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Impact of Application of Biochar-Based Fertilizer on the Content of Phosphorus and Potassium in Soil

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Abstract. The application of chemical fertilizer can increase crop yield, but at the same time, it brings huge environmental pressure. Long-term application of chemical fertilizers resulted in deterioration of soil properties, excessive nitrate content in groundwater and increased emissions of greenhouse gases. The object of this study was to investigate application of biochar-based fertilizer (BBF) on the content of phosphorus and potassium in soil. An in-situ field experiment was conducted over 6 years in plain at Shenyang city in China. The experimental design involved five treatment, no fertilizer (CK), low levels of biochar (C15), high levels of biochar (C50), Chemical fertilization (NPK) and biochar-based fertilizer (BBF), with five three replicates of each treatment. Three (CK, NPK, BBF) was selected to research for the phosphorus and potassium in soil. After continuous application, the total phosphorus and potassium content was not affected by different additive. The content of available phosphorus in soil was increased by 1.19 and 1.42 times under chemical fertilizer and under BBF, respectively. The same phenomenon was also observed on available potassium. BBF can significantly improve the content of available phosphorus and potassium in soil, and the effect is better than applying chemical fertilizer. The peanut yield showed a significant increase under BBF than under others.

1. Introduction

Chemical fertilizer plays an important role in agricultural production. Zhao et al. considered the amount of fertilizer input more than half of total input of agricultural production [1]. However, chemical fertilizer has short effect time, easy loss and low utilization rate, resulting in a large amount of loss and waste. Meanwhile, the environmental problems caused by chemical fertilizers, such as soil consolidation, heavy metal pollution and water pollution, are becoming more and more serious. Therefore, a new type of environment-friendly fertilizer should be applied in agricultural production.

Now we made use of biochar and added some nutrient elements to produce organic-inorganic compound fertilizer, named BBF. Biochar has a lot of role in amending soil, improving soil fertility and crop yield. A large number of research show that biochar has many effects on soil and plants. Over the past ten years, lots of papers have been carried out to study the effects of biochar on soil carbon, nitrogen and enzyme activities [2]. Some literatures [3-6] considered the raw materials of biochar will affect the pH of biochar [7]. Novak et al considered manufacturing technique are also important [8]. Domene et



al. considered the charge contained in biochar can convert some stable state elements into active states [9]. Therefore, biochar can increase cation exchange capacity (CEC) and increase the content of available nutrition and cations in soil. When biochar was applied to the soil, the effective biological nutrients in the soil increased. Novak et al. and Palumbo et al. considered biochar has certain selectivity for nutrient absorption because of its special structure [8, 10]. Therefore, the changing of different elements and forms are not same.

Yang et al. considered BBF can change the fraction of organic nitrogen and increase crop yield as a new fertilizer [11-12]. However, it was not known how long-term application affects soil phosphorus and potassium. Now the experiment was conducted to explore the content of phosphorus and potassium charge under BBF

2. Materials and methods

This study was conducted in a new type fertilizer in Liaoning Province, China (40°48', 123°33'). Average annual precipitation is 547mm, with 60-70% of which occurring between May and September. Annual temperature averages approximately 7.0°C-8.1°C. The soil at the experimental site was a brown soil classified as an alfisol, with hydromica as a dominant clay mineral. This experiment began in 2011 and the basic characteristics of the soil are shown in table 1.

Table 1. Basic properties of soil at the beginning of the experiment (2011)

pH	Organic matter (g/kg)	Total N (g/kg)	Total P (g/kg)	Total K (g/kg)	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
6.81	13.1	0.53	0.67	18.8	56.2	12.5	89.6

The experimental field cropping system consisted of one annual crop of peanuts in continuous cultivation, *Fuhua 12-150GY*. The design involved one treatment factor-nutrient addition, five different additions, with three replicates of each treatment combination (15 experimental plots in total). There were five treatments, no fertilization (CK), low levels of biochar (C15, 225 kg/hm²), high levels of biochar (C50, 750 kg/hm²), Chemical fertilization (NPK, 82.5 N kg/hm², 97.5 P₂O₅ kg/hm², 97.5 K₂O kg/hm²) and biochar-based fertilizer (BBF, 11-13-13, 750 kg/hm²). In this study, we choose there of them, CK, NPK and BBF.

The plots were 27 square meters and established in 2011 using a randomized block design. The ridging spacing was 90 cm and two lines of peanuts were planted. The distance between rows was 30 cm and the plant spacing was 15 cm. All fertilizers were applied to soil at one time in strip-till planting at a depth of 15-20cm. planting and fertilizer activities were performed yearly from May through November from 2011.

Sampling was carried out in early-October 2016. At every plot five replicates of soil samples were taken at 0-20 cm soil depth using a soil auger. Thereafter, soil samples were air-dried, and the sieved (2-mm mesh) to remove roots and other debris. The content of total phosphorous and potassium were determined by sodium hydroxide melting, thereafter were measured by spectrophotometer (722, China) and flame spectrophotometry (M410, England), separately. The available phosphorous and potassium was determined by sodium bicarbonate and ammonium acetate, separately. Thereafter, measured by Molybdenum antimony colorimetric method and flame spectrophotometry (M410, England), respectively. Microsoft Excel 2016 and SPSS 21.0 were used for the statistical analysis of the data.

3. Results and discussion

3.1. Total phosphorous (total P)

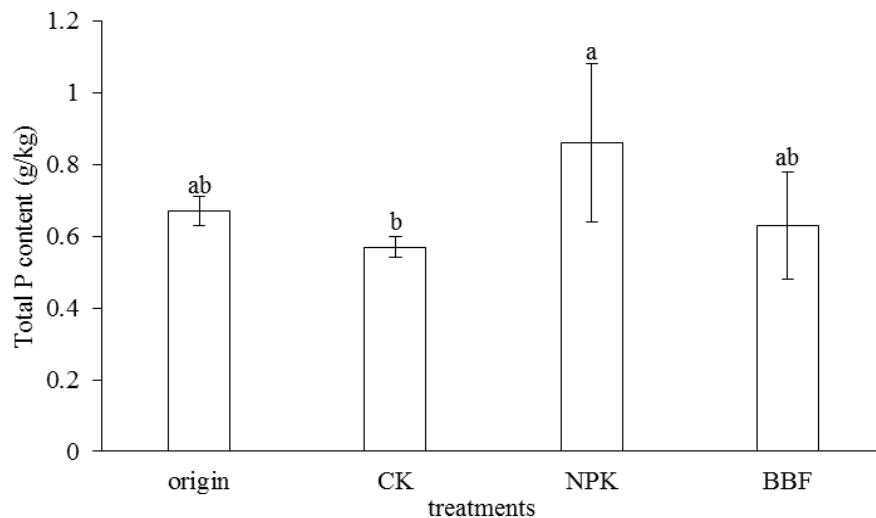


Figure 1. Total P content ($\pm$ SD) in 0-20cm soil after peanut maturity. Significant differences are marked by different letters ($p < 0.05$)

The total phosphorous content was lower under CK than under origin, but it had no effect (Fig.1). That indicate the total phosphorous content in soil would decreased with no fertilizer input. After six years, the total phosphorous content in soil was higher under chemical fertilizer or BBF than under origin. Although there is an increasing trend, the difference is not significant. In the literature [13], the total phosphorous content will obviously improve for a long time fertilizer. As a new type fertilizer, biochar-based fertilizer has no obvious improvement compared with the chemical fertilizer. It indicate that the quantity of inputs per year was basically the same as of crops carried.

3.2. Available phosphorous (available P)

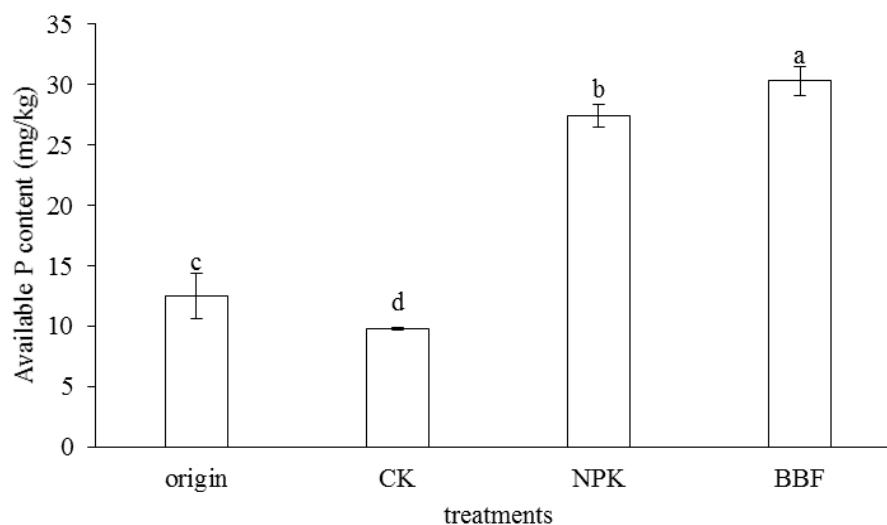


Figure 2. Available P content ($\pm$ SD) in 0-20cm soil after peanut maturity. Significant differences are marked by different letters ($p < 0.05$)

The available P content in soil are very different under all treatment (Fig. 2). The lowest value was observed under CK, and it decreased by 22% compared with the original soil. Without any fertilizer input, the available P content in the soil would be significantly reduced. Application of chemical fertilizer or BBF significantly increased the available P content in soil. After six years, it increased by 1.19 and 1.42 times, respectively. With the input of nutrients, the available components of phosphorous increased significantly. We conclude that a better effect appeared under BBF than under chemical fertilizer. There are a large number of biochar in BBF. Domene et al. considered the charge contained in biochar can convert some stable state elements into active states. Therefore, biochar can increase soil CEC and the available P and cations in soil [9].

3.3. Total potassium (total K)

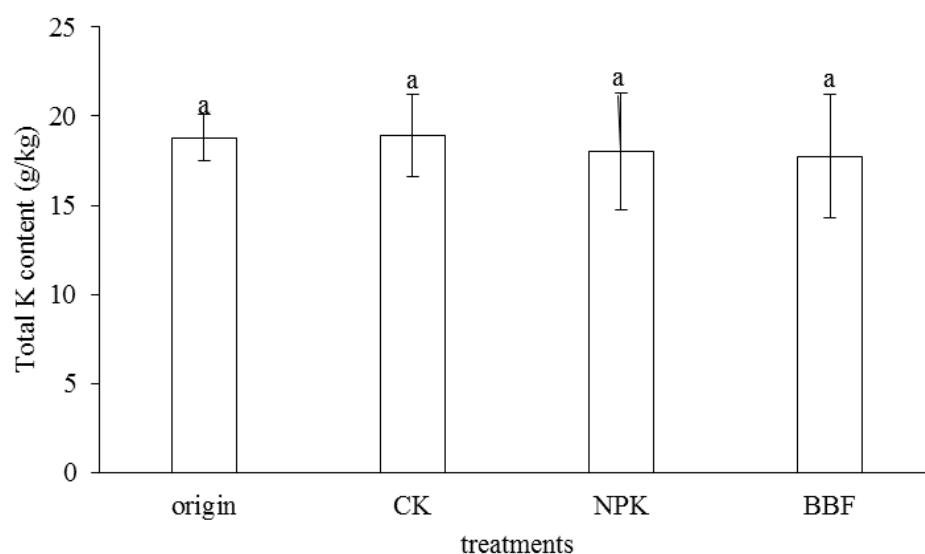


Figure 3. Total K content ($\pm$ SD) in 0-20cm soil after peanut maturity. Significant differences are marked by different letters ($p < 0.05$)

There was no difference in total K content in soil under all treatments (Fig.3). Although it had nothing potassium input, the total K content can't change obviously under CK. The yield was low, and the amount of potassium absorbed was very small. Therefore, the balance of potassium wasn't been broke. Although it had supplied a large amount of potassium nutrients under chemical fertilizer or under BBF, the total K content had not changed due to the high uptake of crops, which was basically in a state of equilibrium.

3.4. Available potassium (Available K)

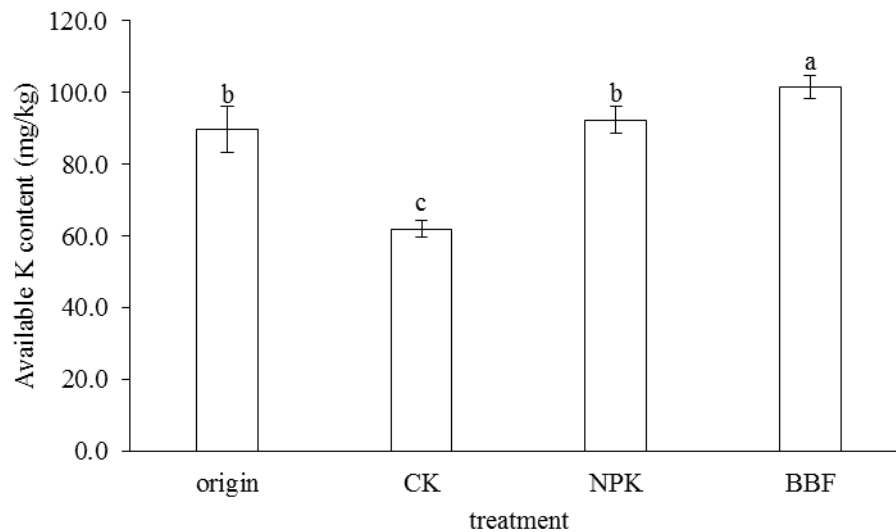


Figure 4. Available K content ($\pm$ SD) in 0-20cm soil after peanut maturity. Significant differences are marked by different letters ($p < 0.05$)

The figure 4 was very similar to figure 3. The available K content was decreased under CK compared to under origin (Fig. 4). Without any fertilizer input, the available K content can markedly decreased because of plant uptake. There was no obviously different between origin and chemical fertilizer. Therefore, a stable equilibrium was appeared under NPK. The available K content was remarkably improved by 10% and 13% compare to under NPK and under origin, respectively. The available K content could effectively improve by applying BBF.

3.5. Yield

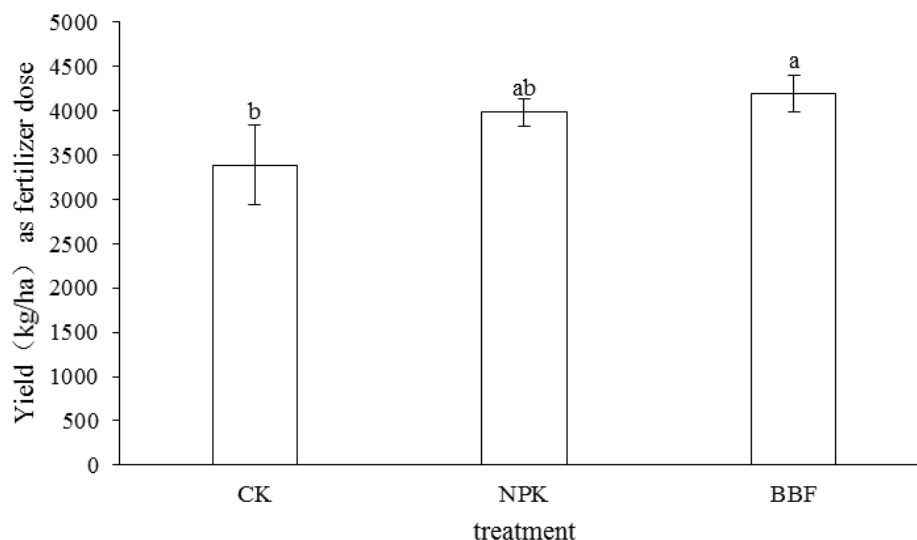


Figure 5. Peanut yield ($\pm$ SD). Significant differences are marked by different letters ($p < 0.05$)

The peanut yield was slightly increased under chemical fertilizer than under CK, but no significant difference (Figure 5). The root of peanut could produce lots of rhizobium during growing stage, and it

fixed a larger number of nitrogen of air into soil. Therefore, long-term applying chemical fertilizer aggravated physical and chemical properties of soil [14]. The rhizobium was decreased with time. A reverse result appeared under BBB. The peanut yield was increased by 5.4%-25.0%, respectively. A better environment for microbial activity was provided under BBF and the nutrient was absorbed quickly and effectivity.

4. Conclusion

After 6 years fertilization, compared with chemical fertilizer, BBF can activate phosphorus and potassium in soil and improve availability of nutrient in soil. Moreover, there was no effect on the total amount of phosphorus and potassium.

Acknowledgments

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