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Table 1 and 2 are available in the Supplementary Files section.

Response of *Elymus nutans* seedling physiology and endogenous hormones to drought and salt stress

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Abstract: *Elymus nutans*, a pioneer plant for the restoration of high quality pasture and vegetation, is widely used to establish artificial grasslands and ecologically restore arid and salinized soils. To investigate the effects of drought stress and salt stress on the physiology and endogenous hormones of *E. nutans* seedlings, this experiment configured the same environmental water potential of PEG-6000 and NaCl stress to investigate the effects of drought stress and salt stress, respectively, on *E. nutans* seedlings under the same environmental water potential. The results showed that although the physiological indices and endogenous hormones of the *E. nutans* seedlings responded differently to drought stress and salt stress under the same environmental water potential, the physiological indices of *E. nutans* leaves and roots were comprehensively evaluated using the genus function method, and the physiological indices of the *E. nutans* seedlings under the same environmental water potential exhibited better salt tolerance than drought tolerance. The changes in endogenous hormones of the *E. nutans* seedlings under drought stress were analyzed to find that treatment with gibberellic acid (GA3), gibberellin A7 (GA7), 6-benzyladenine (6-BA), 6-(y,y-dimethylallylaminopurine) (2.IP), *trans*-zeatin (TZ), kinetin (KT), dihydrozeatin (DHZ), indole acetic acid (IAA), and 2,6-dichloroisonicotinic acid (INA) was more effective than those under drought stress. By analyzing the amplitude of changes in the endogenous hormones in *E. nutans* seedlings, the amplitude of changes in the contents of GA3, GA7, 6-BA, 2.IP, TZ, KT, DHZ, IAA, isopentenyl adenosine (IPA), indole-3-butyric acid (IBA), naphthalene acetic acid (NAA), and abscisic acid was larger in drought stress compared with salt stress, which could be because the endogenous hormones are important for the drought tolerance of *E. nutans* itself. The amplitude of the changes in the contents of DHZ, TZR, salicylic acid, and jasmonic acid was larger in salt stress compared with salt stress. Changes in the content of melatonin were larger in salt stress compared with drought stress, which could indicate that endogenous hormones and substances are important for the salt tolerance of *E. nutans* itself.

Keywords: *Elymus nutans*; drought stress; salt stress; seedling physiology; endogenous hormones

1 Introduction

Salinity and drought have always been important abiotic stress factors that restrict agricultural production (Vicente-Serrano et al., 2022; Van et al., 2020). Currently, there is approximately 955 million hm² of saline land in the world. China contains 10% of this land, which is primarily distributed in the northwestern inland and eastern coastal areas. The area of arid and semiarid arable land accounts for approximately one-half of China's national land area, and there is a trend of increasing expansion (Yang et al., 2019; Zhang et al., 2022). Studying the effects of salt damage and drought adversity stress on the growth of pasture grasses and exploring the corresponding regulatory techniques has been a research hotspot on the resistance of pasture grass to stress (Hu et al., 2022; Amomobo et al., 2022).

Elymus nutans is a perennial herbaceous plant of the Gramineae family, which is resistant to cold and drought, tolerant to salinity, and characterized by its strong tillering ability and abundant fibrous roots (Li et al., 2020; Fu et al., 2017). As an excellent pasture grass in the Qinghai-Tibetan Plateau region in China, it has strong resistance and tolerance to cold, rich nutrients, good palatability, high yield, and tolerance to desert areas among others. It can also prevent winds and fix sands, conserve soil and water, and accelerate the process of ecological restoration of the grassland, which can effectively reduce the economic losses caused by natural disasters (Sun et al., 2022; Ma et al., 2022).

A large number of studies have shown that changes in the physiological indicators, such as the contents of malondialdehyde (MDA), soluble protein (SP), and proline (Pro) and the activities of peroxidase (POD) and superoxide dismutase (SOD), in plant leaves and roots are related to plant stress tolerance (Fang et al., 2014; Magaña et al., 2019). Auxin was the earliest hormone discovered and regulates leaf morphogenesis (Qi et al., 2014). Cytokinin (CTK) regulates the processes of plant cell division, growth and development and the uptake of nutrients by tissues, and organs, as well as those of individuals and biotic and abiotic stresses among others. Gibberellins (GAs) are a group of essential phytohormones during plant growth and development. They regulate processes, such as seed germination, stem elongation, flower formation, and flower and fruit development (Lei et al., 2021). Absciscic acid (ABA) plays an important role in the regulation of plant cell division and amplification. for example of absciscic acid, somatic embryos could sprout adventitious shoots (Fernando and Gamage, 2000; Bari et al., 2009). In summary, phytohormones both independently and synergistically regulate plant growth and development and the processes of environmental responses. Soil drought and salinity, as two major abiotic stressors that affect plant growth and crop yield, are in some sense both stresses (osmotic stress) imposed by the environmental water potential on plants, and they are both similar to each other and different from each other (Yoshida et al., 2014). To study the physiological responses of the *E. nutans* seedling leaves and roots to drought stress and salt stress and the changes of endogenous hormones in *E. nutans* seedlings, we conducted a pot experiment in an artificial climate incubator in the Grass Laboratory of the Tibet College of Agriculture and Livestock, Linzhi, Tibet.

2 Materials and Methods

2.1 Introduction to materials

The experiment was completed in the Grass Science Laboratory of the Tibet College of Agriculture and Animal Husbandry, Tibet Autonomous Region (TAR) (94°20'31.4" N, 29°39'57.5" E). The test material was *Elymus nutans* cv. 'Baqing,' which was provided by the Grass Science Laboratory of the Tibet College of Agriculture and Animal Husbandry. The experiment was conducted on April 1, 2023, and ended on April 28, for a total of 28 days.

2.2 Experimental design

Solutions of PEG-6000 (to simulate drought stress) and sodium chloride (NaCl) (to simulate salt stress) were configured with water potentials of 0 (CK), -0.04, -0.14, -0.29, -0.49, -0.73, and -1.02 MPa (Michel and Kufman, 1973; Michel and Radcliffe et al., 1995). Sand was used as the culture medium, and each germination box (19×13×12 cm) was lined with 1,000 g of dry sand. A volume of 100 mL of solutions of PEG-6000 and NaCl of different gradients were added, and the seeds were sown at a depth of 2-3 cm with a seed volume of 5 g·m⁻² after they had been mixed well. To ensure that the environmental water potential was maintained at a constant level, the germination box was placed in a constant temperature incubator at 25 °C using the weighing

method, and the distilled water was replenished three times a day – in the morning, in the middle, and in the evening – according to the amount of evaporation in the germination box to ensure that the content of the solution in the sand was around 10%. The level of light in the incubator was 1,250 lux; the photoperiod was 12 h, and the dark period was 12 h. Hoagland's total nutrient solution was replenished every 7 days with 20 mL each time, and the physiological indices of the leaves and roots and the endogenous hormone contents of the seedlings were measured after 28 days.

2.3 Measurement indicators and methods

After 28 days, 10 seedlings were randomly selected from each treatment germination box. The fresh and dry weights of the leaves and roots of these seedlings were determined, and the relative water content was calculated. Chlorophyll a and b contents were determined by ethanol extraction. The activity of SOD was determined by the nitroblue tetrazolium (NBT) photoreduction method. That of POD was determined by the guaiacol method. The content of MDA was determined by the thiobarbituric acid (TBA) colorimetric method, and that of Pro was determined by the ninhydrin colorimetric method. The SP content was determined using Coomassie Brilliant Blue G-250. The content of endogenous hormones was determined by ultra-high performance liquid chromatography (UPLC) using a Waters Acquity system (Waters, Milford, MA, USA) and mass spectrometry SCIEX AB 5500 QQQ-MS (SCIEX AB, Redwood City, CA, USA). A volume of 0.1 mL of standard solution ($10.0 \mu\text{g mL}^{-1}$) was removed, and the standard solution was diluted to 1.0 mL with 80% aqueous methanol to form a standard solution of $1,000 \text{ ng mL}^{-1}$. It was used to make a series of standard solutions with 80% aqueous methanol (diluted) to form a concentration of the appropriate standard. The standard solutions were prepared ready to use. The hormone indicators included gibberellins (GA1, GA3, GA4, and GA7), 1-naphthylacetic acid (NAA), indole-3-acetic acid (IAA), 3-indolepropionic acid (IPA), 3-indolebutyric acid (IBA), 2ip-riboside, kinetin (KT), 6-benzylaminopurine (6-BA), 6-(y,y-dimethylallylaminopurine) (2.IP), *trans*-zeatin (TZ), *trans*-zeatin riboside (TZR), DL-dihydrozeatin (DHZ), abscisic acid (ABA), salicylic acid (SA), jasmonic acid (JA), and melatonin (MT).

2.4 Statistical analysis

MultiQuant software (SCIEX) was utilized for integration, and a standard curve was used to calculate the contents of hormones. SPSS was utilized to perform a one-way analysis of variance (ANOVA) of the significance of physiological indices and contents of endogenous hormones in the leaves and roots of seedlings under the stress of PEG-6000 and NaCl. Origin Pro 2021 (OriginLab, Northampton, MA, USA) was used to analyze the principal component analysis of the environmental water potential and physiological indicators of PEG-6000 and NaCl. A Mantel test was used to analyze the effects of endogenous hormones on the physiological indices of the *E. nutans* seedlings. Structural equation modeling (SEM) was used to analyze the relationship between endogenous hormones and the accumulation of water and dry matter in the leaves and roots of these seedlings. The drought tolerance and salt tolerance of the *E. nutans* seedlings were analyzed and compared using the subordinate function method, and the formula for calculating the index was as follows: $X(u) = (X - X_{\min}) / (X_{\max} - X_{\min})$. If the index negatively correlated with drought tolerance, the formula was as follows: $X(u) = 1 - (X - X_{\min}) / (X_{\max} - X_{\min})$. The coefficient of variation of the contents of hormones was analyzed using SPSS.

3 Results

3.1 Effect of treatments on the accumulation of biomass in *E. nutans* seedlings

The accumulation of leaf biomass indicated that the simulation of drought stress by partial treatment with PEG-6000 extremely significantly reduced the fresh weight of *E. nutans* leaves, which was extremely significantly lower than that of the CK in the -0.14 MPa treatment ($P<0.01$), and the fresh weight of leaves was reduced by approximately 17%. As the ambient water potential was reduced, the fresh weight of leaves under the stress of PEG-6000 decreased significantly by approximately 5%. The lowest value was $129.67 \text{ mg} \cdot 10 \text{ plant}^{-1}$ in the -1.02 MPa treatment (Fig. 1A). The treatment with NaCl to simulate salt stress significantly reduced the fresh weight of leaves, which was extremely lower than that of the CK at -0.14 MPa ($P<0.01$), and the fresh weight of leaves was reduced by approximately 5%. The decrease in the ambient water potential when treated with NaCl resulted in a significant decrease of approximately 5% in the fresh weight of leaves. As the ambient water potential decreased, the leaf fresh weight under stress highly significantly decreased ($P<0.01$). The lowest value was measured following treatment with -1.02 MPa, which was only $148.67 \text{ mg} \cdot 10 \text{ plant}^{-1}$ (Fig. 1A). In terms of the accumulation of dry matter, the decrease in ambient water potential also reduced the accumulation of dry matter by the leaves. This value was significantly lower than that of the CK in the treatment of PEG-6000 at -0.14 MPa with a reduction of approximately 12% in the dry weight of leaves. This was the same dry weight as the fresh weight of leaves decreased with the decrease in ambient water potential and reached its lowest value at $52.33 \text{ mg} \cdot 10 \text{ plant}^{-1}$ in the treatment of -1.02 MPa (Fig. 1B). The dry weight of leaves under the NaCl treatment was all highly significantly lower than that of the CK ($P<0.01$). As the ambient water potential decreased, the leaf dry weight decreased, and the lowest was only $55.67 \text{ mg} \cdot 10 \text{ plant}^{-1}$ under the -1.02 MPa treatment (Fig. 1B). In terms of the relative water content, that of the leaves under PEG-6000 stress tended to increase and then decrease, and the relative water content of leaves was 0.52% higher than that of the CK in the -0.04 MPa treatment. The relative water content of the leaves decreased with the reduction in ambient water potential, and the lowest was 59.56% in the -1.02 MPa treatment (Fig. 1C). Under NaCl stress, the relative water content also showed a trend of increasing and then decreasing. The relative water content was slightly higher than that of the CK under the -0.04 and -0.14 MPa treatments and was highly significantly lower than that of the CK when the ambient water potential decreased to -0.29 MPa ($P<0.01$) with a minimum of 62.55% in the -1.02 MPa treatment (Fig. 1C).

In terms of the accumulation of root biomass with the decrease in ambient water potential, the root fresh weight increased and then decreased. Both the fresh weight and dry weight of the roots were significantly higher than those of the CK at -0.04 MPa treatment ($P<0.05$). With the decrease in ambient water potential, the root fresh weight decreased, and the lowest root fresh weight and dry weight were both observed in the -1.02 MPa treatment, which were 113.33 and $19.67 \text{ mg} \cdot 10 \text{ plant}^{-1}$ (Fig. 1D, E). The relative water content of the *E. nutans* root system under drought stress decreased in parallel with the ambient water potential, which was lower than that of the CK in all the treatments, and the lowest was approximately 82.62% in the treatment of -1.02 MPa (Fig. 1F). The fresh and dry weights of the *E. nutans* root system under the stress of NaCl increased and then decreased with the decrease in the ambient water potential. They both reached a maximum value in the -0.14 MPa treatment, which was significantly higher than that of the CK (Fig. 1D). maximum value, which was significantly higher than that of CK ($P<0.05$), and with the further decrease in the ambient water potential, the fresh weight and dry weight of the root system decreased and were the lowest at -1.02 MPa treatment, which was 75.67 and $11.33 \text{ mg} \cdot 10 \text{ plant}^{-1}$,

respectively (Fig. 1D, E). The relative water content of the *E. nutans* root system under NaCl stress and the trend of fresh weight and dry weight of the root system were the same; they increased and then decreased with the lowest value of 85.02% in the -1.02 MPa treatment (Fig. 1F).

3.2 Effect of treatments on the leaf physiology of *E. nutans* seedlings

In terms of chlorophyll, the simulation of drought stress by PEG-6000 extremely significantly reduced the contents of chlorophyll a and chlorophyll b in the *E. nutans* leaves. These values were extremely significantly lower than those of the CK in all the treatments ($P<0.01$), with a minimum in the -1.02 MPa treatment with the contents of chlorophyll a and chlorophyll b of 2.34 and 2.13 mg·g⁻¹, respectively (Fig. 2A, B). Under salt stress, the contents of chlorophyll a and chlorophyll b in *E. nutans* decreased as the ambient water potential of the NaCl treatment decreased. When the ambient water potential reached -0.04 MPa, the content of chlorophyll a was extremely significantly lower than that of the CK ($P<0.01$). However, the content of chlorophyll b was only extremely significantly lower than that of the CK ($P<0.01$) in the -0.14 MPa treatment. The contents of both chlorophyll a and chlorophyll b were lower in the -1.02 MPa treatment. The content of chlorophyll b was the lowest from both stress treatments in the -1.02 MPa treatment at 3.01 and 3.59 mg·g⁻¹, respectively (Fig. 2A, B). Under PEG-6000 stress, the activities of both POD and SOD in the leaves increased and then decreased with the decrease in ambient water potential, and the activities of the two enzymes reached their maximum value in the -0.73 MPa treatment and were 71.88 g·min⁻¹ FW and 323 U·(g·FW⁻¹), respectively (Fig. 2C, D). Under NaCl stress, the activities of both POD and SOD also decreased with the decrease in the ambient water potential. Both showed a similar trend of increasing and then decreasing with the decrease in ambient water potential, and the activities of both enzymes reached a maximum value of 76.10 g·min⁻¹ FW and 361 U·(g·FW⁻¹) in the -0.73 MPa treatment (Fig. 2C, D). In terms of leaf plasma membrane oxidation products and cellular osmoregulatory substances, the MDA content of *E. nutans* leaves under PEG-6000 and NaCl stress increased with the decrease in ambient water potential with the highest contents of 32.44 and 32.43 m mol·g⁻¹ FW in the -1.02 MPa treatment under both types of stresses, respectively (Fig. 2E). The SP content also showed the same trend (increasing and then decreasing) and also reached maximum values of 81.02 and 96.18 mg·g⁻¹ FW in the -0.73 MPa treatment, respectively (Fig. 2F). The Pro content also showed the same trend (decreasing and then increasing) under both stresses and reached maximum values of 13.2 and 15.73 µg·g⁻¹ FW in the -1.02 MPa treatment, respectively (Fig. 2G).

3.3 Effect of treatments on the root physiology of *E. nutans* seedlings

The activities of enzymes in the roots in response to the PEG-6000 and NaCl stress were basically the same. The activities of POD also increased with the reduction in ambient water potential and reached a maximum value of 26.50 and 27.16 g·min⁻¹ FW in the -1.02 MPa treatment, respectively (Fig. 3A). The activities of SOD were basically the same as those of the POD. The activity increased and decreased with the reduction in ambient water potential, and the activity of the enzyme in both treatments also reached a maximum value of 289 and 298 U·(g·FW⁻¹) in the -0.73 MPa treatment, respectively (Fig. 3B). The activities of SOD and POD were basically the same with the decrease in ambient water potential. They increased and then decreased, and the two treatments also reached the maximum values of 289 and 298 U·(g·FW⁻¹) in the -0.73 MPa treatment, respectively (Fig. 3B). The effects of PEG-6000 and NaCl stress on the root system of *E. nutans* seedlings in terms of plasma membrane oxidation products and cellular osmotic

regulatory substances were basically the same. With the decrease in ambient water potential, the content of MDA in the root system increased and reached its maximum values of 35.04 and 33.07 $\text{m} \cdot \text{mol} \cdot \text{g}^{-1}$ FW in the -1.02 MPa treatment, respectively (Fig. 3D). The content of SP increased and then decreased and reached maximum values of 58.32 and 66.66 $\text{mg} \cdot \text{g}^{-1}$ FW in the -0.73 MPa treatment (Fig. 3C). The content of Pro increased and reached maximum values of 58.32 and 66.66 $\text{mg} \cdot \text{g}^{-1}$ FW from the -1.02 MPa treatment and reached maximum values of 40.74 and 54.45 $\mu\text{g} \cdot \text{g}^{-1}$ FW, respectively (Fig. 3E).

3.4 Effect of treatments on the content of GA in *E. nutans* seedling leaves

Under the drought stress simulated by PEG-6000, the content of GA₁ in *E. nutans* leaves decreased and then increased as the ambient water potential decreased. It reached a minimum of 0.22 $\text{pg} \cdot \text{mg}^{-1}$ in the -0.04 MPa treatment, which was highly significantly lower than that of the CK ($P < 0.01$) and reached a maximum of 5.55 $\text{pg} \cdot \text{mg}^{-1}$ in the -1.02 MPa treatment, which was significantly higher than that of the CK ($P < 0.01$) (Fig. 4A). The content of GA₃ was significantly lower than that of the CK ($P < 0.05$) in the -0.04 MPa treatment. It gradually increased with the decrease in ambient water potential and reached a maximum value of 2.86 $\text{pg} \cdot \text{mg}^{-1}$ in the -0.29 MPa treatment before decreasing with the further decrease in the ambient water potential (Fig. 4B). The content of GA₄ decreased with the decrease in ambient water potential (Fig. 4B). The content decreased and then increased with the decrease in the ambient water potential and reached a minimum of 2.11 $\text{pg} \cdot \text{mg}^{-1}$ in the -0.04 MPa treatment, which was highly significant lower than that of the CK ($P < 0.01$). It reached a maximum value of 5.56 $\text{pg} \cdot \text{mg}^{-1}$ in the -1.02 MPa treatment, which was highly significantly higher than that of the CK ($P < 0.01$) (Fig. 4C). The content of GA₇ showed the same trend as that of GA₃, which also occurred in the -0.29 MPa treatment. This value was highly significantly higher than that of the CK ($P < 0.01$) and also reached a maximum value of 4.23 $\text{pg} \cdot \text{mg}^{-1}$ in the -0.29 MPa treatment (Fig. 4D).

Under the salt stress simulated by NaCl, the content of GA₁ in *E. nutans* also showed the same trend of decreasing and then increasing with the decrease in ambient water potential. It reached a minimum of 0.51 $\text{pg} \cdot \text{mg}^{-1}$ in the -0.04 MPa treatment, which was highly significantly lower than that of the CK ($P < 0.01$) and a maximum of 5.35 $\text{pg} \cdot \text{mg}^{-1}$ in the -1.02 MPa treatment, which was highly significantly higher than that of the CK ($P < 0.01$) (Fig. 4A). The content of GA₃ was significantly lower than that of the CK in the -0.04 MPa treatment ($P < 0.05$) and gradually increased with the decrease in the content of GA₃ in the ambient water potential. It reached a maximum value of 1.89 $\text{pg} \cdot \text{mg}^{-1}$ in the -0.29 MPa treatment and decreased with the further decrease in the ambient water potential; the treatments under the stress of NaCl GA₃ content was lower than that of the CK in all the treatments under NaCl stress (Fig. 4B). The GA₄ content decreased and then increased with the decrease in the ambient water potential. It reached a minimum of 3.43 $\text{pg} \cdot \text{mg}^{-1}$ in the -0.04 MPa treatment, which was highly significantly lower than that of the CK ($P < 0.01$) and reached a maximum value of 5.18 $\text{pg} \cdot \text{mg}^{-1}$ in the -1.02 MPa treatment, which was significantly higher than that of the CK ($P < 0.05$) (Fig. 4C). The content of GA₇ followed the same trend as that of the GA₃ with a decreasing-increasing-decreasing trend. It reached a minimum of 3.22 $\text{pg} \cdot \text{mg}^{-1}$ in the -0.04 MPa treatment, which was highly significantly lower than that of the CK ($P < 0.01$). It reached its maximum value of 3.89 $\text{pg} \cdot \text{mg}^{-1}$ in the -0.73 MPa treatment, which was not statistically significant (Fig. 4D).

3.5 Effect of treatments on the contents of growth hormones in the *E. nutans* seedlings leaves

Under the drought stress simulated by PEG-6000, the content of IAA in the *E. nutans* leaves

increased and then decreased with the decrease in ambient water potential. It reached a maximum value of $105.06 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.73 MPa treatment, which was highly significantly higher than that of the CK ($P < 0.01$) (Fig. 5A). The content of IPA increased and then decreased with the decrease in ambient water potential. It reached a maximum value of $169.65 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.04 MPa treatment, which was highly significantly higher than that of the CK ($P < 0.01$) (Fig. 5A). The content of IPA in the 0.04 MPa treatment reached a maximum value of $169.65 \text{ pg} \cdot \text{mg}^{-1}$, which was highly significantly higher than that of the CK ($P < 0.01$). It reached a minimum value of $41.18 \text{ pg} \cdot \text{mg}^{-1}$ in the -1.02 MPa treatment, which was highly significantly lower than that of the CK (Fig. 5B). The content of IBA decreased as the ambient water potential decreased, which was highly significantly lower than that of the CK ($P < 0.01$) in all the treatments. The content of riboside showed a decreasing-increasing-decreasing trend with the decrease in the ambient water potential. It reached a minimum of $4.02 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.04 MPa treatment, which was highly significantly lower than that of the CK ($P < 0.01$) and a minimum of $5.5 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.73 MPa treatment (Fig. 5B). The content of NAA decreased with the decrease in ambient water potential, which was significantly lower than that of the CK in all the treatments ($P < 0.05$). The lowest value was in the -1.02 MPa treatment, which was approximately 78.5% lower than that of the CK (Fig. 5E).

Under the salt stress simulated by NaCl, the IAA content in the leaves of common reed (*Phragmites australis*) increased and then decreased with the decrease in the ambient water potential and reached a maximum value of $37.74 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.29 MPa treatment, which was significantly higher than that of the CK ($P < 0.01$) (Fig. 5A). The content of IPA decreased with the decrease in ambient water potential, which was significantly lower than that of the CK in all the treatments ($P < 0.05$). It reached a minimum value of $73.24 \text{ pg} \cdot \text{mg}^{-1}$ in the -1.02 MPa treatment, which was highly significantly lower than that of the CK (Fig. 5B). The content of IBA decreased in parallel with the ambient water potential and was highly significantly lower than the CK in all the treatments ($P < 0.01$); the lowest value was observed in the -1.02 MPa treatment where the content decreased by approximately 56.3% (Fig. 5C). The content of 2 ip-riboside decreased and then increased as the water potential decreased and reached a minimum of $3.4 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.04 MPa treatment, which was highly significantly lower than that of the CK ($P < 0.01$). It reached a maximum of $5.54 \text{ pg} \cdot \text{mg}^{-1}$ in the -1.02 MPa treatment, which did not reach a significant level of difference with the CK (Fig. 5D). The content of NAA decreased with the decrease in the ambient water potential, which was highly significantly lower than that of the CK in all the treatments except for the treatment of -0.04 MPa ($P < 0.01$). It reached its minimum value in the -1.02 MPa treatment, which was approximately 49.7% lower than that of the CK (Fig. 5E).

3.6 Effect of treatments on the contents of cytokinins in the *E. nutans* seedlings leaves

Under the drought stress simulated by PEG-6000, the content of 6-BA in the *E. nutans* leaves increased and then decreased with the decrease in ambient water potential, and the highest content was $1.38 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.73 MPa treatment, which was highly significantly higher than that of the CK ($P < 0.01$) (Fig. 6A). The content of 2-IP increased with the decrease in ambient water potential, and the highest content was $2.96 \text{ pg} \cdot \text{mg}^{-1}$ in the -1.02 MPa treatment (Fig. 6B). The content of KT increased and then decreased with the highest content of $1.84 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.73 MPa treatment, which was highly significantly higher than that of the CK and other treatments ($P < 0.01$) (Fig. 6C). The content of DHZ showed a decreasing-increasing-decreasing trend with the decrease in ambient water potential. The lowest amount was $3.9 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.04 MPa treatment, which did not reach the level of a significant difference with that of the CK; the highest

content was $7.07 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.49 MPa treatment, which was highly significantly higher than that of the CK ($P < 0.01$) (Fig. 6D). The content of TZ increased and then decreased with the decrease in ambient water potential and the highest content of $3.9 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.73 MPa treatment, which was highly significantly higher than that of the CK and the other treatments ($P < 0.01$) (Fig. 6E). The content of TZR showed a decreasing-increasing-decreasing trend with the decrease in ambient water potential. The content was the lowest at $12.75 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.04 MPa treatment, which was highly significantly lower than that of the CK ($P < 0.01$). The content was the highest at $23.75 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.73 MPa treatment, which was highly significantly lower than that of the CK ($P < 0.01$). (Fig. 6F).

Under the salt stress simulated by NaCl, the content of 6-BA in the *E. nutans* leaves increased and then decreased with the decrease in ambient water potential, with the highest content of $0.63 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.29 MPa treatment, which was highly significantly higher than that of the CK ($P < 0.01$) (Fig. 6A). The content of 2-IP increased and then decreased with the decrease in ambient water potential, with the highest content of $1.43 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.29 MPa treatment. The highest content was $1.43 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.29 MPa treatment, which was highly significantly higher than that of the CK ($P < 0.01$) (Fig. 6B). The content of KT increased and then decreased, and the highest content was $0.74 \text{ pg} \cdot \text{mg}^{-1}$ in the treatment -0.29 MPa , which was highly significantly higher than that of the CK and the other treatments ($P < 0.01$) (Fig. 6C). The content of DHZ showed a decreasing-increasing-decreasing trend with the decrease in environmental water potential and was highly significantly higher than that of the CK and the other treatments ($P < 0.01$) (Fig. 6C). The content of DHZ showed a decreasing-increasing-decreasing trend with the decrease in the ambient water potential, with the highest content of $5.09 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.29 MPa treatment, which did not reach the level of a significant difference with the CK (Fig. 6D). The content of TZ increased with the decrease in ambient water potential, with the highest content of $38.35 \text{ pg} \cdot \text{mg}^{-1}$ in the -1.02 MPa treatment, which was highly significantly higher than that of the CK ($P < 0.01$) (Fig. 6E). The content of TZR decreased and then increased with the decrease in ambient water potential. The lowest content was $6.6 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.04 MPa treatment, which was highly significantly lower than that of the CK ($P < 0.01$). The highest content was $25.56 \text{ pg} \cdot \text{mg}^{-1}$ in the -1.02 MPa treatment, which was highly significantly higher than that of the CK ($P < 0.01$) (Fig. 6F).

3.7 Effect of treatments on the content of abscisic acid and other endogenous substances in the leaves of *E. nutans* seedlings

Under the drought stress simulated by PEG-6000, the content of ABA in the *E. nutans* leaves increased with the decrease in ambient water potential, and the highest content was $46.58 \text{ pg} \cdot \text{mg}^{-1}$ in the -1.02 MPa treatment, which was highly significantly higher than that in the CK ($P < 0.01$) (Fig. 7A). The content of SA decreased with the decrease in ambient water potential, and the lowest content was observed in the -1.02 MPa treatment, which was highly significantly lower than that in the CK by approximately 78.25% (Fig. 7B). The content of JA decreased with the decrease in ambient water potential, and the lowest content was found in the -1.02 MPa treatment, with a decrease of approximately 59.23% (Fig. 7C). The content of MT increased and then decreased with the decrease in ambient water potential, with the highest content of $8.5 \text{ pg} \cdot \text{mg}^{-1}$ in the -0.04 MPa treatment; the highest content was found to be $8.5 \text{ pg} \cdot \text{mg}^{-1}$, which was highly significantly ($P < 0.01$) higher than that of the CK (Fig. 7D).

3.8 Comprehensive analysis

The fresh weight, dry weight and relative water content of the *E. nutans* leaves and roots after the simulation of drought stress using PEG-6000 positively correlated with the contents of chlorophyll a and chlorophyll b and the environmental water potential and negatively correlated with the activities of POD and SOD and the contents of MDA, Pro, and SP in the leaves and roots (Fig. 8A). The accumulation of water and dry matter in the leaves and roots highly significantly correlated ($P<0.01$) with the endogenous hormones measured; the physiological indices of leaves and roots, which did not significantly correlate with GA₃, also highly significantly correlated ($P<0.05$) with the other endogenous hormones measured (Fig. 8C). The growth hormones, ABA and other endogenous substances inhibited the production of cytokinins, while the GAs enhanced their production; the cytokinins enhanced the production of GAs, ABA and other endogenous substances, and the endogenous hormones did not reach the level of a significant difference in the structural equation modeling of the accumulation of water and dry matter in both the leaves and roots (Fig. 8E).

The fresh weight, dry weight, and relative water content of the *E. nutans* leaves and roots after the simulation of salt stress by NaCl positively correlated with the contents of chlorophyll a and chlorophyll b and the ambient water potential; and negatively correlated with the activities of POD and SOD and contents of MDA, Pro, and SP in the leaves and roots (Fig. 8B). The accumulation of leaf biomass did not significantly correlate with the contents of GA7, IAA, 2.IP, KT, 6-BA, DHZ, and JA; the accumulation of root biomass did not significantly correlate with the contents of GA7, IAA, 2.IP, KT, 6-BA, DHZ, and MT; the leaf physiological indices did not significantly correlated with IAA, 2.IP, 6-BA, and DHZ; and the root physiological indices that did not reach significant correlation with IAA, KT, and DHZ (Fig. 8D). The growth hormones and ABA and other endogenous substances enhanced the production of cytokinins, while the GAs inhibited the production of these hormones; cytokinins, growth hormones, ABA, and other endogenous substances inhibited the production of GAs; GAs and the growth hormones inhibited the production of ABA and other endogenous substances; and cytokinins inhibited the accumulation of water and dry matter by the leaves (Fig. 8F).

4. Discussion

4.1 Effects of drought stress and salt stress on the biomass accumulation of *E. nutans* seedlings

The seedling stage is a very sensitive stage of plant growth and development to water, and water stress in the seedling stage will not only affect plant growth and development, which leads to a decrease in yield, but can also cause plant death in severe cases. The final result caused by the water deficit will be synthesized in the biomass of leaves and roots, which is a positive indicator to evaluate the resistance of forage grasses to drought and salinity. In this study, we found that the fresh and dry weight of the *E. nutans* leaves under the same environmental water potential decreased with the decrease in environmental water potential under drought stress and salt stress, which was similar to the results of Ahmed et al., (2022) and Calon et al., (2023). In addition, we found that the fresh and dry weight of the *E. nutans* leaves under NaCl stress were higher than those under the same environmental water potential. Treatment with PEG-6000 caused stress at the water potential, which could be owing to the stronger inhibition of *E. nutans* leaf growth by drought stress than salt stress.

In the absence of water, plants will compensate for the reduction in the area of root area by enhancing root vigor and maintaining a higher root biomass to maintain a high ability of the root

to absorb water. In this study, we found that the two water deficit stressors resulted in "low promotion and high suppression" of the fresh and dry weights of *E. nutans* roots, which was similar to the results of the studies conducted by Chang et al., (2019) and Pang et al., (2020). This study found that the NaCl stresses in the -0.04 and -0.14 MPa treatments resulted in a high capacity of the roots to take up water. In the -0.14 MPa treatments, the fresh weight of *E. nutans* roots under NaCl stress was higher than that of the PEG-6000 treatment. The *E. nutans* roots under drought stress had higher fresh weights than those under salt stress when the ambient water potential was less than -0.14 MPa, and the dry weight of *E. nutans* roots under all the PEG-6000 treatments was higher than that of the NaCl treatment, which could be owing to the decrease in ambient water potential. This could be owing to the stress of drought and salt damage to the root system and the stronger inhibitory effects of Na⁺ and Cl⁻ on plant root growth than a single drought stress.

4.2 Effects of drought stress and salt stress on the physiological indices of *E. nutans* seedlings

The study of physiological responses of plants to drought stress and salt stress helps to reveal the physiological mechanisms of plant adaptation to water adversity. During photosynthesis, with the water deficit and accumulation of reactive oxygen species (ROS), the synthesis of chlorophyll in the chloroplasts is blocked, while its degradation is promoted, which results in a decrease in the content of chlorophyll in plants. In this study, we found that the 2 water deficits resulted in the reduction of the contents of chlorophyll a and chlorophyll b in the leaves, which was similar to the results of Tsai et al., (2019) and Bano et al., (2021). However, except for the -0.04 MPa treatment when the chlorophyll a content of *E. nutans* under the stress of NaCl treatment was lower than that of the PEG-6000, the other treatments were higher than. However, the chlorophyll a content of *E. nutans* was higher than that of the PEG-6000 treatment in all the treatments except the -0.04 MPa treatment, which was lower than that of PEG-6000, which could indicate that the photosynthetic capacity of *E. nutans* in the salinized environment was stronger than that of drought stress under the same environmental water potential.

Studies have shown that under some degree of drought stress, plants are not damaged by ROS, which is owing to the fact that the antioxidant enzyme system in the plant tissues will scavenge the ROS generated by the stress, so that their amount can be controlled in a safe range. POD and SOD play important roles during the process of drought stress and salt stress in the plant, and the amount of their activity has some correlation with the resistance of plants to drought and salinity. Higher activity results in enhanced resistance to drought and salt in plants. In this study, we found that the antioxidant enzyme systems (POD and SOD) of the leaves and roots of the *E. nutans* seedlings under the two stress treatments increased and then decreased with the reduction in ambient water potential, which is similar to the results of Yildiztekin et al., (2018) and Jiao et al., (2023). Moreover, in this study, the salt stress of *E. nutans* seedlings under the same ambient water potential was found to increase and then decrease, which is similar to the findings of Yildiztekin et al., (2018) and Jiao et al., (2023). All the treatments of *E. nutans* seedling leaf and root antioxidant enzyme systems (POD and SOD) were higher when subjected to salt stress than drought stress, which could indicate that the inhibitory effect of salt stress on plant leaves and roots is primarily reflected in the growth of roots, and the effect of salt stress on the antioxidant enzyme systems of plants is weaker than that of drought stress.

Changes in the content of MDA under drought stress can cause damage that reflects the degree of lipid peroxidation in plant membranes. A higher content of MDA results in more serious

damage to the plant cell membranes. In this study, the content of MDA in the leaves and roots of *E. nutans* increased with the decrease in ambient water potential, which was similar to the findings of Gulzar et al., (2021) and Zhao et al., (2023). In addition, the content of MDA in the leaves and roots of *E. nutans* under the same ambient water potential under the PEG-6000 treatment was found to cause more stress than the NaCl treatment. The accumulation of MDA in the leaves and roots of *E. nutans* under PEG-6000 at the same environmental water potential was higher than that under NaCl, which could be owing to the fact that the membrane lipid peroxidation reaction of *E. nutans* under PEG-6000 stress was stronger than that under NaCl stress, which resulted in more serious damage to the cell membranes.

The high or low contents of SP and Pro can reflect the magnitude of drought and salt tolerance in plants, and both of them, as the primary osmoregulatory substances in cells, can alleviate or resist the occurrence of damage under the difficulty of stress. We found that the leaves and roots of *E. nutans* reacted differently in response to environmental water potential stress. The content of Pro in the leaves decreased and then increased with the reduction in environmental water potential, while the content of Pro in the roots increased with the reduction in environmental water potential. The content of SP in the leaves and roots increased and then decreased with the reduction in environmental stress, which was consistent with the results of Kim et al., (2016) and Farooq et al., (2023). Moreover, this study found that the contents of SP and Pro in the leaves and roots of *E. nutans* treated with NaCl were higher than those of PEG-6000 under the same environmental water potential, which could be owing to the higher osmotic pressure imbalance of the *E. nutans* seedlings owing to salt stress compared with drought stress, and the content of soluble proteins was reduced.

The effects of PEG-6000 and NaCl on the physiology of *E. nutans* seedlings at the same ambient water potential showed different results, and the analysis of the physiological indices by the affiliation function method revealed that *E. nutans* was better able to tolerate salt than drought at the same ambient water potential (Table 1).

4.3 Effects of drought stress and salt stress on endogenous hormones and other substances in *E. nutans* seedlings

GAs, as a group of the most important phytohormones, control different aspects of plant growth and development, including seed germination, stem elongation and flower induction, and are important hormones for plant regulation under adverse conditions (Yamaguchi, 2008). In this study, GA₁ showed exactly the same trend of decreasing and then increasing under the two stresses of PEG-6000 and NaCl, which was similar to the results of Liu et al., (2023). This study also found that, under the same ambient water potential treatments, higher ambient water potentials (-0.04, -0.14, and -0.29 MPa) treatments and NaCl stresses resulted in a higher content of GA₁ than treatment with PEG-6000 stress. However, under lower ambient water potential (-0.49, -0.73, and -1.02 MPa) treatments, the content of GA₁ was lower following NaCl stress than that of PEG-6000, which could be owing to the fact that the response of GA₁ to NaCl was more intermediate under lower ambient water potential conditions, which led to an increase in the regulation of GA₁ as the degree of drought stress intensified. The trend of the regulation of contents of GA₄ was the same as that of GA₁, but the content of GA₄ under NaCl stress was only lower than that of PEG-6000 in the -1.02 MPa treatment, which could be owing to the late action of the regulatory mechanism of GA₄ in the face of drought stress and the more direct action of NaCl stress. GA₃ and GA₇ showed the same trend of increasing and then decreasing, but under the

PEG-6000 stress, the content of GA₃ changed dramatically and decreased, while there was no obvious trend in the magnitude of GA₃ changes under NaCl stress (Table 2). GA₇ also showed a large fluctuating trend under PEG-6000 stress, while the regulation of GA₇ content was smaller under NaCl stress. This difference could be owing to the fact that in the face of drought stress, *E. nutans* seedlings actively regulate both GA₃ and GA₇ to resist the damage induced by drought, while the regulation of GA₃ and GA₇ was not very sensitive to the stress of NaCl.

The major natural growth hormone in plants, IAA, orchestrates a large number of developmental responses that are largely dependent on the formation of gradients of growth hormones in plant tissues (Li et al., 2019). IAA metabolism, including biosynthesis, splicing, and degradation, regulates the gradients of growth hormones along with their intercellular and intracellular transport and therefore, is critical for plant growth (Bianco et al., 2009). In this study, we found that the content of IAA in the *E. nutans* leaves was regulated to a greater extent under drought stress conditions than under salt stress, which could be attributed to the fact that IAA is the major hormone for drought tolerance in *E. nutans* seedlings and responds relatively weakly to salt stress. The magnitude of regulation of the contents of IPA and IBA under drought stress was similarly greater than that under salt stress, and the contents of IPA and IBA showed relatively stable contents at higher ambient water potentials (-0.49, -0.73, and -1.02 MPa) for the two treatments, which could be owing to the insensitivity of contents of IPA and IBA to the response at low ambient water potentials. The content of 2ip-riboside reacted highly similarly to drought stress and salt stress, and there was only a small magnitude of the effect of the two solutions on the content of 2ip-riboside. This could indicate that 2ip-riboside is not the primary regulatory hormone involved in the response of *E. nutans* to the ambient water potential. The magnitude of the response to drought stress was significantly larger than that to salt stress, which could perhaps be supplied by means of exogenous NAA during drought tolerance in *E. nutans* (Table 2).

Plant cytokinins play multiple roles in plant development and affect many agriculturally important processes, including growth, nutrient responses, and responses to biotic and abiotic stresses (Papon et al., 2022). In this study, 6-BA, 2.IP, TZ, KT, and DHZ were found to maintain relatively stable regulatory results under PEG-6000 stress at treatments with higher ambient water potentials (-0.04, -0.14, and -0.29 MPa) except for a higher magnitude of variation at lower ambient water potentials (-0.49, -0.73, and -1.02 MPa) treatments, which could indicate that *E. nutans* seedlings rely on the regulation of the five hormones 6-BA, 2.IP, TZ, KT, and DHZ to adapt to drought stress under severe drought conditions. Under NaCl stress, 6-BA, 2.IP, TZ, and KT maintained a relatively stable state with a small magnitude of change. Another possibility is that the four hormones 6-BA, 2.IP, TZ, and KT play an important role in the TZR content in *E. nutans* seedlings that was higher than that of NaCl stress. However, when the ambient water potential reached the degree of NaCl stress induced by the -1.02 MPa treatment, the content of TZR was higher than that of the PEG-6000 stress. It could also indicate that the accumulation of TZR under drought stress decreased following the drought stress treatment at -1.02 MPa, whereas it still accumulated in the NaCl stress treatment at -1.02 Mpa. Another possibility is that the accumulation of TZR in the *E. nutans* seedlings decreased in the treatment at drought stress at -1.02 MPa but still showed a trend of increasing accumulation in the treatment of PEG-6000, or it could indicate that TZR played an important role in response to salt stress (Table 2).

ABA is an important phytohormone that regulates plant growth, development and stress response. It plays a crucial role in a variety of physiological processes in plants, including

stomatal closure, leaf senescence, bud dormancy, seed germination, osmotic regulation, and growth inhibition among others. Similarly, JA, SA, and MT are important endogenous substances that regulate plant growth and improve plant stress tolerance (Ghorbel et al., 2021; Peng et al., 2021; Arnao and Hernández-Ruiz, 2018). In this study, we found that the content of ABA increased in the same manner under the two stresses, but it increased significantly more in the PEG-6000 stress treatment than in the NaCl stress, which could indicate that ABA plays a greater role in drought resistance than salt resistance in *E. nutans* seedlings. Alternatively, the trends of SA and JA contents showed completely opposite results to those of ABA. This could indicate that SA and JA play a greater role in salt resistance than drought resistance in *E. nutans*. The contents of MT basically consistently decreased in response to the decrease in ambient water potentials with the two stresses. However, at lower ambient water potentials (-0.49, -0.73, and -1.02 MPa), the content of MT was higher under NaCl stress than that of PEG-6000 and was relatively stable, or it could indicate that MT was an important endogenous substance for the salt tolerance of *E. nutans* seedlings under NaCl stress at a lower ambient water potential (Table 2).

In summary, the endogenous hormones of *E. nutans* seedlings to PEG-6000 responded differently to NaCl stress, and the endogenous hormones also interacted with each other based on the SEM and Mantel correlation analyses. Therefore, to explore the response of endogenous hormones of *E. nutans* to environmental water potential, further studies are needed to investigate the production and response of endogenous hormones.

5. Conclusions

In this study, we unified the stress of PEG-6000 and NaCl on *E. nutans* by controlling the osmotic potential of the solution to investigate the effects of drought stress and salt stress on the physiology and endogenous hormones of *E. nutans* seedlings under the same environmental water potential. The results showed the following:

Even under the same environmental water potential, the physiological responses of *E. nutans* seedlings to PEG-6000 and NaCl differed, and the physiological indices revealed that the seedlings were more tolerant to salt than drought. This difference was further reflected in the changes in the accumulation of plant biomass.

Analyses of the magnitude of changes in the endogenous hormones in the *E. nutans* seedlings revealed that the magnitude of changes in the contents of GA3, GA7, 6-BA, 2-IP, TZ, KT, DHZ, IAA, IPA, IBA, NAA, and ABA were larger in drought stress than in salt stress, which could indicate that they are important endogenous hormones for the drought tolerance of *E. nutans* itself. The magnitude of changes in the contents of DHZ, TZR, SA, JA, and MT was greater in salt stress than in drought stress. Changes in the contents of DHZ, TZR, SA, JA, and MT were larger compared with drought stress, which could indicate that they are important endogenous hormones and substances for the salt tolerance of *E. nutans* itself.

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Author Contributions

Jianting Long designed the experiment, Dandan Liu, Wei Qiao and Yanwei Wang conducted experiments, Jianting Long wrote papers, Yanjun Miao and Henna Baosai revised the papers.

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Availability of data and materials

Dataset and software will be made available upon request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

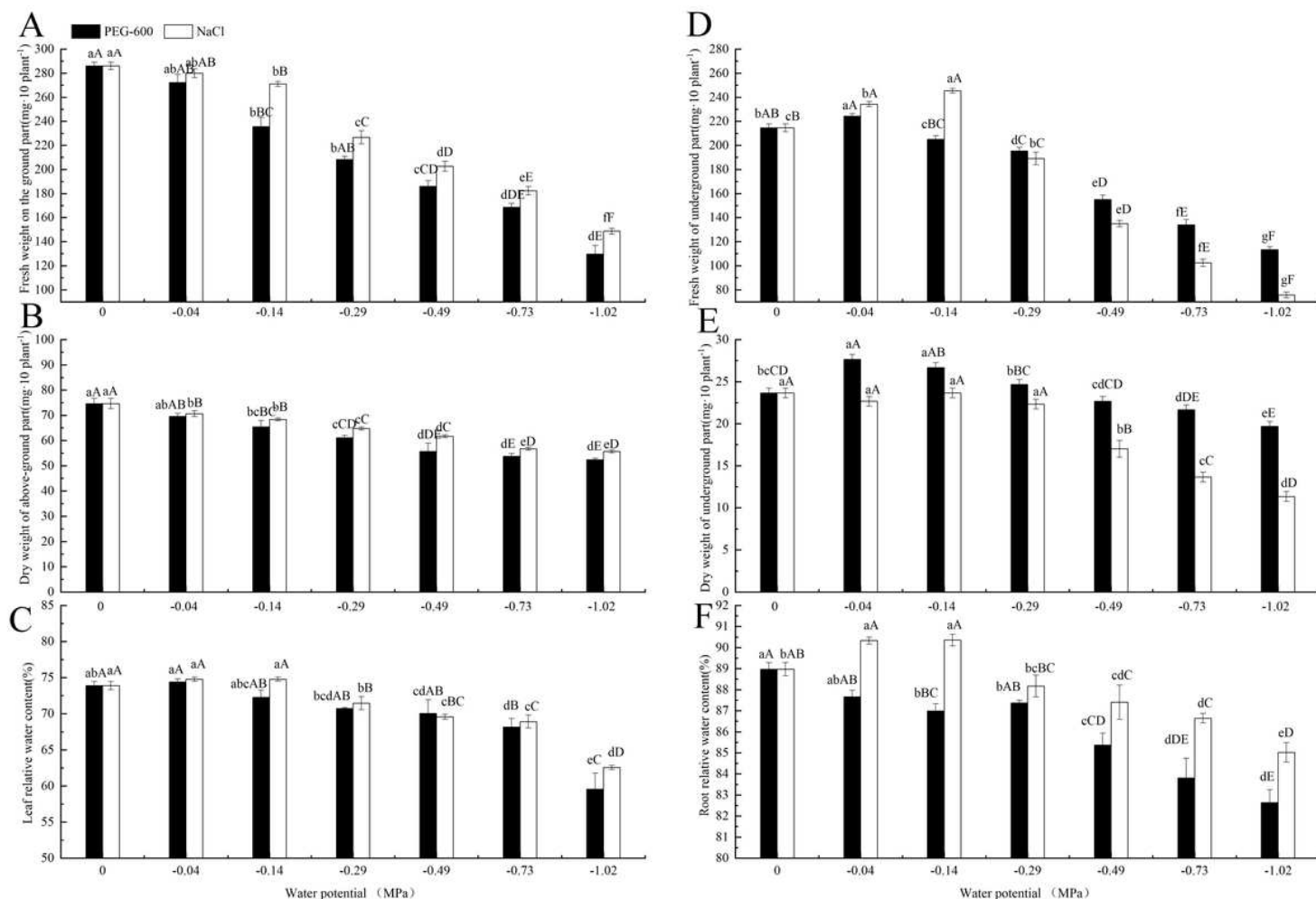


Figure 1

Effects of two solutions on biomass accumulation. Two types of solution stress affect *E. nutans* Leaf fresh weight (A), leaf dry weight (B), Relative leaf water content (C), Root fresh weight(D), root dry weight(E), and Relative water content of the root system(F). Different lowercase letters indicate significant differences in the same solution under different treatments ($P < 0.05$), different capital letters indicate that the differences in the same solution under different treatments reach a highly significant level ($P < 0.01$).

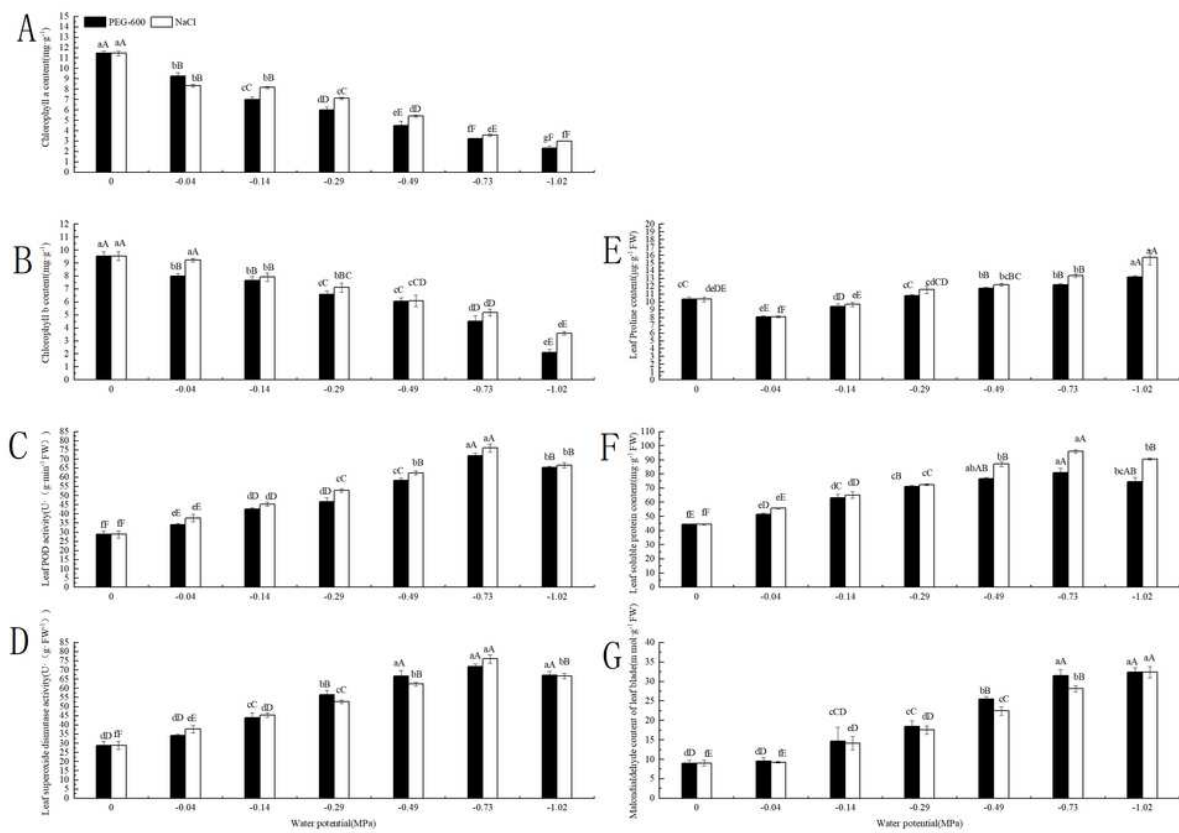


Figure 2

Effects of two solutions on Leaf Physiological Indicators. Two types of solution stress affect *E. nutans* Chlorophyll a content(A),Chlorophyll b content(B), leaf POD activated(C), leaf SOD activated(D), leaf Pro content(E), leaf SP content(F), and leaf MDA content(G). Different lowercase letters indicate significant differences in the same solution under different treatments ($P < 0.05$), different capital letters indicate that the differences in the same solution under different treatments reach a highly significant level ($P < 0.01$).

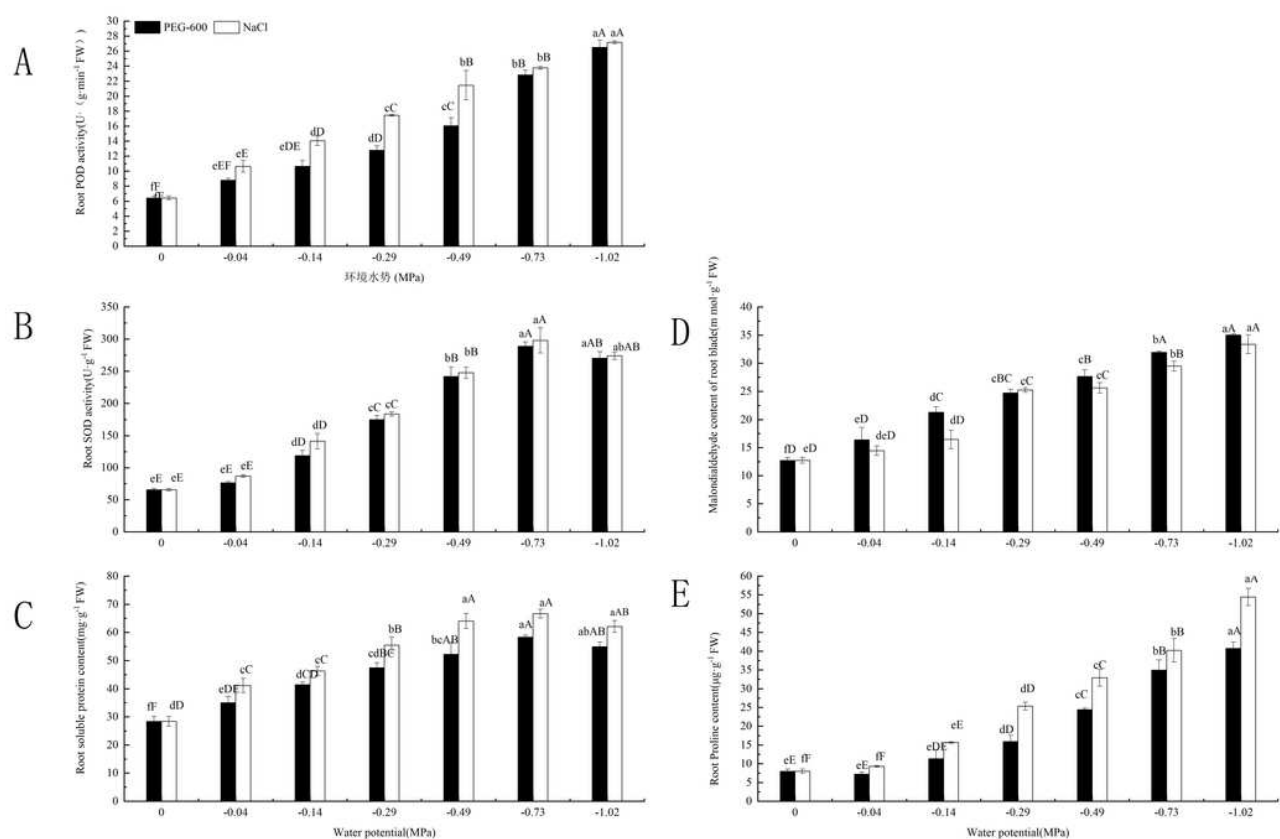


Figure 3

Effects of two solutions on Leaf Physiological Indicators. Two types of solution stress affect *E. nutans* root POD activated(A), root SOD activated(B), root SP content(C), root MDA content(D) and leaf Pro content(E). Different lowercase letters indicate significant differences in the same solution under different treatments ($P < 0.05$), different capital letters indicate that the differences in the same solution under different treatments reach a highly significant level ($P < 0.01$).

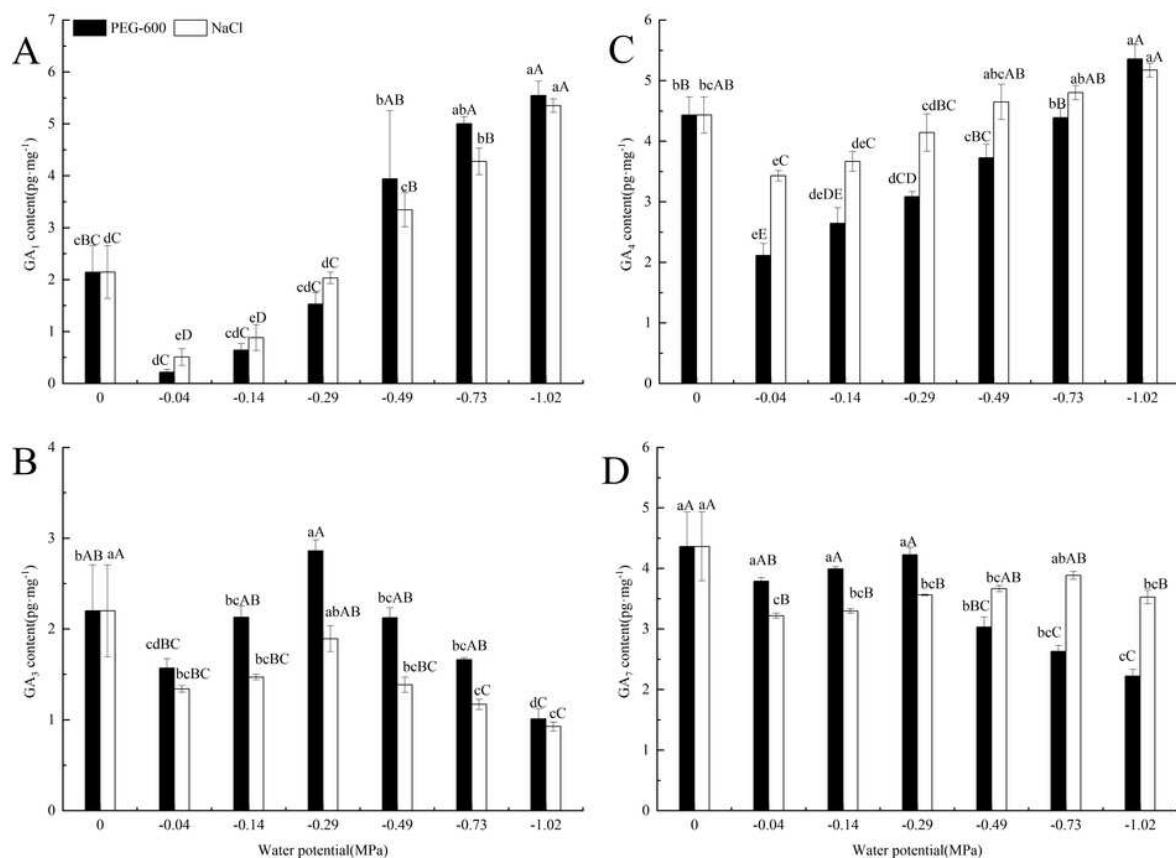


Figure 4

Effects of two solutions on GA content. Two types of solution stress affect *E. nutans* GA₁ content(A), GA₃ content(B), GA₄ content(C) and GA₇ content(D). Different lowercase letters indicate significant differences in the same solution under different treatments (P < 0.05), different capital letters indicate that the differences in the same solution under different treatments reach a highly significant level (P < 0.01).

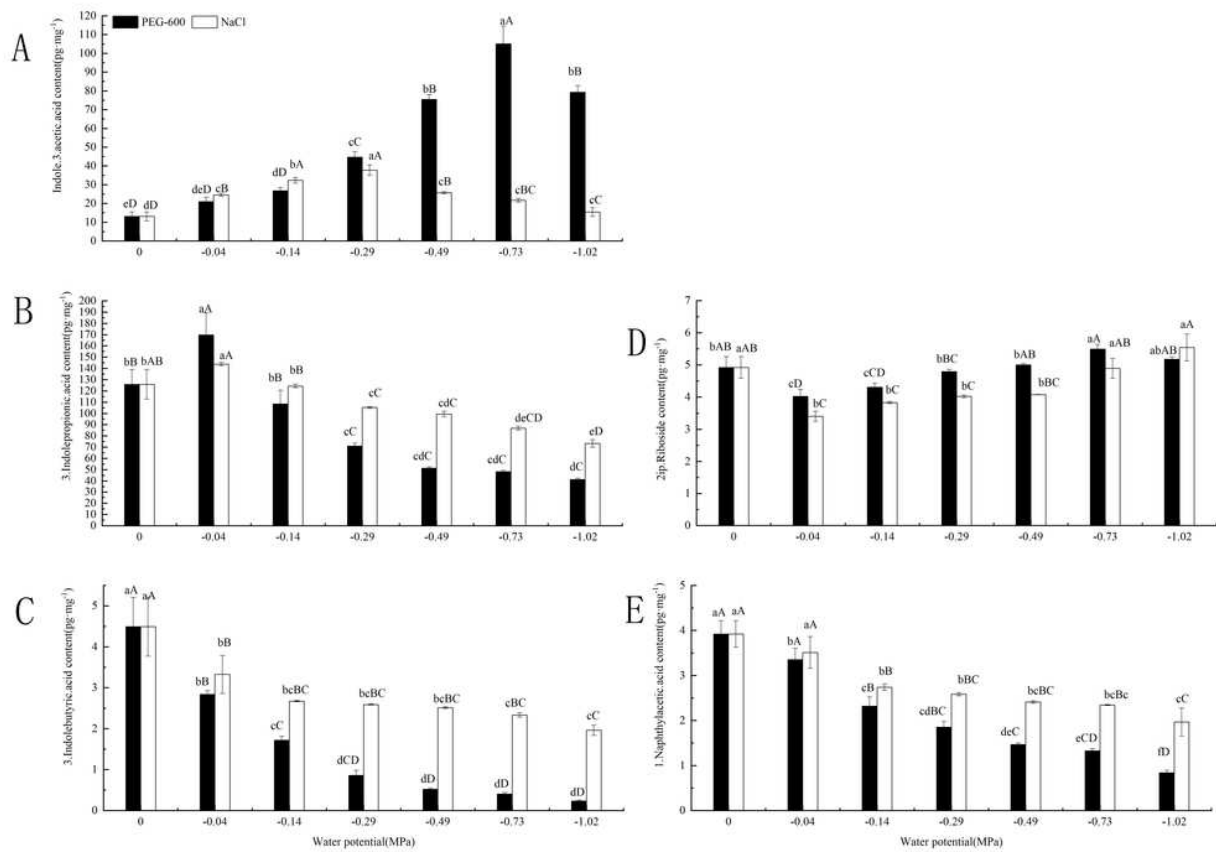


Figure 5

Effects of two solutions on auxin content. Two types of solution stress affect *E. nutans* IAA content(A), IPA content(B), IBA content(C) and 2ip-riboside content(D) and NAA content(E). Different lowercase letters indicate significant differences in the same solution under different treatments ($P < 0.05$), different capital letters indicate that the differences in the same solution under different treatments reach a highly significant level ($P < 0.01$).

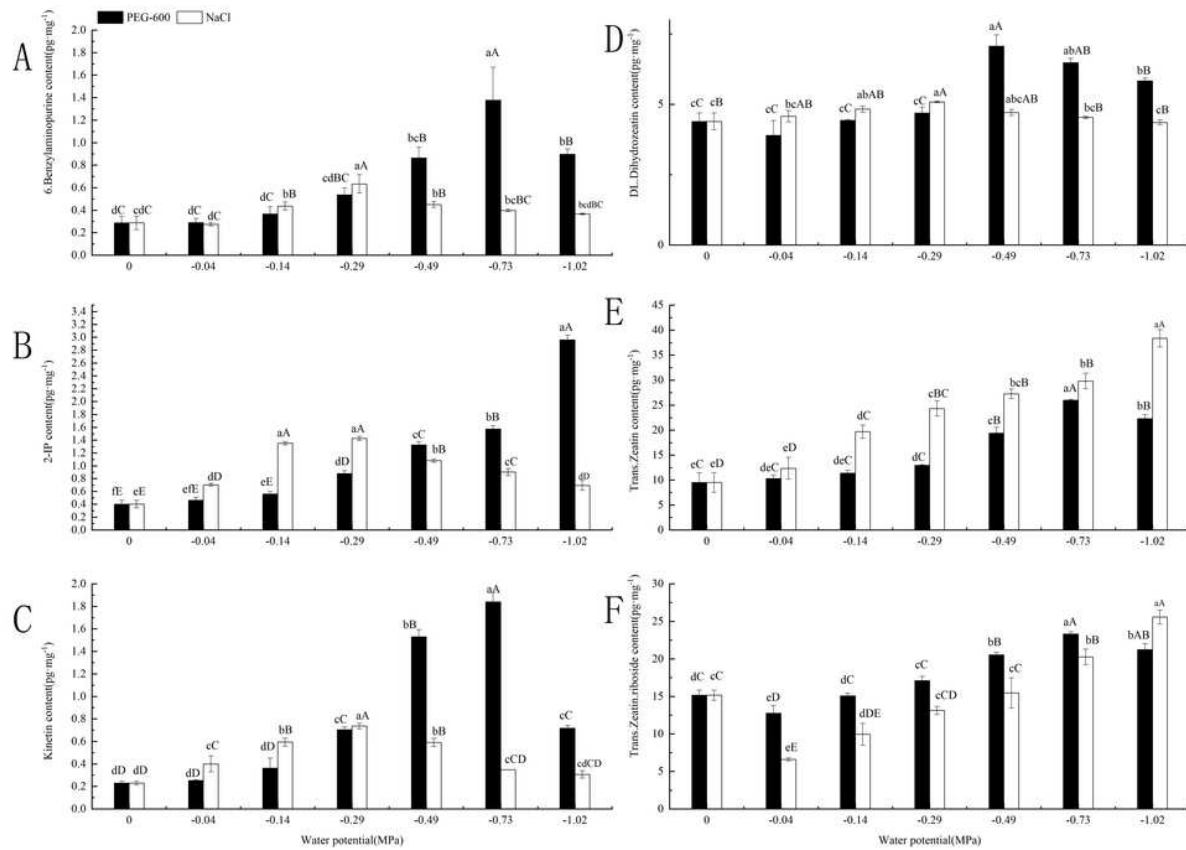


Figure 6

Effects of two solutions on cytokinin content. Two types of solution stress affect *E. nutans* 6-BA content(A), 2-IP content(B), KT content(C), DHZ content(D), TZ content(E) and TZR content(F). Different lowercase letters indicate significant differences in the same solution under different treatments ($P < 0.05$), different capital letters indicate that the differences in the same solution under different treatments reach a highly significant level ($P < 0.01$).

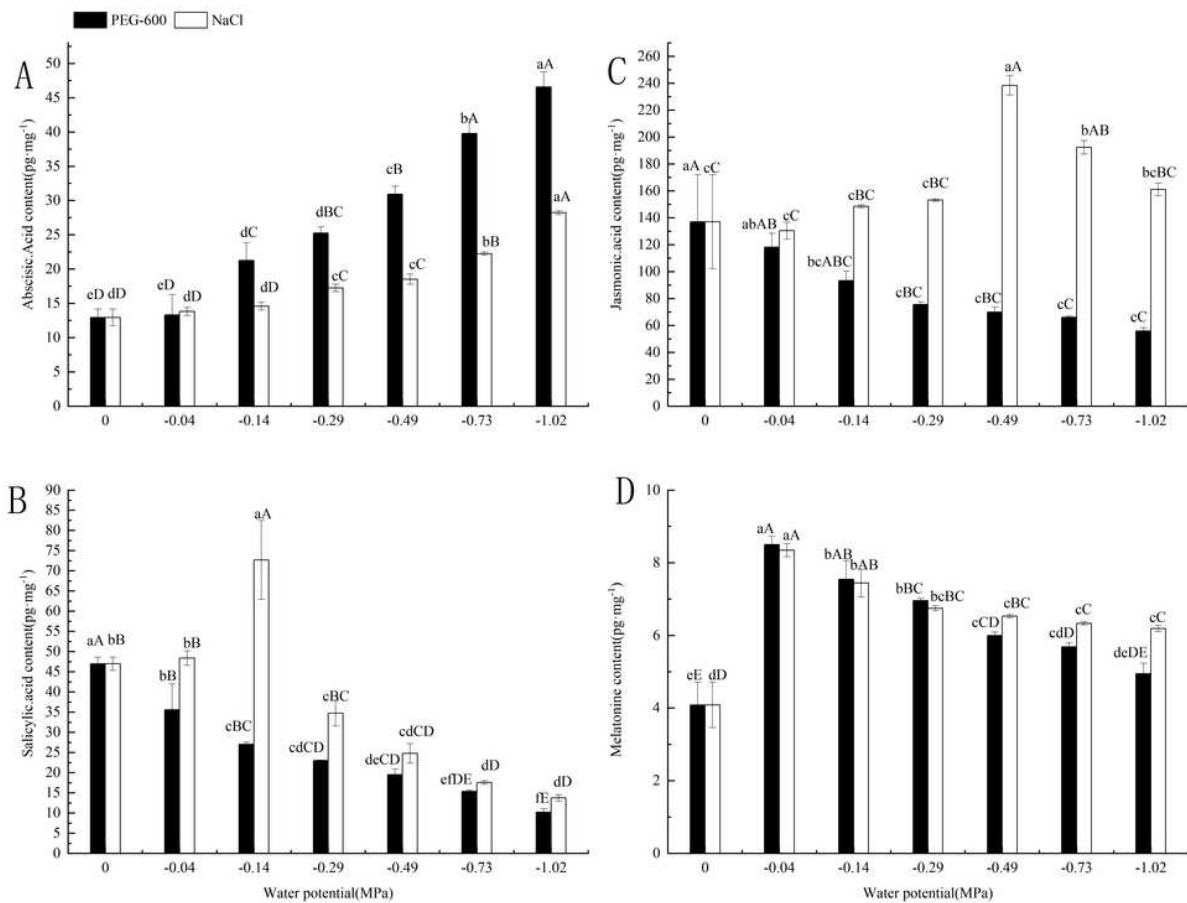


Figure 7

Effects of two solutions on Absciscic acid and other substances content. Two types of solution stress affect *E. nutans* ABA content(A), SA content(B), JA content(C) and MT content(D). Different lowercase letters indicate significant differences in the same solution under different treatments ($P < 0.05$), different capital letters indicate that the differences in the same solution under different treatments reach a highly significant level ($P < 0.01$).

