## Title
Growth, Yield, Fiber Quality and Nutrient Uptake of Two Different Potassium Efficiency Cotton Genotypes in Response to Potassium Deficiency



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## INTRODUCTION

Potassium (K) plays a vital role during plant physiological and biochemical processes. It is important in cotton as it influences cell division, photosynthesis and enzyme activity (Bednarz and Oosterhuis, 1999). Cotton has been estimated to take up K from 110 to 250 kg per hectare, about 54% in the vegetative and 46% in the reproductive organs. Today's cotton cultivars can require up to 4.5 kg K $day^{-1}$ $ha^{-1}$ during peak bloom (Hake *et al*., 1991). Cotton appears to be more sensitive to low K than other field crops (Cassman *et al*., 1990), and often exhibits deficiency symptoms on soils with low available K (Gulick *et al.*, 1989). The sensitivity of cotton to K limitations has led to intensive research (Cassman *et al*., 1990; Rosolem and Mikkelsen, 1991), with the focus of these studies being on yield. However, little is known about the physiological background of K efficiency in different cotton genotypes.

Potassium deficiency in upland cotton has been reported for a diverse range of environments and genotypes, and the detrimental effects that low soil K levels can have on lint yield and fiber quality have been well documented (Cassman *et al*., 1990; Minton and Ebelhar, 1991; Pervez *et al*, 2004). The amount of available K in soils is often insufficient and fertilizers must supply K. Therefore, the improvement of nutrient efficiency in crops is an important issue. Efficient use of nutrients is the relative ability of plants to produce maximal amounts of dry matter or yield (Swaider and Chyan, 1994). Others also defined nutrient efficiency as plant yield per unit of nutrient supplied (Sauerbeck and Helal, 1990). Nutrient use efficiency (NUE) is dependent on two interrelated groups of plant factors, (a) uptake efficiency, and (b) utilization efficiency. Several studies (Liu *et al*, 2001; George *et al*., 2002; Woodend and Glass, 1993) found that a K-efficient line of tomato produced on average 79% more dry weight than an inefficient line and contained 39% less K in their tissue when grown at low levels of K. Woodend *et al.* (1987) studied the uptake and utilization of K in wheat under the condition of K stress. Yang *et al* (2003) reported the relative shoot biomass, relative root length, K concentration and accumulation in shoots as well as harvest index were the most important plant traits for identifying K efficient genotypes in lowland rice.

It is important to identify genotypes with higher NUE and understand the mechanisms of differences in response to K deficiency, and further breed for high NUE genotypes. This study aimed to investigate the biological variations in K efficiency (KE) among cotton genotypes. Experiments were conducted with the following objectives: (1) to study the variation in plant responses to K deficiency; (2) to study the lint yields and fiber quality differences among genotypes under K deficiency; (3) to identify genotypes which are more efficient in K uptake and utilization for further use in breeding.

## MATERIALS AND METHODS

### Soil pot experiment

There were two cotton (*Gossypium hirsutum L.*) cultivars (code: 103 and 122), which were screened from 86 cotton cultivars for KE during 2001 to 2006. The genotype 103 was a high KE and high yield potential genotype, and genotype 122 was a low KE and low yield potential genotype. Namely, 103 was a genotype which could tolerate K stress and obtain high yield with K fertilization, while 122 was a genotype which could not tolerate low K stress and showed lower yield increase with K fertilization. The fertilizers used in this experiment included urea, calcium super phosphate, potassium chloride, $CuCl_2 \cdot 2H_2O$, $ZnCl_2$, $H_3BO_3$, $(NH_4)_6MO_7 \cdot 4H_20$, $MgCO_3$. Plastic pots contained 15 kilograms of soil. The agrochemical properties of the soil are listed in Table 1. Fertilizers applied to the soil prior to planting cotton included N 0.36 g, P 0.12 g, Cu 13 mg, Zn 13 mg, B 13 mg, Mo 13 mg and Mg 30 mg per kilogram of soil. Two K treatments, -K（no K） and ＋K (K 0.44 g $kg^{-1}$ soil), were designed with five replicates. Nitrogen and potassium were applied three times during the entire vegetation period, while other nutrients were applied once before planting. Cotton seeds were first soaked in water, when the buds appeared and transferred to soil, with one plant in each pot.

Table 1. Agrochemical properties of the soil substrate.

| Soil | pH ($H_2O$) | Total nutrient ($g\ kg^{-1}$) | | | | Rapidly available nutrient ($mg\ kg^{-1}$) | | | Slowly available K ($mg\ kg^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| | | O.M. | N | $P_2O_5$ | $K_2O$ | N | P | K | |
| Brown soil | 5.9 | 30.49 | 1.78 | 1.95 | 2.41 | 114.78 | 24.43 | 59.10 | 349.05 |

**Sample preparation and analysis**

After the bolls opened, the seed cotton was picked, weighed, sun dried, to determine lint yield and fiber quality. Soil samples were collected, dried and ground for analysis. The Chinese Ministry of Agriculture analyzed fiber. Rapidly K was tested using $NH_4CH_3COOH$, slowly available K was tested according to the method of Chen Ji-xing (1983) using 1 mol • $L^{-1}$ $HNO_3$.

K efficiency (KE) = -K lint yield (g • plant $^{-1}$) / ＋K lint yield (g • plant $^{-1}$)

K yield potential (KYP) = ［(＋K lint yield) －(-K lint yield)] / $K_2O$ (unit $K_2O$ applied to soil)

Data analyses were performed using SAS statistical software program and Excel software (Microsoft 2000).

## RESULTS

### Effect of potassium fertilization on the growth and lint yield of different cotton genotypes

Table 2 shows that different cotton genotypes had significant differences in KE. Genotype 103 had higher lint yield and higher single boll weight than genotype 122. However, 100 seeds weight was lower in genotype 103 than genotype 122. This indicates that genotype 103 may transport more nutrients to lint to achieve high lint yield. The mechanism at which genotype 103 adjusts its K nutrient perhaps was one of the high K efficiency factors. KE of genotype 103 was higher (0.34) than genotype 122 (0.24). Genotype 103 produced higher lint yield at both -K treatment（15.48 g）and +K treatment（45.08 g). Lint yield of genotype 103 was 1.83 times that of genotype 122 at +K treatment, and 2.57 times that of genotype 122 at -K treatment.

Table 2. Effect of potassium fertilization on yield properties in two cotton genotypes

| Geno type | Single boll weight (g) | | Weight of 100 seeds (g) | | Lint percent (%) | | Lint yield (g • plant $^{-1}$) | | KYP (g •plant $^{-1}$) | KE |
|---|---|---|---|---|---|---|---|---|---|---|
| | -K | +K | -K | +K | -K | +K | -K | +K | | |
| 103 | 2.9a | 4.3a | 7.1b | 10.1a | 40.1a | 39.0a | 15.5a | 45.1a | 29.6a | 0.34a |
| 122 | 2.5b | 3.3b | 7.8a | 10.6a | 33.0b | 32.4b | 6.0b | 24.7b | 18.7b | 0.24b |

Note: Different letters in a row were significantly different at a 0.05 level.

### Effect of potassium fertilization on fiber quality of different cotton genotypes

Table 3 shows that significant differences occurred in fiber length uniformity, elongation and micronaire (measure for the length of a cotton fiber) under different K treatments. The +K treatment did not increase fiber length uniformity and elongation but micronaire only in the K-efficient cultivar to a significant extent. However, the two genotypes differed in fiber quality characters. Genotype 103 had a higher lint percentage and elongation.

Table 3. Effect of potassium fertilization on fiber quality in two cotton genotypes.

| genotype | Fiber length (mm) | | Length uniformity (%) | | Strength ( cN • $tex^{-1}$) | | Elongation (%) | | Micronaire | |
|---|---|---|---|---|---|---|---|---|---|---|
| | -K | +K | -K | +K | -K | +K | -K | +K | -K | +K |
| 103 | 26.7a | 28.2a | 82.3a | 84.9a | 24.9a | 33.9a | 7.16a | 6.52a | 3.22b | 4.32a |
| 122 | 27.5a | 29.0a | 82.8a | 84.6a | 25.7a | 31.9a | 6.67b | 6.00b | 3.43a | 4.48a |

**Effect of potassium fertilization on potassium concentrations in different cotton genotypes**

Potassium concentrations in different parts of cotton plants in the +K treatment were bell shuck > leaf > stem > root > fiber, whereas under –K they were bell shuck > fiber > leaf > stem > root (Table 4). K concentrations in bell shucks were the highest under all circumstances. In –K treatments, the K concentration in fiber was higher than in roots, stems and leaves. This indicates that under K deficiency a major part of K was transported to fiber and contributed there to higher yield formation. Tissue K concentrations were also different between the genotypes. In general, K concentrations were lower for genotype 103. Considering the superior lint yield in Table 1, this suggests that genotype 103 could produce more biomass under low K levels. In contrast, tissue K concentrations for genotype 122 were higher than for genotype 103, yet it produced lower yield. This suggests that genotype 122 requires higher K concentrations to support lint yield formation.

Table 4. Effect of K fertilization on K concentrations in various plant parts in cotton genotypes (g $kg^{-1}$)

| Genotype | Root | | Stem | | Leaf | | Bell shuck | | Fiber | |
|---|---|---|---|---|---|---|---|---|---|---|
| | -K | +K | -K | +K | -K | +K | -K | +K | -K | +K |
| 103 | 1.4a | 8.2b | 1.8b | 10.9b | 2.4b | 21.4a | 13.3b | 36.5a | 3.1b | 6.0b |
| 122 | 1.9a | 11.9a | 2.9a | 18.0a | 4.1a | 17.2b | 18.1a | 39.6a | 5.5a | 10.6a |

## CONCLUSION

Our data show that genotype 103 had better growth, leading to higher boll numbers, a lower rate of boll shed and higher lint yield. The lint yield of genotype 103 was 1.83 times that of genotype 122 under adequate K supply, and 2.57 times that of genotype 122 under K deficiency. These results indicate that genotype 103 has a higher K uptake and better K utilization. Based on KE and lint yield, genotype 103 can be considered as a high KE and high KYP genotype, while genotype 122 has a low KE and is a low KYP genotype.

Different K efficiency genotypes also differed in fiber quality characters with genotype 103 showing higher fiber elongation values. In general, fiber quality characters in the two cotton genotypes were inferior under -K than under＋K, but this difference was not as distinct as for lint yield. It is known that high lint yield usually causes poor fiber quality, and low lint yield usually correlates with higher fiber quality. From our experience this is supported and suggests that it might be difficult to combine high lint yield and good fiber quality in the same genotype. Further research is ongoing for genotype 103.

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