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Synchronized relationships between nitrogen release of controlled release nitrogen fertilizers and nitrogen requirements of cotton

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A B S T R A C T

Controlled release nitrogen fertilizer (CRNF) has been shown to increase yield of crops and improve the nitrogen (N) use efficiency of fertilizer in a number of production systems. However, the synchronized relationships between N release of CRNF and N requirements of cotton were rarely studied. In the present study, the effects of two CRNF including polymer coated urea (PCU) and polymer coating of sulfur-coated urea (PSCU) on yield and nutrients uptake of cotton were investigated under field conditions in 2012 and 2013. The results indicated that the successive release rate of N from CRNF corresponded well to the N requirements of cotton plants. In addition, significant linear correlations between N release rate of CRNF and N requirements of cotton were observed during the whole growth periods of cotton. Moreover, the release rate showed significantly positive correlations with cotton yield, soil inorganic N content, N use efficiency, total N uptake and biomass of aboveground. The seed cotton yields in treatments which applied PCU and PSCU once were increased by 14.81–18.15% compared with U1 (urea applied as basal fertilizer). However, there was no significant difference between CRNF and U2 (twice-split applications of urea fertilizer). Although the numbers of bolls and lint percentage were not significantly enhanced by using CRNF, the boll weight was 3.63–11.51% higher than that in urea treatments. In addition, the N uptake and N use efficiency of cotton plant were improved by CRNF compared to the urea treatments. The inorganic N content supplied by soil was also enhanced by using CRNF, especially from full bloom stage to initial boll-opening stage. The results suggest that the release rate curves of CRNF were ideal patterns which could synchronize N release with N requirements pattern of cotton. In addition, it could be economical and eco-friendly and widely used for cotton production.

1. Introduction

Numerous fertilizer experiments implied that the yield of agricultural crops have been strongly depended on the supply of mineral nutrients, especially N, which has been widely used in crop cultivation (Khan, 1996). Chemical fertilizer is the important way to replenish nutrition, and also the basis of cotton production. Increasing the N fertilizer applications has been a major measurement which significantly contributes to the improvement of crop yield (Guo et al., 2010). However, the N use efficiency (NUE) of fertilizer is very low that with an average of 27.15% in China (Zhang et al., 2008). Large amounts of external N inputs and the improper ways of fertilization resulted in a low NUE. Moreover, it caused serious soil degradation, groundwater pollution, emission of ammonia and greenhouse gases (Galloway, 1998; Hanafi et al., 2000; Spiertz, 2010). Therefore, making the optimization of N application (amount and time) to meet crop N requirement is the key approach to increase crop yield and NUE and to protect agricultural environment (Fang et al., 2006).

Cotton growth needs nutrients supplied continuously but plants absorb nutrients differently in quantity and speed during growth periods, because they assimilate critical nutrients in different periods (Xue et al., 2008). Nitrogen is required more consistently and larger amounts than other nutrients for cotton production (Hou et al., 2007), and proper application of N fertilizers has been con-

Abbreviations: CRNF, controlled release nitrogen fertilizer; PSCU, polymer coating of sulfur-coated urea; PCU, polymer coated urea; U, urea; CK, a controlled treatment with no nitrogen fertilizer; U1, urea applied as basal fertilizer; U2, twice-split applications of urea fertilizer, with 40% before sowing seeds and with 60% at the first bloom stage.

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Table 1
Some properties of tested soil before cotton planting.

Year	pH Value	Organic matter ($g\,kg^{-1}$)	Total N ($g\,kg^{-1}$)	NO_3^--N ($mg\,kg^{-1}$)	NH_4^+-N ($mg\,kg^{-1}$)	Available P ($mg\,kg^{-1}$)	Available K ($mg\,kg^{-1}$)	Clay (%)	Sand (%)	Silt (%)
2012	7.90	16.30	0.98	32.30	23.08	48.04	204.80	14.35	9.55	76.10
2013	7.85	14.50	0.85	28.20	20.50	26.54	186.23	12.74	9.03	78.23

sidered as one of the most important measures to improve the lint yield of cotton (Dong et al., 2012). Especially fruiting structures (bolls) have a high requirement for N, and N-sufficient cotton extend the boll setting periods and increase the total boll numbers (Gerik et al., 1998). Hu et al. (2011) studied the characteristics of N accumulation of cotton during the whole growth periods, and then found the maximum absorption period of N was appeared from late square-early bloom to bolling stage. On the other hand, the excessive N supply will be not beneficial to increase the yield of cotton, because it makes vegetative growth excessively (McConnell et al., 1996). Moreover, some researches indicated biomass accumulation could also be altered by fertilization frequency at the same fertilizer rate (Shah, 2008). Although one-time fertilization at the first bloom stage shortened the cotton seedling period, the flowering and boll-setting period were extended without changing the total growth period than split fertilization (Yang et al., 2011a, 2012a). Yeates et al. (2010) showed that more N fertilization in full bloom stage extended the boll period. However, split application of fertilizer was more costly than one-time fertilization, which reduced the profit from cotton planting (Knowles et al., 1994). Therefore, it is imperative to develop new fertilizers that are low cost, high N use efficiency and convenient application.

Recently, the use of CRNF has become a new trend to save fertilizer consumption duo to the great potential for enhancing fertilizer use efficiency (Jat et al., 2012), reducing environmental pollution (Shaviv and Mikkelsen, 1993; Kiran et al., 2010) and labor/time-saving (Zebarth et al., 2009; Ye et al., 2013). Some researches indicated the yield of cotton increased by 12.38–34.51% by using CRNF compared with common urea treatment (Li et al., 2007; Wang et al., 2013). The fiber strength, length and maturity were also enhanced by using CRNF compare to urea fertilizer (Li et al., 2011). However, it is crucial to develop CRNF which can synchronize nutrient release rate with the crop's requirement pattern in natural field (Yang et al., 2011b).

Most researches were focused on the yield and fiber quality of cotton which used CRNF, but the synchronized relationships between nutrient release rate of CRNF and nutrient requirements of cotton were rarely reported. Therefore, the accumulative release rate of CRNF in water and soil, the change of soil inorganic N content and the dynamics changes of N uptake by cotton plant were investigated in the present study. The objectives of this study were: (i) to explore whether it is possible to synchronize the N release pattern from CRNF with N uptake pattern of cotton; (ii) to compare laboratory and field methods for determining nutrient release rates of CRNF; (iii) to investigate the effects of PCU and PSCU on cotton yield and N use efficiency. This can then be provided scientific basis for CRNF technology innovation and high efficient economic application.

2. Material and methods

2.1. Experimental materials

The experiments were performed during two cotton growing seasons (2012–2013) using the cotton cultivar 'Guoxin 3' which is sensitive to N fertilizer in a soil of Calcaric Ochri-aquic Cambosols. The soil texture was silt loam. The experiment sites were selected at Dezhou, Shandong Province (N37°26′18″, E116°22′30″) in 2012 and Hengshui, Hebei Province (N37°32′14″, E115°28′59″) in 2013, respectively. Basic properties of top soil (0–20 cm) are as described in Table 1. This region has a typically warm, temperate and monsoon climate, which is very suitable for cotton cultivation.

Two typical CRNF used in the study were polymer coating of sulfur-coated urea (PSCU, 35% N, the longevity was 3 months) and polymer coated urea (PCU, 43% N, the longevity was 4 months) provided by Kingenta Ecological Engineering Co., Ltd., China. Other three conventional fertilizers were urea (46% N) as N fertilizer, superphosphate (16% P_2O_5) as P fertilizer, and potassium chloride (60% K_2O) as K fertilizer, respectively.

2.2. Experimental design and field management

There were 5 treatments with triple replicates in the present experiment: no N fertilizer (CK); urea used as basal fertilization one time before sowing seeds (U1); urea used as twice-split fertilization, 40% at preplant and 60% at the first bloom stage (U2); PCU used as basal fertilization one time before sowing seeds (PCU); PSCU used as basal fertilization once before sowing seeds (PSCU). All treatments were measured with same field management and with an application rate of 180–150–210 (N–P_2O_5–K_2O) kg ha^{-1}.

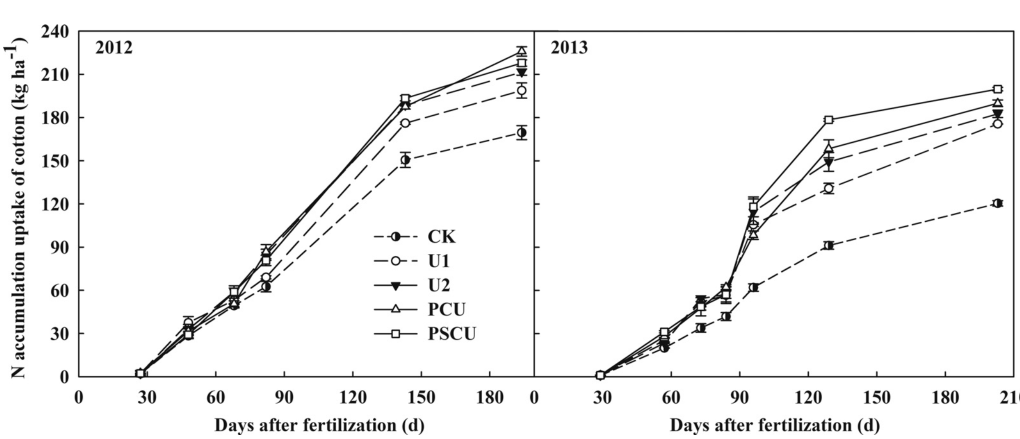

Fig. 1. Cumulative N uptake of cotton plant at different ontogenic stages under different treatments during the 2012 and 2013 growing seasons.