The Effects of Biochar on Germination and Growth of Wheat in Different Saline-alkali Soil

Guijun WANG[1,2]*, Zhenwen XU[2]

1. College of Life Science, Northeast Normal University, Changchun 130024, China; 2. College of Urban and Environmental Sciences, Changchun Normal University, Changchun 130032, China

Abstract Saline alkali soil can cause physiological drought on crops, so only some salinity tolerant crops can grow in saline alkali soil. Biochar can increase the utilize efficiency of nutrient and the water retention of the soil, and affect the growth of the plant. In this research, four different proportion of biochar was added in five different levels of saline-alkali soil for pot culture experiment. The pH of the soil increases as the proportion of biochar increase in same saline-alkali level soil, while the EC decrease as the proportion of biochar increase. The germination rate of wheat seeds varies as the different of soil's saline-alkali level. Notable among these results is the germination of wheat seeds in the serious saline-alkali soil without biochar added is 0, while in 45% biochar added in serious saline-alkali soil, the germination rate get to as high as 48.9%. Also, biochar improve the growth of wheat seedling, while for mild saline alkali soil and normal soil. Biochar had no obvious effect on the growth of wheat seedling.

Key words Biochar, Saline Alkali Soil, Wheat seed germination, Wheat seedling growth

Saline alkali soil includes two different characteristics, which are salt and alkali soil. When soil has too much Na_2CO_3, it can present strong alkalinity when the percentage of sodium ion exchange for cation exchange capacity is more than 5%, it called alkaline soil when the percentage of sodium ion exchange for cation exchange capacity is more than 15%[1]. Saline alkali soil can cause physiological drought of plant. When the mass fraction of soluble salt in the soil is too high, it will cause the crops to absorb water difficulty, even if the soil water content is adequate, the plant will still appear physiological drought, sometimes lead plants to die[2]. Excess alkaline salt can cause strongly alkaline reaction, make the plant nutrient phosphate, iron, manganese, zinc etc. easy to form insoluble compounds, which are hard to be absorbed by plants. Saline-alkali soil is widely distributed on earth, occupying about 25% of the total land area, distributing in more than 100 countries. The whole area of saline alkali soil in China, is above 3 466 700 hm^2, while only 30% of which has been cultivated, so the saline alkali soil is an important resource of land. With the increasing of the population, decreasing of arable land and the serious pressure shorting of fresh water resource, how to use saline-alkali soil to develop sustainable agriculture, has become a major issue in the international agricultural science and technology, which need to be pay more attention to.

Biochar is a new term in recent years, which is reserved for the plant biomass-derived materials contained within the black carbon continuum. Biochar includes chars and charcoal, and excludes fossil fuel products or geogenic carbon[3-5]. Materials that form the black carbon continuum are produced by partially combusting carbonaceous source materials, e. g. plant tissues[6-8], and have both natural as well as anthropogenic sources. According to the source of biomass materials, biochar can be divided into charcoal, bamboo, straw, rice husk carbon, animal feces and so on. Because of rich in organic carbon, biochar can increase the content of soil organic carbon, soil organic matter and water contention, and improve soil nutrient holding capacity and water holding capacity. Biochar also contains a huge amount of holes, which can increase the content of mineral nutrients in soil, such as phosphorus, potassium, calcium, magnesium, and nitrogen. The effects of biochar are usually obvious in some nutrient supplement effect on nutrient poor soil and sandy soil[9].

Although most biochar is alkaline, it can be used for agricultural improvement and increases soil fertility, improves soil crop productivity, promotes the sustainable use of soil and crop yield, and promotes the sustainable development of agriculture. But there are rarely studies about the effect of biochar on the alkaline soil. In this study, we try to use pot culture to detect if the biochar can affect the soil physical chemical properties, and the germination of the wheat seeds and the growth of plant seedlings. The objection of this paper is to explore the role of biochar on improvement of saline alkali soil, and to provide experimental data for the sustainable utilization of saline alkali soil.

1 Materials and methods

1.1 Experimental materials In this paper, wheat Yannong 19 seeds were selected as the test plants for pot culture. The test soil includes saline soil and black soil. The saline-alkali soil was got from surface layer soil of grassland serious alkali spot soil in Western Jilin Province; black soil was got from the forest surface soil in

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* Corresponding author. E-mail: joycewgj@gmail.com

Changchun Normal University. Biochar is got from Biochar Research Center of Shenyang Agricultural University, which is made of maize straw. The dried saline alkali soil and black soil were crushed, and sieved by 1 mm diameter aperture sieve. Then, saline-alkali soil and black soil were mixed with the ratio of 10:0, 6:4, 4:6, 2:8, 0:10 in weight, which simulate five different saline-alkali level: serious, medium-serious, medium, mild and none saline-alkali separately. Biochar were sieved by the same method, then fully mixed with soil samples by 4 different concentrations: 0%, 15%, 30% and 45%. There is total 20 treatments, each treatment was replicated 3 times. Select 30 full wheat seeds to sown on the 15 diameter plastic pot which contains the different soil sample, then put 1mm thick soil evenly on the surface of each pot, water it with distilled water until saturation. After sowing, all the pots were put into the greenhouse for pot culture.

1.2 Experimental methods Soil pH value was measured by PHB – 100 type electronic pH meter. Soil electrical conductivity was measured by using the CON1000 type of conductivity meter. After sowing 24h, began to observe wheat seeds' germination condition, and account the germination (sprout longer than 2mm) number every other 24h, and calculate the germination energy (GE), germination rate (GP) and germination index (GI)[10] at the eighth day.

Germination energy (GE) = the germination of seed number before 4 days/ the total number of seeds × 100%.

Germination rate (GP) = the germination of seed number within 8 days/the total number of seeds × 100%.

The original data of the test were analyzed by Excel software and SPSS 11.0.

2 Results and analysis

pH and EC are two of important indexes of the saline-alkali soil, which can affect the availability of soil nutrients, and soil water soluble salt which can help us make a more accurate judgment on soil fertility and appropriate kinds of crops in saline-alkali soil. The pH and EC of the treatments in this study were listed in Table 1 and Table 2. It can be seen from Table 1, the pH different significantly in different treatments, with the increase of soil quality, soil pH value decreased gradually, pH value change range was: pH10:0 > pH6:4 > pH4:6 > pH2:8 > pH0:10. pH values increased with the added of biochar, the higher the biochar concentration in the same salinization degree, the soil pH value was higher, and the pH value increased more significant. The same proportion of soil pH from high to low was: BC3 > BC2 > BC1 > BC0.

Table 1 The pH of soil samples in different treatment

Treatment (saline-alkali: black)	BC0	BC1	BC2	BC3
10:0	10.2	10.25	10.33	10.31
6:4	8.98	9.1	9.31	9.53
4:6	8.63	8.69	8.7	9.34
2:8	7.93	8.38	8.2	8.73
0:10	7.06	7.72	7.93	8.1

Table 2 The EC of soil samples in different treatment (ms/cm)

Treatment (saline-alkali: black)	BC0	BC1	BC2	BC3
10:0	4.631	4.039	4.448	3.1
6:4	2.538	2.396	2.383	1.985
4:6	2.198	2.07	1.913	1.721
2:8	1.214	1.265	1.218	1.208
0:10	0.25	0.454	0.578	0.207

As can be seen from Table 2, the electronic conductivity (EC) of different ratio of soil samples was different. Electrical conductivity of soil significantly reduced with the ratio of black soil increased in same proportion of biochar. Also, the EC decreased with the proportion of biochar increased. The more biochar added, the more significant the EC decreased. Variation range of EC with the same biochar concentration in soil sample was: pH10:0 > pH6:4 > pH4:6 > pH2:8 > pH0:10, conductivity changes with a ratio of soil sample size was: BC0 > BC1 > BC2 > BC3.

2.1 Effect of biochar on wheat germination index It can be seen from Fig. 1 and Fig. 2, the biochar treatment of wheat germination energy and germination rate were higher than that of the control which no biochar added. It indicates that the wheat germination rate increases gradually with the lower of saline-alkali degree in different soil treatment. The germinate rate of wheat seeds is highest in the treatments of black soil (ratio of saline-alkali soil and black soil is 0:10) either biochar added or not. In the treatment of ratio 2:8 and 4:6), which are similar in germination rate, in the ratio of 6:4 (medium to serious saline-alkali soil) the germination rate is lower significantly than black soil. In serious saline-alkali soil, most of the seeds can't germinate, only in the treatment of BC3 the wheat seeds germinated which will be discussed follow. The germination rate of wheat also changed with the biochar's concentration, in the ratios of 10:0, 6:4, 4:6 and 2:8, wheat seed germination rate was higher with the higher biological carbon concentration. Especially in soil 10:0 ratio which we need to pay more attention to, the germination rate of BC0, BC1, BC2 group are all 0%, while the germination rate in BC3 (45% biochar added) is as high as 48.9%.

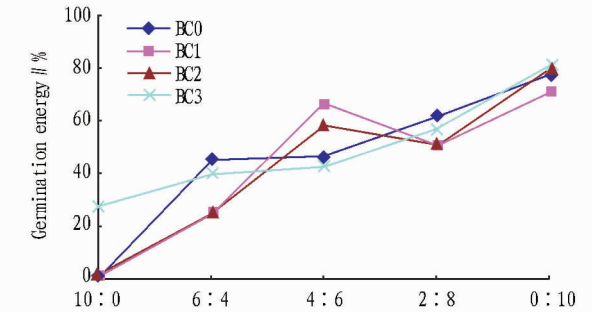

Fig. 1 The germination energy of wheat seeds in different treatments annotation: x – coordinate indicates the rate of saline – alkali soil: balck soil (simili)

The data shows that: biochar promote the germination of wheat, generally, the germination energy and germination rate of wheat were increased with the increasing of the biochar concentration. The germination rate increased with increasing concentration

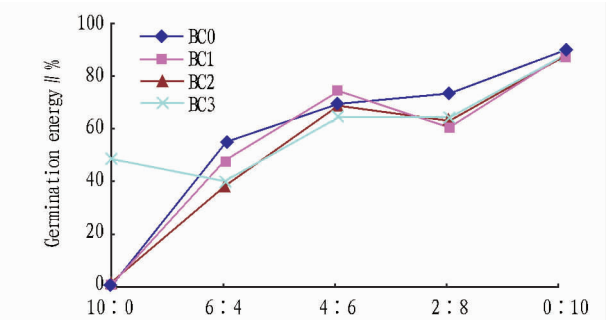

Fig. 2 The germination rate of wheat seeds in different treatments

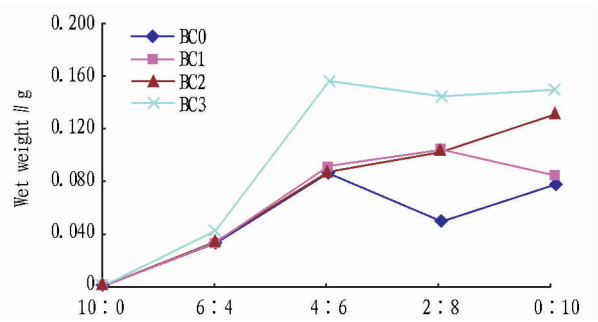

Fig. 3 The wet weight of wheat seedlings at ninth day in different treatment

of biochar. In mild, medium, medium-serious saline-alkali soil, the germination rate increased with increasing the concentration of biochar in general. While in black soil, the effect of biochar on the germination of wheat seeds is not significant. For the serious saline-alkali soil, biochar has positive effected on wheat germination; for mild saline-alkali soil, wheat seeds germination could be promoted in BC2, BC3 groups.

2.2 Effects of biochar on growth of wheat plants The above 4 figures were the plant fresh weight and dry weight of wheat at ninth and twenty-first days. From Fig. 3 and 4, it can be seen that with the increase of biochar's concentration, fresh weight and dry weight of wheat seedlings increased correspondingly; the biomass of wheat seedling was higher as the proportion of black soil increased. From Fig. 5 and 6, it can be seen that along with the growth of wheat, biochar begin to have inhibition effect on the growth of wheat seedlings. In the same saline-alkali level, the fresh weight and dry weight of wheat no longer increase with the increase of the biochar proportion. For 10∶0, 6∶4, 4∶6 three ratio of soil samples, the fresh and dry weight of wheat were increased with the increasing of biochar's concentration; for 2∶8 and 0∶10 two ratio of soil samples, fresh weight and dry weight of wheat seedlings were highest in the treatment of no biochar treatment, and for soil of the addition of biochar, the fresh weight and dry weight of wheat decreased with the increasing of biochar's concentration. The highest level of the fresh weight and dry weight of wheat seedling was in 2∶8 soil treatment (mild saline-alkali soil).

To sum up, in the early growth edge (about 12th days), with the increase of biochar's concentration, wheat grow better, the wheat germination rate, fresh weight, dry weight were gradually increased. At the later stage of wheat seedling (about 13th to 21st days), for 6∶4, 10∶0 4∶6 three ratio of soil sample, wheat seedlings growth better with the increase of biochar's concentration and the quality of black soil; for 2∶8 and 0∶10 two ratio of soil sample. The wheat seedlings in no biochar added treatment growth better than the treatment of biochar added, so biochar had inhibiting effect on the growth of wheat seedlings in this growth period. The improvement effect of biochar on severe saline-alkali soil improvement effect was obvious; for mild saline-alkali soil was not obvious, the biochar's concentration of BC3 group had inhibited wheat growth.

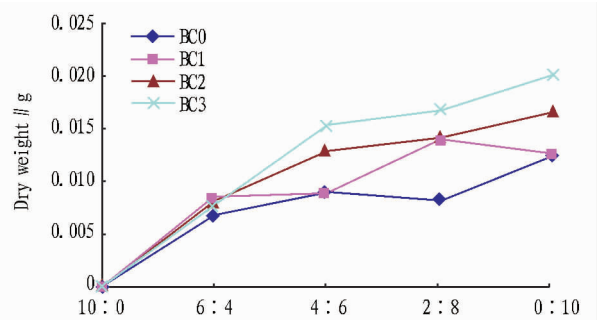

Fig. 4 The dry weight of wheat seedlings at ninth day in different treatment

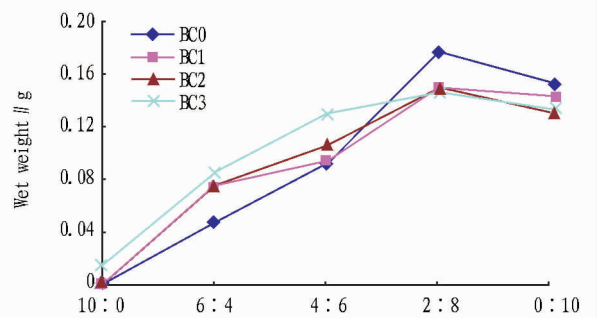

Fig. 5 The wet weight of wheat seedlings at twenty-first day

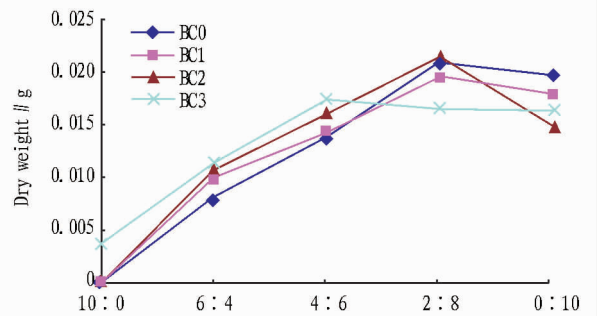

Fig. 6 The dry weight of wheat seedlings at twenty – first day

3 Conclusions and discussions

Biochar is alkalescent, applied in the saline-alkali soil will increase the value of the pH. Through the test data can also see that the biochar increased the soil pH value, and the biochar's concentration was high, the soil pH value is greater. The EC changed reduced significantly with increase of soil quality and the higher pro-

portion of biochar. The decrease of EC can alleviate salt damage of soil to the plant growth, which may be one of more important instruction the pH for saline-alkali soil level. Biochar is weakly alkaline, it will make the saline-alkali soil salinization degree aggravate, but it contained a certain amount of mineral element, is benefit to wheat growth. In this experiment, for the 10∶0, 4∶6, 6∶4 three ratio of soil (severe saline-alkali soil), biochar not only promoted the wheat germination, but also promoted the growth of wheat seedlings in early growth period. The higher the biochar's concentration, the better the growth of wheat seedlings. Thus, for severe salinization soil the positive effect of biochar was obvious. In this experiment, the higher the biochar concentration, the better improvement in soil samples; for mild salinization soil, the positive effect of biochar was not significant. Biochar had a certain degree of adsorption, and contains a certain amount of mineral element, can increase the content of mineral elements of soil, which may promote the nutrient for the germination of seeds and the growth of plant. Especially for the serious saline-alkali soil, the effect of biochar was obvious in higher concentration of biochar. This experiment only tests the effect of biochar on the germination of wheat seeds and the growth of seedlings. There are more questions need to be discuss further in the future experiment. Such as long period pot culture or field culture to detect the detail and the mechanism of the biochar's effect on the different growth stage of crops to give more guidance for agricultural use of saline-alkali soil, especially serious salinity soil.

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