Effect of Consecutive 3-yr Sand-Covering on the Physicochemical Properties of Saline-alkaline Soil in Northern Shaanxi, China

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Abstract. In order to study the effect of sand-covering on the improvement of saline-alkali land in northern Shaanxi, the soil samples of consecutive 4-yr were taken as the research object, and the effects of sand-covering on the physical and chemical properties of the saline-alkali soil in the area were compared and studied by statistical methods. The study found that the soil pH, water-soluble salt content, degree of alkalinity and bulk density of the tillage layer were significantly lower by covering sand than the sand-covering free, and decreased with the extension of the cultivation period year by year. In addition, the soil porosity, available phosphorus and available potassium content increased significantly, and increased with the extension of the cultivation period year by year. The results showed that sand-covering significantly improved the physicochemical properties of the soil in the cultivated layer of saline arable land in the area; with the increase of the cultivation period, the improvement effect increased year by year, which further indicated that sand-covering is an effective measure to improve the salinized arable land in the area.

1. Introduction
Soil salinization is one of the most serious environmental problems faced by mankind today. The world's salinized land area totals about 8.97×10^6 km^2, accounting for about 6.5% of the world's total land area. China's salinized land area is about 2.0×10^5 km^2, accounting for about 2.1% of the total land area [1]. For a long period of time in the future, my country’s food security will continue to be a very serious problem. With the rapid development of my country’s economy and the acceleration of industrial urbanization, the quantity and quality of my country’s arable land have shown varying degrees of decline1.2×10^9 hm^2 of arable land will be broken [2-3]. Therefore, expanding the available arable land is one of the important ways to ensure food security.

Saline-alkali land in northern Shaanxi is located in the transition zone between the Loess Plateau and the Mu Us Sandy Land. Sandy soil has low salt content and loose structure. After being mixed with...
saline-alkali soil, the capillary pores on the surface of the cultivated layer are large, and the siphon effect is weakened, which effectively inhibits the phenomenon of surface salt return [4]. Zhou found that 40%-60% of aeolian sandy soil is added to the saline-alkali soil, the soluble salt content of the soil decreases by 20%-50%, and the alkalinity decreases by 40%-60% when they studied the effect of sand-covering on saline-alkali soil improvement in the Songnen Plain [5]. Research by Wang found that sand covering significantly reduced the pH and total water-soluble total salt of saline soil in the farming-pastoral ecotone of the Loess Plateau and Mu Us Sandy Land, but it lacked continuous research and investigation for many years [6].

Based on this, this study uses soil samples from the area before the sand-covering (2015) and three consecutive years after sand-covering (2016, 2017, 2018) to compare and analyze the physical and chemical properties of saline-alkali soils in different years. Changes are expected to provide a theoretical basis and technical reference for the reform of sand in the area.

2. Materials and Method

2.1. Sampling Design
The study area is located in Wangtanzi Village (108°20′E, 37°54′N), Duiziliang Town, Dingbian County. The terrain is flat and the soil is uniform. The sand-covering was implemented in 2015, that is, about 30 cm of sand was covered on the surface of the saline-alkali soil, and the soil was shallowly mixed to loosen the cultivated layer. It was idle that year, and began farming on April 30, 2016. The planted crop is corn, which is one season per year. 6 quadrats (10 m × 10 m) were set up in the study area, with a distance of approximately 15 meters. Respectively in 2015 (before the sand-covering, CK), 2016 (one year after the sand-covering, T1), 2017 (two years after the sand-covering, T2), 2018 (three years after the sand-covering, T3) After the corn was harvested in late September, a five-point sampling method was used to collect soil samples of the cultivated layer at the same location of the test field, and mixed them as one sample, totaling 24 samples. Take some fresh soil samples for the determination of alkaline nitrogen; and the remaining soil samples are air-dried, pass through a 2mm sieve for the determination of soil physicochemical properties.

2.2. Soil Analysis
The soil pH value is determined by the water-soil ratio 2.5 : 1 water leaching method, the soluble salt content is determined by the drying method; the bulk density and total porosity are determined by the ring knife method; the soil organic carbon is determined by the combustion oxidation-non-dispersive infrared method; Nitrogen is determined by semi-micro Kjeldahl method; available nitrogen is determined by alkaline solution diffusion method; available phosphorus is determined by NaHCO3 extraction-molybdenum antimony colorimetric method; available potassium is determined by ammonium acid extraction-atomic absorption spectrophotometry [7].

2.3. Statistical Analysis
Microsoft Excel 2013 software was used to organize the data. First, all experimental data were tested for normal distribution. Secondly, ANOVA was used to test the difference in soil physicochemical properties between different years, and Duncan's multiple comparison method was used to compare the difference in soil physicochemical properties between four years. Finally, the R language "PerformanceAnalytics"and "corrplot" packages are used for Pearson correlation analysis between different soil physicochemical properties [8].

3. Results and analysis

3.1. Analysis of differences in soil physical properties
The results of analysis of variance showed that soil pH, alkalinity, salinity, porosity, and soil bulk density were significantly different among different years (All P <0.01). The results of the study further showed
that the physical properties of the soil have improved year by year after being covered with sand. With the increase of farming years, soil pH decreased by 8.04%, 12.41%, and 14.64%, alkalinity decreased by 7.79%, 16.42%, and 15.37%, and salinity decreased by 24.46%, 34.78%, and 14.64%, respectively. 33.15%, soil bulk density decreased by 19.61%, 36.60% and 33.33% respectively. Compared with the treatment, the porosity increased by 8.23%, 2.46%, and 25.54% after the sand-covering (Table 1).

| Treatment | pH        | DOA (%) | SC (%) | POR (%) | SBD (g/cm³) |
|-----------|-----------|---------|--------|---------|-------------|
| CK        | 9.70±0.06a| 4.88±0.31a| 1.84±0.11a| 33.38±0.82b| 1.53±0.13a  |
| T1        | 8.92±0.04b| 4.50±0.15ab| 1.39±0.11b| 36.13±1.50b| 1.23±0.07ab |
| T2        | 8.49±0.17c| 4.08±0.08b| 1.20±0.07b| 37.54±0.65ab| 0.97±0.14b  |
| T3        | 8.28±0.06c| 3.13±0.06c| 1.23±0.04b| 41.91±1.82a| 1.02±0.08b  |

**Summary of treatment**

**Note:** Degree of alkalinity, DOA; Salt content, SC; Porosity, POR; Soil bulk density, SBD; *, P < 0.05; **, P < 0.01; ***, P < 0.001.

3.2. Analysis of differences in soil chemical properties

The results showed that there was no significant difference in soil organic matter, total nitrogen and available nitrogen between the years before and after the sand reform (All P> 0.05). Compared with before the sand reform, the soil organic matter and available nitrogen showed an increasing trend after the sand reform, but did not reach a statistically significant level. Soil available phosphorus and available potassium increased by 3.31%, 108.57%, 107.01%, 9.32%, 43.45%, 46.04%, respectively, with the increase in farming years after the sand reform; The difference between years is significant (All P <0.05) (Table 2).

| Treatment | SOM (g/kg) | TN (g/kg) | AN (mg/kg) | AP (mg/kg) | AK (mg/kg) |
|-----------|------------|-----------|------------|------------|------------|
| CK        | 1.32±0.08a | 0.03±0.00a| 20.82±1.10a| 5.13±0.74b | 84.62c     |
| T1        | 1.46±0.09a | 0.03±0.00a| 23.78±1.72a| 5.30±0.37b | 92.51bc    |
| T2        | 1.35±0.15a | 0.03±0.00a| 24.83±1.29a| 10.70±1.82a| 121.39ab   |
| T3        | 1.34±0.06a | 0.03±0.00a| 23.74±1.68a| 10.62±0.85a| 123.58a    |

**Summary of treatment**

**Note:** Soil organic matter, SOM; Total nitrogen, TN; Available nitrogen, AN; Available phosphorus, AP; Available potassium, AK; *, P < 0.05; **, P < 0.01; ***, P < 0.001.

3.3. Correlation analysis of soil physical and chemical properties

Through the correlation analysis between the physical and chemical properties of soil, it is found that soil porosity is significantly negatively correlated with pH, water-soluble salt content, bulk density, and alkalinity (All P < 0.05), and the correlation coefficients are -0.65, -0.67, and respectively, 0.68 and -0.53. The physical properties of soil (except porosity, pH, water-soluble salt content, bulk density, alkalinity) are significantly positively correlated (All P < 0.05). There was a significant positive correlation between total soil nitrogen and organic matter (P < 0.05), with a correlation coefficient of 0.51, and a significant positive correlation between soil available potassium and available phosphorus and available potassium (All P < 0.05), with correlation coefficients of 0.46 and 0.67, respectively. In
addition, soil pH has a strong positive correlation with available phosphorus and potassium, with correlation coefficients of -0.60 and -0.69, respectively; alkalinity also has a significant negative correlation with available phosphorus and potassium, with correlation coefficients of -0.57 and -0.57 (Table 3).

### Table 3. Pearson correlation analysis of soil physical and chemical properties.

|     | pH    | SC    | SBD   | POR   | DQA   | SOM   | TN    | AN    | AP    | AK    |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| pH  | 1     | 0.72*** | 0.62** | -0.65*** | 0.67*** | -0.02 | -0.25 | -0.40 | -0.60** | -0.69*** |
| SC  | 1     | 0.38  | -0.67*** | 0.55**  | -0.043 | 0.13  | -0.28 | -0.50* | -0.51*  |
| SBD | 1     | -0.68** | 0.56**  | 0.013  | -0.10  | -0.10 | -0.34 | -0.43* |
| POR | 1     | -0.53** | 0.11  | 0.13  | 0.26  | 0.034 | 0.36  |
| DOA | 1     | 0.11  | -0.10  | -0.22  | -0.57** | -0.57** |
| SOM | 1     | -0.067 | 0.51*  | -0.072 | 0.054  | 0.012 |
| TN  | 1     | 0.74  | 0.17  | 0.46*  |
| AN  | 1     | 0.67*** |
| AP  | 1     | 0.67*** |

Note: Degree of alkalinity, DOA; Salt content, SC; Porosity, POR; Soil bulk density, SBD; Soil organic matter, SOM; Total nitrogen, TN; Available nitrogen, AN; Available phosphorus, AP; Available potassium, AK; *, P < 0.05; **, P < 0.01; ***, P < 0.001.

4. Discussion and Conclusions

It can be seen from Table 1 that sand covering significantly reduces soil pH, water-soluble salt content and soil bulk density, and increases the total soil porosity. In addition, with the accumulation of sand reform time, the decline of soil pH, water-soluble salt content and soil bulk density gradually decreased, and basically reached equilibrium after 2 years, while the total soil porosity increased year by year with the extension of time. Wang and others also found that sand covering significantly reduced the pH and soluble salt content of saline soil [5, 6]. The analysis of the reasons found that compared with the salinized soil, the soil capillary pores formed by the aeolian sandy soil are large and cannot form a strong siphon effect, which effectively limits the return of the bottom salt to the cultivated layer [9]; secondly, the mixed low salt content from the aeolian sandy soil to the saline-alkali soil with high salt content, the saline-alkali content (pH, water-soluble salt content) of the mixed tillage layer is relatively low in theory [10]; finally, the saline soil has a compact structure and less aggregate structure. Adding aeolian sandy soil with larger particle size and larger voids through sand covering, resulting in larger soil porosity and lower soil bulk density.

It can be seen from Table 2 that sand covering significantly increased the available phosphorus content and available potassium content of the cultivated layer, but had no significant effect on soil organic matter, soil total nitrogen and soil available nitrogen. Although the impact of sand covering on the organic carbon and available nitrogen of the salinized soil is not significant, compared with before the remediation, the soil organic matter and available nitrogen of the cultivated layer have an increasing trend after the remediation. This may be due to the decay and degradation of crop residues during the cultivation process, which increased soil organic carbon and available nitrogen content. However, the total nitrogen in the soil may not show a regular increase or decrease due to the short experimental span. Soil available phosphorus and available potassium gradually increase with the extension of tillage time after renovation. Tian also found that after the improvement of saline-alkali soil in northern Shaanxi, the content of soil available phosphorus and available potassium increased [11]. The reason for the analysis may be that the sand reform has effectively improved the growth environment of soil microorganisms, and the life activities of soil microorganisms and protozoa have been strengthened, thereby improving soil enzyme activities related to soil phosphorus and potassium mineralization [12]. This has been confirmed in the research of Liu [13].
To sum up, sand-covering significantly improved the soil physical and chemical properties of the saline-alkali cropping layer in Northern Shaanxi. Soil pH, water-soluble salt content, degree of alkalinity and soil bulk density decrease, and soil porosity, available phosphorus and available potassium increase. In addition, soil pH, water-soluble salt content, and soil bulk density decrease with the increase of tillage years year by year, and soil porosity, available phosphorus and available potassium increase with the increase of tillage years year by year, indicating that sand covering is an effective measure to improve the saline soil in this area.

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