# Research Progress of Suaeda Heteroptera and in Ecological Restoration of Coastal Wetland

Yuting Wei[1,2], Yubo Cui[1,2,*], Peijing Kuang[1,2], Junwen Ma[1] and Zhaobo Chen[1,2]
[1]*Key Laboratory of Biotechnology and Bioresources Utilization, Ministry of Education, Dalian Minzu University, Dalian 116600, China*
[2]*College of Environment and Resources, Dalian Minzu University, Dalian 116600, China*

Keywords: Salt Stress, Phytoremediation Techniques, Suaeda Heteroptera.

Abstract: Coastal wetland ecosystems are important ecosystems linking freshwater and seawater. With the rapid economic and social development, the total amount of pollutants discharged into the near-shore sea through various ways and means remains high, with saline, heavy metal and antibiotic pollution. In order to gain a comprehensive understanding of the salinity tolerance mechanism of the suaeda salsaand the mechanism of soil improvement, this study summarises its salinity tolerance mechanism at the morphological, physiological and biochemical levels as well as at the molecular level, and compares the research progress on the management of heavy metals and antibiotics in soil. On the basis of this study, we suggest that more attention should be paid to the exploitation of the key genes of saline alkali ponies, the role of saline alkali ponies in the succession of saline plant communities, and the mechanism of how saline alkali ponies and microorganisms can jointly improve the soil.

## 1 INTRODUCTION

Soil salinity is an ecological and environmental problem faced worldwide and is one of the important abiotic stressors affecting plant growth and development and agricultural production. Coastal wetlands are in the transition zone of evolution from sea to land, with complex and fragile ecological environment, and are high-risk ecosystems that are highly vulnerable to damage. High soil salinity can adversely affect photosynthesis, energy metabolism and protein synthesis of plants (Parida AK, 2018). Currently, soil salt stress has become one of the major problems limiting agricultural production (cao 2018). Therefore, researchers hope to solve the problem of plant productivity limitation by soil salinity by resolving plant salt tolerance mechanisms and enhancing plant salt tolerance.

Suaeda salsa belongs to the genus Alkali poncho of the family Laiidae as an annual herb and is a pioneer plant in saline lands. Its fleshy leaves and unique resilience mechanism make it extremely salt and drought tolerant, and it is widely distributed in China, making it an important wild planting resource. Its above-ground parts can carry away a large amount of salt, and it is currently widely used in the improvement of saline agricultural and grazing fields in Xinjiang, China. The adaptability of Suaeda salsa on high concentration salt soils is of great importance for the study of physiological mechanisms of salt tolerance, molecular mechanisms of salt tolerance and the breeding of salt-tolerant plants. It has a strong salt tolerance and can significantly reduce soil salinity and improve soil structure. It has been shown that it has significant effect in remediation of organic and heavy metal contaminated soil, especially in saline soil conditions. However, there is still insufficient research on the mechanism of salt tolerance and soil improvement of Salicornia salina.

## 2 MORPHOLOGICAL STUDIES ON THE SUAEDA HETEROPTERA

Plants have been able to complete their life histories and evolve a variety of survival strategies to adapt to adversarial environments, and seed dimorphism is one of these important strategies. Seed dimorphism enhances the ability of plants to cope with unpredictable environmental changes. It has been



Wei, Y., Cui, Y., Kuang, P., Ma, J. and Chen, Z.
Research Progress of Suaeda Heteroptera and in Ecological Restoration of Coastal Wetland.
DOI: 10.5220/0011196400003443
In *Proceedings of the 4th International Conference on Biomedical Engineering and Bioinformatics (ICBEB 2022)*, pages 220-224
ISBN: 978-989-758-595-1

shown that the black and brown colored seeds of Suaeda heteroptera have significant differences in dormancy characteristics, salt tolerance, and germination: the volume of brown seeds and ion concentration in seed cells are higher than those of black seeds; the water uptake rate, germination potential, and salt tolerance of brown seeds are significantly stronger than those of black seeds; brown seeds can still achieve 30% seed germination at a salt concentration of 0.78mol/L(Zhang, 2021). The germination rate of brown seeds could still reach more than 30% at a salt concentration of 0.78mol/L, while black seeds could not germinate at a salt concentration of 0.59mol/L. The higher ion concentration in the cells of brown seeds may be a major reason for the higher salt tolerance of their seeds. In contrast, black seeds can remain dormant under high salt concentration conditions, and after a long period of storage, the seeds are still very vigorous, thus broadening the time of seed germination, reducing the risk of seeds germinating out at once, and facilitating the completion of the plant community of Suaeda heteroptera under unfavorable environmental conditions (Xia, 2020).

Plant roots are the first organ to sense soil salinity and are the first barrier to control soil salinity into the plant. However, there are relatively few studies on the response of the root system in salt stress, especially on the mechanism of salt stress response of the root system of saline plants. The root system of Suaeda heteroptera is not fleshed out, and the roots are mainly distributed in the 30cm soil layer, which is a shallow-rooted functional root system that reduces the accumulation of salts in the root system by rapid upward transport of salts. The study showed that the root system of Suaeda heteroptera showed obvious salt aggregation under low salinity conditions and salt rejection under high salinity conditions, and its root depth increased with increasing salinity, which may be related to the higher surface salinity. The salinity of the soil between the roots of H. finasteri was examined and found that the inter-root salt concentration of H. finasteri was much higher than the inter-root salt concentration of non-saline plants, indicating that H. finasteri has a certain enrichment function for salts. The root marginal cells are the first to feel the salt stress in the soil and play an important role in the signal perception and conduction of plant stress tolerance, and their number is directly related to the salt tolerance of plants. The number and activity of root marginal cells of sweet-soil plants decreased sharply under higher salt concentration, while the number and activity of root marginal cells of Suaeda heteroptera increased significantly without any effect. The same mechanism may also exist in the root system of the Suaeda heteroptera.

Suaeda heteropteraare dilute salt plants and their above-ground parts are the main organs for salt enrichment. Leaf fleshing is an important strategy for saline plants to be able to grow and complete their life history in saline environments. The fleshing of leaves allows the plant cells to increase in number and volume, allowing them to absorb and store large amounts of water, which results in a significant increase in water content per unit weight and volume of tissue, thus diluting the salt ion concentration in the leaf cells and maintaining the osmotic balance of the leaf cells. The accumulation of $Na^+$ and $Cl^-$ in the leaf is the main cause of leaf fleshing, which in turn leads to an increase in the number of cells and the regional isolation of large amounts of Na+ in the vesicles, thus reducing the osmotic stress and ionic stress caused by $Na^+$ to the plant and facilitating the survival of Suaeda heteropteraunder high salt concentration conditions.

## 3 PHYSIOLOGICAL AND BIOCHEMICA RESPONSE OF SUAEDA HETEROPTERA UNDER SALT STRESS

Under salt stress, plants are harmed mainly from osmotic stress and ion toxicity. High salt concentrations can disrupt the metabolic pathways of substances in plants as well as ion homeostasis, thus affecting the growth activities of plants. To resist salt stress, plants have evolved multiple pathways such as osmoregulation, ion homeostasis systems, ROS elimination systems, and hormone signaling to counteract the damage caused by salt stress (Pan 2018).

Seed water uptake is critical for seed germination. Higher external salt concentrations can cause osmotic stress on seeds and thus affect plant seed uptake. Under saline soil conditions, salinity is the main factor affecting the germination of Suaeda heteroptera. During the germination stage, seeds resist salt stress mainly by regulating the osmotic balance. Soluble sugars, soluble proteins and proline are important osmoregulatory substances in the plant body, and their contents are an important indication of the plant's ability to maintain osmotic balance. Within a certain range, the contents of soluble sugars, soluble proteins, and proline generally increased in the seeds of P. finasteri as the salt concentration increased, indicating that P. finasteri maintained osmotic balance mainly through the synthesis of osmoregulatory substances. However, as the salt concentration continued to increase, the content of proline began to decrease, while soluble sugars, which are signal transduction substances, continued to increase. In addition, it has been found that the $Na^+$ concentration in the seeds of Salicornia salina did not increase with the increase of salt concentration in the external environment, especially the $Na^+$ concentration. This may be an important reason for the normal germination of the Suaeda heteroptera in soils with higher salinity concentrations. When the salt concentration in the external environment increased to a certain value, the water uptake rate of the seeds decreased significantly or even stopped. This ensures that seeds do not initiate germination in a high salt concentration environment, thus maintaining seed activity.

The seedling stage is an important stage of plant establishment, and vital activities such as energy and material metabolism are strongly influenced by the external environment. Studies have shown that the $CO_2$ uptake rate, stomatal conductance, and photochemical reactions of the photosynthetic system (PSII) of Suaeda heteroptera were not significantly affected at a salt concentration of 400mmol/L. Metabolites are directly related to plant life activities, and under conditions of adversity, the plant body can counteract adversity by regulating the synthesis of metabolites. The most direct of these are changes in primary metabolites: small molecules such as amino acids, soluble sugars, and lipids play an important role in resisting osmotic stress caused by adversity. The synthesis of more complex secondary metabolites: enzymes, flavonoids, ROS scavenging, and signal transduction pathway substances are also subject to change. A comparative analysis of the metabolome of leaves of Suaeda heteroptera seedlings under high versus low salt concentration conditions revealed significant differences in the intermediate substances of the secondary metabolite synthesis pathways, including those of flavonoids, polyphenols, and organic acids. This may be closely related to the involvement of these substances in vital activities such as cell membrane structure, intracellular osmotic balance homeostasis and scavenging of free radicals in plants under salt stress.

# 4 A STUDY OF THE MOLECULAR MECHANISMS OF SALT TOLERANCE IN THE SUAEDA HETEROPTERA

The physiological and biochemical responses of the plant body in response to adversity are fundamentally determined by genes. Stress tolerance in plants is a complex process involving multiple aspects of life activities such as physiology, biochemistry, and signaling. At present, the research on signal perception, signaling and signal response of salt stress is not very deep. However, the common signaling pathways of adversity stress have been studied in depth, and the functions of some key genes have been studied in depth.

Under high salinity conditions, salt regionalization is an important mechanism for salt tolerance in plants, and the genes that have been cloned to play important roles in Na ion regionalization in Suaeda heteroptera: SeNHX1, SeVHA-A and SeVP1, which encode $Na^+/H^+$ transport proteins, V-$H^+$-ATPase enzyme and V-$H^+$-PPase enzyme, respectively, play important roles in vesicle V-$H^+$-ATPase and V-$H^+$-PPase, respectively, play important roles in vesicle Na ion regionalization. The expression of SeNHX1 was significantly increased in leaves under high concentration of salt stress, and the transgenic results showed that SeNHX1 was able to reduce the concentration of Na ions in the leaf cytoplasm, increase the K/Na ion ratio, and significantly increase the photosynthetic rate as well as the chlorophyll II concentration in plants. The up-regulated expression of SsVHA-H and SsVHA-B, genes encoding $H^+$-ATPase in the vesicles, provided a proton gradient for Na ion translocation across the membrane into the vesicles and reduced the ion concentration in the cytoplasm, thus avoiding damage to the organelles caused by high salt ion concentrations. External salt concentration is too high and plants are exposed to osmotic stress. Plants generally maintain internal homeostasis through organic small molecules and inorganic ions. Betaine and proline are important osmoregulators in the cytoplasm, and two important genes, SsBADH and SsCMO, in the synthetic betaine pathway, and SsP5CS, a key gene in the proline synthesis pathway, have been successfully cloned. It was found that the expression of these three genes was significantly elevated under salt stress. High salt concentrations cause oxidative stress in plants, and saline plants have evolved a strong peroxide-clear system, which reduces the damage caused by free radicals to the plant body. The peroxide-clearing genes SsGST, SsPrxQ, SsCAT1, SsCAT2, SsAPX, Ss.sAPX, and SsTypA1 have been successfully cloned in Suaeda heteropteraplants, and the overexpression of these genes in plants showed a significant decrease in hydrogen peroxide as well as MDA content, indicating that these genes play an important role in reducing oxidative damage to cell membranes.

With the development of high-throughput sequencing technology, it has become possible to study plant salt tolerance mechanisms from the transcriptome level. Whole-transpringome sequencing of roots and leaves of Suaeda heteroptera treated with distilled water and high concentrations of salt showed that genes related to the synthesis of signaling substances such as growth hormone, ethylene and jasmonic acid, which sense salt stress signals and play important roles in transducing salt stress signals, were up-regulated under high concentrations of salt stress; K/Ca ion channels, choline monooxygenase, and $Na^+/H^+$ transporters, V-$H^+$ATPase genes were up-regulated; Fe-SOD, glutathione, L-ascorbic acid, and flavonoid-related genes involved in free radical scavenging were also up-regulated. This is consistent with the previous findings: it indicates that Suaeda heteroptera resist salt stress through a series of integrated responses such as sensing adversity signals, transducing adversity signals and resisting adversity stress.

# 5 RESEARCH ON THE TREATMENT OF SALINE CONTAMINATED SOIL BY SUAEDA HETEROPTERA

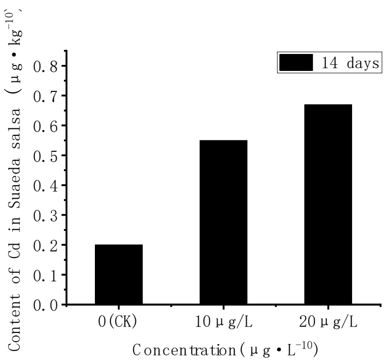


Fig. 1. Cd uptake by the roots of the Suaeda salsa.

Figure 1 shows the uptake of Cd by Suaeda salsaat different concentrations, which gradually increased with increasing Cd concentration. Organic matter and heavy metal pollution are two important types of soil pollution, and a lot of results have been achieved in the research of contaminated soil management. Engineering measures are currently the main means to carry out contaminated soil management, but have certain limitations, so biological management has gradually become a hot spot in contaminated soil management research, especially the joint plant and microbial management research. The special soil properties of saline soils have limited the application of many plants and microorganisms. As a pioneer plant in saline soils, winged alkali poncho has a relatively well-developed resilience mechanism, and thus has a strong tolerance to survive under many adversity conditions. And the plants have similarities in physiological and biochemical responses, signal sensing pathways, signal transduction pathways, and stress-tolerant substances to resist different adversities. This suggests that Suaeda heteroptera may have some potential in saline soil pollution management.

At present, the treatment of heavy metals in soil mainly transforms heavy metals from activated state to stable state by activator, and then extracts them from soil by thermal desorption, electrochemical method and extraction method (Zhu, 2005). Activators have strict requirements on soil pH, etc. In saline soils, activators may lose their activity. Therefore, Suaeda heteroptera also play an important role in the remediation of such contaminated soils. Lead contamination is a common type of soil heavy metal contamination. It has been shown that moderate concentrations of NaCl can enhance the activity of SOD, POD, and CAT in the peroxide scavenging system of P. finasterides thereby reducing the damage of Pb to P. finasterides; the inter-root uptake of Pb is increased by about 35% at 1% NaCl compared to 0.1% NaCl. This indicates that salinity contributes to the uptake and enrichment of Pb by Suaeda heteroptera. The highest uptake rates of heavy metals Cu, Zn, Pb, and Cd could be reached 31, 101, 34, and 62 mg/(kg-d) by Suaeda heteroptera. The intercropping of H. alba and its inter-rooted microorganisms was also able to abate the content of heavy metals in the soil.

# 6 CONCLUSIONS AND EXPECTATION

## 6.1 Mining and Utilization of Salt Tolerance Genes in Suaeda Heteroptera

The cloning and functional analysis of genes controlling important traits such as yield, quality and disease resistance in major food crops have been basically completed. At present, the focus of research is on the regulatory networks of genes controlling important traits in major food crops and the application of these key genes in breeding practice. With the advent of the genomic era, molecular breeding has become an important direction for future breeding work. However, the progress of research on plant resistance, especially the mining of resistance genes, is still slow, partly due to the lack of resistance plant resources, and partly due to the complexity of plant resistance systems. As a pioneer species of the saline plant community, the winged alkali poncho is one of the few plants on earth that can tolerate 3% salt, and the winged alkali poncho grows well under a variety of adversities such as drought stress and water stress. The ability to adapt to alternating environments of salt stress, drought stress and water stress suggests that Suaeda heteroptera may have evolved mechanisms to adapt to most adversities. Therefore, it is important for the breeding of salt-tolerant plants to explore the salt-tolerance genes and elucidate their salt-tolerance mechanisms.

## 6.2 Research on the Application of Suaeda Heteroptera in Ecological Restoration

The cloning and functional analysis of genes controlling important traits such as yield, quality and disease resistance in major food crops have been basically completed. At present, the focus of research is on the regulatory networks of genes controlling important traits in major food crops and the application of these key genes in breeding practice. With the advent of the genomic era, molecular breeding has become an important direction for future breeding work. However, the progress of research on plant resistance, especially the mining of resistance genes, is still slow, partly due to the lack of resistance plant resources, and partly due to the complexity of plant resistance systems. As a pioneer species of the saline plant community, the winged alkali poncho is one of the few plants on earth that can tolerate 3% salt, and the winged alkali poncho grows well under a variety of adversities such as drought stress and water stress. The ability to adapt to alternating environments of salt stress, drought stress and water stress suggests that Suaeda heteroptera may have evolved mechanisms to adapt to most adversities. Therefore, it is important for the breeding of salt-tolerant plants to explore the salt-tolerance genes and elucidate their salt-tolerance mechanisms.

# ACKNOWLEDGEMENTS

The research was financed by the Natural Science Foundation of Liaoning, China (2020-MZLH-02) and Science and Technology Innovation Foundation of Dalian, China (2018J12SN080).

# REFERENCES

G.W. Zhang, C.Y. Tian, Z.S. Wang, et al. Clinical Journal of Chinese Medicine. *Chemical Ingredients, Pharmacological Action, Development and Utilization of Suaeda heteroptera(L.) Pall*, **13**, 120-122+136 (2021).

M.H. Zhu, Y.S. Ding, D.C. Zheng, et al. Environmental Pollution and Prevention. *Cumulative Uptake and Mechanisms of Common Heavy Metals by The Tidal Beach Salt Marsh Plant, Phyllostachys Nobilis*, **27**, 84-87 (2005).

N. Xia, R. Meng, H.F. Wei, et al. Environmental Ecology. *Effect of Soil Salinity on The Growth of Suaeda heteroptera*, **02**, 52-56 (2020).

Parida AK, Das AB. Ecotoxicology and Environmental Safety. *Salt Tolerance and Salinity Effects on Plants: A Review*, **60**, 324-349 (2005).

S.Y. Cao. Dalian Ocean University. *Transcriptome-wide Study of Suaeda heteroptera Under High Salt Stress*, (2018).

Y.W. Pan, Y.B. Gu, Z.H. Tang, et al. Soil and Crop. *Effects of Salinity and Nitrogen Adition on Growth and Biomass Allocation of Phragmites Australias Seedlings in Saline-alkali Wetland*, **07**, 257-265 (2018).