POTASSIUM PARTITIONING IN THE COTTON PLANT AS INFLUENCED BY SOIL AND FOLIAR POTASSIUM FERTILIZATION UNDER WATER DEFICIT STRESS

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RESEARCH PROBLEM

Precise, timely management of potassium (K) fertilizer inputs throughout the growing season are essential for maximum cotton (*Gossypium hirsutum* L.) lint yields and high fiber quality. However, questions remain unanswered about the management of K fertilizer inputs for maximum production profitability when water is limiting under irrigated or rainfed systems. The impact of water deficit on soil K deficiency and partitioning is not well understood, particularly during the flowering and peak boll development stage when K needs are greatest (Oosterhuis, 1995).

BACKGROUND INFORMATION

Potassium (K) is crucial for cotton fiber development and quality; therefore, judicious management of K during the cotton growing season is critical. Under irrigated or dryland systems, water is important for growth such as leaf area development, tissue turgor, and canopy architecture. Furthermore, the importance of K in maintaining adequate water relations for metabolic and photosynthetic processes, and manipulation of turgor to control stomatal opening and closing has been well documented. Cotton is more sensitive to low soil K than most other major field crops and K deficiency in cotton can occur on soils not considered low in K (Cassman *et al*., 1989).

Although the roles of water and K in cotton production are clear, the impact of water deficit stress on K uptake, partitioning, and deficiency is not well understood, particularly during the flowering and boll development stages when K needs are greatest. Therefore, we hypothesized that the water status of the plant directly affects K partitioning, the efficiency of foliar-applied K, and final yield components. Therefore, the objective of this study was to evaluate the effect of water deficit stress and soil K deficiency on K distribution, K uptake into plant organs, and on the dry matter yield of field-grown cotton.

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RESEARCH DESCRIPTION

Cotton growth and K partitioning under limited water and K inputs were studied in 1998 at the Arkansas Agricultural Research and Extension Center in Fayetteville (Coker and Oosterhuis, 1999) and 1999 at the Southeast Research and Extension Center (SEREC), Rohwer. Eight treatment combinations of well-watered (W) or dryland (D) conditions, high-soil K (H) or low-soil K (L), and with foliar-applied K (F) or without foliar K (O) were arranged in a split-split plot design with six replications. Each plot consisted of four rows 40 ft long, spaced 38 inches apart. Cultivar 'Suregrow 125' was planted into a moderately well-drained Hebert silt loam on 11 May 1999. Granular KCl fertilizer was hand broadcast to designated plots on 26 May 1999 according to soil test recommendations (Sabbe, 1998). Foliar KNO_3 was applied for four consecutive weeks starting one week after first flower with a CO_2 backpack sprayer. Beginning at the pinhead square (PS) stage, the soil water status was monitored using screen-cage thermocouple psychrometers buried to a 24 cm depth, and plant water status was monitored using end-window thermocouple psychrometers and infrared thermometry. Growth, dry matter, photosynthesis, and K concentration in organ tissues were measured at key phenological stages [PS, first flower (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

Dry Matter Partitioning and Yield

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 1). Only negligible changes in boll weight occurred due to foliar K application under the high or low soil K condition. There was a trend for slightly increased lint yield due to foliar-applied K under the low soil K condition. Foliar-applied K significantly ($P \leq 0.05$) affected the number of open bolls under well-watered or dryland conditions, although boll weight did not change. We observed that lint yield increased by a numerically greater margin under well-watered compared to dryland conditions in response to the foliar-applied K.

Organ K Content at 3 Weeks After First Flower

Potassium content of stem, petiole, leaf, and the whole plant, including potassium use efficiency (KUE) averaged over the water treatments increased significantly in response to foliar K application under the low soil K but not the high soil K condition at 3 weeks after first flower (Tables 2 and 3). We observed a significant ($P \leq 0.05$) soil x foliar K interaction for stem, petiole, leaf, carpel wall, and whole plant K, including KUE. The magnitude of change in leaf K content appeared to be most sensitive to foliar-applied K followed by petiole and stem K content. Under high soil K, the addition of foliar K significantly ($p \leq 0.05$) increased the square K content and significantly ($P \leq 0.05$) decreased the carpel wall K content; whereas, foliar K application under low soil K had little effect on square and carpel wall K content. Soil solution K resources being more limited under the low soil K treatment seemed to enhance uptake of foliar-applied K and increase KUE, particularly in the vegetative organs.

When averaged over the soil K levels, the addition of foliar-applied K significantly ($P \leq 0.05$) increased stem, petiole, leaf, and whole plant K content under the well-watered condition and leaf K content under the dryland condition (Table 2). A significant ($P \leq 0.05$) increase in KUE due to foliar K application seemed to indicate little loss in the efficacy of foliar-applied K under conditions of water deficit stress (Table 3), particularly when coupled with low soil K (data not shown). No significant ($P \leq 0.05$) changes in square or carpel wall content were observed from the addition of foliar-applied K under the well-watered or dryland condition at 3 weeks after first flower.

The addition of soil-applied K fertilizer had a significant ($P \leq 0.05$) effect on stem K content and increased petiole K content by 18.5% under well-watered conditions when averaged over the foliar K treatment at 3 weeks after first flower (Table 4). Only minor changes in K content of stem, petiole, leaf, squares, and carpel wall occurred under the dryland condition. We also observed a significant ($P \leq 0.05$) water x soil K interaction for stem and petiole K content at the same growth stage. Total plant K content did not change significantly ($P \leq 0.05$) in response to added soil K fertilizer at planting under the well-watered or dryland system (data not shown). However, KUE was significantly affected by soil-applied K fertilizer under the well-watered system at first flower plus 3 weeks. Stem, petiole, leaf, square, and total plant K contents, including KUE averaged over soil K and foliar K were significantly ($P \leq 0.05$) greater under well-watered compared to dryland conditions. These results appeared to be consistent with earlier reports that soil water potential plays a crucial role in the uptake and use of available soil solution K.

PRACTICAL APPLICATION

The trend for yield increases we observed in response to foliar-applied K occurred in plots where soil K was not added at the beginning of the season and where irrigation was used. Positive lint yield responses that resulted from foliar K applications were primarily due to an increased boll number. The response of organ K contents to foliar K fertilization was largely governed by the availability of K in soil solution. Thus, where soil K resources fell into the marginal to upper medium range of current Arkansas standards prior to planting, vegetative organ K contents increased in response to the foliar applications of K. The response to foliar-applied K in stem, petiole, and leaf K contents was greater under well-watered compared to dryland conditions at 3 weeks after first flower. Potassium deficiency in our cotton appeared to be enhanced by water deficit. More specifically, organ K content changed very little in response to soil-applied K under the dryland compared to the well-watered system. This research should benefit farmers growing cotton under irrigated and dryland systems in the Mississippi Delta region of Arkansas where K and water shortages occur.

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Table 1. Yield response of field-grown cotton to foliar K averaged over the water and soil K treatments, Rohwer, 1999.

	Components of Yield		
Treatment	Open Boll	Boll Weight	Lint
	no. m^{-2}	g $boll^{-1}$	kg ha^{-1}
Averaged over Water			
High soil K, no foliar K	83	3.96	1272
High soil K, with foliar K	95	3.82	1270
	0.002[z]	**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**
Averaged over Soil K			
Well-watered, no foliar K	97	4.12	1531
Well-watered, with foliar	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**
Averaged over Water and Soil K			
No foliar K	83	3.96	1260
With foliar K	92	3.96	1281
	0.0005	1.00	0.5

[z] probability level of difference.

Table 2. Organ K content in field-grown cultivar 'SG 125' at 3 weeks after first flower averaged over the water and soil K treatments, Rohwer, 1999.

	Potassium Content				
Treatment	Stem	Petiole	Leaf	Squares	Carpel Wall
	---------- K (kg ha^{-1}) ----------				
Averaged over Water					
High soil K, no foliar K	26.5	11.4	18.6	1.6	11.1
High soil K, with foliar K	26.6	11.5	19.4	2.6	7.6
	0.95^{z}	**0.83**	**0.67**	**0.03**	**0.01**
Low soil K, no foliar K	23.2	9.4	15.3	2.3	8.7
Low soil K, with foliar K	28.7	12.3	23.1	2.1	9.7
	0.006	**0.003**	**0.0006**	**0.72**	**0.46**
Soil K ∞ Foliar K	**0.05**	**0.03**	**0.02**		**0.02**
Averaged over Soil K					
Well-watered, no foliar K	29.0	13.1	22.0	3.2	10.4
Well-watered, with foliar K	33.2	15.3	26.4	3.9	9.6
	0.03	**0.02**	**0.03**	**0.13**	**0.53**
Dryland, no foliar K	20.7	7.7	11.9	0.69	9.4
Dryland, with foliar K	22.1	8.5	16.1	0.83	7.7
	0.45	**0.33**	**0.04**	**0.73**	**0.18**
Averaged over Water and Soil K					
No foliar K	24.8	10.4	17.0	1.9	9.9
With foliar K	27.6	11.9	21.2	2.4	8.6
	0.04	**0.02**	**0.005**	**0.19**	**0.17**

^{z} probability level of difference.

Table 3. Total-plant K content and K use efficiency (KUE) at FF + 3 in field-grown cultivar Suregrow 125 from foliar K or none applied at first flower plus 3 weeks and averaged over the water and soil K treatments, Rowher, 1999.

Treatment	Total Plant K	KUE
	K (kg ha^{-1})	K (g kg^{-1})
Averaged over Water		
High soil K, no foliar K	69.2	15.1
High soil K, with foliar K	67.7	15.1
	0.77[z]	**0.98**
Low soil K, no foliar K	58.9	1.3
Low soil K, with foliar K	75.9	1.5
	0.003	**0.001**
Soil K ∞ Foliar K	**0.02**	**0.02**
Averaged over Soil K		
Well-watered, no foliar K	77.7	15.1
Well-watered, with foliar	88.4	15.6
	0.04	0.45
Dryland, no foliar K	50.4	13.1
Dryland, with foliar K	55.2	14.8
	0.35	**0.01**
Averaged over Water and Soil K		
No foliar K	64.0	14.1
With foliar K	71.8	15.2
	0.04	**0.02**

[z] probability level of difference.

Table 4. Organ K content in field-grown cultivar 'SG 125' at FF + 3 from soil-applied K or none averaged over the water and foliar K treatments, Rohwer, 1999.

Treatment	Potassium Content				
	Stem	Petiole	Leaf	Squares	Carpel Wall
	----------------------------------	K (kg ha^{-1})	-------------------------------------		
Averaged over Water					
Well-watered, high soil K	33.4	15.4	25.4	3.4	9.9
Well-watered, low soil K	28.8	13.0	23.0	3.6	10.1
	0.04[z]	**0.07**	**0.23**	**0.74**	**0.86**
Dryland, high soil K	19.7	7.5	12.6	0.8	8.7
Dryland, low soil K	23.0	8.7	15.4	0.7	8.3
	0.12	**0.33**	**0.18**	**0.95**	**0.70**
Water ∞ Soil K	**0.02**	**0.05**			
Averaged over Water and Foliar K					
High soil K	26.5	11.5	19.0	2.1	9.3
Low soil K	25.9	10.9	19.2	2.2	9.2
	0.66	**0.48**	**0.90**	**0.85**	**0.88**
Averaged over Soil K and Foliar K					
Well-watered	31.1	14.2	24.2	3.5	10.0
Dryland	21.4	8.1	14.0	0.8	8.5
	0.0001	**0.0001**	**0.0001**	**0.0001**	**0.07**

[z] probability level of difference.