WATER DEFICIT AND K PARTITIONING IN COTTON

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Abstract

The impact of water deficit on potassium K deficiency and partitioning in the cotton (*Gossypium hirsutum* L.) plant during peak boll development is not well understood. Inconsistent yield responses to soil and foliar-applied K fertilizers may be related to water deficit stress from irrigated or rain- fed systems. Cotton growth, lint yield, and K partitioning under limited K and water were studied in a field environment. Eight treatment combinations of well-watered or dryland conditions, high or low soil K, and with or without foliar-applied K were arranged in a split-split plot design with six replications. Growth, dry matter, leaf photosynthesis, and K concentration in above-ground organs were measured at key phenological stages [pinhead square (PS), first flower (FF), first flower + 3 weeks (FF+3), and first flower + 5 weeks (FF+5)]. Final lint yield was determined by mechanical harvest and components of yield were determined by hand harvesting. At FF+3 (peak boll development stage), stem and petiole K concentrations were significantly reduced ($P \leq \leq 0.05$) from high to low soil K under the well-watered, but not the dryland, conditions. Foliar application of K consistently increased stem, petiole, and leaf K concentration only under the low soil K condition. Foliar application of K increased leaf K concentration by a greater margin under dryland, low soil K compared to well-watered, low soil K conditions. Lint yield responded best to foliar K under low soil K and under well-watered conditions. Potassium deficiency in cotton appeared to be exacerbated by water deficit, although water deficit did not reduce the efficacy of foliar-applied K.

Introduction

Kramer and Boyer (1995) concluded that water deficit is the principal cause of reduced crop yields throughout the world. The importance of water for cotton leaf area development, tissue turgor, and canopy architecture under irrigated or dryland systems has been well documented (Kramer and Boyer, 1995). Furthermore, the importance of K maintaining adequate water relations for metabolic and photosynthetic processes (Kerby and Adams, 1985) has been well documented. This includes K manipulation of turgor to control stomatal opening and closing. Cassman et al. (1990) demonstrated that adequate K is crucial for cotton fiber development and quality.

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Potassium deficiencies have reportedly been widespread across the U.S. Cotton Belt but the explanation for this phenomenon remains unclear. Cotton is more sensitive to low soil K than most other major row crops and K deficiency can occur on soils not considered low in K (Cassman et al., 1989). Although K may be taken up in luxury amounts by the cotton plant prior to peak demand, Oosterhuis (1995) observed that K deficiencies still occur late in the growing season when the large developing boll load becomes the dominant sink for available K. He also suggested that late-season widespread K deficiency was related to higher yielding, quicker maturing cultivars, soil fixation, inadequate root growth, and Verticillium wilt.

Although the roles of water and K in cotton production are clear, the impact of water deficit stress on K deficiency is not well understood. Also, the effect of water deficit and K deficiency on K partitioning and on the efficiency of foliar uptake by cotton is not clear, particularly during the flowering and boll development stages when plant K needs are greatest. We hypothesized that K use by cotton and the onset of K deficiency could be strongly influenced by water relations. Therefore, our objectives were to (1) evaluate the effect of water deficit stress and K deficiency on K partitioning and dry matter accumulation, and (2) to determine the effect of water deficit and K deficiency on the absorption and benefit of foliar-applied K.

Materials and Methods

Cotton growth and K partitioning under limited water and soil K inputs were studied in 1998 in greenhouse and field environments at the Arkansas Agricultural Research and Extension Center in Fayetteville (Coker and Oosterhuis, 1999). The following information reflects the same study expanded in 1999 to include foliar K feeding in a field environment at Rohwer in southeast Arkansas. Eight treatment combinations of well-watered or dryland conditions, high soil K or low soil K, and with foliar-applied K or without foliar K were arranged in a split-split plot design with six replications. Each plot consisted of four rows 12.2 m long, spaced 0.96 m apart. Cotton cultivar Suregrow 125 was planted into a moderately well-drained Hebert silt loam on 11 May 1999. Based on pre-season soil sample results, granular KCl fertilizer was hand broadcast (averaging 62.3 kg K ha^{-1}) to high soil K plots on 26 May 1999. An equation was used (Sabbe, 1999) to achieve 392 kg K ha^{-1} in the high soil K plots and no additional KCL fertilizer was applied to the low K plots. Foliar KNO_3 at 4.3 kg K ha^{-1} was applied for four consecutive weeks starting one week after first flower (FF) with a CO_2 backpack sprayer. Beginning at the pinhead square (PS) stage, the water status of the soil profile in each plot was monitored using screen-caged thermocouple psychrometers buried parallel to the surface at a depth of 30 cm. The plant water status of all treatments was monitored using end-window thermocouple psychrometers and infrared thermometry starting at PS. Growth, dry matter, leaf photosynthesis, and K concentration in above-ground organs were measured at key phenological stages [PS, FF, first flower + 3 weeks (FF+3), and first flower + 5 weeks (FF+5)]. Final lint yield and components of yield were determined by mechanically harvesting the two center rows of each plot and by hand-picking a 1-m length of one yield row and counting the number of bolls.

Results and Discussion

Tissue K Concentration

Three weeks after first flower (FF+3), stem and petiole K concentrations were significantly reduced ($P \leq 0.05$) from high to low soil K under the well-watered but not the dryland condition (Table 1). We also observed a significant ($P \leq 0.05$) water x soil K interaction for petiole and leaf K concentrations at the FF+3 stage. These results seemed to indicate that plant uptake of soil-applied K was reduced and plant K partitioning was altered by water deficit stress in the dryland treatment.

Foliar K averaged over the water treatments consistently increased ($P \leq 0.05$) stem, petiole, and leaf K concentrations under the low soil K but not the high soil K condition at FF+3 (Table 2). Also, we observed a significant ($P \leq 0.05$) soil by foliar K interaction for petiole and leaf K concentrations at this peak boll development stage. Apparently, as a result of soil K resources being more limited under the low soil K treatment, a greater response in the uptake of foliar-applied K occurred. The magnitude of leaf K concentration appeared to be most sensitive to foliar-applied K followed by petiole and stem K concentrations. The addition of foliar-applied K had a significant ($P \leq 0.05$) effect on leaf K concentration under the well-watered, low soil K condition but not the well-watered, high soil K condition (Table 3). However, foliar K had a very highly significant effect ($P \leq 0.0004$) on leaf K concentration under the dryland, low soil K condition but not the dryland, high soil K condition. This observation seemed to indicate little loss in the efficacy of foliar-applied K under conditions of water deficit stress coupled with low soil K.

Yield

When foliar K was averaged over the water treatments, there was a significant ($P \leq 0.05$) effect of foliar-applied K on the number of open bolls under high or low soil K conditions (Table 4). Changes in boll weight in response to foliar-applied K were negligible under the high or low soil K condition. We observed that lint yield increased by 3.6% in response to foliar-applied K under low soil K but changed negligibly under the high soil K treatment.

Table 5 represents means averaged over soil K, with the emphasis on foliar-applied K. Again, foliar-applied K significantly ($P \leq 0.05$) affected the number of open bolls under well-watered or dryland conditions. However, boll weight was not affected by foliar-applied K under the well-watered or dryland condition. Lint yield increased by a numerically greater margin under well-watered compared to dryland conditions in response to foliar-applied K addition.

Conclusions

The effect of water deficit stress and soil K deficiency on K partitioning, dry matter yield, and on the absorption of foliar-applied K has been documented. Water deficit stress impeded the uptake and partitioning of soil-applied K. Foliar-applied K accumulation in plant tissues was enhanced by lower soil K conditions. Dryland conditions with extended periods of water deficit stress beginning at the FF stage did not impede the absorption of foliar-applied K into leaves. The yield increases we observed in response to foliar-applied K added after the FF stage tended to have an advantage where soil K was not added at the beginning of the season and where irrigation was used. Our results indicated that the positive responses in lint yield from foliar-applied K inputs under dryland or irrigated conditions were due principally to an increase in boll number.

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Table 1. Effect of soil-applied K on stem, petiole, and leaf K concentration from field-grown cotton at the FF+3 stage. Rohwer, AR 1999.

	K Concentration		
Treatment	**Stem**	**Petiole**	**Leaf**
	------------g kg^{-1}-----------		
Averaged over Foliar K Treatments			
Well watered, high soil K	13.5	34.9	13.1
Well watered, low soil K	11.8	29.8	11.3
	0.02*	**0.01**	**0.07**
Water × Soil K		**0.05**	**0.04**
Dryland, high soil K	12.0	27.7	10.2
Dryland, low soil K	11.7	27.8	11.3
	0.63	**0.91**	**0.21**

*probability level of difference

Table 2. Effect of foliar K on stem, petiole, and leaf K concentration from field-grown cotton cv. Suregrow 125 at the FF+3 stage. Rohwer, AR 1999.

	K Concentration		
Treatment	**Stem**	**Petiole**	**Leaf**
	------------g kg^{-1}-----------		
Averaged over Water Treatments			
High soil K, no foliar K	12.8	31.6	11.2
High soil K, with foliar K	12.7	31.0	12.1
	0.84*	**0.73**	**0.28**
Low soil K, no foliar K	11.2	26.5	9.5
Low soil K, with foliar K	12.4	31.2	13.1
	0.02	**0.01**	**0.0003**
Soil % Foliar K	**0.07**	**0.04**	**0.03**

*probability level of difference

Table 3. Effect of water deficit stress on leaf uptake of foliar-applied K by field-grown cotton cv. Suregrow 125 at the FF+3 stage. Rohwer, AR 1999.

	Leaf K Concentration	
Treatment	**Well Watered**	**Dryland**
	---------g kg^{-1}---------	
High soil K, no foliar K	13.1	9.3
High soil K, with foliar K	13.1	11.0
	1.0*	**0.13**
Low soil K, no foliar K	10.2	8.9
Low soil K, with foliar K	12.5	13.6
	0.05	**0.0004**
Soil % Foliar K		**0.03**

*probability level of difference

Table 4. Yield response of field-grown cotton to foliar K averaged over the water treatments. Rohwer, AR 1999.

Treatment	**Open Boll**	**Boll Weight**	**Lint**
	# m^{-2}	**g $boll^{-1}$**	**kg ha^{-1}**
Averaged over Water Treatments			
High soil K, no foliar K	83	3.96	1272
High soil K, with foliar K	95	3.82	1270
	0.002*	**0.39**	**0.96**
Low soil K, no foliar K	83	3.96	1248
Low soil K, with foliar K	90	4.10	1293
	0.03	**0.39**	**0.32**

*probability level of difference

Table 5. Yield response of field-grown cotton to foliar K averaged over the soil K treatments. Rohwer, AR 1999.

Treatment	**Open Boll**	**Boll Weight**	**Lint**
	# m^{-2}	**g $boll^{-1}$**	**kg ha^{-1}**
Averaged over Soil K Treatments			
W. watered, no foliar K	97	4.12	1531
W. watered, with foliar K	109	4.06	1561
	0.002*	**0.69**	**0.5**
Dryland, no foliar K	69	3.80	989
Dryland, with foliar K	76	3.86	1002
	0.03	**0.69**	**0.77**

*probability level of difference