Field Crops Research 212 (2017) 145–152

Contents lists available at ScienceDirect

Field Crops Research

journal homepage: www.elsevier.com/locate/fcr

Effects of polymer-coated potassium chloride on cotton yield, leaf senescence and soil potassium

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ARTICLE INFO

Keywords:
Cotton
Polymer coated potassium chloride
Yield
Fiber quality
Potassium use efficiency

ABSTRACT

Potassium (K) is one of the most important nutrients influencing plants, including cotton growth and metabolism. Because of toxicity from chloride ions, potassium sulfate (K_2SO_4) usually is used instead as a potassium fertilizer, especially for cotton, although it is lower in K_2O content and dearer than potassium chloride (KCl). The objective of this study was to investigate the effects of polymer-coated potassium chloride (PCPC) fertilization on cotton yields, yield components, fiber qualities, potassium use efficiencies and leaf senescence under saline conditions. A 2-yr field experiment was conducted in the Yellow River Delta of China with a high-yielding cotton cultivar ('Guoxin 99-1'). The experiment had the following six treatments with varying potassium fertilization: 70% PCPC mixed with 30% K_2SO_4 applied once before planting; PCPC applied once before planting; K_2SO_4 (KCl) applied twice with one application (40%) before planting and second application (60%) during first bloom stage; K_2SO_4 (KCl) applied once before planting; and fertilization none potassium as the control. The release rate of PCPC appeared to be slow before the squaring stage, but accelerated between the first bloom and boll-setting stages, and then decreased during the late stage including harvest. The number of cotton bolls was 8.99–19.71% higher and seed yields 4.39–28.10% higher, in 70% PCPC mixed with 30% K_2SO_4 treatment than in the other potassium fertilizer treatments. Also, the potassium recovery efficiency and net profits were increased by 3.38–40.90% and 5.77–137.26%, respectively, in the 70% PCPC mixed with 30% K_2SO_4 compared with the other potassium fertilizer treatments. Available soil potassium contents, fiber qualities and leaf photosynthetic indices were all significantly improved by using PCPC instead of the more standard potassium fertilizers. Hence, combining PCPC with K_2SO_4 at a 7:3 potassium ratio can delay leaf senescence, increase yields and fiber qualities, and improve potassium use efficiencies and economic benefits in cotton.

1. Introduction

Potassium (K) is a fundamental macronutrient important in plant growth and metabolism, such as maintaining ionic charge balances, cytoplasmic pH homeostasis, osmotic potential, and regulation of stomatal activity and translocation of photosynthates (Oosterhuis et al., 2014). Plants must acquire and use potassium efficiently for optimal growth and development. defined potassium use efficiency as the ability of plants to obtain relatively high yields or biomasses in the presence of low potassium supplies when compared with less efficient plants (Arif et al., 2010). Potassium deficiencies have been found to decrease cotton biomass production and yields (Zhao et al., 2001; Gormus, 2002; Dong et al., 2010) in addition to reducing photosynthesis and the quality of cotton fibers (Pettigrew et al., 2005; Oosterhuis et al., 2014). Potassium deficiencies have become more common in cotton, which have limited its production in China, because of decreasing availability of soil potassium caused by low potassium applications (Oosterhuis et al., 1994; Zhang et al., 2007). Preventing these deficiencies in cotton is therefore very important.

The world potash resources are extensive, but scarce in China (Roberts and Stewart, 2002). Here, three-fourths of paddy soils are deficient in potassium because of the limited supply and use of potassium fertilizers (Rengel and Damon, 2008), which has also become a limiting factor for Chinese cotton production (Zhang et al., 2007). Potassium fertilizers can be supplied to cotton plants by side-dress applications before planting and again in mid-season. In recent years, potassium deficiencies have markedly increased across 30 Chinese provinces, thus limiting crop growth and development, and threatening

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http://dx.doi.org/10.1016/j.fcr.2017.07.019
Received 22 June 2017; Received in revised form 25 July 2017; Accepted 26 July 2017

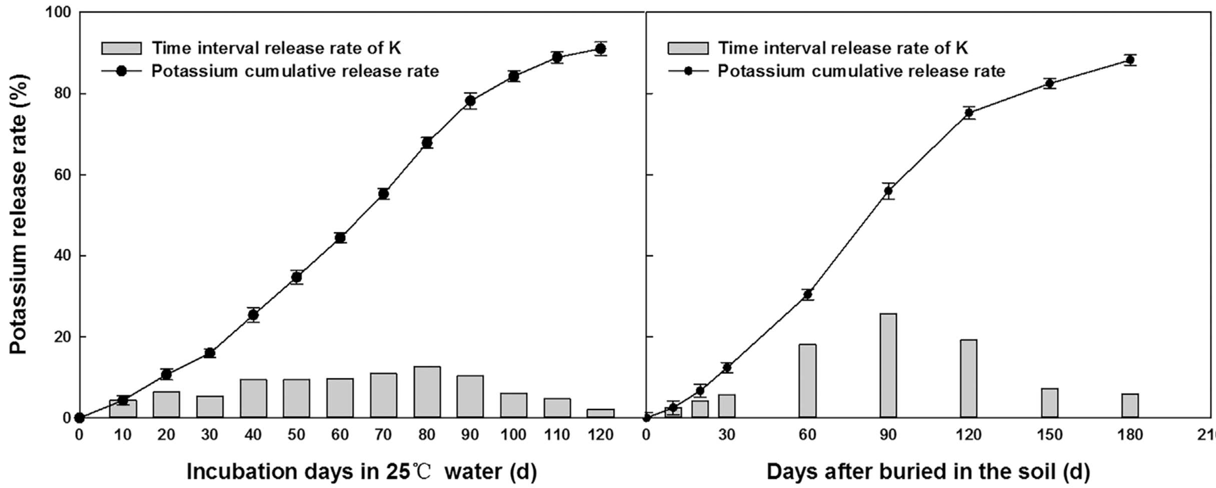

Fig. 1. Release of potassium from PCPC cumulatively and per time period in the field and in the laboratory(water, 25 °C)in 2016.

Table 1
Yield components and total yields for different potassium treatments in 2015 and 2016.

Treatments	2015					2016				
	Bolls	Boll weight	Seed cotton yield	Lint percentage	Lint yield	Bolls	Boll weight	Seed cotton yield	Lint percentage	Lint yield
	(no./m^2)	(g)	(kg ha^{-1})	(%)	(kg ha^{-1})	(no./m^2)	(g)	(kg ha^{-1})	(%)	(kg ha^{-1})
Control	59.5 f	5.10 f	2966.08 f	40.47 a	1200.38 f	60.1 f	5.06 f	3019.76 g	40.57 a	1225.10 g
BBF	76.9 a	5.74 a	4444.75 a	40.52 a	1801.04 a	77.6 a	5.84 a	4523.78 a	40.63 a	1837.91 a
PCPC	75.9 b	5.61 b	4257.98 b	40.50 a	1724.47 b	76.1 b	5.66 b	4308.04 b	40.61 a	1749.52 b
KS1	74.0 c	5.57 b	4054.07 c	40.50 a	1641.90 c	74.3 c	5.56 c	4115.28 c	40.61 a	1671.26 c
KS2	71.6 d	5.33 c	3803.45 d	40.34 a	1534.44 d	72.5 d	5.40 d	3883.85 d	40.59a	1576.34 d
KC1	71.5 d	5.24 d	3773.52 d	40.49 a	1527.83 d	72.1 de	5.27 d	3786.24 e	40.60 a	1537.07 e
KC2	69.9 e	5.13 e	3469.79 e	40.45 a	1403.48 e	71.2 e	5.25 e	3707.44 f	40.55 a	1503.57 f
Source of variance										
Year (Y)	0.0005**	0.0396*	< 0.0001**	0.0148*	< 0.0001**					
Treatment (T)	< 0.0001**	< 0.0001**	< 0.0001**	0.9073	< 0.0001**					
Y × T	0.6598	0.675	< 0.0001**	0.9854	0.0009**					

Note: Means followed by different lowercase letters in the same column were significantly different based on analyses with ANOVAs followed by Duncan tests ($P < 0.05$).

Table 2
Quality of cotton fiber from potassium treatments in 2016.

Treatment	Fiber length (mm)	Fiber uniformity (%)	Micronaire	Fiber elongation (%)	Fiber strength (cN tex^{-1})
Control	25.6 e	80.3 e	5.2 b	6.5 b	24.0 e
BBF	26.8 a	83.7 a	5.3 a	6.6 a	29.1 a
PCPC	26.7 ab	83.4 ab	5.3 a	6.6 a	28.7 ab
KS1	26.6 b	83.1 b	5.3 a	6.6 a	28.3 b
KS2	26.4 c	82.4 c	5.3 a	6.6 a	27.5 c
KC1	26.4 c	82.4 c	5.3 a	6.6 a	27.4 c
KC2	26.1 d	81.3 d	5.3 a	6.6 a	25.9 d

Note: Means followed by different lowercase letters in the same column were significantly different based on analyses with ANOVAs followed by Duncan tests ($P < 0.05$).

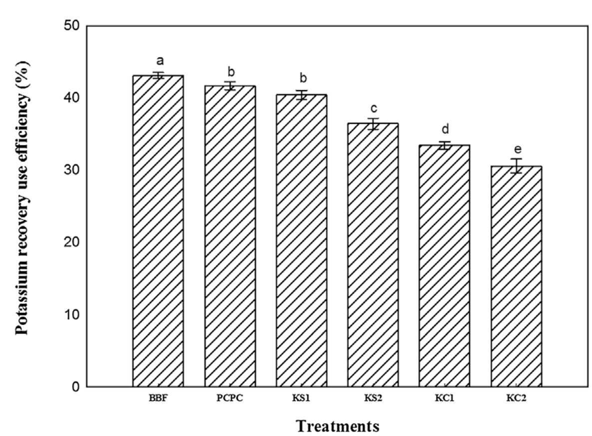

Fig. 2. Potassium recovery use efficiency per treatment, 2016.

future production of the crop in China (Hu et al., 2015). In China, the potassium fertilizers used mostly in agricultural production included potassium sulfate (K_2SO_4) and potassium chloride (KCl). Potassium chloride (KCl), a natural mineral mined from deep deposits, is the major source of potassium fertilizers in presently use. Nevertheless, K_2SO_4 without chloridion toxicity is also commercially available and used as a potassium fertilizer for cotton, although it is dearer and less available nutrient per unit than KCl (Zörb et al., 2014). More effort should be placed into optimizing potassium fertilizers input to meet the cotton crop requirements and to reduce production costs. However with market shortages, increasing prices, and probable environmental problems using inorganic potassium fertilizers, a strategy is needed to minimize the dependence on these compounds for cotton production (Yu et al., 2016).

Hence, a new potassium fertilizer named polymer coated potassium chloride (PCPC) is produced by the National Engineering Laboratory for Efficient Utilization of Soil and Fertilizer Resources in China, whose traits include reducing soil K fixation, enhancing supply capability of soil potassium, improving K use efficiency, and is easy to apply. Further