

# Effects of controlled-release urea application on the growth, yield and nitrogen recovery efficiency of cotton

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## ABSTRACT

Field experiments were conducted to study the effects of the controlled release urea (CRU) application on growth yield and nitrogen recovery efficiency of cotton in the main cotton zone of the Yangtze River basin in 2010. Different nitrogen levels were set in order to determine the suitable dosage of CRU on cotton. The special purpose was to provide evidence for the CRU application in cotton fields. The results show that the application of CRU promotes the growth of cotton significantly and enhances the nitrogen supply in the whole period. Compared to the treatment with total N as base fertilizer (UB), the bud, flower, little bolls and total bolls are increased significantly. There are no significant differences in the yield between the CRU treatment and the treatment of controlled release urea and urea combined application (60%CRU + 40%U), but an increase by 12.38% - 22.67% compared to the UB treatment, and an increase by 4.49% - 7.23% compared to the treatments of total N split application (UD). The nitrogen uptake of CRU treatment was significantly increased by 13.01% - 48.32% and 30.27% - 13.01% than UB treatment and UD treatment, respectively. The nutrient recovery efficiency of CRU treatment is increased by 16.42 - 20.59, 5.92 - 11.29 and 4.22 - 12.59 percentage points compared to the UB treatment, UD treatment and 60%CRU + 40%U treatment, respectively. In this study, there was a good linearity relationship

between the cotton yield and amount of CRU in Wuxue site. The yield of cotton response to amount of CRU could be described by the model of linear plus plateau in Jingzhou site.

**Keywords:** Controlled Release Urea; Cotton; Yield; Nitrogen Recovery Efficiency

## 1. INTRODUCTION

Slow/controlled release fertilizer nutrient release rate was accordant with plant nutrient absorption. One-off fertilization can satisfy the need of crops throughout the growing season [1]. Cotton is one of the important economic crops in China and a quarter of the world's annual cotton production is from China. China has been the main cotton production country. The cotton growth would be influenced by the varieties of genetic characteristics, environmental conditions and the common cultural practices and many other factors. Reasonable fertilization is an important measure to improve the cotton yield and quality. The nitrogen plays a decisive role in almost all the cotton growth processes [2]. Appropriate N application can promote the cotton growth and development and make the relationships among the leaf-buds-bell system more coordinated [3] for cotton with high yield [4]. Unreasonable nitrogen application leads to the disorder of cotton growth, over growing or earlier senescence, and seriously affects the yield and quality of cotton [5-7].

The economic benefit of cotton is high, so fertilizer inputs per unit area are much higher than general field crops. Nitrogen fertilizer proportion is the largest in any of fertilizer inputs, about 60% [8]. With the development

of science and technology, the application of controlled release fertilizer in agricultural production is becoming more and more widely. Researches at home and abroad show that slow/controlled release fertilizer fertilization can significantly improve rice [9-11], wheat [12-14], corn [15,16] and other crops yield and fertilizer use efficiency, reduce the amount of fertilizer and the labor costs, and so on; but little research has been done on the fertilization of cotton. Therefore exploring the feasible nitrogen fertilizer management mode is of great significance that can improve the cotton yield and nitrogen use efficiency, and reduce labor costs and the environmental pollution, by studying the effect of controlled release urea application on developmental growth characteristics, yield of the cotton and fertilizer use efficiency, and exploring the application effect and optimum amount of the CRU on the cotton, in order to provide the theory basis for popularization and application of CRU on cotton.

## 2. MATERIALS AND METHODS

### 2.1. Experiments Condition

The tested materials (CRU) was provided by Agrium Advanced technologies (N44%). The preliminary solubility rate of nitrogen of organic polymer coating controlled release urea is 1.7% and the release duration was 50 d in soil. Two field experiments on the effect of controlled release urea application on cotton were conducted by Nutrient Management Group, College of Resources and Environment, Huazhong Agricultural University from April 2010 to December 2010. The field experiment sites were in Wuxue city (E 115°55'464", N 29°85'23") and Jingzhou city (E 112°15'34", N 30°26'73"), Hubei province, respectively. Physical and chemical properties of the soils were listed in **Table 1**.

### 2.2. Experiment Method

#### 2.2.1. Fertilization Effect

The experiment was designed five treatments, (1) No N fertilizer (-N), (2) The treatment with total N as base fertilizer (UB); (3) The treatments of total N split application (UD); (4) The controlled release urea as base fertilizer (CRU); (5) The combined application of CRU and Urea (60%CRU + 40%U). Nitrogen treatment during whole growth period of N amount is 300 kg/hm<sup>2</sup>. And nitrogen was applied as base fertilizer except the treatment of total N application (30%-20%-30%-20%). The content of total apply fertilizer of each treatment was P<sub>2</sub>O<sub>5</sub> 90 kg/hm<sup>2</sup>, K<sub>2</sub>O 180 kg/hm<sup>2</sup> and borax 15 kg/hm<sup>2</sup>. All phosphorus, potash and borax was applied as base fertilizer Fertilizer varieties was common urea (N 46%), calcium superphosphate (P<sub>2</sub>O<sub>5</sub> 12%), potassium sulfate (K<sub>2</sub>O 60%), borax (B 12%), and CRU (N 44%), respectively.

The area of each plot was 20 m<sup>2</sup> with randomized blocks and three repetitions in this test. The variety of cotton in Wuxue site is EK288. The basal fertilizers were applied on May 27, 2010. Cotton was transplanted on May 29, and transplanting density was 24,000 plant/hm<sup>2</sup>. The variety of cotton in Jingzhou site is hybrid cotton 27F1. The seeds were sown on Apr. 16, 2010. Cotton seedlings were transplanted on May 10, and transplanting density was 21,000 plant/hm<sup>2</sup>. Other management measures like farmers in habit.

#### 2.2.2. Optimum Rate of CRU Application

The experiment was designed five treatments, (1) No N fertilizer (-N), (2) CRU 150 kg N/hm<sup>2</sup>, (3) CRU 225 kg N/hm<sup>2</sup>, (4) CRU 300 kg N/hm<sup>2</sup>, (5) CRU 375 kg N/hm<sup>2</sup>. All CRU was applied one time as base fertilizer and three repetitions in this test. Other fertilization and management measures was the same as method 2.2.1 described before.

### 2.3. Analysis and Determination Methods

**Growth indexes:** Investigate the cotton plant height, branch number, buds number, flowers number, little bolls, farming bolls, falling bolls and the total bolls in Wuxue (Sep. 15, 106 days after transplanting) and Jingzhou (Sep. 9, 120 days after transplanting) sites.

**Nutrient content:** Two plants were harvested random from the two sites on Sep. 15 (Wuxue) and Sep. 9 (Jingzhou). The plants were separated into root, stalk, leave, boll hull and cotton fibre, and then weighed after air-drying. Plants samples from each treatment were analyzed for N content [17].

**Nitrogen Use Efficiency (RE) (%) =** (N uptake of N treatment – N uptake of N deficiency treatment)/amount of N fertilize × 100.

**Agronomic N efficiency (AUE) (kg/kg) =** (yield N treatment – yield N deficiency treatment)/amount of N fertilizer.

## 3. RESULTS

### 3.1. Effect of CRU and Urea Application on Growth Indicators of Cotton

The effect of controlled release urea (CRU) and common urea application on growth indicators of cotton was analyzed in **Table 2**. Nitrogen application significantly increased the cotton plant height. The plant height of nitrogen application treatment increased by 12.00% - 34.67% compared to the no nitrogen fertilizer treatment (-N). The number of fruit branch, buds, flowers, little bolls, forming bolls and total bolls of nitrogen application treatment increased by 14.23%, 47.59%, 89.29%, 57.41%, 48.7 %, 17.73% and 31.88%, respectively, and the number of falling bolls has increased by 19.63% on

**Table 1.** Physical and chemical properties of the soils.

Trial site	pH	OM (g/kg)	Total N (g/kg)	Avail. N (mg/kg)	Avail. P (mg/kg)	Avail. K (mg/kg)
Wuxue	6.57	35.6	1.52	115.3	17.8	95.4
Jingzhou	5.62	32.4	1.23	110.1	17.7	131.7

**Table 2.** Effect of CRU and common urea application on growth indicators of cotton.

Site	Treatment	Height (cm)	Fruit branch	Bud	Flower	Little bolls	Forming bolls	Falling bolls	Total bolls	Rate of falling (%)
Wuxue	-N	121	16.4	7.3	0.7	7.0	22.9	45.0	82.9	49.9
	UD	144	17.6	11.2	1.4	8.5	34.7	47.0	102.8	45.7
	UB	139	17.9	9.3	0.9	6.9	26.1	47.6	90.8	46.5
	CRU	143	17.8	11.1	1.1	8.5	36.3	48.3	105.3	47.6
	60%CRU + 40%U	143	17.7	12.1	0.9	9.1	34.7	52.6	109.4	48.2
Jingzhou	-N	75	14.7	6.7	0.4	3.3	10.7	28.3	49.4	57.4
	UD	86	17.0	9.3	0.9	5.3	15.8	30.3	61.6	49.1
	UB	84	17.0	6.7	0.4	4.3	15.3	28.3	55.0	51.4
	CRU	101	19.0	13.0	1.2	10.7	20.3	47.0	92.2	51.0
	60%CRU + 40%U	93	17.7	10.0	1.1	5.7	14.3	38.0	69.1	55.0

Note: Forming bolls = green bolls + batt bolls, Falling = buds drop + flowers drop + bolls drop, Total bolls = bud + flower + little bolls + Forming bolls + falling.

average, but the average loss rate was reduced by 4.34%. There are no significant difference in plant height, fruit branch, forming bolls, falling bolls and the rate of falling between different nitrogen treatment, while the number of the total N split application treatments (UD), controlled release urea as base fertilizer treatment (CRU) and the combined application of CRU and urea treatment (60%CRU + 40%U) of buds, flowers, the little bolls and total bolls significantly increased by 19.35% - 94.03%, 0 - 200.00%, 23.19% - 148.84% and 12.00% - 67.64% compared with the treatment with total N as base fertilizer (UB). There are no significant difference in the number of buds, flowers, and little bolls among the treatment of UD, CRU and 60%CRU + 40%U, while the total bolls of CRU treatment increased by 49.68% and 33.43% compared with UD treatment and 60%CRU + 40%U treatment.

### 3.2. Effect of CRU and Urea Application on Yield and Agronomic Efficiency of Cotton

The effect of CRU and common urea application on yield and agronomic efficiency of cotton was analyzed in **Table 3**. Nitrogen application significantly increased the cotton yield. The yield of nitrogen application treatment increased by 34.9% - 69.5% compared to the -N treatment. The yield of UD treatment, CRU treatment and 60% CRU + 40% U treatment were significantly in-

creased by 7.56% - 22.67% than that of UB treatment. The yield of CRU treatment significantly increased by 4.49% - 7.23% than UD treatment. There are no significantly difference in the cotton yield between the 60%CRU + 40%U treatment and CRU treatment. The agronomy efficiency rule of different nitrogen application treatment show the same performance in two sites, as the CRU treatment > 60% CRU + 40% treatment ≥ UD treatment > UB treatment.

### 3.3. Effect of CRU and Urea Application on Nutrient Uptake and Recovery Efficiency of Cotton

Nitrogen uptake of different fertilizer treatments on cotton was analyzed, the **Table 4** show that nitrogen application significantly promoted the nitrogen uptake of cotton about 30.98% - 215.31% compared with the -N treatment. The N uptake of UD treatment, CRU treatment and 60% CRU + 40% treatment were significantly increased by 15.98% - 90.04% compared to the UB treatment. The N uptake of CRU treatment significantly increased by 13.01% and 52.03% compared to the UD treatment and 60% CRU + 40% U treatment, respectively. And the N uptake of the UD treatment is significantly increased by 34.53% than 60% CRU + 40% U treatment in Wuxue site. There are no significantly difference in N uptake between the CRU treatment and 60% CRU + 40% U treatment, while both of them were significantly increased

**Table 3.** Effect of CRU and common urea application on yield and agronomic efficiency of cotton.

Treatment	Wuxue				Jingzhou			
	Yield kg/hm <sup>2</sup>	Increase kg/hm <sup>2</sup>	Rate of increase%	AUE kg/kg N	Yield kg/hm <sup>2</sup>	Increase kg/hm <sup>2</sup>	Rate of increase%	AUE kg/kg N
-N	2932 d	-	-	-	2854 d	-	-	-
UD	4682 b	1750	59.7	5.8	4511 b	1657	58.1	5.5
UB	4353 c	1421	48.4	4.7	3850 c	996	34.9	3.3
CRU	4892 a	1960	66.9	6.5	4837 a	1983	69.5	6.6
60% CRU + 40% U	4716 ab	1784	60.8	5.9	4717 ab	1863	65.3	6.2

Note: Different letters at the same column mean significant differences at the 5% level.

**Table 4.** Effect of CRU and urea application on nutrient uptake and recovery efficiency of cotton.

Treatment	Amounts of N uptake (kg/hm <sup>2</sup> )		RE (%)	
	Wuxue	Jingzhou	Wuxue	Jingzhou
-N	66.78 e	32.98 c	-	-
UD	136.48 b	70.11 b	23.23	12.38
UB	87.47 d	54.72 b	8.56	7.25
CRU	154.23 a	103.99 a	29.15	23.67
60% CRU + 40% U	101.45 c	91.33 a	16.56	19.45

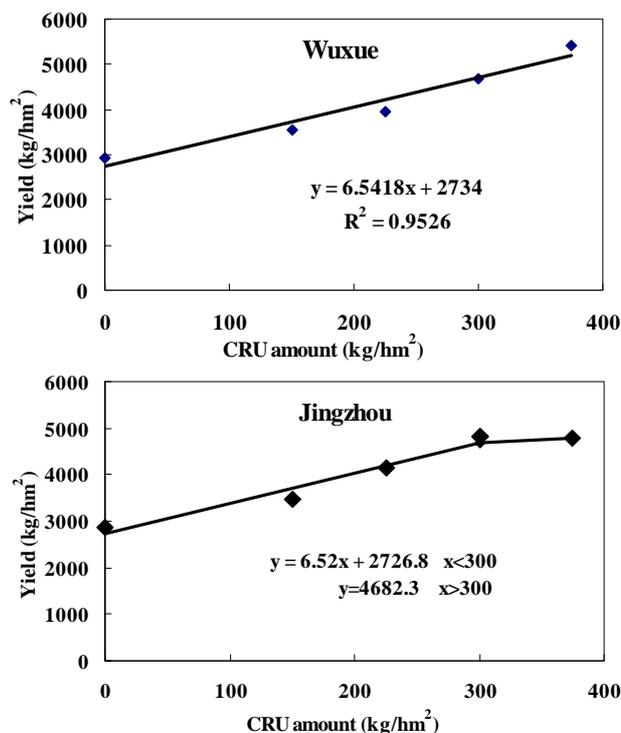
Note: Different letters at the same column mean significant differences at the 5% level.

by 48.32% and 30.27% than that of UD treatment in Jingzhou site, respectively.

Two sites show that the nitrogen use efficiency of the UB treatment was 8.56% and 7.25%, respectively, it was the lowest. The nitrogen use efficiency of the CRU treatment was 29.15% and 23.67%, respectively, and it was the highest, and increased by 20.59 percent and 16.42 percent than the UB treatment, increased by 5.92 - 11.29 percent than the UD treatment, increased by 4.22 - 12.59 percent than 60% CRU + 40% treatment. There are still inconsistencies in the law of the nitrogen use efficiency of the UD treatment and 60% CRU + 40% U treatment at two sites. The nitrogen use efficiency of the UD treatment was 6.67% higher than 60% CRU + 40% U treatment in Wuxue site, while the 60% CRU + 40% U treatment was 7.07% higher than UD treatment in Jingzhou site.

### 3.4. The Proper Dosage of CRU on Cotton

In **Figure 1** the CRU application significantly increased the yield of cotton by 21.30% - 84.35% compared to the -N treatment in Wuxue experiment site. There were a linear relation between the yield of cotton and the amount of CRU application. It indicated that improving the application amount of CRU can increase the yield of cotton. The CRU application also significantly increased the yield of cotton by 21.86% - 69.48% compared to the -N treatment in Jingzhou site. The significantly linear and platform correlation had been shown

**Figure 1.** Effect of CUR application on the yield of cotton.

between the yield of cotton and the amount of CRU application. When the amount of CRU application was less than 300 kg/hm<sup>2</sup>, the seed cotton yield increased with the amount of CRU, when the amount of CRU is larger than

300 kg/hm<sup>2</sup>, the cotton yield is tends to be stable 4682.3 kg/hm<sup>2</sup>.

#### 4. CONCLUSIONS AND DISCUSSIONS

Cotton is very sensitive to nitrogen, and nitrogen has important effect on cotton growth. Nitrogen fertilization can improve the cotton growth significantly in the test. The plant height, branch number, bud number, flower, little bolls, forming bolls and total bolls of the cotton were increased significantly after the nitrogen fertilizer application. The number of buds, flower, little bolls and total bolls of the controlled release urea as base fertilizer treatment, total N split application treatment and the combined application of CRU and urea treatment were obviously increased than the treatment with total N as base fertilizer, while there are no significantly difference in the number of buds, flower and little bolls among them. The outcome was the same as in the Lingli Li [18] study. The total bolls of the treatment of the controlled release urea as base fertilizer were increased significantly than both of the treatments of total N split application and the combined application of CRU and urea in Jingzhou site.

Nitrogen fertilization can significantly improve the yield of cotton. The treatment of controlled release urea as base fertilizer significantly increased the yield than the treatment of common urea as base fertilizer, slightly increased than the treatment of total N split application, while there are no significant differences in the yield between the treatment of CRU and the combined application of CRU and urea. The best amount of application of CRU was more than 375 kg/hm<sup>2</sup> at Wuxue site with high yield, while the best amount of application of CRU was 300 kg/hm<sup>2</sup> at Jingzhou site. The recommended dosages of CRU should be combined with the local cotton yield in different cotton.

The nitrogen uptake of CRU treatment is significantly increased by 13.01% - 48.32% compared to the treatment of total N split application, so the nutrient release of controlled release urea was more conducive to the absorption of nitrogen than the treatment of total N split application. There was no significantly difference in nitrogen uptake between the controlled release urea treatment and the total N split application treatment in Jingzhou site, while the nitrogen uptake of the CRU treatment increased by 52.03% compared to the total N split application treatment in Wuxue site. The nitrogen uptake of cotton was above the set point because of Wuxue site located in high cotton yield area.

The nitrogen use efficiency of the CRU treatment was 29.15% and 23.67%, respectively, and increased by 20.59 percent and 16.42 percent than the UB treatment, increased by 5.92 - 11.29 percent than the UD treatment, increased by 4.22 - 12.59 percent than 60% CRU + 40%

treatment. CRU fertilization decreases the time of fertilization and increases the nitrogen use efficiency and agronomic N efficiency. The nitrogen use efficiency is low in two sites, and may be associated with sampling time. The nutriment accumulation may be not the biggest stage of cotton when sampling. In addition, removing the vegetative shoot had led to the nutrient loss, so we compared the nitrogen use efficiency results of various fertilizer treatments during a specified period in this study.

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