Genotypic Variations in Potassium Uptake and Utilization in Cotton

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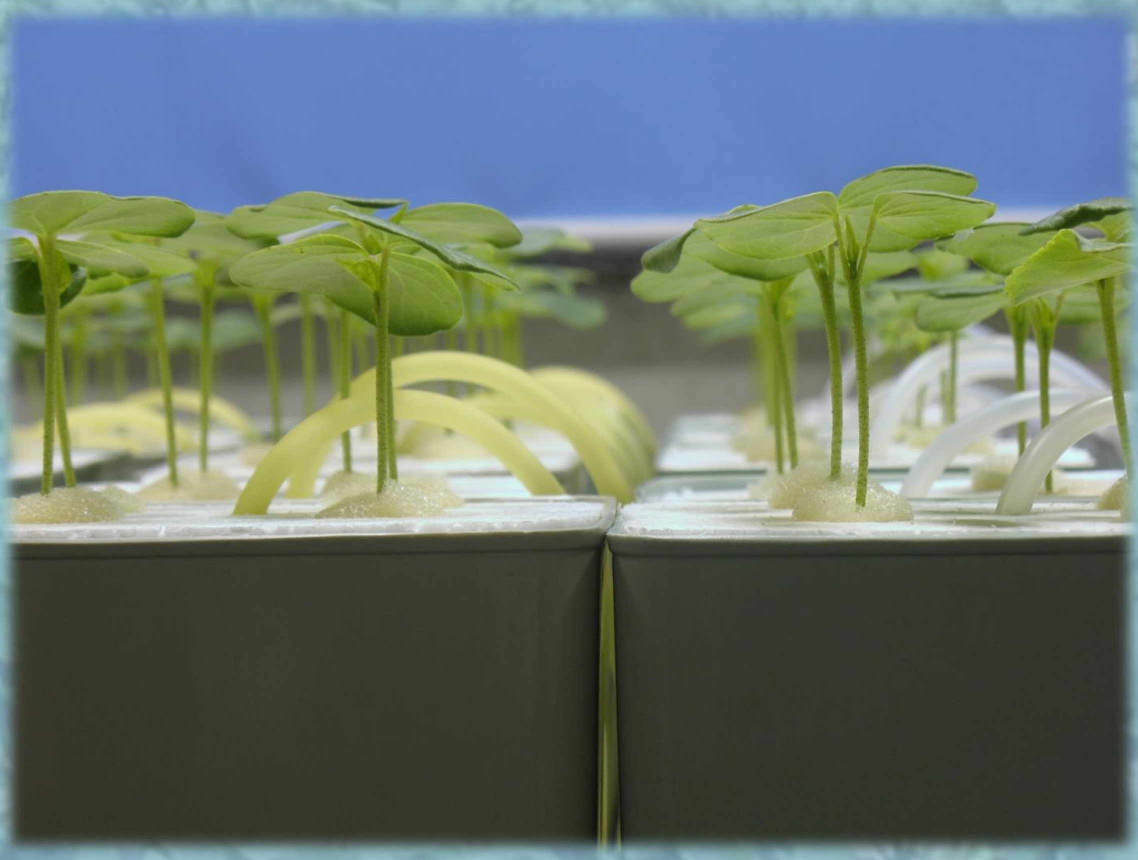
Introduction

The rapid mining of soil K by increased cotton yield in recent years, coupled with the insufficient application of K fertilizers, has resulted in negative K balances in cotton fields in China. In addition, transgenic insect-resistant cultivars, being popularized in the Yangtze River and Yellow River areas of China, are more sensitive to K deficiency than conventional cotton cultivars. Therefore, K deficiency has become one of the major constraints to cotton production. In the present study, we compared four cotton cultivars with high biomass yield with the other four yielding relatively lower biomass under low K level (0.02 mM).

Materials and methods

Plant material: A subset of 8 cotton genotypes with contrasting dry matter yield in a K deficient solution (0.02 mM) was selected from 50 predominant cotton genotypes in China in 2004, after a preliminary experiment. Four of the K inefficient cultivars (SGK3, SCRC18, SCRC21 and SCRC22) produced the lowest dry matter at the 5-leaf stage, whereas the other four K efficient cultivars (Nannong8, Xiangza2, Xinluzao12 and Xiangza3) produced the most.

Growth chamber experiment: Seeds were germinated in a K-free sand medium and cultured hydroponically by transferring to plastic pots filled with modified Hoagland’s solution. All solutions were changed twice per week.
A completely randomized design was used with three replications (pots). Plants were harvested at the five-leaf stage, about 21 d after transferring, to determine biomass and K concentration.



Field experiment: A field experiment was conducted in 2006 at Shangzhuang Experiment Station (40°08´ N, 116°10´ E) of China Agricultural University. The available K in soil was 60 mg kg^{-1}. A randomized complete block design was adopted with three replications. The field management followed conventional practices. Potassium fertilizer was not applied during the growing season. At maturity, 3 representative plants from each genotype were harvested for determination of dry weight of reproductive organs.

Results

Dry matter yield of seedlings: The relative dry weight of K efficient genotypes was greater than that of K inefficient genotypes, suggesting that K efficient genotypes also had higher tolerance to inadequate K supply. Alternatively, K inefficient genotypes had better response to K application; averaged for the four cultivars, the increased dry matter yield per unit of added K was 3.99 and 1.69 mg DW mg^{-1} K for inefficient and efficient cultivars, respectively.

Genotypes	$DW_{0.02}$[a] (g plant^{-1})	$DW_{2.5}$[b] (g plant^{-1})	$DW_{0.02}$/ $DW_{2.5}$[c] (%)	RKS[d] (mg DW mg^{-1} K)
K inefficient				
SGK3	0.27 c	1.02 a	26.1 c	3.54 ab
SCRC18	0.28 c	1.18 a	23.5 c	4.23 a
SCRC21	0.30 c	1.17 a	25.4 c	4.09 a
SCRC22	0.30 c	1.17 a	25.9 c	4.09 a
Mean	0.29	1.13	25.2	3.99
K efficient				
Nannong8	0.67 b	1.14 a	58.7 b	2.21 bc
Xiangza2	0.73 ab	1.17 a	62.6 b	2.07 c
Xinluzao12	0.76 a	0.96 a	79.0 a	0.95 c
Xiangza3	0.79 a	1.16 a	68.2 b	1.75 c
Mean	0.74**	1.10	67.2**	1.69**

[a] Dry weight of seedlings grown in K-deficient solutions (0.02 mM)
[b] Dry weight of seedlings grown in K-sufficient solutions (2.5 mM)
[c] Relative dry weight in K-deficient vs. K-sufficient medium
[d] Response of dry matter to K supply

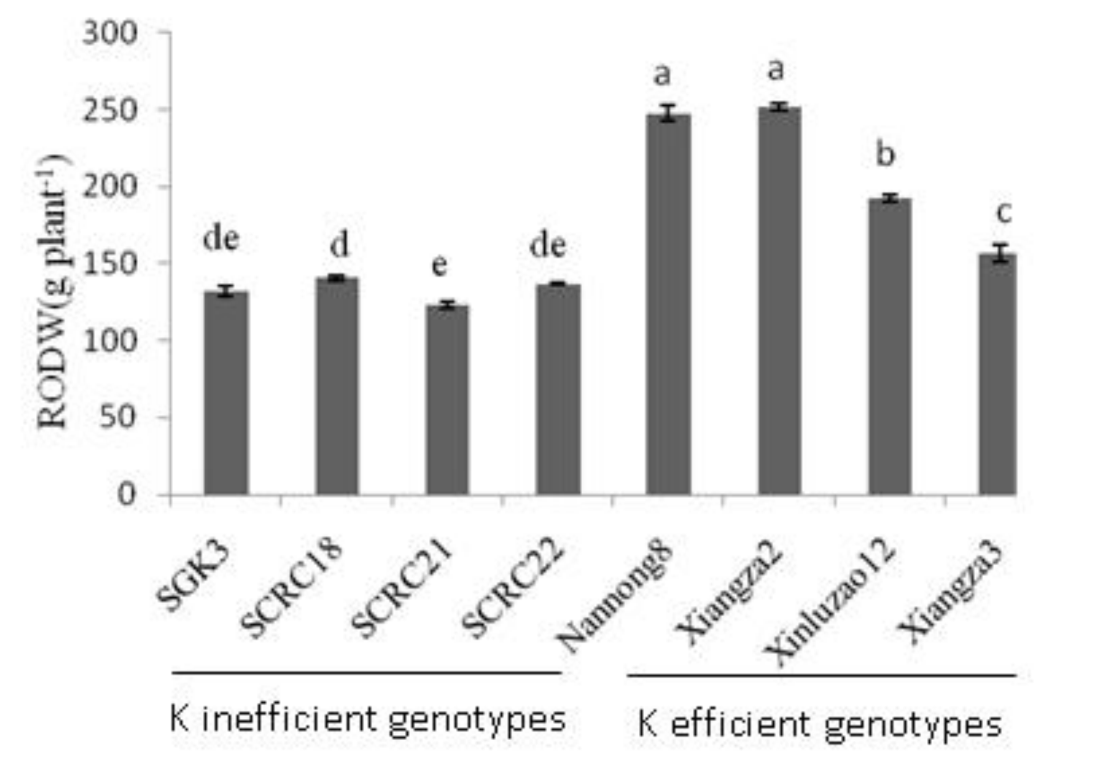
K accumulation and uptake efficiency of seedlings: The higher net K uptake of K efficient cultivars mainly resulted from their larger root system, which exceeded that of K inefficient cultivars by 158%. Furthermore, K efficient cultivars had an advantage in uptake activity (mg K g^{-1} root dry weight) to some extent. The mean K uptake efficiency of K efficient cultivars was 38% ($P < 0.01$) higher than that of K inefficient cultivars, despite the marginal differences among genotypes.

Genotypes	KA_{0d}[a] (mg plant^{-1})	KA_{21d}[b] (mg plant^{-1})	NKU[c] (mg plant^{-1})	RDW[d] (g plant^{-1})	KUE[e] (mg K g^{-1} RDW)
K inefficient					
SGK3	0.61 a	0.94 c	0.33 cd	0.032 b	10.31 bc
SCRC18	0.61 a	1.08 c	0.47 c	0.038 b	12.37 ab
SCRC21	0.71 a	0.99 c	0.28 d	0.038 b	7.37 c
SCRC22	0.73 a	1.13 c	0.40 cd	0.042 b	9.52 bc
Mean	0.67	1.03	0.37	0.038	9.87
K efficient					
Nannong8	0.70 a	1.82 b	1.12 b	0.091 a	12.31 ab
Xiangza2	0.69 a	2.04 ab	1.35 a	0.097 a	13.92 ab
Xinluzao12	0.80 a	2.25 a	1.45 a	0.097 a	14.95 a
Xiangza3	0.69 a	2.11 a	1.42 a	0.106 a	13.40 ab
Mean	0.72	2.06 **	1.34 **	0.098 **	13.67 **

[a] K accumulation in seedlings just before transferring to solutions
[b] K accumulation in seedlings grown in solutions for 21 d
[c] Net K uptake in seedlings during hydroponic culture period
[d] Root dry weight
[e] K uptake efficiency

K utilization efficiency of seedlings: In contrast to the K accumulation, the K concentration in the whole plant of K efficient cultivars was generally lower than that of K inefficient cultivars under K-deficient condition. Therefore, the K utilization efficiency (i.e., total dry mass per unit of K concentration) averaged across the four K efficient cultivars was 233% higher than that of the four K inefficient cultivars.

Dry weight of reproductive organs determined from the field experiment: Field experiments showed the similar genotypic variations, the mean dry weight of reproductive organs (RODW) averaged across the four K efficient cultivars was 212.0 g plant^{-1} or 59% higher than the 133.2 g plant^{-1} for the four K inefficient cultivars.



Discussion

It has been well documented that genotypic differences in nutrient efficiency within a plant species result from differences in uptake efficiency and/or utilization efficiencies. Use efficient plants could produce high yields with a low K concentration in their dry matter; uptake efficient plants could realize a higher K uptake in spite of low K availability to guarantee better growth.

In the present study, the K efficient cultivars had either higher K efficiency ratio or higher K utilization efficiency than the K inefficient cultivars, but the differences of K efficiency ratio between K efficient and K inefficient cultivars were less pronounced.

Acknowledgement

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