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Yield and potassium use efficiency of cotton with wheat straw incorporation and potassium fertilization on soils with various conditions in the wheat–cotton rotation system

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ABSTRACT

Potassium (K) deficiencies have occurred increasingly in cotton due to increased use of nitrogen (N) and phosphate (P) fertilizers and high yielding varieties in China. Crop residue retention can improve soil K concentration, however, the replacement effects of K fertilizer by various wheat straw incorporation rates in different soil textures were seldom reported. As a result, the effects of wheat straw incorporation and K fertilization rates on cotton yield and K use efficiency in the wheat–cotton rotation system were studied for 3 years at two sites (Nanjing and Dafeng) in the down reaches of Yangtze River in China. Compared with control, the lint yields after applying wheat straw and K fertilizer were improved by 102.4–143.5% and 44.2–144.3% at Nanjing in 2012 and 2013, respectively, and by 33.7–42.3% at Dafeng in 2013. There was no significant difference between treatments in lint yield at Dafeng in 2012. Potassium source (from wheat straw or inorganic K fertilizer) had no significant effect on lint yield and yield components. Soil available K concentration and K uptake by cotton were significantly affected by K input (wheat straw or K fertilizer). Potassium use efficiencies were typically higher in fields with wheat straw incorporation than with K fertilization. Potassium replacement amounts by wheat straw (9000 kg ha^{-1}) were above 150 kg K_2O ha^{-1} of inorganic K fertilizer when the soil available K concentration before cotton transplantation was above 125 mg kg^{-1} and about 115 kg K_2O ha^{-1} when soil available K concentration was below 125 mg kg^{-1} at Nanjing. Moreover, K replacement effect by wheat straw was non-significant at Dafeng because of high soil available K concentration. In conclusion, K release from wheat straw can at least partly, even totally, replace chemical potash according to soil available K concentration in actual cotton production.

1. Introduction

In China, one-third of cultivated land is used for multiple cropping. The wheat–cotton rotation system is a major component of multiple cropping on the main cotton producing regions namely the Yellow River Valley and the Yangtze River Valley in China (Zhang et al., 2007), the benefits of which contain low risks of crop failure, high total yield and resource use efficiency, etc. (Zhang and Li, 2003; Zhang et al., 2007; Du et al., 2015).

With the addition of N ad P fertilizer applications, prevention techniques against insect and higher-yielding crop varieties, K deficiencies have become widespread (Jin, 1997; Oosterhuis, 2002; Wang et al., 2008; Liu et al., 2009; Dong et al., 2010). Compared with most other field crops including wheat, cotton is considered to be inefficient at obtaining K from the soil and more sensitive to K deficiencies which occur more frequently and with greater intensity (Mullins and Burmester, 2010).

World reserves and resources of potash are extensive, however, the potash reserves of China are penurious (Roberts and Stewart, 2002). Subsequently, China imports a large quantity of K fertilizers every year, which is costly (Sheldrick et al., 2003). While the output of straw in China is estimated at 6×10^8 t per year (Cao et al., 2008). As an important renewable resource, straw contains abundant C, N, P and K (Singh et al., 2004). Potassium exists as K^+ in the cells or tissues in plants and can be extracted by water easily. Potassium cumulative release rates of crop straw were 91.98–96.24% after 90 days past incorporation, while those of C, N and P were 48.29–66.55%, 48.35–67.49% and 54.83–75.46%, respectively, calculated by different cultivation models (Wu et al., 2011). Unfortunately, farmers incline to choose a convenient way

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to burn straw in order to save time to transplant the next crop. About 23% of crop straw in China has been openly burnt in field (Cao et al., 2008), and only 16.2% of straw is recycled in field (Zeng et al., 2007). Burning the straw reduces the organic matter which could be incorporated and results in a waste of resource and atmospheric pollution (Cao et al., 2008).

Several studies have been conducted to determine the effect of crop straw incorporation on cotton yield (Daniel et al., 1999; Nyakatawa et al., 2000; Jalota et al., 2008). Among six treatments with varied winter cover crops, Daniel et al. (1999) reported that cotton lint yield differed among winter cover crop treatments in 1995, but in 1996 no cover crop treatment effects were observed. In southeastern USA, the treatment with winter rye cover and poultry litter to cotton field under no-till system promoted early seeding emergence, good plant growth, and high lint yield (Nyakatawa et al., 2000). In the cotton-wheat cropping system, tillage + wheat straw was found to significantly increase seed cotton yield than that in minimum tillage treatment by Jalota et al. (2008). Additionally, most of researches on crop residue management were focused on soil organic matter (Soon and Lupwayi, 2012; Dai et al., 2013; Huang et al., 2013a,b; Su et al., 2014), water use efficiency (Zhang et al., 2008, 2013, 2014; Wang et al., 2011), nitrogen use efficiency (Fan et al., 2005; Xu et al., 2010; Huang et al., 2013a,b; Yuan et al., 2014), tillage technologies (Gürsoy et al., 2010; Xu et al., 2010; Wang et al., 2012), weed control (Döring et al., 2005; Olesen et al., 2007; Bunna et al., 2011; Dai et al., 2013), etc. Recently, Zhao et al. (2014) reported that straw return and K fertilization could increase soil K fertility, K input and crop yield in wheat-maize rotation system in north-central China. However, little is known about the influence of wheat straw incorporation without K fertilization on cotton yield, K uptake and K use efficiency under differing soil conditions.

With the increasing price in chemical K fertilizer, low straw incorporation rate and the sensitivity of K deficiency in cotton, it is necessary to find a way to substitute part or all of inorganic K in order to lessen the relaying on chemical K fertilizer. The objective of this research was to investigate the effects of inorganic K fertilizer and wheat straw (organic K) on soil nutrient concentrations, cotton K uptake, yield, and K use efficiency.

2. Materials and methods

2.1. Sites descriptions

The field experiments were conducted in Experimental Station of Jiangsu Academy of Agricultural Sciences in Nanjing (32°20′ N and 118°52′ E), and Dafeng Basic Seed Farm in Dafeng (33°24′ N and 120°34′ E), Jiangsu from 2011 to 2013. The two test sites are all located in the down reaches of Yangtze River in China and different in their soil texture and fertility. The soil at Nanjing is clay loam, while the soil at Dafeng is sandy loam. The physicochemical properties of soil samples at 0–20 cm depth of the both sites were determined in June 2011 before cotton transplantation (Table 1). The pH of the clay loam soil was slightly acidic (pH = 5.7) and the sandy loam was slightly alkaline (pH = 7.9). The clay loam had lower SOC, TN, available P and available K, especially available K, than the sandy loam, thus the field at Dafeng was considered as more fertile than that at Nanjing.

2.2. Experiment design

Siza 3, a widely-planted commercial cotton variety with early maturity and high-yield in the reaches of Yangtze River Valley in China, and Ningmai 13 and Yangmai 16, two different wheat

Table 1
Physical and chemical properties of soils at both experimental sites in 2011.

Site	Clay (%)	Silt (%)	Sand (%)	pH (H_2O)	SOC ($g\,kg^{-1}$)	WSOC ($mg\,kg^{-1}$)	TN ($g\,kg^{-1}$)	Av-N ($mg\,kg^{-1}$)	Av-P ($mg\,kg^{-1}$)	Av-K ($mg\,kg^{-1}$)	Av-S ($mg\,kg^{-1}$)
Nanjing	29.5	49.0	21.5	5.7	9.5	42.2	0.90	24.2	15.1	154.6	33.5
Dafeng	6.8	36.2	57.0	7.9	12.1	48.2	1.18	26.4	22.2	316.4	34.6

SOC: soil organic carbon; WSOC: water-soluble organic carbon; TN: soil total nitrogen; Av-N: soil available nitrogen; Av-P: soil available phosphor; Av-K: soil available potassium; Av-S: soil available sulfur.