

# Comparison of the effects of different maize straw returning methods on saline soil improvement

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**Abstract.** Using corn straw as raw material, the effects of three different ways of returning corn straw to the field, namely direct returning corn straw to the field, decomposed corn straw returning to the field and maize straw biochar returning to the field, on saline-alkali soil were studied by indoor culture. The results showed that maize straw directly returned to the field was the best way to improve the stability of saline-alkali soil aggregates; maize straw biochar returned to the field was the best way to reduce the alkalinity of saline-alkali soil; maize straw directly returned to the field and decomposed maize straw returned to the field enhanced the activity of soil urease and alkaline phosphatase, while reducing the activity of soil catalase. Maize straw biochar returned to field reduced soil urease activity and increased soil catalase activity, but had no significant effect on soil alkaline phosphatase activity.

## 1 Introduction

China is rich in crop straw resources. According to statistics, the main crop resources in 2016 in China amounted to 984 million tons, of which maize straw accounted for 41.92%, which is the main source of straw[1]. Straw returning is a direct and effective way to utilize straw resources, which can be divided into direct returning and indirect returning. Direct returning refers to the direct application of untreated straw into the field; indirect returning refers to the chemical treatment of straw and then returned to the field, including: high temperature composting, composting with decomposing agent, thermal cracking carbonization[2, 3]. Numerous studies have shown that straw returning can improve soil fertility, soil physical structure and soil microbial community structure, and increase crop yield[4-6]. At present, there are many studies on the utilization of straw returning in saline-alkali soil treatment[7-9], but there are few studies comparing the effects of different straw returning methods on saline soil improvement[10]. Therefore, through indoor incubation experiments, this study studied the effects of applying maize straw, decomposed straw and maize straw biomass charcoal into saline soil on its physical and biological characteristics, in order to provide theoretical basis and practical guidance for promoting straw returning to improve saline soil.

## 2 Materials and Methods

### 2.1 Test Material

The test soil was sampled from the saline soil of Jilin Songyuan. After the soil was collected, it was naturally air-dried at room temperature and passed through a 2 mm sieve for use. The soil sample has a pH value of 9.67, an EC value of 0.274 mS/cm, an alkalinity of 21.6%, a soil organic carbon content of 13.9 g•kg<sup>-1</sup>, and a soil total nitrogen content of 2.1 g•kg<sup>-1</sup>. The test maize stalks were taken from the experimental field of China Agricultural University; The test straw decomposition products were prepared by adding decomposing agent after crushing straw and adjusting the C/N ratio of 30:1, moisture content of 60%. The above samples have been air-dried and crushed through 0.25 mm sieve for reserve. The tested straw biochar was prepared by drying and crushing the tested straw in oven under the condition of 75°C after washing, passing through 20 mesh sieve and pyrolysis for 4 h in vacuum muff furnace at 400°C.

### 2.2 Test Design

In order to study the effect of different straw returning methods on saline-alkali soil improvement, it was verified by laboratory culture experiments. There are 7 treatments in the experiment: CK, no added substance; B5, adding 5% straw biochar; B1.5, adding 1.5% straw biochar; S5, adding 5% straw; S1.5, adding 1.5% straw; SD, add 5% straw rot material; SD1.5, add 1.5% straw rot material. Each treatment was repeated 3 times, and each material was mixed with the 2 mm sieve dry soil in the above ratio. The amount of mixed soil sample added to each flask is 200 g (total weight of air-dried soil and added materials), distilled water is added to 60% of the maximum water holding capacity in the field, and the cap is covered, but not completely sealed for gas exchange.

The culture was carried out under the constant temperature of (25±1) °C, and the water was supplemented by the weighing method during the cultivation to keep the soil water content constant. After the end of the culture (day 54), the soil samples were measured for water-stable agglomerate distribution, agglomerate stability, catalase activity, urease activity, and alkaline phosphatase activity.

### 2.3 Measuring items and methods

Grading and calculation of soil aggregates: The soil agglomerates were classified by wet sieve method. Three soil samples were taken for each treatment, 100 g each, and the soil samples were soaked in deionized water for 20 min and then poured into a sieve. The sieve aperture is 2, 0.25 and 0.053 mm from top to bottom, and is sieved at a frequency of 20 r/min for 15 min using agglomerate analyzer. Soil samples are divided into <0.053 mm, 0.053-0.25 mm, 0.25 mm~2 mm and >2 mm. The obtained agglomerates are transferred to an aluminum box, dried at 50 °C. The average weight diameter (MWD) and geometric mean diameter (GMD) were calculated according to formula (1) and formula (2) according to the aggregates data obtained after wet sieving.

$$MWD = \sum_{i=1}^n X_i W_i \quad (1)$$

$$GMD = \sum_{i=1}^n (\ln X_i) W_i \quad (2)$$

Soil alkalization degree: NH<sub>4</sub>OAc-NH<sub>4</sub>OH flame photometry [11].

Soil urease activity: determined by indophenol blue colorimetric method[12], expressed in milligrams of NH<sub>3</sub>-N per gram of dry soil after 24 hours of culture at 37 °C.

Soil catalase activity: permanganate titration method was used to determine[12], expressed in milliliters of 0.1 N potassium permanganate per gram of dry soil after 20 minutes.

Soil alkaline phosphatase activity: determined by the phenylphosphonium phosphate method[12], expressed as millimoles of phenol released per gram of dry soil after 24 hours of culture at 37 °C.

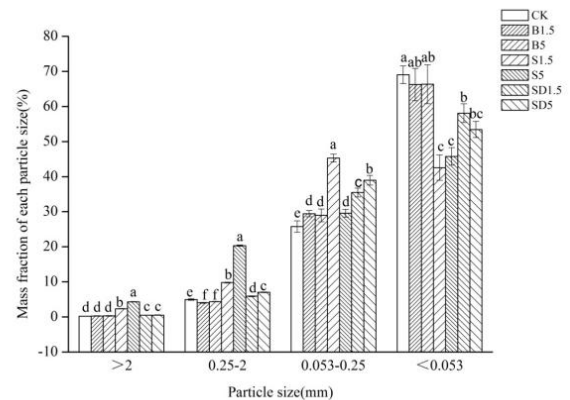
### 2.4 Data Analysis

The test data was recorded and sorted by Excel. The data was analyzed by ANOVA using SPSS 22, and multiple comparisons were performed by LSD method (α=0.05). The data was plotted by Origin 8.0 software.

## 3 Results and analysis

### 3.1 Effect of Different Straw Returning Ways on Distribution of Water Stability Aggregates in Saline-alkali Soil

Aggregates are the basic unit of soil structure, which are closely related to the conservation and supply of soil nutrients. As shown in Figure 1, both S and SD significantly increased the content of >2 mm size agglomerates, large agglomerates (0.25-0.2 mm) and microaggregates (0.053-0.25 mm) compared to CK, where S pairs >2 mm particle size aggregates and large agglomerates (0.25-0.2mm) content is better than SD; B significantly reduced the content of soil macroaggregates (0.25-0.2 mm); all treatments significantly increased the content of micro-aggregates (0.053-0.25 mm); all treatments reduced the content of clay (<0.053 mm), and all treatments except B significantly decreased, of which S1.5 and S5 decreased the most, 38.3% and 33.7% respectively.



**Fig.1.** Effect of different treatments on soil aggregate content

Note: Error bars represent standard errors. Different letters indicate significant differences between treatments ( $P<0.05$ ). The same below

### 3.2 Effect of different straw returning methods on the stability of saline-alkali soil aggregates

Mean weight diameter (MWD) and geometric mean diameter (GMD) are important indexes for evaluating the stability of soil aggregates. As shown in Table 1, compared with CK, MWD and GMD of B had no significant difference. The other treatments significantly increased MWD and GMD, with the order of increase being S5>S1.5>SD5>SD1.5. The increase rates were 182.4%, 83.1%, 30.9%, 18.4% (MWD); 92.7%, 52.4%, 23.2%, 14.6% (GMD), respectively.

**Tab1** Effect of different treatments on the stability of soil aggregates

Treatment	MWD(mm)	GMD(mm)
CK	0.136±0.007d	0.082±0.003d
B1.5	0.131±0.010d	0.084±0.008d
B5	0.135±0.002d	0.083±0.008d
S1.5	0.249±0.005b	0.125±0.006b
S5	0.384±0.006a	0.158±0.006a
SD1.5	0.161±0.011c	0.094±0.004cd
SD5	0.178±0.007c	0.101±0.005c

### 3.3 Effect of different straw returning methods on alkalinity of saline-alkaline soil

Exchangeable sodium percentage (ESP) is the percentage of soil exchangeable sodium in cation exchange capacity. As shown in Table 2, all treatments significantly reduce ESP in soil, with B5 decreasing by 41.3%. The decrease of ESP in all treatments increased with the increase of the dosage.

**Table 2** Effects of different treatments on soil ESP

Treatment	ESP(%)
CK	0.206±0.006a
B1.5	0.147±0.002d
B5	0.121±0.003e
S1.5	0.182±0.003b
S5	0.155±0.005d
SD1.5	0.167±0.005c
SD5	0.147±0.004d

### 3.4 Effects of Different Straw Returning Ways on Activities of Saline-alkali Soil Enzymes

Soil urease is one of the most important hydrolases in soil. Its activity can reflect the nitrogen utilization of soil. As shown in Table 3, compared with CK, B significantly reduced the activity of soil urease, and the other treatments significantly increased the activity of soil urease, of which S5 increased the most, which was 39.6%. The soil urease activity of each treatment was proportional to the addition amount.

Soil catalase promotes the decomposition of hydrogen peroxide in the soil and prevents hydrogen peroxide from harming soil organisms. As shown in Table 3, only B1.5 and B5 significantly increased soil catalase activity, with an increase of 34.5% and 24.1%, respectively. S and SD reduced soil catalase activity to a different extent, and SD decreased significantly.

Soil alkaline phosphatase plays an important role in improving soil phosphorus availability. Soil alkaline phosphatase activity was significantly increased by S1.5, S5 and SD5, with an increase of 19.4%, 37.1% and 36.3% respectively. Soil alkaline phosphatase activity of B1.5 and B5 decreased compared with CK, but the difference was not significant.

**Table 3** Effects of different treatments on soil enzyme activities

Treatment	Urease	Catalase	Alkaline phosphatase
CK	2390±122c	0.50±0.03b	12.4±2.5b
B1.5	1720±107d	0.68±0.04a	13.1±2.2b
B5	2021±166d	0.62±0.03a	12.2±1.4b
S1.5	2717±119b	0.42±0.03c	14.8±2.3ab
S5	3337±130a	0.44±0.04bc	17.0±1.7a
SD1.5	2637±160bc	0.36±0.02c	12.2±1.9b
SD5	2775±130b	0.21±0.03d	16.9±1.9a

## 4 Discussion

Soil aggregates are an important part of soil and the material basis of soil fertility, which is closely related to the transmission and transmission of water, fertilizer, gas and heat in soil and microbial species and activities [13]. The effects of different straw returning methods on soil aggregates have become a research hotspot in recent years. The existing researches show that fresh straw and decomposed straw returning to the field can significantly increase the content of soil >0.25mm size aggregates, reduce the content of soil clay powder (<0.053mm), and fresh straw is more conducive to the formation of soil water stable aggregates than decomposed straw[14, 15]. The reason is that when fresh straw is decomposed in soil, it will form polysaccharides with strong ability of cementing soil granules[16]; in addition, when fresh straw is imported into soil, it will become a place for microbial activities and form aggregate core[17]. This is consistent with the results of this study. However, the effect of straw biochar on soil aggregates is controversial. Liu[18] found that when the amount of biochar applied was 40 t·ha<sup>-1</sup>, the MWD of soil water-stable aggregates increased by 28.02%; Dai[19] found that MWD decreased by 18.9%–43.2% during the three years of biochar application to the soil; while Hou[20] found that single application of biochar had no significant effect on soil GMD and MWD, which was consistent with the results of this study. The reason may be that the organic carbon in biochar is mainly inert carbon, which is low in the utilization rate of microbial decomposition, and does not produce sticky substances in the decomposition process to promote the formation of agglomerates[21, 22].

ESP is an important indicator for evaluating the alkalinity of soil. The larger the ESP, the worse the soil quality. At present, there are few studies on the effect of straw returning on soil alkalization. Fan[23] believes that organic acids in the process of decomposition of organic matter in straw will release cations and replace Na<sup>+</sup> on soil colloids, thus reducing soil ESP; Chen[24], Yu[25] research found that biochar can reduce ESP of saline soil, on the one hand, the surface of biochar is rich in exchangeable Ca<sup>2+</sup> and Mg<sup>2+</sup>; on the other hand, biochar increases soil porosity by virtue of its porous structure, which makes Na<sup>+</sup> more easily removed by leaching. This study also proves that all kinds of straw returning methods can reduce ESP in saline soil.

Many studies have shown that straw returning has a significant impact on soil enzyme activity. Among them, there are many studies on the effects of fresh straw and decomposed straw on soil enzyme activity, and the mechanism is thoroughly analyzed. Tang[26] believed that straw returning could increase a lot of energy for soil microorganisms and promote the biological cycle of soil substances, thereby improving soil enzyme activity; some scholars believe that straw can affect soil enzyme activity by adjusting soil carbon-nitrogen ratio, temperature and water content[27, 28]. At present, there are few studies on the effect of straw biochar on soil enzyme activity. Bailey[29] studies have shown that biochar binds to the substrate of the enzymatic reaction

and inhibits the enzymatic reaction, thereby inhibiting the enzyme activity. At the same time, they believe that the effect of biochar on soil enzyme activity is highly variable, depending on the nature of the target substrate. In this study, the activities of soil urease and alkaline phosphatase were significantly increased by returning fresh straw and decomposed straw to field, and the increase was positively correlated with the addition amount, which was consistent with the results of Lu[30], Yang[31]. The study observed that fresh straw and decomposed straw returning significantly reduced soil catalase activity, which may be related to the length of culture[32]; The straw biochar significantly increased the soil catalase activity, but significantly reduced the soil urease activity, which is contrary to the results of Pan[33], which may be related to the different preparation conditions, structural properties[34] and soil properties[35].

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