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Experimental Research on Improving the Salt Tolerance of Plants in Coastal Saline Soil - A Case Study of Huanghua City in Hebei Province of China

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ABSTRACT

Given the increasing pressure imposed by the social economy upon land supply, the improvement and utilization of saline-alkali soil has been included in the development and remediation plans of land resources. However, coastal saline-alkali land cannot be easily improved because of its simple ecosystem structure, weak ecological environment, and exposure to tide invasion. In order to explore viable improvements and sustainable utilization methods as well as to improve the ecological environment quality and utilization efficiency of coastal saline-alkali land, this study performed field experiments on coastal saline-alkali soil by growing plants in the state-owned Zhongjie Friendship Farm in Huanghua City. In the experiments, salt-tolerant plants were planted in a field without any organic fertilizer and soil conditioner, and their survival rates, growth amounts, and states were subsequently analysed. Twelve plant species with certain salt tolerances were selected. The experimental results demonstrate that *Lagerstroemia indica* L., *Rhus typhina* Nutt and *Lycium chinense* (leaf use) grow well in the field as well as show high adaptability and the highest survival rates (100%) among all selected species. *Fraxinus americana* (fast-growing), *Ligustrum vicaryi* and *Koelreuteria paniculata* Laxm have survival rates of over 85%, while *Buxus megistophylla, R. typhina* Nutt, *Hibiscus syriacus* Linn., *Parthenocissus semicordata* (Wall.) Planch., and *Fraxinus chinensis* Roxb. have high survival rates ranging from 67.5% to 70%. The experimental results also reveal that the adaptability of salt-tolerant plants to coastal saline-alkali soil is higher than their transformation ability. Root growth also has a certain effect on the improvement of soil fertility. This study provides references for the treatment and sustainable utilization of saline-alkali land in a coastal area with moderate salinization.

INTRODUCTION

Saline-alkaline soil is widely distributed in the coastal areas of China. Various saline soils can be found in the 18,000 km total coastal area of China and in the 5×10^6 hm^2 land area of coastal provinces, municipalities, and autonomous regions (Yang Jinsong 2008). Coastal areas are vulnerable to be invaded by tides, and conventional saline-alkali land management measures can hardly achieve the desired results because of serious salinity problems, harsh natural conditions, simple ecosystem structure, poor stability, and fragile ecological environment. The inadequate freshwater resources further hamper the rehabilitation and utilization of saline-alkali land, thereby seriously restricting the sustainable development of agriculture and social economy (Zhang et al. 2017). Therefore, a strategy for the effective use of land resources must be implemented in China, a country which has more people but few land. Given the increasing pressures exerted by socioeconomic development upon land supply, the land utilization degree and efficiency in China must be improved. From the "existence is reasonable" perspective, saline-alkali lands offer a potentially important resource for human beings.

Saline-alkali soil can be utilized in two ways. First, saline-alkali soil can be used to create a favourable growing environment for plants by employing remediation works and agronomic improvement measures, including irrigation, drainage, guest soil modification, organic fertilizer application, chemical modifiers, and salt barriers (Pan et al. 2006). However, based on experience, these methods are costly and difficult to maintain in coastal areas. Second, saline-alkali soil can be improved by planting salt-resistant plants (Wang et al. 2011). These plants are directly planted via conventional irrigation or can thrive under natural rainfall conditions without requiring additional conditions and facilities. Given that these plants absorb salt from soil to promote growth, the soil salinity migrates away from the root soil layer. Based on this process, we can rebuild the vegetation system of saline-alkali land, optimize and improve its ecological system, and eventually improve its ecological environment quality. And this approach is less affected by tide invasion, thereby increasing the potential for the sustainable utilization of saline-alkali soil in coastal areas (Niu et al. 2002). Most importantly, the second way can reduce the cost of saline-alkali soil improvement. Massive salt wastelands in coastal areas can be included in the scope of agricultural utilization, thereby promoting agricultural structure adjustment and industrial upgrading. Many researchers have also begun to focus on the resource exploration and utilization of salt-tolerant plants, such as crops and herbs. However, only few studies have conducted experiments on the introduction of tree species, and tree species with economic and ecological values are especially rare. By taking trees and shrubs in economic and ecological landscapes as examples, this study systematically designs introduction and screening experiments for field test to improve the utilization degree of coastal saline-alkali soil and to promote the ecological environment of coastal areas in China.

STATE OF THE ART

As natural plant groups in salinized habitats, salt-tolerant plants usually live in a soil environment with an osmotic potential of -0.33 MPa. By salt-tolerance mechanism study, suitable salt-tolerant plants are successfully introduced, selected and cultivated, and the saline-alkali soil is effectively improved to promote agricultural development and achieve certain economic benefits (Rozema et al. 2013, Roy et al. 2014). However, local and foreign studies on the salt tolerance and salt tolerance mechanisms of plants revealed huge differences in the growths of different plants subjected to salt stress (Belkheiri et al. 2013, Vermue et al. 2013, Katschnig et al. 2013, Zhang et al. 2016). Recent studies have conducted introduction and screening experiments on salt-tolerant plants to determine the plant species that can survive in coastal saline-alkali lands. *Spartina anglica* Hubb was identified as a salt-tolerant plant grown in coastal saline-alkali lands in certain countries. Reddy et al. planted *Salvadora persica* in saline-alkali soil to obtain seeds with 40% to 45% oil content (Reddy et al. 2008). In their field experiments, Akhter et al. planted the halophyte *Leptochloa fusca* (L.) Kunth, which significantly improved the physical properties of the soil after three years of growth (Akhter et al. 2004). Ashutosh Mishra et al. greatly improved the physicochemical properties of saline soils by planting *Eucalyptus tereticornis* Smith for many years (Mishra et al. 2003). Studies on saline-alkali soil have also been recently conducted in China because of the rich saline-alkali soil resources in the country. For example, Chong-Xin Zhong of Nanjing University introduced *S. anglica* Hubb to China to promote the reconstruction of beach vegetation in the northern coastal area of Jiangsu (Zhong 1983). Pei Qin introduced 20 types of salt-tolerant plants, including *Atriplex triangularis, S. alterniflora*, and *Kosteletzkya virginica*, which had high economic value and laid the foundation for the forestation of coastal saline-alkali land (Qin et al. 2003, Xu et al. 1996). Kang Junshui et al. successfully introduced 36 types of ground cover plants, including *Sedum-spectabile, Achillea sibirca*, and *Iris japonica*, in coastal saline-alkali areas (Kang et al. 2003).

Some advancements in the exploration and utilization of salt-tolerant plant resources in China have also been reported. However, relatively few studies have been performed on such topics, and most of the existing studies have focused on crops and herbs (Zhang et al. 2012, Zhang et al. 2015, Guo et al. 2015). Meanwhile, only few experiments have focused on the introduction of tree species, even though rare tree species with large scale, economic, and ecological values have been successfully introduced (Song et al. 2006). In addition, few studies have conducted introduction and screening experiments for the purpose of utilizing coastal saline-alkali soil. This study selected Huanghua city of the Cangzhou Coastal district as an example. Based on a systematical investigation of soil salinization, the experiment base was rationally selected to determine the plant species. Introduction and screening experiments on salt-tolerant plants were conducted to provide methods and technical support for the reconstruction and utilization of saline-alkali soil in the coastal area.

MATERIALS AND METHODS

Experimental field: Huanghua city has an average salt content (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, CO_3^{2-}, HCO_3^{-}, Cl^{-},and SO_4^{2-}) of 4.58 g/kg (minimum and maximum of 37.66 g/kg and 0.22 g/kg, respectively), which indicates severe salinization. According to the grading standards proposed by Zhu & Wang (1989) for the degree of soil salinization, the saline soil area in Huanghua City can be classified into five levels (see Fig. 1). The non-salinized soil (salt content<1 g/kg) has the lowest area ratio of 8.49%, while the mildly salinized soil (1 g/kg<salt content<2 g/kg) has the highest area ratio of 31.93%. Meanwhile, the salinized soil (salt content>10 g/kg), moderately salinized soil (2 g/kg<salt content<10 g/kg), and severely salinized soil (4 g/kg<salt content<10 g/kg) have area ratios of 27.09%, 20.25%, and 12.25%, respectively. At present, the unutilized salt-alkali soil in Huanghua City covers 33,176 hm^2 land area. This experimental study aims to make an effective use of these land resources.

The state-owned Zhongjie Friendship Farm in Huanghua city has a flat terrain with excellent road and water conservancy infrastructures (Fig. 1). The soil salt content in this area can be classified into all levels mentioned above, with the exception of salinized soil, thereby making this area an

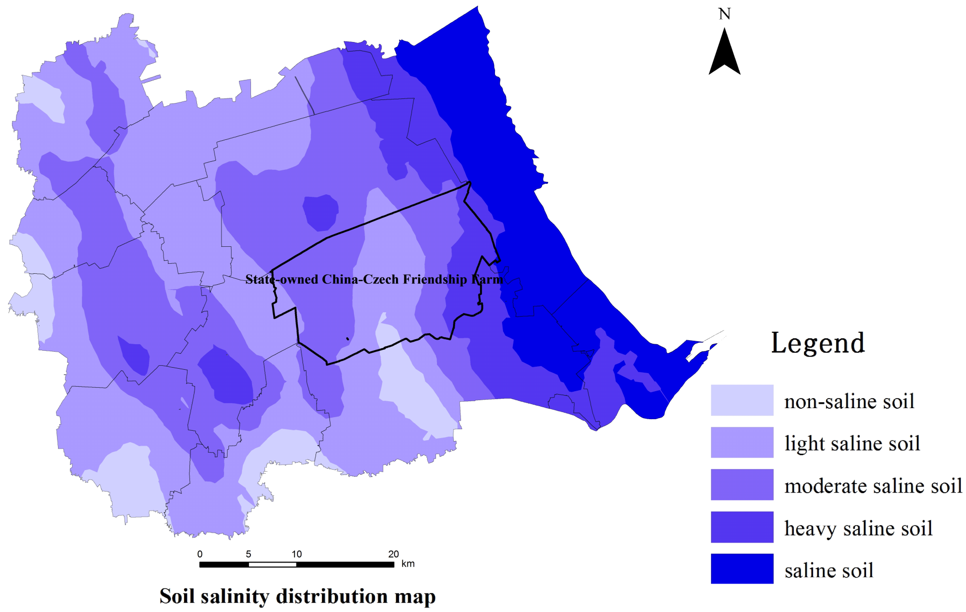

Fig. 1: Spatial distribution map of soil salt content in Huanghua city.

ideal setting for the introduction and screening of salt-tolerant plants. Therefore, the experimental base of Team 18 of Zhongjie Friendship Farm by Hebei Agricultural University, was selected as the experimental site for this study. The specific geographical coordinates of this area are 38°20’20.2" north and 117°31’29.9" east.

Introduction and Screening Experiments on Salt-tolerant Plants in Fields

Experimental material: The experimental plant species were selected according to the following principles:

1. Those varieties for which economic and ecological values match those of local plants in the Cangzhou Coastal Area are generally preferred.
2. The selected plant species must mainly include trees and shrubs with excellent salt tolerance, adaptability to local saline soil, and aesthetic and economic values.
3. The selected plant species must demonstrate a rapid growth, show certain self-fertility ability, and can improve soil fertility.

Following these principles, the following tree species were selected for this study:

1. Liana: *Poimenesperus thomsoni*, *Parthenocissus semicordata* (Wall.) Planch. and *Euonymus fortune* (Turcz.) Hand.-Mazz.
2. Shrub: *Ligustrum vicaryi, Buxus megistophylla*, *Lycium chinense*, *L. chinense* (leaf use), *Lonicera japonica*, *Vitis amurensis* and *Rosa multiflora*.
3. Arbor: *Hibiscus syriacus* Linn., *Malus spetabilis* Royalty, *Rhus typhina* Nutt, *Malus micromalus* Makino, *Fraxinus chinensis* Roxb., *Spathodea campanulata* Beauv., *Prunus cerasifera* Ehrhar f., *Morus alba* Linn. *Albizia julibrissin* Durazz, *Koelreuteria paniculata* Laxm., *Fraxinus americana* (fast-growing) and *Lagerstroemia indica* L.

L. chinense (leaf use) seedlings were obtained from the Specimen Park of the Hebei Agricultural University, in mid-August 2014, while the other seedlings were obtained from the Anguo Seedling Base of Baoding, Hebei in April 2014.

Test area planning and plant cultivation methods: We identified three experimental fields, namely, Land No. 1 for the cultivation of liana, and Land Nos. 2 and 3 for the cultivation of trees and shrubs.

The soil in Land No. 1 had a 0.2% to 0.3% salt content (moderately salinized) and 8.32 average pH value. This experimental field was divided into several test areas, with each test area having a 4 m length and 4 m width. In these areas, we planted two vine species, including *V. amurensis* and *P. semicordata* (Wall.) Planch. Sixteen plants were cultivated for each of these species. The planting density was 1m×1m, while the size of the planting hole was 0.5×0.5×0.5 m. We set a 2 m protection line between the districts (Fig. 2 shows the planting diagram). Before planting, the trunks were cut to 0.5 m to minimize the difference in growth during the test.

Land No. 2 had high terrain and scattered salt stains on the surface. The soil had 0.6% to 1.0% salt content (severely salinized) and 8.63 average pH value. The cultivated species in this area included *P. thomsoni*, *L. Japonica* and *E. fortune* (Turcz.) Hand.-Mazz. Land No. 2 was divided into several test areas, with each test area having a 5 m length and 2 m width. Ten plants were cultivated for each of the aforementioned species. The planting density was 1 m ×1 m, while the size of the planting hole was 0.5×0.5 ×0.5 m. We set 2 m protection line between the districts (Fig. 3 shows the planting diagram). Before planting, the trunks were cut to the height of 0.5 m.

Land No. 3 was planted with trees and shrubs. The soil had 0.2% to 0.3% salt content (moderately salinized) and 8.46 average pH value. Land No. 3 was divided into several test areas, with each area having a 10 m length and 3 m width. Five plants were cultivated for each species, which include *L. vicaryi*, *B. megistophylla*, *R. multiflora* and *L. chinense* among others. The planting density was 1.5 m×2.0 m, while the size of the planting hole was 0.8×0.8×0.8 m. We set 3 m protection line between the districts. Four plants were taken as one group for random ranking. Fig. 4 shows the planting diagram of *L. vicaryi*, *B. megistophylla*, *R. multiflora* and *L. chinense*. *F. Americana*, *P. cerasifera*, *H. syriacus* Linn., *Malus micromalus* and *Malus micromalus cv.* were cut to the height of 1.2 m before planting. *L. japonica* and *L. chinense* were two-year-old cutting plants. The arbors were planted with mass of soil, except for *M. alba* Linn. Sp., *M. alba* Linn. Sp., *R. typhina* Nutt, and *K. paniculata* Laxm.

Test procedure items and methods: On April 19, 2014, all the experimental plants were planted in a field experiment farm. Organic fertilizer or soil conditioner was not applied after planting. The plants were thoroughly watered after trans-

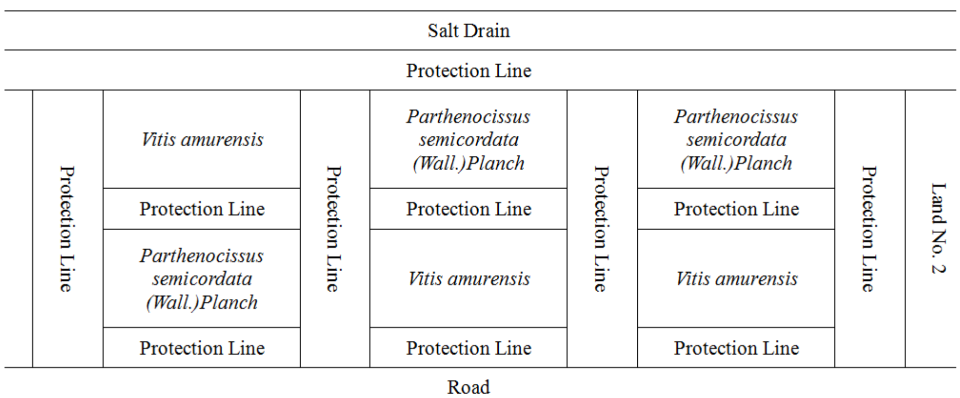

Fig. 2: Planting diagram of Land No. 1.

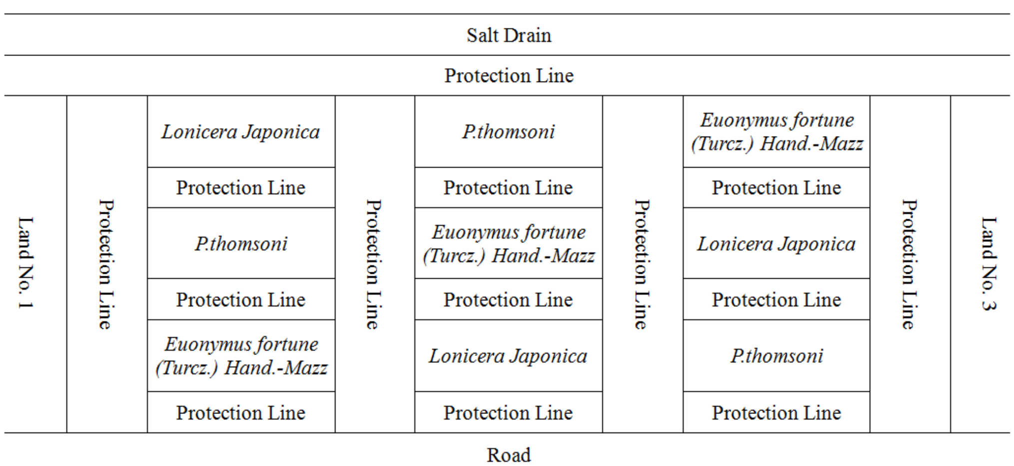

Fig. 3: Planting diagram of Land No. 2.

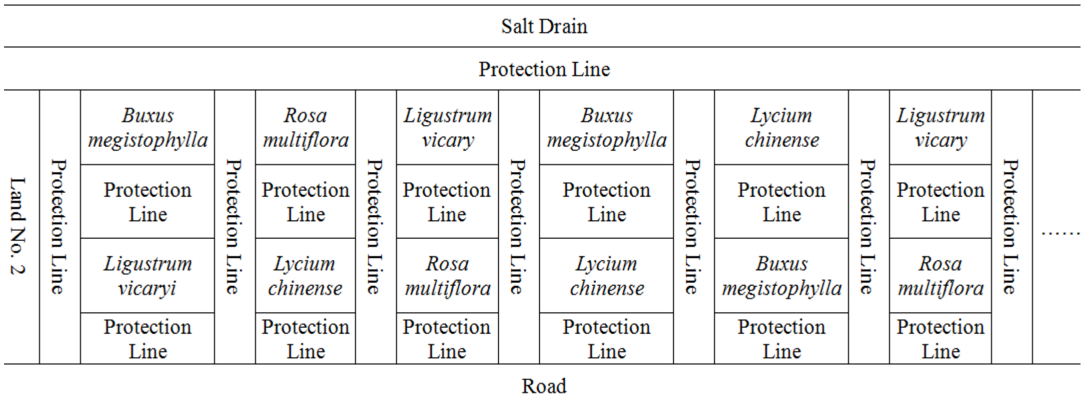

Fig. 4: Planting diagram of Land No. 3.

planting and earthed up the next day for another watering. These plants were watered according to the soil aridity (the irrigation water from the Yellow River has a mineralization of 0.50 g/L to 0.65 g/L). In June 2014, we investigated the survival rates and salt damage to the introduced plants to measure their new branch growth in the growing season.

The pH value, salt content and organic matter content of the experimental field were measured by using the potentiometric method, conductivity method and potassium dichromate volume method, respectively (Li 2009). Sampling, detection, and analysis were then conducted in each experimental field from April to October 2014.

RESULTS AND DISCUSSION

The introduced plants in Land No. 2 did not survive. Therefore, no samples were taken from this area for analysis, and we only evaluated the observation data for Land Nos. 1 and 3.

Analysis of the variations in the observed soil physicochemical properties: The pH value, salt content and organic matter content of the experimental field were measured by applying the same methods as described earlier. Afterward, we observed the changes in the physicochemical properties of soil in Land Nos. 1 and 3. Figs. 5 to 7 show the observation results obtained from April to October 2014.

As shown in Fig. 5, Land Nos. 1 and 3 have pH values ranging from 7.79 to 9.04 and from 7.87 to 8.97, respectively. No significant differences were observed between different soil layers at the same location and time. The deep soil had a slightly high pH value. During the observation period, the soil was strongly alkaline, and the pH values of Land Nos. 1 and 3 slightly fluctuated twice. The sampling in June and August was performed after the rainy season, and a high amount of rainfall was recorded in the local area in September. Therefore, the soil had low pH values in June, August and September and had high pH values in May, July and October. The observation curve in Fig. 5 shows that the changes in the pH values of soil in Land Nos. 1 and 3 are mainly affected by climate and rainfall. Cultivation of plants did not show any obvious impact on the changes in soil alkalinity. However, the pH value of Land No. 3 had a larger amplitude than that of Land No. 1 due to the topography and amount of rainfall in the former. Nevertheless, the growth of arbors in Land No. 3 was not significantly affected by this factor, thereby suggesting that those trees and shrubs with strong root systems have higher saline-alkaline resistance compared with lianas.

Fig. 6 shows that Land Nos. 1 and 3 have soil contents ranging from 1.6 g/kg to 2.4 g/kg and from 1.7 g/kg to 2.5 g/kg during the initial observation period, respectively. Rainfall was recorded in these areas in June, during which the average soil salt content in Land Nos. 1 and 3 reached their minimum (1 g/kg 24 and 1.52 g/kg). The salinity of these soils started to rise as the warm weather approached. In July, the average soil salt content in Land Nos. 1 and 3 were as high as 2.84 g/kg and 3.02 g/kg, respectively. Given the increased amount of rainfall in August, the salinity of these soils moved down towards the deep soil along with rainwater. The salt content in the 0 cm-40 cm soil layer reached the lowest value. The amount of rainfall in these areas gradually decreased after September, and their soil salinity increased along with surface evaporation and severe air drying. The soil salt content in Land No. 3, which had a high terrain, rapidly reached its maximum levels in October. However, this salt content also showed great fluctuations that did not significantly affect the growth of the tested trees and shrubs. Therefore, those trees and shrubs with strong roots had a higher salt tolerance than the lianas.

The organic matter content in soil directly affected the growth of plants. Fig. 7 shows that the soil at 0-10 cm in the experimental field has an organic matter content of 8.89 g/kg to 17.83 g/kg (12.39 g/kg on average) and has a medium

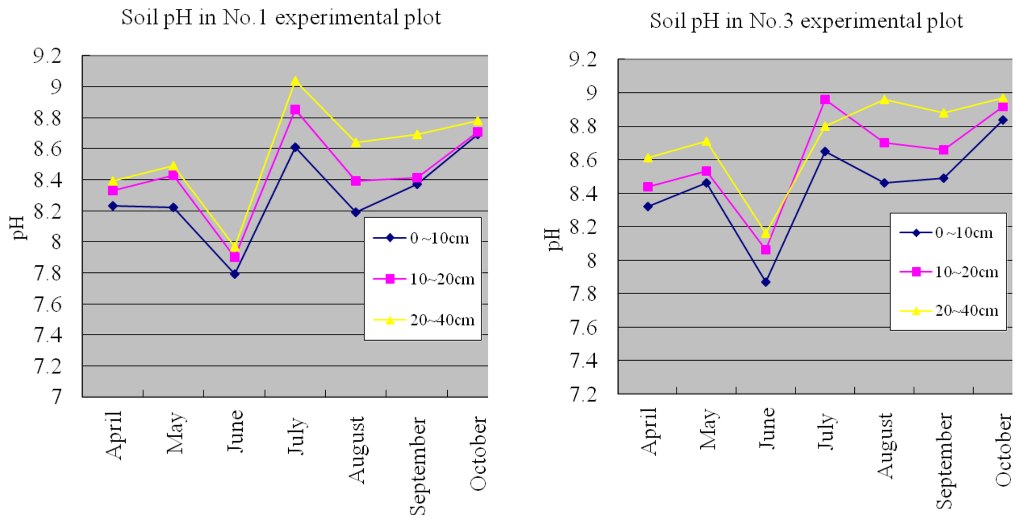

Fig. 5: The changes in soil pH in Land Nos. 1 and 3.

fertility. Meanwhile, the soil at 20-40 cm has insufficient fertility. The organic matter content of this soil also increased after showing an initial decrease. The organic matter content of soil in Land No. 1 obviously increased and decreased in the early and late observation periods, respectively, while the organic matter content in its surface and middle layers slightly recovered at the end of the observation period. The soil in Land No. 3 showed a lower increase in its organic matter content compared with the soil in Land No. 1. In the late observation period, the organic matter content in the former showed a small decreasing amplitude. The organic matter content in each of its soil layers obviously increased to its maximum at end of the observation period. No fertilizers were applied during the experiment. The observation results showed that those plants with a strong root system have an excellent ability to improve the organic matter of soil.

Statistical analysis of the growth status of experimental species: The growth status of the introduced tree species is an important symbol of the success or failure of introduction, because such growth can accurately reflect the objective relationship between the experimental plants and the soil environment. The introduced tree species in Land No. 2 did not survive because of the high soil salt content in this area. To understand the adaptabilities of the introduced tree species in Land Nos. 1 and 3, we observed several indicators, including the survival rate and new branch growth of the experimental plants. The introduced tree species were categorized as those that adapt to local soil (survival rate: above 80%), those that better adapt to local soil (survival rate: 50% to 80%), and those that do not adapt to local soil (survival rate: below 50%). Table 1 shows the growth status of these tree species.

A total of 12 introduced plants showed favourable adaptabilities from the start of the planting to the middle of October (see Table 1). Among these plants, *Lagerstroemia Indica* L., *Albizia julibrissin* Durazz and *L. chinense* (leaf use) grew well and showed the highest survival rate (100%). *F. Americana* (fast-growing), *L. vicaryi*, *M. alba* Linn. Sp., and *K. paniculata* Laxm. had survival rates of above 80% and showed high adaptabilities. Meanwhile, *B. megistophylla*, *R. typhina* Nutt, *H. syriacus* Linn., *P. semicordata* (Wall.) Planch., and *F. chinensis* Roxb. grew well with survival rates of 70%, 70%, 67.6%, and 67.5%, respectively. In late August, some of the surviving *P. semicordata* (Wall.) Planch. gradually gave birth to new roots. Ten tree species had survival rates of below 50%. *P. thomsoni, E. fortune* (Turcz.) Hand.-Mazz, and *L. japonica* had no surviving seedlings because of the high soil salt content. Meanwhile, *P. cerasifera* Ehrhar f. did not survive because of its poor adaptability.

Comprehensive evaluation of the planted tree species: We comprehensively analysed the function and value of 12 introduced shrub species that showed a high survival rate and adaptability. Table 2 presents the analysis results.

1. Given their ornamental characteristics, all shrubs can be used as ornamental tree species in salinized cities for promotion, thereby increasing the economic value of these plants. For example, *L. vicaryi*, *B. megistophylla*, and *Berberis thunbergii f. atropurpurea* form a shrub-like colour block with a strong colour contrast. Given their excellent ornamental effect, these shrubs are commonly used in composing various patterns, constructing hedges, and greening urban roads. *F. americana*, which has long florescence and beautiful colours,

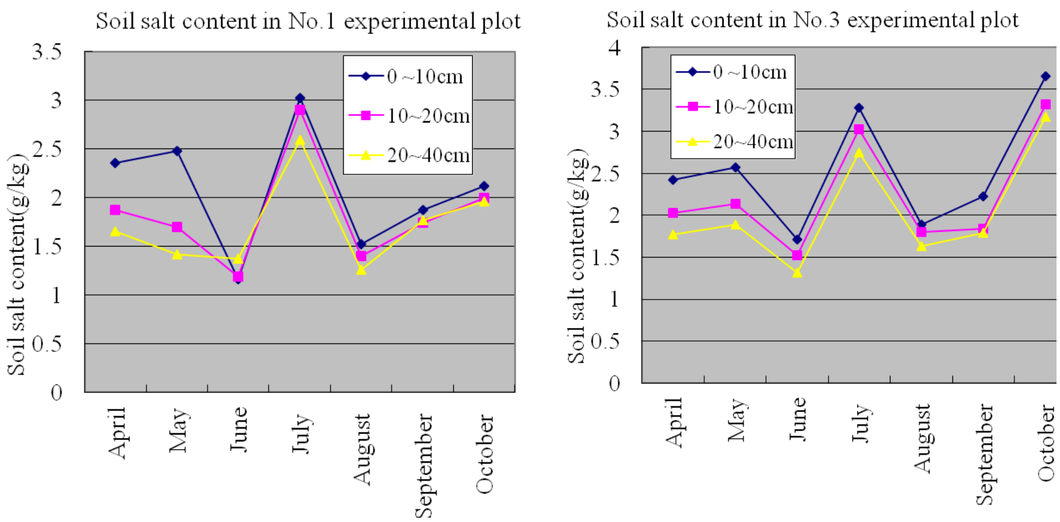

Fig. 6: The changes in soil salt content in Land Nos. 1 and 3.

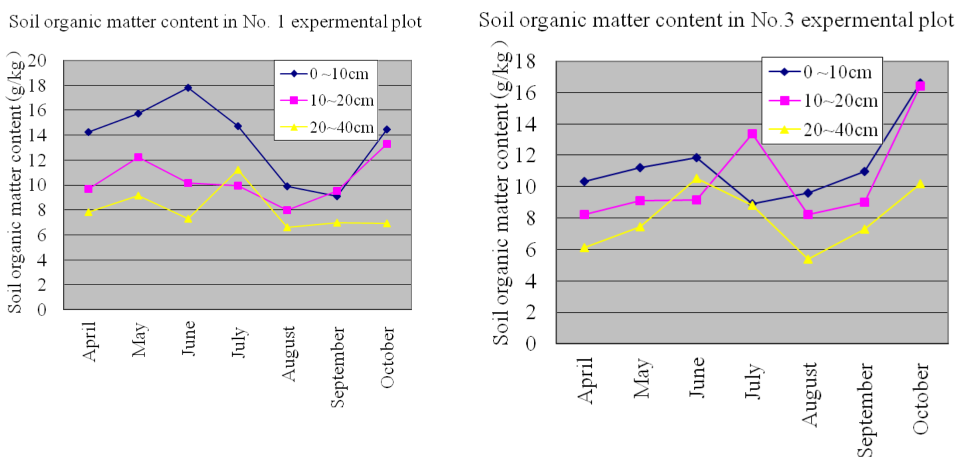

Fig. 7: The changes in soil organic matter content in Land Nos. 1 and 3.

blooms from June to September during which only few other flowers are in bloom, thereby satisfying the demands for summer flower viewing. Therefore, *F. americana* is commonly used in urban landscapes as well as for greening and ornamental purposes. This species also offers excellent material for bonsais and has a strong market demand. Given their beautiful flowers, *H. syriacus* Linn. and *R. typhina* Nutt have an excellent viewing effect and are used in public greening, decorating courtyards, and beautifying villas.

2. These shrubs have certain medical values. For example, the leaves, roots, skins, tender leaves, ears, wood, and parasites of *M. alba* Linn. Sp. can be used to prevent diseases. Mulberry root and its skin can be used to treat fright-induced epilepsy, muscle pains, hypertension, and bloodshot eyes. In addition to their heat-clearing, blood-cooling, and liver-clearing effects, mulberry tender leaves can improve vision and moisten lungs to relieve coughs. In compendium of *Materia Medica*, Li Shizhen stated that the skin, wood, and flower of *F. americana* can be used to promote blood circulation, reduce swelling, and relieve pain or heat.

3. Some trees and shrub species have edible, decontamination, and other economic values. For example, mulberry, the fruit of *M. alba* Linn. Sp., was used as a royal tonic by Chinese emperors 2000 years ago. This fruit has also been called the "civil fruit" and has been praised as "the best health fruit in the 21st century" by professionals in the medical field. In addition to its application in landscaping, *L. chinense* is usually consumed as a vegetable. *P. semicordata* (Wall.) Planch. and *H. syriacus* Linn. can absorb air contaminants, such as SO_2. *K. paniculata*

Table 1: Statistical results for the total growth and adaptability of the introduced plants.

Plant Name	Total Growth of New Branch/cm	Survival Rate/%	Adaptability
Vitis amurensis	100-140	27	Not Adapted
Parthenocissus semicordata (Wall.)Planch.	220-400	68	A little adapted
P. thomsoni	0	0	Not Adapted
Lonicera japonica	0	0	Not Adapted
Euonymus fortune (Turcz.) Hand.-Mazz	0	0	Not Adapted
Ligustrum vicaryi	40-60	90	Adapted
Buxus megistophylla	40-65	70	A little adapted
Lycium chinense	44-68	25	Not Adapted
Rosa multiflora	90-105	25	Not Adapted
Morus alba Linn. Sp.	110-120	86	Adapted
Rhus typhina Nutt	50-57	100	Adapted
Koelreuteria paniculata Laxm.	60-70	85	Adapted
Rhus typhina Nutt	30-46	70	A little adapted
Fraxinus Americana (fast-growing)	70-80	90	Adapted
Lagerstroemia indica L.	50-75	100	Adapted
Prunus cerasifera Ehrhar f.	0	0	Not Adapted
Spathodea campanulata Beauv.	90-120	36	Not Adapted
Fraxinus chinensis Roxb.	45-55	68	A little adapted
Hibiscus syriacus Linn.	10-15	70	A little adapted
Malus spetabilis Royalty	12	4	Not Adapted
Malus micromalus Makino	30-45	14	Not Adapted
Lycium chinense (leaf use)	40	100	Adapted

Table 2: Utilization value of planted trees and shrubs.

Plant name	Medical Value	Economic and ecological value
Parthenocissus semicordata (Wall.)Planch.	Rattans used as medicine	Strong resistance to harmful gas such as SO_2
Ligustrum vicaryi	Fruits as medicine	-
Buxus megistophylla	Roots and leaves as medicine	-
Morus alba Linn. Sp.	Leaves, roots, fruits, woods and parasites as medicine	Mulberry leaves are used to feed silkworm; the grown-up trunks can be used to make the timbers; the fruits are used to produce drinks.
Rhus typhina Nutt	Barks and flowers as medicine	Wood is used to make furniture.
Koelreuteria paniculata Laxm.	Roots and flowers as medicine	-
Rhus typhina Nutt	Barks, roots and leaves as medicine	The fruits are used to produce drinks; the seeds are used to make soaps, candles and woods.
Rhus typhina Nutt	Barks as medicine	With good material, the branches can be used to make frames.
Fraxinus americana and Fraxinus americana (fast-growing)	Barks, leaves, stems, flowers, seeds and roots as medicine	The hard woods with corrosion resistance can be used to make farm tools and furniture.
Fraxinus americana	Flowers, roots, barks, stem skins and fruits as medicine	It resists dust and harmful gas such as hydrogen fluoride to clean air.
Lycium chinense (leaf use)	Stems, leaves and fruits as medicine	Tender stems and leaves can be used to make tea.

Laxm. can secrete grease to absorb dust on trees, thereby clearing the air and improving environmental quality. *M. alba* Linn. Sp. and *F. americana* have also been identified as excellent wood species.

CONCLUSIONS

This study explored the improvement and utilization engineering of saline-alkali plants in coastal areas. Without using organic fertilizers and soil conditioners, introduction experiments on salt-tolerant plants were conducted in Huanghua City of the Cangzhou Coastal District. The following conclusions were drawn:

1. *Lagerstroemia indica* L., *Albizia julibrissin* Durazz, *F. americana* (fast-growing), *L. vicaryi*, *M. alba* Linn. Sp., *K. paniculata* Laxm., *B. megistophylla*, *R. typhina* Nutt, *H. syriacus* Linn., *P. semicordata* (Wall.) Planch., *F. chinensis* Roxb. and *L. chinense* (leaf use) grow well in a moderately salinized local soil environment where they

demonstrate high survival rates and adaptabilities.

2. All plants had zero survival rate in severely salinized land.
3. In the coastal area, large amount of wasteland with salt content below moderate levels are included in the scope of agricultural utilization. The vegetation systems in such areas are also upgraded to enhance the quality of the ecological environment as well as to greatly improve their land use efficiency and sustainable utilization degree.
4. The observation data show that cultivation and growth of salt-tolerant plants insignificantly improves the salinity and alkalinity of coastal soil. Therefore, these plants show a high adaptability. However, root growth plays a certain role in the regulation of soil fertility. Therefore, those species with high adaptabilities to a saline-alkali environment must be selected in the application of coastal soil without considering the effect of plants on a saline-alkali environment. However, salt-tolerant plants hardly improve the salt alkalinity of soil in geological conditions with invasive seawater.

To observe the saline-alkaline resistance of the tested varieties, the field experiments fully relied on the self-fertilization capacity of the tested plants, that is, no fertilizer or modifier was used in the testing process. Therefore, the adaptabilities of the selected varieties to coastal saline-alkali soil were highly practical. Most coastal saline-alkali soils have poor fertility. Therefore, fertilizers must be appropriately applied to enhance soil fertility and to improve the saline-alkali resistance of the planted species. In addition, the saline-alkali soil with above moderate salinization was not used by any improvement measure that was employed in the experiment. The survival rates of the tested varieties changed under special treatment conditions. Under different utilization conditions, the scope and degree of utilization need to be proven by further testing.

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