4R Potassium Management Practices for Cotton in Northern China

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Potassium fertilization is important for higher lint yield and better quality of cotton in northern China, but its application remains inadequate within the region. Research demonstrates a benefit to combined applications of preplant K used along with an in-season K topdressing. Fertilizer K source had little consistent impact on the agronomic response, but economics often governs source selection for the farmer. Banding at depth and drip fertigation can significantly improve K use efficiency where these placement options are available.

Cotton is the major fiber crop that is grown in 25 provinces of China, covering a total area of 5 million (M) ha and producing 6.5 M t of lint. In northern China, cotton is mainly planted in Xinjiang, Henan, Hebei, and Shandong and accounts for over 67% of the total area and production in China. Many farmers in northern China rely on cotton as their main cash crop.

Cotton requires more K than most other field crops. Potassium can improve plant photosynthesis, metabolism and resistance to diseases like anthocyanosis or "bronze-wilt" disease. Therefore, K fertilization plays an important role in improving lint yield and quality. Many studies (Pettigrew et al., 1996; Oosterhuis et al., 2014) have reported reduced fiber length, maturity and micronaire in cotton crops not adequately supplied with K. Despite this, fertilizer K is used in insufficient amounts in cotton production in northern China. Also, K is generally applied once before planting using compound fertilizer sources, and is rarely applied again during the growing season. This has led to lower cotton yields and poor fiber quality, which in turn, impacts farmer income. This review details how application of the 4R principles of nutrient stewardship for K application (i.e., applying fertilizer K using the right source at the right rate, right time, and right place) can often boost yields and improve cotton quality in northern China.

Right Source

There are many K fertilizer sources, but KCl and K_2SO_4 are widely used in northern China's cotton production. The source of K can often have little effect on the allocation of dry matter throughout the cotton plant, but economic differences between products commonly dictate source preferences. Sulfur containing sources such as K_2SO_4 is the preferred K fertilizer in S-deficient soils, and has a low salt index and non-hygroscopic characteristics.

Physical properties of K sources may also affect cotton yield and quality. For example, Wang et al. (2011) indicated that granular KCl could slowly release K to soil, which was better for cotton at later growth stages as it helped to reduce K leaching. Mid-season development of K deficiency in cotton often appears in northern China due to the high K demand during flowering, or following periods of high rainfall, particularly on sandy soils.

Abbreviations and notes: N = nitrogen; K = potassium; S = sulfur; Cl^- = chloride; KCl = potassium chloride; K_2SO_4 = potassium sulfate; KH_2PO_4 = potassium phosphate.

Table 1. Total plant K uptake by cotton plant to produce 1 t of cotton lint at various application rates of K in three provinces of northern China.

Hebei		Shandong		Xinjiang	
K applied, kg K_2O/ha	Total plant K uptake, kg K_2O/t	K applied, kg K_2O/ha	Total plant K uptake, kg K_2O/t	K applied, kg K_2O/ha	Total plant K uptake, kg K_2O/t
0	68	0	89	0	145
38	80	30	93	20	145
75	77	60	99	38	149
150	89	120	99	75	150
225	85	180	104	112	148
300	89	240	106	150	150

Regions with low rainfall or little irrigation have risks associated with possible over accumulation of Cl^- in the soil profile when using KCl. In these areas, excess Cl^- is not readily leached out of the surface soil and can contribute to soil salinity (Kafkafi et al., 2001). It is important to understand the Cl^- balance for a soil-crop system to determine the appropriate amount of KCl or ratio of KCl to K_2SO_4 when used together.

Right Rate

The total plant K uptake by cotton generally exceeds that of N and P. IPNI experiments in northern China show that cotton requires a total uptake of 68 to 150 kg K_2O/ha to produce 1 t of lint (**Table 1**). Cotton yield and the corresponding K uptake are commonly higher in Xinjiang than in Hebei or Shandong.

The K fertilizer requirement depends on the yield potential

Table 2. Effect of K application timings on cotton lint yield (kg/ha) in three provinces of China.

	Hebei		Shandong		Xinjiang	
Treatment	2012	2013	2012	2013	2012	2013
No K	1,430a	1,370c	1,490b*	1,190c	1,270c	1,530b
100% at planting	1,520a	1,430abc	1,610ab	1,280ab	1,440ab	1,810a
50% at planting, 50% at first flower	1,510a	1,440abc	1,670a	1,340a	1,500a	1,770a
50% at budding, 50% at boll forming	1,540a	1,550a	1,630a	1,230bc	1,520a	1,910a
50% at budding, 50% at boll opening	1,540a	1,510ab	1,620a	1,220bc	1,420b	1,770a
50% at first flower, 50% at boll opening	1,500a	1,400bc	1,570ab	1,210bc	1,380b	1,790a

*Different letters following numbers within columns indicate significant difference ($p < 0.05$)

Plots comparing K application timings in cotton grown in northern China.

and the soil K status. In soils containing moderate amount of K, maintenance of existing K supplies may be a suitable goal. For example, for a target yield of 1,500 kg/ha on a medium-K soil, the recommended K application rate would range from 104 to 225 kg K_2O/ha, which is about equal to the total plant K uptake when no crop residue is returned to the field. In some areas, the K application rate can be greatly reduced if the residues are returned since only 29 to 45 kg K_2O/ha is commonly removed through harvested lint and seed. In soils with low amounts of K, a common recommendation is to apply enough K to meet the immediate cotton crop need, while adding an additional amount to build soil K concentrations. In the high-K soils of Xinjiang, the K application rate can be somewhat reduced from the recommended maintenance rate, depending on fertilizer cost.

The yield response of cotton to KCl fertilizer varies according to local conditions (**Figure 1**). The optimum economic rates of KCl were calculated as 150, 212 and 136 kg K_2O/ha for cotton in Hebei, Shandong and Xinjiang with soil exchangeable K values of 89, 82 and 177 mg K/kg, respectively.

Right Time

IPNI research has indicated that maximum K uptake occurs between the flowering to boll-forming stages, which accounts for 50 to 60% of the total plant K uptake (**Figure 2**). While not significantly different from applying all K at planting, maximum cotton lint yield was obtained when 50% of the recommended K was applied at planting, and the remaining K topdressed at flowering or boll-forming stage (**Table 2**). Therefore, maintaining a sufficient supply of K during the later cotton growth stage is quite important for yield. This has been attributed to the rooting system of cotton, which is less dense than some other crops, and cotton root growth slows during the boll development period (Pearson and Lund, 1968).

Foliar application of KH_2PO_4 at later growth stages can increased boll number, boll weight, seed yield, lint yield, lint percentage, and promote normal growth and maturity (Wang et al., 2007). Split application of K_2SO_4 between planting and topdressing at early flowering is effective at increasing cotton yield, quality and K use efficiency (Li et al., 2012). Fu et al.

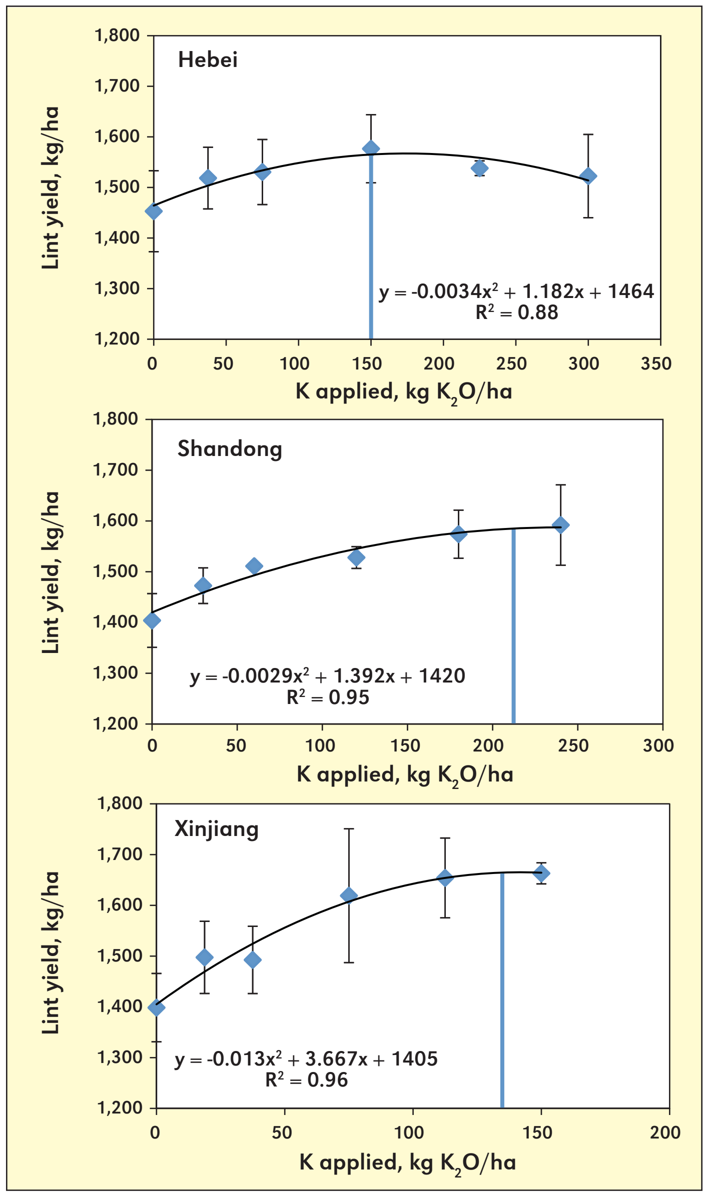

Figure 1. Relationships between fertilizer K rates and cotton lint yield in three provinces of North China.

(2013) and Xu (2013) found maximum seed cotton yield with 120 kg K_2O/ha in two similar split applications.

Right Place

Since cotton is a deep-rooted crop, K fertilizer is best placed at close proximity to this root mass for maximum benefit. Pre-plant application of K fertilizer should be incorporated 20 to 30 cm deep, while fertilizer K applied in-season can be banded 5 to 10 cm away from cotton plants. Cotton seedlings are very sensitive to Cl^- at concentrations of 100 to 200 mg Cl^-/kg of soil, so avoidance of placing KCl in the seed row is often recommended (Kafkafi et al., 2001).

In northern China's drip-irrigated cotton under plastic mulching, fertilizer K is applied with water. Other application methods like deep banding also improve K use efficiency and increase cotton yield. Adeli and Varco (2002) indicated that a combination of band and broadcast application of K fertilizer was more effective in increasing cotton lint yield than either method alone. Specifically, they reported a maximum lint yield with the application of 34 kg K/ha banded plus 136 kg K/ha broadcast.

Summary

This research review provides strong evidence that cotton requires an abundant supply of K, with fertilizer additions balanced between preplant application and an in-season topdress application. While fertilizer K source had little consistent impact on the agronomic response, more economic sources can increase returns to the farmer. Where fertilizer placement is an option, band application or drip fertigation can significantly improve K use efficiency. Careful consideration of K management based on 4R principles can support higher yield and quality in cotton. BC

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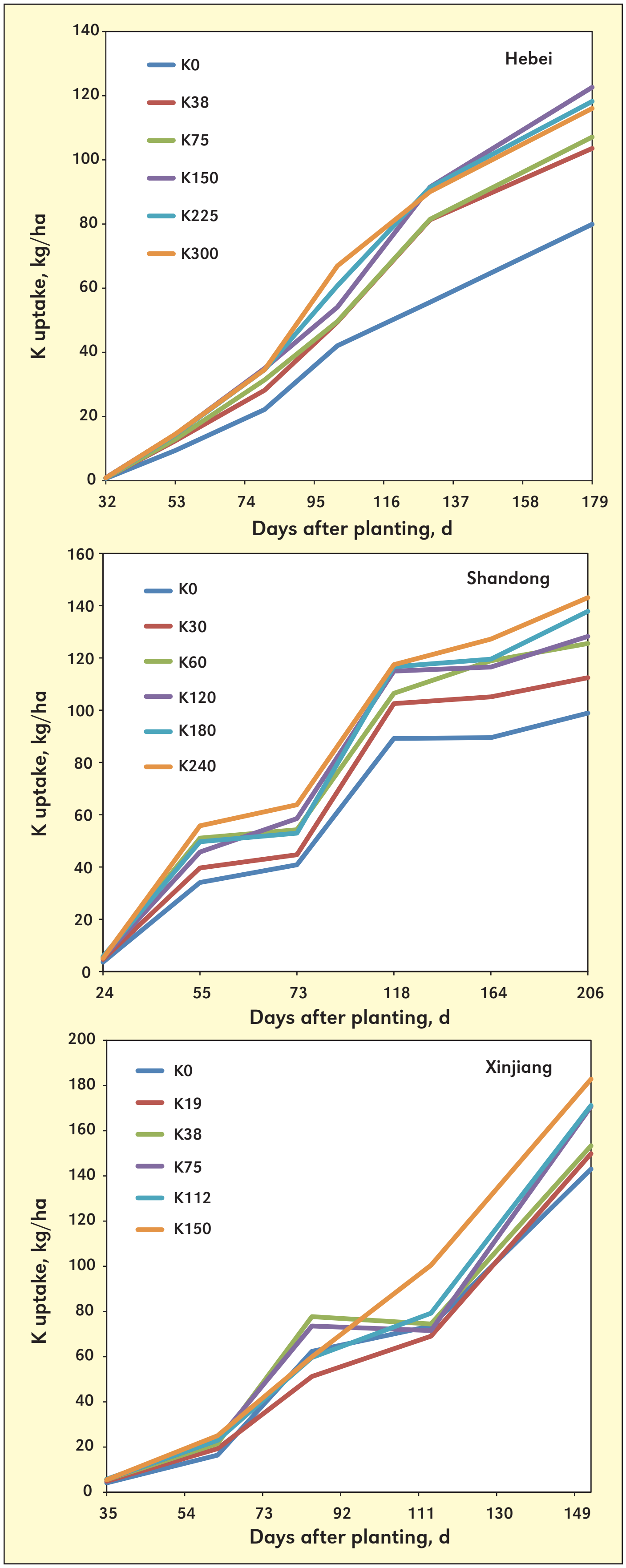

Figure 2. Seasonal K uptake by cotton under different fertilizer K rates (kg/ha) in three provinces of China.