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Effect of Sulfur-humic Acid on Agricultural Production Including Grape Growth on Saline-alkali Soil in Gansu Province, P. R. China

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Abstract: Saline-alkali soil mainly spreading in the northeast China has a problem on low crop production caused from high electric conductivity and low water potential by salinity and micronutrient unavailability by high pH. In order to improve saline-alkali soil, usage of mixture of elemental sulfur and humic acid (hereafter referred to as "DS") has been proposed. The objectives of the study are 1) to clarify the mechanism how DS worked for soil improvement and 2) to evaluate DS on agricultural production including grape seedling on saline-alkali soil in Gansu Province, P. R. China. As the results of a pot incubation trial concerning 1), all of soil pH in the three locations decreased after 3 months. The reduction of pH show the tendency to be bigger as the initial soil pH was higher. Effect of DS application depended on soil samples. Sulfate changes were not related with soil pH, therefore sulfate production was partly accompanied with pH reduction. Results of Denaturing Gradient Gel Electrophoresis (DGGE) showed that bacterial community started to change as soon as 2 weeks after incubation, in addition that the difference between soils was large. 2) Grape seedlings with DS in the plant nursery were transplanted to moderate saline alkaline soil. The survival rate retained >50% even 2 years after the transplanting, whereas the survival rate for the past several years by conventional transplanting had showed approximately 20%.

Key Words: Humic acid, Improvement, P. R. China, Saline-alkali soil, Sulfur

1. Introduction

Saline-alkali soil mainly spreading in the northeast China is estimated at least 346,000 km^2 (Wang *et al*., 2007). The soil has a problem on low crop production caused from high electric conductivity and low water potential by salinity and micronutrient unavailability by high pH. Calcium compound such as gypsum (US Salinity Laboratory Staff, 1954), flue gas desulfurization gypsum (Sakai *et al*., 2004; Chun *et al*., 2001), or sulfur compound such as elemental sulfur (El-Tarabily, *et al*., 2006) and mixture of elemental sulfur and humic acid (Japan International Cooperation Agency, 2003) were proposed as chemicals to ameliorate saline-alkali soil. Mixture of elemental sulfur and humic acid named as Desalination of Soil (referred hereafter to as DS) has been developed mainly in Shanxi province and was reported to have positive effect for yield of crop especially corn, which is one of major crops in Shanxi province. The local research institute is recently trying to spread DS to other provinces.

Grape is cultivated on a large scale in the northern rural area of Lanzhou in Gansu province. They control the harvest season to early January by sunshade cover reducing sunshine in the early summer. Because early January is a "niche" period for fresh fruit supply in domestic food chains, the grapes are traded with extremely high prices. Thus local grape farmers afford to pay relatively more expenses for soil addtives to improve the disadvantageous soil condition than farmers in other areas.

In the present study, the objectives are the following:

1) to clarify the distribution of saline-alkali soil around grape cropping area in Gansu Province
2) to clarify the mechanism of how DS which consisted of sulfur, humic acid, and organic matter worked for soil improvement and
3) to evaluate DS on agricultural production including grape seedling on saline-alkali soil

2. Materials and Methods

2.1. Soil properties in northern Gansu province

Soil samples were collected from 11 typical farm lands including grape greenhouse, from Yondeng prefecture, approximately 70 km northwestern of Lanzhou city to north border of Lanzhou city (**Fig. 1**) in March 2009. Surface soil (0-10cm) were air-dried and passed through 2 mm mesh thieve before pH (1:2.5 with deionized water) and electric conductivity (EC; 1:5 with deionized water) were determined.

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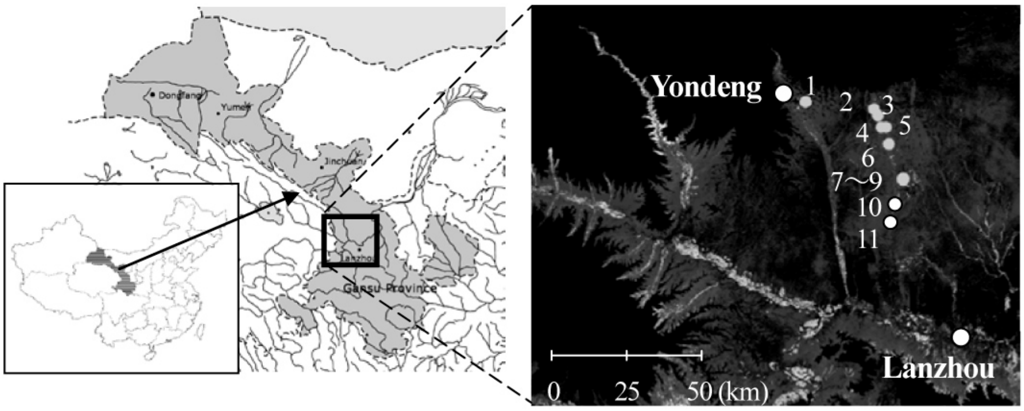

Fig. 1. Location of the survey sites. White circles in the right figure represent the sampling points. No.1 and 9 were utilized as green house, No. 2 – 8 and 10 were crop fields, and No.11 was a bare land.

2.2. Soil chemical and microbial changes in incubation test

2.2.1. Mechanism how DS worked for soil improvement

250 g soil collected from the potting soil in the grape seedling nursery near No.1 in Figure 1 was filled into a beaker along the following treatments; without additives (Control), with elemental sulfur (+S), with humic acid (+HA), with DS (+DS) according to standard application rate of DS, i.e. 2.25 tDS ha^{-1}. Sulfur was used as a form of powder with reagent grade (Kanto Kagaku), and humic acid was extracted from local charcoal treated with nitric acid by a local company. Content of DS was showed in **Table 1** After they were incubated with water of 60% of field capacity in 30ºC for approximately 3 months (2009/7/24～10/20), the soils were dried to determine pH and SO_4^{2-} content.

2.2.2. Microbial changes with DS application

Three of 250 g soils collected from the fresh potting soil in the grape seedling nursery near No.1 and from wheat crop field near No. 2 in Figure 1 were filled into beaker without DS (-DS) / with DS (+DS) according to standard application rate, i.e. 2.25 tDS ha^{-1}. They were incubated with water of 60% of field capacity in 30ºC for approximately 3 months (2009/7/24 ～10/20). Soil samples were collected every 2 weeks to analyze Denaturing Gradient Gel Electrophoresis (DGGE) for microbial diversity and were collected at the termination of the incubation to determine pH and SO_4^{2-} content.

Table 1. Content of mixture of elemental sulfur and humic acid (DS).

	content (%w/w)
Total nitrogen	2.13
Total P_2O_5	0.80
Total K_2O	1.24
Water soluble MnO	0.71
Water soluble B_2O_3	0.03
Water soluble Fe	1.41
Water soluble Zn	0.68
Water soluble Cu	0.03
Water soluble Mo	0.0016
Total Sulfur	41.70

2.3. Effect of sulfur-humic acid on agricultural production including grape growth

Grape seedlings grown with DS from January 2008 were transplanted into a greenhouse in November 2008 where the transplanting had rarely succeed because of saline-alkali soil (pH 8.07, EC 1.02 ds m^{-1}). By counting the living plants before the transplanting, the previous survival numbers were estimated. Survival rate was calculated as the number of survival seedlings / total planted seedling × 100(%).

3. Results and Discussion

3.1 Saline-alkali soil in Gansu province

Soil pH and salinity series were shown in **Figure 2**. Soil pH ranged from 7.79 to 8.61, whereas soil electric conductivity ranged 1.25 to 6.27 dS m^{-1}. The sampling point showing the

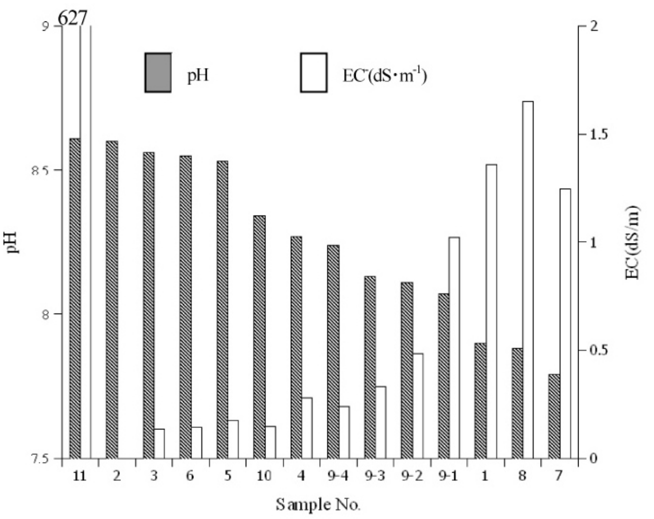

Fig. 2. Soil properties in Gansu province. Sample number means the location number in Fig. 1.

highest EC, i.e. No. 11 was located the downstream of the local river. No significant relationship between geological location and soil pH neither EC were shown. Soil samples with high pH show the tendency of low EC except No. 11. Compared with pH of severe alkali soil in Shanxi or Heilongjian Provinces showing more than 10 (Japan International Cooperation Agency, 2003, He *et al*., 2008), the alkalinity on the sites was comparatively moderate because the samples were collected from present farming area.

3.2. Soil chemical and microbial changes in incubation test

3.2.1. Mechanism of how DS worked for soil improvement

Soil pH and sulfate content after 3 months of incubation with different soil additives was shown in **Figure 3**. Soil pH with sulfur and DS show the tendency to drop slightly larger than control; the difference was approximately 0.1. On the other hand, sulfate content in the two additives, sulfur and DS, especially with DS remarkably increased than control. The results suggested that sulfur oxidization process was partly accompanied with sulfate production in the soil condition. The reason why the pH reduction was limited compared with the trial conducted in Shanxi Province (Japan International Cooperation Agency, 2003) would be that the soil pH was originally low and would be that the number of native sulfur oxidization bacteria was small.

Changes of soil pH and sulfate content were shown in **Table 2**. The higher the pH was originally, the bigger the reduction of pH after the incubation was. The result that sulfate increase was not exactly related with soil pH decrease suggests sulfate production partly contributes pH reduction. Effect of DS application on saline-alkali soil varied with soil samples because pH buffering ability can be different between the soils.

Figures 4 and 5 showed DGGE analyses at the beginning of the incubation and 2 week incubation, respectively. At first the band pattern differed among the soil, whereas the

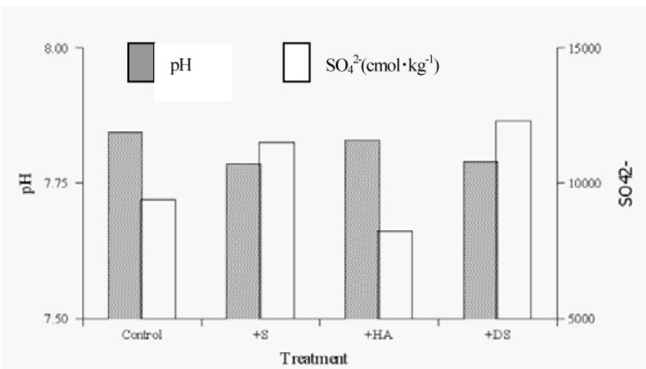

Fig. 3. Soil pH and sulfate content changes with additives after 3 month incubation. In Treatment 'Control' means without additive, and '+S', '+HA', and '+DS' means added with sulfur, humic acid , and DS respectively.

Table 2. Soil pH and sulfate content changes after 3 month incubation.

Soil	+/-DS	pH	SO_4^{2-} (cmol·kg^{-1})
A	-DS	7.75	4089
	+DS	7.71	9692
B	-DS	7.97	377
	+DS	7.83	4543
C	-DS	8.48	148
	+DS	8.09	4772

In '+/-DS' column, '-DS' and '+DS' means added without / with DS respectively.

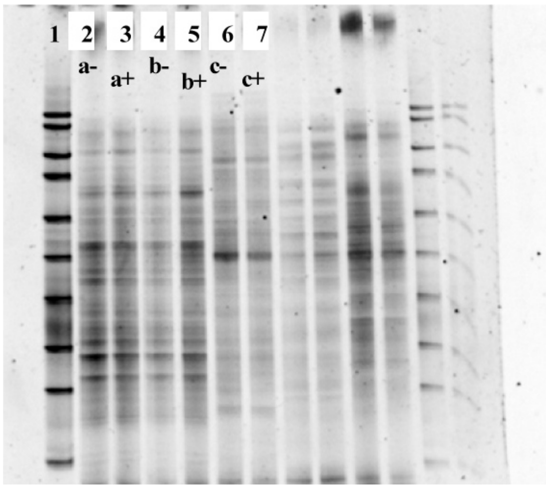

Fig. 4. DGGE analysis in each soil at the beginning of incubation (2009/07/24). Lane 1 is a marker. Lane 2-7 represents each sample. Different alphabets mean kinds of soil and '-'/'+' mean without/with DS respectively.

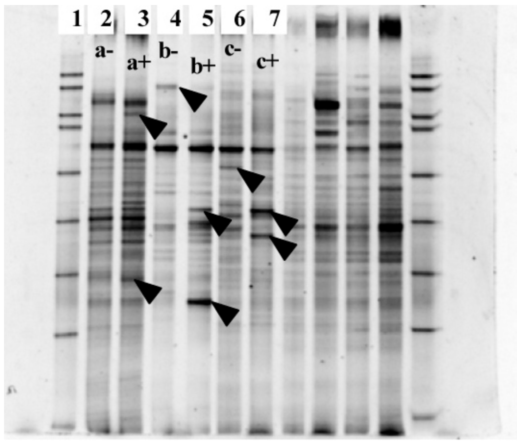

Fig. 5. DGGE analysis in each soil 2 week after incubation started (2009/08/08). Lane 1 is a marker. Lane 2-7 represents each sample. Different alphabets mean kinds of soil and '-'/'+' mean without/with DS respectively. Angled triangles point out new bands or significant strong bands compared with counter lane.

presence of DS made no effect on the band pattern in Figure 4. Two weeks after, distribution of bands with DS was apparently changed from those without DS. Bacterial communities

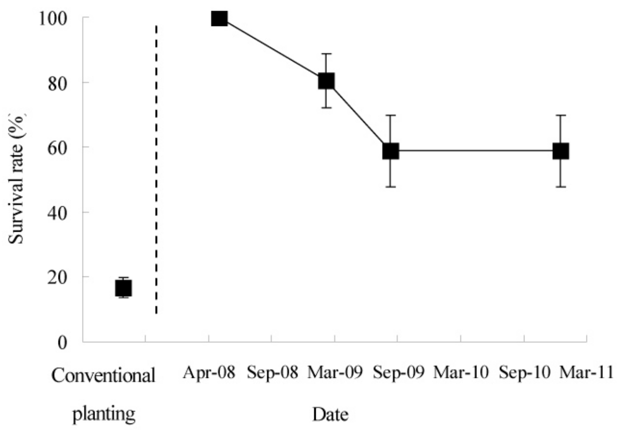

Fig. 6. Time course of survival rate (=survived number of seedlings / transplanted number of seedlings) of grape seedlings.

concerning nutrient or sulfur metabolism in DS were activated to explode within 2 weeks.

3.3. Effect of sulfur-humic acid on agricultural production including grape growth

Conventional transplanting without any saline-alkali soil amendments had succeeded in only 17% of survival rate (**Fig. 6**). The survival rate agreed with farmer's interview (the estimated survival rate was 25%). The seedlings with DS in the nursery were able to keep in growth and the survival rate showed as high as 80% even after 9 months and gradually dropped up to 50% for 2 years.

The local grapes can be harvested from 2-3 years after the transplanting into a greenhouse. By the farmer's observation, 10% of the grape trees with DS produced fruit by contrast those in the conventional planting had no fruit. They could harvest the first grapes in the early January, 2010 without heavy hail in the November, 2010.

4. Conclusion

The survey of saline-alkali soil northwestern of Lanzhou indicated cropping area in Gansu Province had moderate saline-alkali soil. Soil incubation did not show apparent effect on pH reduction with content of DS, because of moderate pH and its poor microbial population, on the other hand DGGE analysis suggested apparent change of microbial community at the early stage of the incubation. DS application can stimulate microbial community in the grape cultivation. Unfortunately, harvest in the season was failed by heavy tail. We need to investigate effect of DS on yield and quality of grape in the area for further study.

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