IOP Conference Series: Earth and Environmental Science

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To cite this article: Na Li *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **108** 032036

IOP Conf. Series: Earth and Environmental Science **108** (2018) 032036 doi:10.1088/1755-1315/108/3/032036

Effects of Long-term Fertilization on Potassium Fixation Capacity in Brown Soil

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Abstract. This study concentrated on the research of features of fixation. The objective of this study was to provide theoretical foundation of rational application of potassium fertilizer along with improving fertilizer availability ratio. A 32 years long-term experiment was conducted to evaluate the effects of fertilizer application on potassium changes and the factors affecting K fixation on brown soil by simulation in laboratory. When the concentration of exogenous potassium was in range of 400~4000 mg·kg-1, potassium fixation capacity increased along with the rise of concentration of exogenous potassium, whereas K fixation rate reduced; Compared with no-potassium fertilizer, application of potassium fertilizer and organic fertilizer reduced soil potassium fixation capacity. Potassium rate and fixation-release of potassium character in soil should be taken into comprehensive consideration for rational fertilization to maintain or improve soil fertility for increasing potassium fertilizers efficiency in agriculture.

1. Introduction

The availability of potassium for plants was effectively influenced by physical and chemical processes in soils; potassium fixation is one of the most important processes [1, 2]. Potassium fixation with dual roles in decreasing the effectiveness of soil potassium and reducing the leaching loss and luxury absorption of potassium by crops [3]. Therefore, it is critical to study characteristics of soil potassium fixation for guiding reasonable fertilization. K+ and exchangeable potassium adsorbed on the particles of soil could enter into adsorption sites of 2:1 type clay mineral, with reducing the effectiveness of potassium, this phenomenon is called K fixed. K fixation will be impacted by clay minerals, pH, organic matter, CEC, soil moisture, temperature, potash and cultivation [4-8]. And long-term fertilization can effect on the characteristic of potassium fixation based on one or more of these factors [9]. Shaimukhametov etc. [10] studied status of potassium in Russia typical soil under long-term fertilization showed the amount of fixed potassium of long-term application of NPK fertilizer and organic manure was much less than the no fertilization. Hui-min Zhang [7, 9] studied k fixation capacity of the Chinese typical soils, the results showed that compared with no fertilization, K fixation and fixation rate of potassium fertilization was reduced, and the difference of K fixation capacity mainly caused by K-bearing minerals, slowly available potassium and K^+ saturation. Brown soil is one of main cultivated soils in northeast China, therefore the potassium fixation characteristics of brown soil is unclear. This article studied fixation capacity to exogenous potassium of brown soil and its influencing factors by simulation test under 32 years long-term rotation fertilization, for providing theoretical basis for rational fertilization of potassic fertilizers.

2. Material and methods

2.1. Site description
Brown Soil Long-term Fertilizer Experiment Station was initiated in 1979 at Shenyang agricultural university, China (40°48′N, 123°33′E). The climate is temperate, moist semi-moist monsoon. Precipitation is varies from 574 to 684 mm yr^{-1}, with nearly all occurring between June and August. Average annual temperature was 7.0~8.1℃.

2.2. Experiment design
The experimental design consisted of 18 treatments, nine of treatments were chosen for this study and abbreviated as follows for ease of labeling: a control without any fertilizer(CK); nitrogen fertilizer(N); nitrogen and phosphorus fertilizer(NP); nitrogen、phosphorus and potassium fertilizer(NPK); manure in low level(M_1); manure in high level(M_2); manure in high level along with nitrogen fertilizer(M_2N); manure in high level along with nitrogen and phosphorus fertilizer(M_2NP); manure in high level along with nitrogen、phosphorus and potassium fertilizer(M_2NPK). The farmyard manure at a rate of 27 Mg·ha^{-1} (69.4, 5.6, 3.6 and 9.1 g·kg-1 as total C, N, P and K). The N, P_2O_5 and K_2O were equivalent to 120, 60 and 60 kg·ha-1 for maize, and the fertilizers were applied in the form of Urea, superphosphate and K_2SO_4. The soil was farming brown soil. The rotation system was maize-maize-soybean.

2.3. Soil sampling
After the maize harvested in 2010, soil samples was collected from the surface soil (0-20 cm). Then, each sample was air-dried and sieved through a 1 mm mesh for test. The properties of the sampled surface soil are shown in Table 1.

2.4. Simulation experiment
Laboratory test simulation of potassium fixation was tested by wetting and drying method, as described below. Add 5.00 g sample passed 1 mm sieve into 50 ml seven levels of K solutions (0, 0.4, 0.8, 1.6, 2.4, 3.2, 4.0 g·L^{-1}, equivalents to 0, 400, 800, 1600, 2400, 3200 and 4000 mg K kg^{-1} soil), with sufficient mixing and incubating for one week. Potassium was applied as KCl solution to the soil for the alternative wetting and drying and incubation period studies. And three repeated for each sample. After air drying, 50 ml NH_4OAc at the rate of 1 mol·L^{-1} were used to extract K^+, then tested by flame photometer.

K fixation and K fixation rate were calculated employing the formulas as follow:

K fixation=Added K – (Exchange K after adding-Exchange K without adding)

K fixation rate (%)= (K fixation×100) / Added K

3. Results

3.1. K-fixation characteristics of brown soil under long-term fertilization

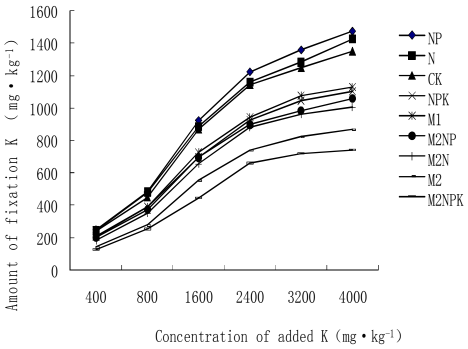

Fig. 1 Amount of K fixation in different treatments under long-term fertilization

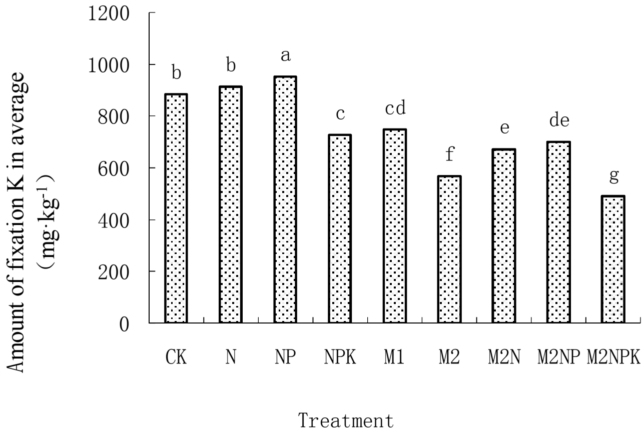

Fig. 2 Amount of K fixation in average in different treatments under long-term fertilization

Amount of soil potassium fixation can be used as an index of evaluation of potassium in the soil condition. Fig.1 appears that the fixed K of each treatment was increased with the concentration increasing at level of added K from 400 to 4000 mg·kg^{-1}. Among the chemical fertilizer treatments, K-fixation amount of NPK treatment was 209.3~1101.9 mg·kg^{-1}, the N and NP were 243.2~1428.8 mg·kg^{-1} and 250.9~1476.6 mg·kg^{-1} respectively.

Fig. 2 reflected the mean of K-fixation amount in different concentration of added K. Analysis of variance showed the NP and NPK were significantly higher than CK, and NP's mean of K-fixation was 69.3 mg·kg^{-1} more than CK, and the NPK was 156.5 mg·kg^{-1} less than CK. The results showed long-term application of potassic reduced amount of fixed K, and long-term no potassic application increased the K-fixation when using chemical fertilizer alone.

Application of manure (M_1, M_2) Amount of K-fixation were 206.7~1131.7 mg·kg^{-1} and 142.6~867.4 mg·kg^{-1} respectively. Compared with CK, both M_1 and M_2 were significantly lower, less than 136.9 mg·kg^{-1} and 212.2 mg·kg^{-1}, respectively. In conclusion, application manure resulted in a decrease in K fixation, and the K fixation dropping more along with the increasing application amount.

K fixation of manure and chemical fertilizer (M_2N、M_2NP and M_2NPK) were 182.9~1004.6 mg·kg^{-1}, 200.6~1057.9 mg·kg^{-1}, and 127.5~741.4 mg·kg^{-1}, respectively. Means of these treatments were lower than CK. Among three treatments, the M_2NPK fixed the least K. There was a good source of potassium in manure which could explain that K fixation was closely related to application rates of potassic, and the more potassic application, the less K fixation by soil.

Fig.3 showed the variation of K fixation rate of different fertilization. Combined with Fig.4, at level of added K from 400 to 4000 mg·kg^{-1}, K fixation rate of different fertilization showed the same trends such as the more added K, the K fixation rates were decreasing with increasing of added K. Among the treatments, K fixation rate of NP was highest at 62.7%~36.9%; however, the lowest was M_2NPK at 31.9%~18.5%. The change of K fixation rate was the same as K fixation amount such as K fixation rate with application of potassic was lower than no potassic, and which showed that long-term fertilization of potassic resulted in decreasing the K fixation rate.

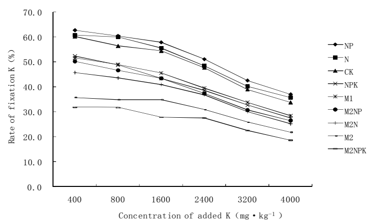

Fig. 3 Rate of K fixation in different treatments under long-term fertilization

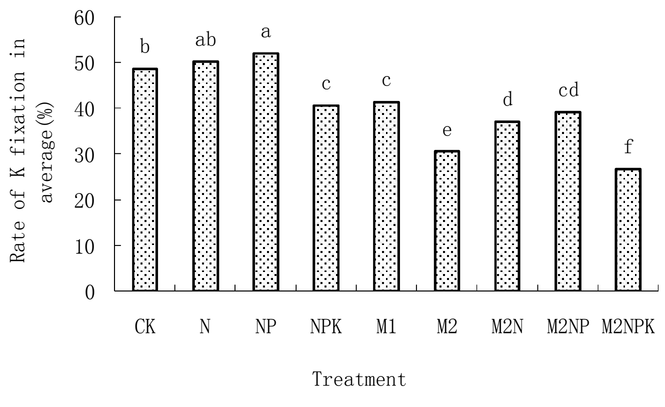

Fig. 4 Rate of K fixation in average in different treatments under long-term fertilization

4. Conclusion

Amount of K fixation were increased, and the K fixation rate decreased along with the concentration of added K raised range from 400 to 4000 mg·kg^{-1} after 32 years long-term fertilization. K fixation capacity of brown soil had changed under long-term fertilization, such as: K fixation capacity of potassium fertilizer application decreased, however the non-potassium fertilization increased among the treatments of single application of chemical fertilizer; K fixation capacity of organic fertilizer application all decreased. Potassium rate and fixation-release of potassium character in soil should be taken into comprehensive consideration for rational fertilization to maintain or improve soil fertility for increasing potassium fertilizers efficiency in agriculture.

Acknowledgments
This work was financially supported by National Key Research and Development Program of China (2016YFD0200105) (2017YFD0300702)

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