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Response of soil aggregate-associated potassium to long-term fertilization in red soil

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ABSTRACT

Potassium (K) deficiency is commonly observed during crops grown in the red soil (which is a typical Plinthosol based on the IUSS guidelines) of China, but few studies have examined soil aggregate-associated K. In a long-term field experiment (initiated in 1986), the following treatments were applied: no fertilizer (CK), nitrogen and phosphorus fertilizers (NP), NP and K fertilizers (NPK) and a combination of manure and NPK (NPKM). After 30 years of fertilization, the nonexchangeable K (Nonex-K), and exchangeable K (Ex-K) contents or stocks in most aggregates varied among different treatments. Compared with NP treatment, the Nonex-K contents in the aggregate fractions of > 2-, 1–2-, 0.5–1-, 0.25–0.5- and 0.053–0.25-mm under NPKM treatment were increased by 40.57%, 40.78%, 42.71%, 40.82% and 55.43%, respectively. The Nonex-K contents in 0.5–1-, 0.25–0.5-, 0.053–0.25- and < 0.053-mm aggregates of the NPK treatment were 29.17%, 31.63%, 43.48% and 35.42% higher than those of the NP treatment, respectively. The Ex-K contents in all aggregates of the NPKM treatment were significantly ($p < 0.05$) higher than those of the other treatments (CK, NP and NPK). Compared with the NP treatment, the Ex-K contents in 1–2-, 0.5–1-, 0.25–0.5- and 0.053–0.25-mm aggregates of NPKM treatment were significantly increased by 30.30%, 32.65%, 33.67% and 33.33%, respectively. Moreover, the Ex-K stocks in the > 2-, 1–2-, 0.5–1- and 0.053–0.25-mm aggregates of NPKM treatment were significantly increased by 74.36%, 123.63%, 44.88% and 37.47%, respectively, compared with those of the NPK treatment. Furthermore, a random forest model showed that K stocks in the > 2-, 1–2- and 0.5–1-mm aggregates were the main factors affecting the uptake of K by maize. The relationships between the uptake of K by maize and K stocks in the > 2-, 1–2- and 0.5–1-mm aggregates could be fitted by linear equations. Therefore, the long-term combination of chemical fertilizers with manure improved K contents and stocks for most aggregate sizes in red soil, especially Ex-K. We found that the turnover rate of K in the > 2-mm aggregates was faster than in the other aggregates (1–2- and 0.5–1-mm) through slopes of linear regressions, allowing the soil to meet the requirements for crop K uptake.

1. Introduction

Potassium (K) is a primary nutrient element for plant growth (Römheld and Kirkby, 2010). Soil total K (TK) is found in the following four different forms, which are obtained using different extraction methods (Sparks, 1987): water-extractable K, exchangeable K (Ex-K, K extracted with 1 mol·L^{-1} NH_4OAC solution), non-exchangeable K (Nonex-K, K extracted with 1 mol·L^{-1} hot HNO_3 subtracted the Ex-K), and structural K (water-extractable K, Ex-K and Nonex-K were subtracted from the TK). In general, soil contains a small fraction of water-extractable K that is readily available to plants, whereas Nonex-K is slowly or only potentially available to plants (Pal et al., 1999; Jalali and Zarabi, 2006).

In southern China, soil K deficiency is a common phenomenon in red soil, which is a typical Plinthosol, based on IUSS guidelines (IUSS, 2006). Thus, K fertilizer application is necessary for attaining a high

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