS	0.547**	1.000	0.125	0.054	0.173	0.191
MDA	0.178	0.529**	1.000	0.239	0.409**	0.388**
P5CS	0.815**	0.162	0.061	1.000	0.009	0.479**
δ-OAT	0.205	0.495**	0.308*	0.353**	1.000	0.561**
SOD	0.065	0.179	0.257	0.415**	0.625**	1.000

* denotes significant correlation at p<0.05 (two-sided test), ** denotes significant correlation at p<0.01 (two-sided test). The lower left area is a simple correlation analysis. The upper right area is a partial correlation analysis

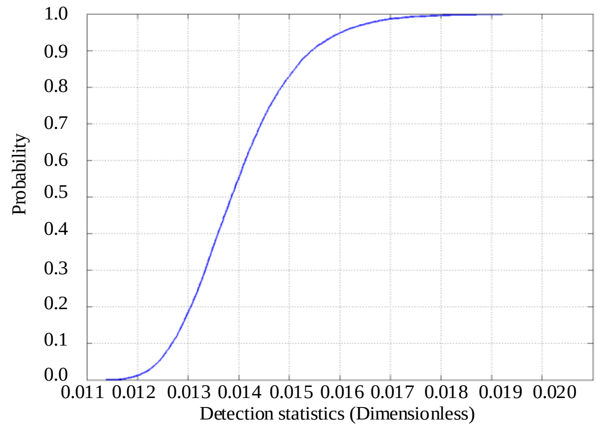

Fig. 5: Evaluation probability distribution of the anti-biotic characteristics of salt alkali-resistant corn under high-concentration salt stress

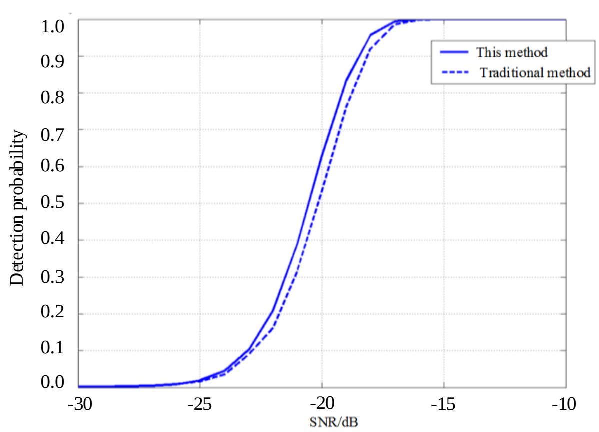

Fig. 6: Performance comparison

To evaluate the physiological traits of salt alkali-resistant maize under high-concentration salt stress, this study further evaluated the detection probability of different methods. The results are shown in Fig. 6. Figure 6, the intelligent evaluation system designed in the study has good evaluation performance and intelligence in evaluating the physiological status of salt alkali-resistant corn under salt stress.

Discussion

Endogenous reactive oxygen species scavengers such as SOD can protect the membrane structure under stress, thereby enabling plants to tolerate and resist stress to a certain extent. The level of SOD in the organism shows an intuitive indicator of aging and death. As the stress time prolongs, the activity of protective enzymes in the leaves and roots of different genotypes of maize undergoes a process of initial decline, which is consistent with the research results of other scholars (Ding *et al*., 2019). Some scholars have found that salt stress tolerance is related to the clearance of SOD during seed germination, which has root development and osmotic protection functions (Dvořák *et al*., 2021). This indicates that when plants are subjected to stress, there will be a short-term process of adapting to the stress environment. At this time, the plant's protective ability will decrease and the plant itself will have a direct destructive effect on the antioxidant system. As the salt alkali concentration increases and the degree of damage increases, the activity of protective enzymes will be affected, resulting in a decrease in activity and a decrease in the ability to clear reactive oxygen species. Some scholars believe that the MDA content of plants increases continuously during salt stress, indicating that the degree of membrane lipid peroxidation in plants increases after salt stress (Moradbeygi *et al*., 2020). Some scholars have improved plant antioxidant tolerance by introducing rhizosphere bacteria that promote plant growth under salt stress. The results showed that MOD decreased while antioxidant capacity and antioxidant enzymes increased (Neshat *et al*., 2022). The research data results indicate that with the increase of salt alkali stress concentration and the extension of stress time, the content of MDA in the leaves and roots of maize seedlings of Changfeng 1 and Demeiya 1 first decreases and then increases. The reason for this phenomenon may be that in the early stage of salt alkali stress, namely the 12-24 h stage, the resistance mechanism of maize to membrane lipid peroxidation is activated, which eliminates a part of its own MDA and protects its normal physiological activities, However, with the prolongation of salt stress time, the plant's protective mechanism cannot resist external stress, leading to an increase in MDA content.

Conclusion

To more accurately understand the stress resistance physiological traits of maize under salt stress, this study focuses on maize seedlings and proposes an evaluation method based on statistical analysis and quantitative recursive analysis. Using the method of statistical analysis and sample monitoring, the samples of high-concentration salt stress are sampled. The method of high-concentration salt stress is used to construct the big data distribution model of high-concentration salt stress and the method of quantitative regression analysis. The results showed that high-concentration salt stress would affect the content of Malondialdehyde, proline, soluble sugar, and the activity of antioxidant enzymes in maize. Under Na_2SO_4 stress treatment, the MDA content in the leaves of two genotypes of corn varieties showed a trend of first decreasing and then increasing with the extension of stress time. After 24 h of stress, the MDA content in the leaves of Changfeng 1 was the lowest. In the correlation analysis of physiological and biochemical indicators in corn, the partial correlation between MDA content and soluble sugar content was positive, reaching a significant level. Under the increase in salt stress, δ-OAT activity directly participated in the clearance of MDA. The detection probability of the research method was slightly higher than that of traditional methods, indicating that the detection accuracy of the research method was relatively high. The physiological characteristics of salt alkali-resistant maize under salt stress were understood through research methods and they were well evaluated. There are still certain shortcomings in the research, as there are not many experimental samples. In the future, more corn varieties can be evaluated to further analyze their stress resistance physiological characteristics under high-concentration salt stress.

Acknowledgment

Thank you to the publisher for their support in the publication of this research article. We are grateful for the resources and platform provided by the publisher, which have enabled us to share our findings with a wider audience. We appreciate the efforts of the editorial team in reviewing and editing our work and we are thankful for the opportunity to contribute to the field of research through this publication.

Funding Information

The research was supported by the key scientific and technological project of Henan Province "coupling mechanism of soil water and nitrogen in maize alternate irrigation and key technologies for water saving and efficiency enhancement," grant number: 232102111004.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and that no ethical issues are involved.

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