

Research Status on *Suaeda heteroptera* Kitag

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Abstract

The utilization value, morphological characteristics, biological characteristics, mechanism of salt tolerance, soil-repairing function, degradation, planting and breeding technology, development prospect and significance of *Suaeda heteroptera* Kitag were described, and the attentions which should be paid in its study and utilization in the future were put forward.

Keywords: Utilization value, Morphological characteristics, Biological characteristics, Degradation, Planting and breeding technology, *Suaeda heteroptera* Kitag

1. Introduction

Nearly one billion hectares of land are salt-affected throughout the world, which account for about 25% of the whole land area. In China, various types of salt-affected land's area are about 34.6 million hectares (Zhang *et al.*, 2007). Excessive soil salinity can cause water deficit, ion toxicity, and nutrient deficiency leading to molecular damage and even plant death (Wang *et al.*, 2007). While the halophytes can be very tolerant of salt, complete their life cycles normally under salt stress and are very abundant in nature. Growing salt-tolerant plants in saline soil, on one hand, these halophytes have the potential to be used as vegetable, forage and possess certain economic value; on the other hand, it's also an effective measure to soil reclamation. Therefore, the exploitation of halophytes has lately been receiving more attention (Khan *et al.*, 2006). *S. heteroptera* is one of the most important halophytes in China. Researches indicated that *S. heteroptera* with high nutrient value is a pioneer plant of saline soil due to its special physiological characteristics and morphological structure. It is also a kind of plant very strong in salt tolerance and can decrease the salt content of saline soil. Its soil ameliorating effect on coastal saline soil is significant (Lin *et al.*, 2005; Li *et al.*, 2007). Various aspects of *S. heteroptera* were reviewed, which could provide reference material and scientific basis for the further exploitation and utilization, environmental evaluation and environmental protection in intertidal zone and saline areas.

S. heteroptera, belonging to *Suaeda* of the Chenopodiaceous family, is an annual herbaceous plant and also known as *Suaeda salsa* L. It is native to salinity soil and adapted to the high salinity region in the Asia and Europe. It always occurs in lakeside, desert, river and coastal regions and widely distributes in Hebei, Shanxi, Qinghai, Zhejiang, Jiangsu and Shandong province in China.

2. Utilization Value

S. heteroptera is a potential wild plant resource, which has a high value for development. *S. heteroptera* has important economical value because it richly contains the nutrition, medicine and other ingredients. It has a broad prospect and huge potential in manufacturing health care edible oil, health care medicine and high-quality cosmetics. Modern medical researches have found that it has the effects of reducing blood sugar, dilating blood vessels, preventing and curing heart disease and enhancing human immunity. The fresh branches of *S. heteroptera* are widely consumed as a favorable vegetable due to its sufficient nutrient components, including 7 vitamins, 18 essential amino acids, 5 essential elements and other antioxidant ingredients (Wang *et al.*, 2007). Its seeds contain approximately 40% oil, rich in unsaturated fatty acids, which can be easily converted to chemical compounds for industrial and pharmaceutical use (Zhao 1998). State Oceanic Administration of China has produced conjugated linoleic acid with the oil of *S. heteroptera* seed. *S. heteroptera* is also a potential feedstock for some production such as bio-ethanol (Li *et al.* 2013).

Planting *S. heteroptera* can affect water content in soil, increase humidity in the air, and lower down temperature and wind speed, as well as decrease evaporation of water in soil (Zhao *et al.*, 2002). The development of *S. heteroptera* is conducive to the environment virescence and vegetation restoration of saline environment, then will prevent soil and water loss to maintain and rescue the ecological environment which is on the verge of destruction. *S. heteroptera* can effectively reduce the soil salinity, increase soil organic matter content, improve the content of N、P、K in the soil. Therefore, *S. heteroptera* has remarkable effects for improving the ecosystem of coastal saline soil. It also would play an important role in

exploiting coastal tideland resource, developing coastal tideland agriculture and protecting the ecological environment.

The natural *S. heteroptera* community can come into being beautiful “red carpet” landscape, which is an important ecological tourism resource. The “red carpet” not only has ornamental value but also is the paradise of some precious species. Autumn is the mature season of the “red carpet” seeds. The seeds can provide plenty of food for precious birds and even create a favorable breeding habitat for *Saunders’ Gull*, *red-crowned crane* and other precious species. Therefore, *S. heteroptera* has very high economic value, ecological value and landscape value.

3. Morphological Characteristics

High leaf or stem water content, succulence, is an adaptive feature, which contributes to the regulation of internal ion concentrations in many halophytic species (Short & Colmer, 1999). *S. heteroptera* is a popular halophyte and has the typical shape and structure characteristics of halophytes with small, linear and succulent leaves. All of the mesophyll is the aqueous tissue. Leaf’s epidermis cuticle is developed. Length and width of leaves are 10mm-30mm and 2mm-3mm, respectively. The palisade tissue and aqueous tissue of its leaves are very developed, and that’s the result of adaptation to resistance to high-salt and drought stresses. Its stems are erect with some vertical red stripes. And its branches are slender. The shoots of *S. heteroptera* plants are green in early growth stage, but red-violet in late autumn. The plant height is about 20cm-80cm and can be up to 120cm after well cultivation. The annual capacity of the stems and leaves of *S. heteroptera* is about 0.45-0.9 dry tons per hectare. Song and the others had carried on the comparative study of four kinds of pollen morphology of *S. heteroptera* under different habitat conditions, and the results indicated that the pollen of *S. heteroptera* is spherical; pollen size is 15.4 μ m - 24.0 μ m; the number of aperture is 46 - 65; the diameter of the aperture is 3.1 μ m - 5.4 μ m. The surface of pollen grain is smooth. There are many small granular protuberances distributing on the surface of pollen grain and the aperture (Cui *et al.* 2009). *S. heteroptera* produces dimorphic seeds (soft brown seeds and hard black seeds). The seeds are so small that thousand seed weight is about 2.7g. The seed production of wild *S. heteroptera* is low, while the yield can increase by 3-4 times after artificial cultivation and physical processing.

4. Biological Characteristics

S. heteroptera grows in temperate saline areas of China (Li *et al.*, 2005), where the dominant ions in soil are Na⁺, Mg²⁺, Cl⁻ and SO₄²⁻ (Wang, 1993). The temperature suitable to growth of *S. heteroptera* is 20 \square ~30 \square , and the sunshine percentage suitable to growth is above 60%. *S. heteroptera* starts growing in Spring when the temperature is above 8 \square . After germination in spring, the seedling growth is inhibited because of the temperature of the saline soil increasing slowly, and the biomass increases sluggishly too. After the middle of May, the peak period of growth, temperature stabilizes more than 20 \square . During this period, the plant height can increase 40cm-50cm. After flowering, the plant growth speed slows down again, and the plant water content is reducing while the dry weight is increasing. Seeds of *S. heteroptera* germinate in late April, plants flower from July onwards, while seeds start to mature in late October and die in late November. *S. heteroptera* has strong stress resistance, especially prominent salinity resistance. It can survive in 4.3% sea water. It is a pioneer plant in the saline soils and can develop normally and complete life cycle in saline environment. Some researches had shown that the soluble salt content suitable to growth of *S. heteroptera* was 10g kg⁻¹-16g kg⁻¹. *S. heteroptera* can grow in the ocean and swamp zone, even can

survive in the desert and arid grassland zone, which indicates that *S. heteroptera* possesses the advanced characteristics of cold-tolerance, drought-tolerance, salt-tolerance and strong adaptability.

5. Mechanism of Salt Tolerance

The direct impact of salt on plant growth could be due to the decrease in osmotic potential in the soil solution, the toxicity caused by excessive Na^+ and Cl^- in plant cells, and the nutrient imbalance in plant tissues (Evelin *et al.*, 2009). Salt resistance of plants to a great degree depends on ionic metabolization. Analyses have shown that the shoot and root salt content of *S. heteroptera* can be 23%-27% and 10%-12% of dry weight, respectively (Jia *et al.*, 1977). Zhang (2002) reported that Na^+ and Cl^- content of leaves and roots increased with the increasing NaCl concentrations, and had similar accumulating tendency. Na^+ , Cl^- and the total ions content in roots were evidently lower than that in leaves under salt treatments, and a characteristic adaptability to salt environment that a large number of ions (Na^+ , Cl^-) were preferentially accumulated in leaves was suggested (Zhang, 2002). Aboveground parts accumulates lots of ions, which is beneficial to increase the osmotic potential difference between aboveground parts and root, promote the water transportation from root to aboveground parts, and improve the water conditions of aboveground parts, then to promote growth. Under salt stress, *S. heteroptera* maintains relatively stable of K^+ and Ca^{2+} in the leaves, meanwhile increases the selective absorption of K^+ in root, thus ensure the required concentration of plant metabolism. For another, it accumulates lots of ions (Na^+ , Cl^-) in the leaves, meanwhile adjusts the balance of Na^+ and Cl^- by growing fast or increasing succulence, and best meets the needs of osmotic regulation without producing ions poison. This may be the regulating mechanism of *S. heteroptera* under salt stress.

6. Soil Remediation

6.1 Salt-affected Soil

S. heteroptera can absorb salts from saline soils and accumulate them within the plant tissue to significantly decrease the salt content. At a density of 15 plants m^{-2} , *S. heteroptera* can potentially remove more than 3000k Na^+ ha^{-1} from saline soil, suggesting that it can be used to improve the quality of saline soils (Zhao 1991). The improving function displays in improving soil structure, reducing soil salinity, increasing soil porosity, increasing the content of soil organic matter and total nitrogen and improving the soil biological activity significantly. Lin and the others (2005) reported the bioremediation of coastal saline soil in the Tianjin estuarine area by planting *Suaeda salsa*. The electric conductivity, content of organic matter and microbial amount of soil were compared. The result showed that the electric conductivity had decreased by 13%; the organic matter and total nitrogen had increased by 43% and 18; the microbial amounts had increased, which indicated that the *S.salsa* had remarkable effects for improving the saline soil.

6.2 Heavy Metal Polluted Soil

S. heteroptera is a potentially suitable heavy-metal biomonitor and applicable for the phytoremediation of heavy metal polluted soil. Due to the anthropogenic activities in recent decades, heavy metal contaminants such as Cd, Pb, Cu and Zn have become a serious threat to water and soil ecosystems because of the persistent nature, long distance transport, and adverse effects of heavy metals to organisms. *S. heteroptera* has a high capacity of heavy metal accumulation and significantly reduces the levels of toxic metals from saline soils. Accumulation of Cd, Pb, Cu and Zn in the plant was studied. Zhu and the others (2005)

reported that the plant had more obvious accumulation above four heavy metals in different tidelands, and the contents in sequence were Zn>Pb>Cu>Cd. The accumulation contents had the remarkable distinction in different parts of the plant owing to the selective tolerance to heavy metals of the plant. Contents of Cu in the plant were root>stem>leaf, Zn Leaf>root>stem, Pb root>leaf>stem and Cd root>stem≈leaf (Zhu *et al.* 2005).

6.3 Petroleum Hydrocarbon Contaminated Soil

S. heteroptera has certain restoration effect on saline soil which is contaminated by petroleum hydrocarbon. It can help to reduce the oil polluted to the soil. Phytoremediation for the saline soil polluted by oil with *S. heteroptera* is a low-cost and effective strategy, and it also can be used in the remediation of large-scale contamination. Planting *S. heteroptera* can gradually eliminate the harm of petroleum hydrocarbon in saline soil, which is conducive to the restoration of coastal zone ecosystem (Xu *et al.*, 2007).

7. Population Degradation

Degeneration mechanism research of *S. heteroptera* wetland was studied. Salt is an important factor influencing the degradation. When the soluble salt content was higher than 16g kg^{-1} , *S. heteroptera* would grow slowly, or even die; when the soil salt was less than 10g kg^{-1} , *S. heteroptera* could grow, but some plants appeared green in spring and summer. The nitrogen and phosphor and organic nutrition of plant, and organic matter of soil is the important source of mineral and organic nutrition of plant. In four different types of wetland, the nitrogen, phosphor and organic matter contents were all at low level, but the growth status in four types of wetland were different greatly, which indicated that the nutrients in soil was not the reason of the degeneration. Wang and the others (2010) reported that comparing the flourishing wetland to degenerating wetland, the flourishing wetland was submerged by diurnal tide everyday, the soluble salt content in soil was effected by tide, and the salinity in tide changed smoothly, while the degenerating wetland is submerged only by spring tide. The repeated dipping of tide avoids the salt accumulation in soil because of evaporation. So water is another important reason that causes *S. heteroptera* wetland degenerate. Many researches have shown that human activity is the key factor that causes *S. heteroptera* wetland degenerate, such as the building of dam, shrimp pond and road. These activities occupied directory *S. heteroptera* wetland and make the acreage of *S. heteroptera* wetland decrease (Wang *et al.*, 2010).

8. Planting and Breeding Technology

8.1 Soil Preparation

The range of soil salinity that *S. heteroptera* adapted to is very wide. Sandy soil contained saline is advisable. The optimum pH is 8-8.5. Select field and rake the land to be 1.2m wide. Each 667 m^2 is fertilized with 2500kg organic fertilizer before sowing. Irrigate the land with enough water.

8.2 Seed Collection

At the end of October, most of the seeds are mature. Harvest and dry the plant then choose good ones from the seeds.

8.3 Sowing

Soak the seeds 6-8h before sowing to promote the germination. Seeds of *S. heteroptera* germinate in late April, plants flower from July onwards, while seeds start to mature in late

October and die in late November. Therefore, outdoor sowing is conducted from late March to early April. Due to its small seeds, thousand seed weight is 2.7g, sow 1000-2000g seeds per 667m².

8.4 Field Management

Spray the herbicide before sowing to reduce weeds and avoid hurting the roots of seedlings by pulling weeds.

8.5 Periodic Detection

Periodic detection is conducted in planting areas. Record the density, biomass, plant height and the other indicators.

8.6 Harvest

The optimum harvesting time of *S.heteroptera* is when its new shoots grow to 20-25cm.

Zhao and the others reported the high frequency adventitious shoot induction and plantlet regeneration from immature inflorescence explants of *S. heteroptera*. Adventitious shoots were induced from immature inflorescence cultured on Murashige and Skoog (MS) medium supplemented with 1.0mg·L⁻¹ 6-benzylaminopurine (6-BA) and 0.4mg·L⁻¹ indole-3-acetic acid (IAA) for 25 days. Adventitious shoots were further multiplied vigorously and maintained for a long time on the same medium for adventitious shoot induction. Rooting was achieved on MS medium without any plant growth regulators after adventitious shoot was transplanted for 2-3 weeks (Zhao *et al.* 2006).

9. Development Prospect and Significance

9.1 Agricultural Sustainable Development

With the development of industrialized production and increase of population in our country, arable land area declines sharply. The unreasonable irrigation caused lots of secondary salinization of the fields. Excess salt in soil may inhibit the growth of most plants, thus limiting the crop yield. Accordingly, how to exploit and make use of a large area of salinization land while reducing the secondary salinization of soil and increasing the crop production is what our agricultural production has to solve in urgently. *S. heteroptera* growing in saline soil can absorb and accumulate considerable amounts of salt within the plant, thereby decreasing the salt content of the soil. Planting a large area of *S. heteroptera* in wasteland not only greatly increases production but also can make good use of wasteland and saline soil to produce high-quality food and edible raw materials. The development and utilization of *S. heteroptera* contribute greatly to the development of ecological agriculture. Therefore, *S. heteroptera* possesses a great significance to the agricultural sustainable development in the future.

9.2 Protect Fresh Water

Water resource shortage is one of the problems that affect human being, and China is one of 13 countries with serious water lack all over the world, while the traditional agriculture depends greatly on fresh water, which becomes the main contradiction of agricultural development. In traditional agriculture, higher-paying salt-leaching works are used. Conventional crops are planted after the soil ameliorating. The traditional agriculture is limited by fresh water resources shortage. There is an abundant seawater resource and underground salt water in our country, but these resources can not be used for traditional

agriculture. *S. heteroptera* can be irrigated with seawater or underground water, and the contents of fat, protein, vitamin, minerals and trace elements are rich. We can make good use of its own unique character instead of higher-paying salt-leaching works, thus not only conserves fresh water resources but also makes it become a salt-tolerant economic crop and will provide experience and a basis for seawater irrigating agriculture.

9.3 Maintain Ecological Environment

All kinds of wetland in China with a total area of 66 million hectares, account for 10% of the world's total wetland area. Cui and the others (2008) reported that the high soil salinity is the key environmental factor for the degradation of wetland due to the inhibition of plant growth caused by salinity in Yellow River Delta (Cui *et al.* 2008). Due to its characteristics of shorter plant growth period, greater biomass and convenient harvest, *S. heteroptera* has a certain significance of improving and increasing the wetland's ecological environmental quality. *S. heteroptera* grows on tidal flat as a pioneer plant and its growth increases the composition of the organic matter in coastal saline soil and makes the salinity reduce gradually and then creates conditions for the growth of wetland plant. Currently, a quarter of China is desert, an area that is expanding by around 5000 square kilometers a year. *S. heteroptera* is an important sand-fixation plant. Planting a large area of *S. heteroptera* can make the sand dune fixed to prevent the migration of desert. *S. heteroptera* also plays an important role for the reclamation of desert areas.

S. heteroptera is an important material of forage, food, medicine, chemistry and industry. It not only can regulate soil environment, but also can provide considerable amounts of biomass. Planting *S. heteroptera* in saline soil and making them grow naturally will be able to obtain good economic benefit and ecological benefit. We work in the future not only should strengthen the research in the mechanism of salt tolerance and the effect of saline soil improvement, but also should expand its utilization range and maximize its potential values.

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