Experimental Study on Soil Amelioration of Saline-alkali Land

A case study of saline-alkali soil ameliorated by coal ash and coal gangue

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***Abstract*—Through pot experiment, the paper explored the impact of saline-alkali soil ameliorated by coal ash and coal gangue on the growth tamarisk. The experimental results indicated that the amelioration effect of saline-alkali soil by adding 15 % coal ash and 15% silt was distinctly better than adding 10 % coal ash, 10 % coal gangue and 10 % silt, also better than adding 20 % coal ash. Adding coal ash to matrix had acceleration effect in enhancing sprouting rate, shortening branches' sprouting time and improving sprouted branches' survival rate of tamarisk. Adding different amounts of coal ash to saline-alkali soil had different amelioration effect, that was 15 %>20 %>10 %. This experiment reached the original requirements and expectations, and the analysis of acquired data was scientific and practicable, so it had reference significance.**

***Keywords*- coall ash; coal gangue; tamarisk; saline-alkali soil**

I. INTRODUCTION

Salinization and alkalization of soil in arid area is one of the main symbols of land degradation [1]. Northwestern China was the arid or semiarid area where the natural environment was quite bad. The annual precipitation here is less than 200mm, and the aridity is over 4 [2], which resulted in soil hardening, monotonous plant types, and decreasing of ecosystem function. How to remediate the saline-alkali land in northwestern area has become a key problem causing national concern and scientific study. Coal ash is one of the main wastes affecting environment in the world at present [3], but its physicochemical property test indicated that the bulk density, pH value and alkaline matter content of soil could decrease by adding coal ash[4-6,10]. Coal gangue is an ideal matrix to carry animalcule of nitrogen-fixing, phosphate-dissolving and potassium-releasing. The physical properties of soil like bulk density and porosity can be improved by adding proper amount of coal gangue [7-8,11]. There have been many researches on saline-alkali land and its amelioration, but studies on saline-alkali land amelioration by coal ash and coal gangue still have some problems which bring many uncertain factors [3-4,9]. Therefore, the author held experimental study on the amelioration of saline-alkali land in northwestern area.

II. EXPERIMENTAL DESIGN

A. Experimental Materials

The soil in this experiment was the saline soil from Yinbei area of Ningxia City; the experimental plant was the basal part of two-year old Tamarisk from the nursery land of Hebei Biological Institute; the modifiers added were coal ash, coal gangue and silt, and the first two were collected from the thermal power plant in Chenghua District of Chengdu City, Sichuan Province while the silt were from the pond 0.5km away from the thermal power plant.

Table 1 Chemical Properties of Saline-alkali Soil

depth (cm)	PH	Total salt (g/kg)	Ion composition (cmol/kg)							Soluble Na (%)
			CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-} -	Ca^{2+}	Mg^{2+}	Na^+	
0-20	7.7	2.525	0	4.98	14.11	12.01	4.76	4.76	24.08	71.67

Table 2 Chemical Component Test of Modifiers*

Testing number	Sample type	Testing items and their content (10^{-2})							
		SiO_2	Al_2O_3	TFe_2O	CaO	MgO	TiO_2	SO_3	Loss
2007y-2	Coal ash	45.25	33.33	3.39	1.98	0.56	1.08	1.05	10.42
2007y-2350	Coal ganguee	38.86	23.66	2.19	0.12	0.25	0.81	1.19	30.27

***tested by southwestern metallurgy geological test centre**

B. Experimental Methods

- Amelioration methods: take tamarisk as study object, shake the saline-alkali soil and silt through a sieve of 3mm after natural airing, the ameliorated composite soil used in the experiment included 6 compositing methods: a) saline-alkali soil + coal ash, the content of coal ash in each pot was 0%, 10%, 20%, 30% of the total composite soil (2.0 kg), signed as CK, A1, A2, A3 respectively; b) saline-alkali soil + coal gangue, the content of coal gangue in each pot was 10%, 20%, 30% of the total composite soil (2.0 kg), signed as B1, B2, B3 respectively; c) saline-alkali + coal ash + coal gangue, add coal ash and coal gangue of the same amount, the total content of them in each pot was 10%, 20%, 30% of the total composite soil (2.0 kg), signed as C1, C2, C3 respectively; d) saline-alkali + coal ash + silt, with the same compositing proportion as c), signed as D1, D2, D3 respectively; e) saline-alkali + coal gangue + silt, with the same compositing proportion as c), signed as E1, E2, E3 respectively; f) saline-alkali + coal ash + coal gangue + silt, add silt with the same amount as total coal ash and coal gangue, the content of the three in each pot was 10%, 20%, 30% of the total composite soil (2.0 kg), signed as F1, F2, F3 respectively.
- Experimental processing: according to the above 6 contrasting experimental teams, make 4 teams' repeated processing of each one, and plant 1 basal part of Tamarisk in each pot.
- Phenological observation: observe once 5 days, record the sprouting time, sprout number, branch number and length, final survival number of each experimental team.

C. Data Analysis

Calculate the AGR (Absolute Growing Rate) and RGR (Relative Growing Rate) of tamarisk branches respectively according to Blackman formula [12] as follows:

$$AGR(Li) = (Li+1 - Li)/(Ti+1 - Ti) \quad (1)$$

$$RGR(Li) = (\ln Li+1 - \ln Li)/(Ti+1 - Ti) \quad (2)$$

where Li, Li+1 is the branch growth at the time of Ti, Ti+1 respectively. Based on the observed data from May to September in 2008, analyze the survival branches' average growing length, AGR and RGR by Excel 2007 and SPSS 13.0.

III. RESULTS AND ANALYSIS

A. Different amelioration methods' affect on the survival ratio and sprouting time of tamarisk

The experimental results showed only tamarisk saplings of Team D3, Team A2, Team F2 survived. The sprouting time of Team D3 was clearly earlier than that of Team A2, and the difference was great. The sprouting time of Team A2 was earlier than that of Team F2, but the difference was unconspicuous. The survival ratios of Team A2 and Team F3 were the same. The soil of the survival teams all had coal ash of different proportions, and compared with amelioration method of other teams (survival ones), the experimental results proved adding coal ash helped to ameliorate saline-alkali soil. The activated SiO_2 (vitreous SiO_2C and activated Al_2O_3 (vitreous Al_2O_3) in coal ash had hydration under the alkaline condition, which reduced the pH value of soil, and ameliorate the saline-alkali soil, so improved the survival ratio and sprouting rate. The effect of Team D3 in the ameliorating experiment was the best, which indicated adding 15% coal ash and 15% silt was more beneficial to saline-alkali soil amelioration.

B. Difference analysis of growth indexes of tamarisk under different amelioration methods

In the experiment, two basal parts of Team A2 sprouted, and one finally survived; four of Team D3 all survived; four of Team F3 sprouted, and three survived. Comparing of branch number, maximal length, average length and aboveground growth amount (using total length of branch length instead) among each team (Table 3) showed those of Team D3 were better than those of other two teams. Comparing the growth condition between Team A2 and Team F3, Team F3 was better in survival rate of basal part, maximal growth length of branch and total growth amount, while Team A2 was better in survival number of branch and average length.Analyzing each experimental team's survival condition, as in Team A2 only one tamarisk finally survived, its average value of indexes relatively had biggish chanciness, and could not be completely regarded as the credible indexes to measure amelioration effect. Index analyzing of Team D3 and Team F3 reached the basic requirement of experimental statistics, and could be regarded as comparing index. Therefore, in analysis of Team A2, only survival rate could be regarded as a comparing index, and the result showed that of the Team D3 and Team F3 was clearly better than that of Team A2. Comparing of each index between Team D3 and Team F3 showed Team D3 was better than Team F3 with great differences. Combining the over analyzing results, the effect of saline-alkali soil amelioration in Team D3 was greatly better than that in Team F3 and Team A2.

Table 3 Comparing of each growth index of the survival experimental teams

Experimental teams	Number of Survival branch	Survival rate （%）	Maximal length （cm）	Average length （cm）	Total length （cm）
Team A2	5	25	9.50	8.00	9.50*
Team D3	20	100	46.00	14.03	63.00
Team F3	4	75	11.00	6.75	19.00

*only one of the sprouting branches survived, and the others died in latter period

C. Response of tamarisk's growing rate to different amelioration methods

The change laws of survival tamarisk branch's growing rate in the experimental teams and their comparative analysis could reflect the mechanical differences of soil. The growing rate of plant can be divided into AGR and RGR, and the former reflects the plant's cumulate amount and change while the latter reflects the change rate of plant's cumulate amount.

The experiment compared the growing rate change of tamarisk branches in Team D3, Team F3 and Team A2. The result showed the change curves of tamarisks' AGR in the three experimental teams were relatively complete, and the maximum peaks of Team D3 and Team F3 were prominent while the curve of Team A2 was gently with small peak. Viewing from growth time, the tamarisk of Team F3 sprouted latter than Team A2, but the maximum AGR of Team F3 was far over Team A2. Viewing from the peak of change trend, the RGR of Team D3 took on positive increasing trend with two peaks in late June and earth July respectively, while Team A2 and Team F3 each had one peak in late June and early August respectively. Viewing from maximum net cumulate efficiency (namely maximum RGR), that of Team D3 was 1.990 cm plant-1 t-1 cm-1 on June, 20, that of Team A2 was 0.246.cm plant-1 t-1 cm-1 on July, 25, and that of Team F3 was 0.754 cm plant-1 t-1 cm-1 on August, 10. Synthetic analysis showed the tamarisk branch growth of Team D3 was best, the following was Team F3, and the final was Team A2.

The net cumulate amount of tamarisk in each team mainly concentrated in the early growth period. The tamarisk's growing rate of each experimental team varied in the whole growth period. By adding modifier in saline-alkali soil, the growing potential of tamarisk was great in its early growth period to adapt the soil environment. Then the growing rate became unstable, the AGR took on different peaks, and the RGR took on decreasing trend in general. To sum up the experimental results, tamarisk of Team D3 grew best, and adding 15% coal ash and 15% silt had the best effect to ameliorate saline-alkali soil.

IV. CONCLUSIONS AND DISCUSSIONS

A. Coal ash can ameliorate saline-alkali soil effectively

When the other factors were the same, soil matrix was the main factor restricting the growth of tamarisk basal part. Comparing the sprout and growth condition of tamarisk under different amelioration methods, the survival time, survival rate and branch growing amount of Team D3 were all better than those of Team F3 and Team A2, and the differences among different teams were great. Comparing soil matrix of each experimental teams found the soil matrix of survival teams were all added in coal ash of different percentage, which indicated coal ash could ameliorate saline-alkali soil effectively, and adding 15% coal ash and 15% silt had relative better amelioration effect.

B. Discussion on amelioration effect of coal gangue

Comparing of chemical composition between coal gangue and coal ash (table 2) showed their differences of SiO_2 and Al_2O_3 contents were not distinct, and the two chemical components took a large proportion. About the two kinds of modifiers, SiO_2 and Al_2O_3 were the precondition to ameliorate saline-alkali soil. According to the experimental results, among the survival teams, only soil matrix of Team F3 was added in coal gangue, and none of the tamarisks in other experimental teams added in coal gangue survived. The soil matrix of survival experimental teams was all added in coal ash. Therefore, this experiment displayed coal gangue and coal ash had comparatively great different effects in ameliorating saline-alkali soil. Whether this explained coal gangue had no effect in ameliorating saline-alkali soil? The chemical composition could negate this conclusion, but why did the experiment results gain an opposite conclusion? Therefore, to solve this question, further amelioration experiment and physical property analysis of gangue was required.

C. Discussion on best method to ameliorate saline-alkali soil

The experimental results educed adding 15% coal ash and 15% silt had the best effect to ameliorate saline-alkali soil. Combining the experimental analyzing results of Team F3 and Team D3, it could see that when the added modifiers had the largest proportion, the survival rate and growth amount were all great. So if increase the adding proportion of modifiers, better amelioration effect may be received. Besides, there have been conclusions that silt can ameliorate saline-alkali soil, but there haven't been conclusions about its adding proportion and the amelioration effect when blended with modifiers like coal ash and coal gangue of different proportions. Therefore, it advised to make further experimental study on maximum adding amount and best blending proportion of coal ash, coal gangue and silt to ameliorate saline-alkali soil.

D. Filed experiments research

Through simulating the experimental method, this study analyzed the observed data according to the condition of saline-alkali land in northwestern area. The experimental results have primarily filtered out the modifiers and their blending proportion to ameliorate saline-alkali soil, but

whether suitable to all saline-alkali land still need further field experiments research.

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