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Research on Improvement of Light to Moderate Salinization and Alkalinization Farmland in Northeast China

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Abstract: The soil barrier factors currently present in Tuquan County, Northeast China, such as drought, waterlogging, stickiness, salt, alkalinity, and barrenness. This study chose to build a core demonstration area of 50 mu in Xinglongshan Village, Tuquan County. Seven improvement measures were adopted for soil improvement, including straw returning, alkaline amendment, desulfurization gypsum, organic fertilizer, deep tillage and deep loosening, furfural residue, and salt alkali tolerant variety screening. After adopting the above measures, the average soil pH value decreased by 0.4-0.9, the total salt content decreased by more than 10%, and the organic matter increased by more than 0.2 percentage points. The physical and chemical properties of the soil in the experimental area were significantly improved. These measures not only significantly improve the soil fertility of saline alkali farmland and increase the average grain yield by more than 15 percentage points, but also play a role in protecting farmland, thus forming a virtuous cycle.

1. Introduction

Tuquan County has an arid and semi-arid monsoon climate, with more wind and less rain in spring and cold and dry winter. In recent years, the surface evaporation has exceeded 6 times the rainfall, and due to the limitations of natural conditions, the region is generally lacking in water. The main contradiction in the project area is the harsh natural environment, poor basic conditions, and large funding gap, resulting in the extremely fragile ecological environment system of the county. The overall trend of ecological deterioration in the county has not been effectively curbed, and the situation remains severe. At present, the total area of saline alkali land in the county is 801800 mu, including 619500 mu of mild saline alkali land and 182300 mu of severe saline alkali land. The area of key development zones in the county's saline alkali land is 798900 mu, with the southern saline alkali land accounting for 40% to 50% of the total area. The groundwater resources in the central and northern mountainous areas are insufficient, and the irrigation conditions are poor. The soil fertility of the entire county gradually decreases from north to south, with organic matter content ranging from 3.49% to 4.98% and nitrogen content ranging from 0.21% to 0.27%. The soil is generally lacking in phosphorus, with a pH value of 7.0-8.8. It is difficult to increase agricultural production, and drought, thinness, and alkalinity have become the main obstacles to agricultural production in the entire county. Different soil improvement methods have their own advantages and disadvantages, therefore, it is urgent to find a fast, stable and sustainable method for improving and applying the saline alkali land in Tuquan County.

At present, there are generally unfavorable factors such as drought, waterlogging, sticky weight, high salinity, alkalization, and barrenness in the saline alkali land of the entire county. This manuscript analyzes the types and degrees of saline alkali in saline alkali farmland in Tuquan County. Combining mature soil improvement technology measures, this project has constructed a core demonstration area of 50 acres in Xinglongshan Village, and carried out soil improvement through seven measures: straw returning, alkaline amendment, desulfurization gypsum, organic fertilizer, deep tillage and deep loosening, furfural residue, and salt alkali resistant variety screening. Through the technical route of "engineering drives scientific research, scientific research serves engineering" and "conducting experiments, summarizing, demonstrating, and promoting at the same time", the comprehensive production capacity of saline alkali cultivated land in Tuquan County is comprehensively improved.

2. Materials And Methods

2.1. Study area

From Table 1, it can be seen that the soil in Xinglongshan Village is sandy loam. According to the grading standards for soil salinization and the classification of soil salinity and alkalinity[1-3], the saline alkali farmland soil in

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Xinglongshan Village is classified as slightly saline alkaline soil. After considering the basic physical and chemical properties, cultivation habits, and irrigation system of the soil in Xinglongshan Village, this manuscript adopts 7 measures including straw returning, alkaline amendments, desulfurization gypsum, organic fertilizer, deep tillage and deep loosening, furfural residue, and corn salt alkali tolerant crops (5 varieties) for demonstration and promotion in the core demonstration area(50acres)[4-10]. As show in figure 1.

Figure 1. Location of the study area (17 sampling points)

Table 1. Basic physicochemical properties of soil in the research area

Code of soil sample	pH	Total salt	Conductivity	Organic matter
		g/kg	ms/cm	g/kg
X1	8.3	1.15	0.215	32.03
X2	8.61	1.22	0.23	30.03
X3	8.55	1.16	0.164	30.74
X4	8.59	1.39	0.331	31.42

2.2. Data and Method

The research crop is corn (distant family 105D), with a suitable sowing period from late April to early May. Generally speaking, corn can be sown when the soil temperature in the 5cm~10cm cultivation layer reaches 8 ℃~10 ℃, with a sowing depth of about 2.5cm and a sowing amount of 2.5kg/mu. Adopting the planting mode of "one film and two rows", the spacing of plants is determined based on density. The recommended planting density range is between 4500-5500 plants per mu. According to the conventional fertilization in this area, urea (containing 46% of pure N), calcium superphosphate ($P_2O_5 \geq 12\%$) and potassium sulfate (containing 50% of pure K_2O) are used as basal fertilizers every year before planting. It is suggested that in the early stage of Maize Jointing, the intertillage fertilizer applicator should be used for topdressing, and the Topdressing Urea should be 6 kg/mu~8 kg/mu, and the intertillage, fertilization and soil covering should be completed simultaneously. From the late jointing stage to the filling stage, urea was topdressing with irrigation of 12 kg/mu~15 kg/mu in three times. For the first time, urea was applied at 6 kg/mu~8 kg/mu in the late jointing stage of maize. For the second time, 4 kg/mu~5 kg/mu of urea was applied at tasseling stage of maize. The remaining urea was applied during the third grouting period. Alkaline soil is prone to zinc deficiency, so it is suggested to apply zinc fertilizer appropriately. After 15-20 days of physiological maturity of maize, when the moisture content of grain is less than or equal to 25%, mechanical grain harvest can be carried out, and the stubble height is less than 15cm. See Table 2 for the test scheme.

Table 2. Experimental plan for soil improvement

Improvement measures	Implementation area (mu)	sampling points	Improved materials	Measure unit	Number of measures
Seed screening	5	P1	Yuanke105D	kg/mu	2.5
	5	P2	Mengao188	kg/mu	2.5
	5	P3	LinghangGD-1583	kg/mu	2.5
	5	P4	Ziyu 3117	kg/mu	2.5
	5	P5	Q1088	kg/mu	2.5
Desulfurized gypsum	2	P6	Desulfurized gypsum	kg/mu	300
	2	P7	Desulfurized gypsum	kg/mu	600
Alkaline improver	2	P8	Calcium and magnesium fertilizers	kg/mu	42
	2	P9	Calcium and magnesium fertilizers	kg/mu	84
Organic fertilizer	2	P10	well-rotted farmyard manure	m^3/mu	2
	2	P11	well-rotted farmyard manure	m3/mu	4
Straw crushing	2	P12	Straw crushing and returning to the field	kg/mu	400
	2	P13	Straw crushing and returning to the field	kg/mu	600
Furfural residue	2	P14	furfural residue	kg/mu	225
	2	P15	furfural residue	kg/mu	450
Deep plowing and deep loosening	2.5	P16	Crushed ridge cultivation	mu	/
	2.5	P17	Conventional tillage	mu	/

To avoid the impact of external factors such as terrain and soil characteristics on field trial data, during the experimental period (April to October 2023), a total of 17 soil samples were taken, and random sampling methods were used in various locations. Samples were taken layer by layer using a soil drill at a distance of 0-20cm and 20-

40cm from the surface. Soil samples from the same soil layer were collected three times at different points, and the soil samples obtained from the three times were thoroughly mixed. Remove visible plant residues (such as roots, stems, leaves) and animals from the soil, and place them in sterile polyethylene self sealing bags. The experimental observation includes the depth of soil and groundwater, mineralization, and conductivity before and after each irrigation. the sampling area is selected as relatively flat and adjacent bare land. Remove visible plant residues (such as roots, stems, leaves) and animals from the soil, and place them in sterile polyethylene self sealing bags. The experimental observation content includes the depth of soil and groundwater, salinity, conductivity, etc. before and after each irrigation. Indoor testing indicators include soil particle analysis, pH value, total salt content, and organic matter.

(1)Determination of total salt content in soil

Weigh 10g of dried soil that has passed a 1mm sieve, then place it in a 100ml glass measuring cup, add 50ml of distilled water, and add water in a 5:1 ratio of water to soil. Stir with a stirring rod and let it stand for 30 minutes to allow it to naturally clear.Then filter the solution.

Insert the electrode into the soil solution and gently shake it. After the instrument reading stabilizes, record the measurement results. After each sample is tested, rinse the electrodes with distilled water and gently dry them with filter paper before proceeding to the next measurement.

The content of water-soluble salts in soil is determined by the quality method, and the conductivity Ec is determined by the conductivity method. Fit the total salt content and conductivity using Excel to obtain the following Equation 1.

$$y=3.2517St-0.1385 \qquad (1)$$

In the equation, y is soil water-soluble salt (g/kg), and St is electrical conductivity (ms/cm).

(2)Determination of soil pH value

The steps for measuring pH value are slightly different from the method for measuring total salt content. Firstly, calibrate the pH meter using standard buffer solutions with pH=6.86 and 9.18. The remaining steps are the same as determining the total salt content.

(3) Determination of soil organic carbon content

After the soil sample is air dried, crushed and sieved, the content of soil organic carbon and carbonate equivalents is determined. Using potassium dichromate volumetric method external heating method to analyze soil organic matter content.

3. Results

(1) Changes in soil pH value

According to Table 3, after adopting different technical measures, the soil pH value in the project area decreased from 8.0-9.0 at the beginning of the year to the current 7.5-8.5. Among them, the four improvement techniques of returning straw to the field, desulfurization gypsum, organic fertilizer, and deep tillage and deep loosening have shown significant effects, with a decrease in pH value of 0.6-0.9.

(2) Changes in total salt content of soil

As shown in Table 3, the total salt content of the soil in the study area decreased from 0.82-1.39g/kg to 0.73-1.25g/kg. Among them, the four improvement techniques of organic fertilizer, desulfurization gypsum, straw returning, and deep tillage and deep loosening had significant effects, with a decrease of 0.10-0.13g/kg in total salt content.

(3) Changes in organic matter content of soil

As shown in Table 3, the soil organic matter in the project area increased from 19.94-37.14 to 19.98-37.15g/kg. Among them, the four improvement techniques of organic fertilizer, calcium and magnesium fertilizer, straw returning, and deep tillage and deep loosening showed significant effects, with an increase of 0.05-0.06g/kg in organic matter.

(4) Changes in crop yield in the research area

As shown in Table 3, The average yield of corn in the project area is 806.10 kg/mu, with the highest yield being the crop variety Yuanke 105D. The average corn yield in the research area in 2022 was 700kg/mu, while in 2023, the average corn yield increased by more than 15 percentage points, reaching 806.10 kg/mu.

Table 3. The comprehensive utilization research area for moderately saline alkali cultivated land in Tuquan County

sampling points	PH value (before implementation)	PH value (after implementation)	Total salt (g/kg) (before implementation)	Total salt (g/kg) (after implementation)	organic matter (g/kg) (before implementation)	organic matter (g/kg) (after implementation)	crop yield (kg/mu)
P1	8.47	8.012	0.88	0.78	29.75	29.80	845
P2	8.4	7.951	0.98	0.89	31.71	31.75	760
P3	8.39	7.949	1.37	1.24	35.09	35.14	725
P4	8.44	8.025	1.38	1.25	36.98	37.02	730
P5	8.48	8.048	0.84	0.75	30.08	30.12	726
P6	8.38	7.7	0.86	0.75	33.60	33.64	863
P7	8.23	7.6	0.94	0.83	31.55	31.60	867
P8	8.44	8.44	0.95	0.85	35.78	35.84	860
P9	8.53	8.53	0.96	0.86	27.63	27.69	867
P10	8.33	7.72	0.97	0.85	34.43	34.50	854
P11	8.34	7.69	1.2	1.08	34.62	34.68	860
P12	8.37	7.79	0.95	0.84	31.80	31.84	872
P13	8.57	7.89	1.15	1.02	26.74	26.77	880
P14	8.55	7.89	1.39	1.25	30.31	30.35	850
P15	8.33	7.75	0.96	0.87	27.99	28.03	857
P16	8.36	7.65	0.83	0.73	32.99	33.03	810
P17	8.61	8.25	0.82	0.74	22.08	22.12	805

4. Discussion

According to the changes in soil pH, total salt, and organic matter content in the project area, it can be seen that the soil improvement technology model of straw returning, desulfurization gypsum, organic fertilizer, and deep tillage and loosening will have a significant effect in 2023. In the selection of salt alkali tolerant crop varieties for corn, the germination rate and yield of Yuanke 105D are higher than those of other varieties.

(1) Adding organic fertilizer. Saline alkali land generally has the characteristics of low temperature, thin soil, and poor structure. Organic fertilizer is decomposed and transformed by microorganisms to form humus, which can promote the formation of soil particle structure, increase porosity, improve soil porosity, enhance permeability, facilitate salt leaching, and inhibit salt return. Humus can react with sodium carbonate to form sodium humate, reducing soil alkalinity, and sodium humate can also stimulate crop growth and enhance crop salt resistance.

(2) Deep plowing and deep plowing.

The distribution of salt in soil is more in the surface layer and less in the lower layer. After plowing, the salt content in the surface soil can be turned over to the lower layer, and the soil with less salt in the lower layer can be turned over to the surface to desalination the surface soil. Moreover, tillage can loosen the soil, cut off the capillary water transport of salt to the surface, and inhibit evaporation and salt return.

(3) Crush straw and return it to the field to suppress evaporation and salt return. Choose appropriate crops such as straw to cover the surface and suppress evaporation and salt return.

(4) Desulfurization gypsum improves saline alkali soil. The Ca^{2+} ions generated through leaching and dissolution can replace exchangeable Na^{+} ions on soil colloids. The use of desulfurization gypsum can significantly improve soil physical and chemical properties, while providing mineral nutrients such as Ca and S to promote plant growth and enhance plant stress resistance. It is a low-cost and fast soil amendment. Applying desulfurization gypsum improves soil physical and chemical properties, increases soil microbial activity, and enhances soil enzyme activity.

(5) Scientific irrigation and drainage. Using drip irrigation to prevent the groundwater level from rising.

(6) Reasonably apply chemical fertilizers. Fertilizer promotes crop growth and enhances salt tolerance of crops. At the same time, fertilizers can change soil composition and inhibit the adverse effects of salts on plants.

5. Conclusions

After conducting experiments with different treatments, analyzing field data, integrating technical models, and summarizing stage achievements, it was found that the average pH value of saline alkali soil in the project area decreased by 0.4-0.9, from 8.0-9.0 in the initial stage of the project to the current 7.5-8.5. The total salt content in the soil decreased by 10%, from 0.82-1.39g/kg to 0.73-1.25g/kg. Soil organic matter increased by 0.2 percentage points, from 19.94-37.14 to 19.98-37.15g/kg. The average grain production has increased by more than 15 percentage points.

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