

Cotton Response to Foliar Application of Potassium Compounds at Different pH Levels

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The pH of potassium (K) solutions used in foliar fertilization of cotton has a major effect on leaf burn, leaf expansion, K uptake by leaves, movement to the bolls, and lint yield. Leaf burn was decreased, while K concentration of plant organs and lint yield were increased at neutral to acidic pHs.

WIDESPREAD K deficiencies have been reported across the U.S. Cotton Belt. These deficiencies are associated with the introduction of early-maturing, short-season cultivars with higher fruit loads. Deficiencies can be corrected by soil or foliar applications of K. Soil application at mid-to-late season may be less beneficial because of inefficient K uptake by the root system during boll development.

Foliar applications have the advantage of rapid absorption into the leaf and efficient movement to the developing bolls. However, the response to foliar fertilization with K has been inconsistent. Research in Tennessee has indicated that lowering the pH of foliar-applied potassium nitrate (KNO_3) solutions increases K absorption by the leaf. Our study examined the effect of lowering solution pHs of various commercial K compounds on foliar burn, leaf absorption, and accumulation of K in the boll.

The field study was conducted at the Arkansas Agricultural Experiment Station, Fayetteville, in 1994 on a Captina silt loam soil with an initial soil test level of 231 lb K/A. Treatments and their pH values (**Table 1**) included a control and eight foliar applied K compounds: KNO_3 , potassium chloride (KCl), potassium sulfate (K_2SO_4), potassium thiosulfate ($\text{K}_2\text{S}_2\text{O}_3$), potassium carbonate (K_2CO_3), potassium hydroxide (KOH), potassium bicarbonate (KHCO_3), and potassium acetate (CH_3COOK). The treatments were applied

Table 1. Standard (S) and adjusted (A) pHs of K solutions prepared to deliver 4.4 lb $\text{K}_2\text{O/A}$ in 10 gallons of water.

K compound	pH	
	Standard (S)	Adjusted (A)
KNO_3	9.4	4.0
KCl	9.4	4.0
K_2SO_4	9.9	4.0
$\text{K}_2\text{S}_2\text{O}_3$	6.8	4.0
K_2CO_3	11.6	7.0
KOH	13.6	7.0
KHCO_3	8.2	- ¹
CH_3COOK	8.3	- ¹

¹Not adjusted due to excessive volume of buffer needed.

four times with a carbon dioxide - pressurized backpack sprayer at 4.4 lb $\text{K}_2\text{O/A}$ at weekly intervals starting two weeks after appearance of the first white flower.

All K compounds were tested at the standard pH (S) of the K compound when mixed with water at an equivalent rate of 4.4 lb $\text{K}_2\text{O/A}$ in 10 gallons of water. Potassium nitrate, KCl, K_2SO_4 and $\text{K}_2\text{S}_2\text{O}_3$ were also tested at a lower pH of 4, produced by adjusting the pH (A) using Xtra Strength buffer XS (Helena Chemical Company). The pHs of K_2CO_3 and KOH were adjusted to 7, and KHCO_3 and CH_3COOK were tested only at their standard pH values due to the excessive volume of buffer needed to lower the pH.

Visual observations of leaf burn were recorded 24 hours after foliar treatment applications. Visual symptoms of

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phytotoxicity were rated from zero (no burn) to 100 percent (full canopy burn). Forty-eight hours after foliar applications, samples of five fully expanded upper canopy leaves along with their petioles and five developing bolls, with diameters less than an inch, were collected. Petioles were immediately excised from the leaf blades. The leaf area of each treatment was recorded to observe the treatment effect on leaf growth. Leaf, petiole and boll K concentrations were analyzed to determine treatment effects on the uptake of K by leaves and K movement to the bolls.

At standard pH, K_2SO_4 did not cause any leaf burn, KNO_3 caused <0.5 percent, and KCl 3.5 percent. In contrast, substantial leaf burn was caused by KOH (39.2 percent), K_2CO_3 (36.3 percent), $K_2S_2O_3$ (32.5 percent), $KHCO_3$ (28.3 percent) and CH_3COOK (22.1 percent).

When the pHs of KOH and K_2CO_3 were lowered to 7, the phytotoxic effects were decreased significantly to 3.75 percent and 3.25 percent respectively. As a result, the leaf burning effects of KOH and K_2CO_3 were not significantly different from the leaf burning effects of KCl, KNO_3 , K_2SO_4 and the untreated control. When the pH of $K_2S_2O_3$ was decreased, its phytotoxicity was also significantly decreased from 32.5 to 26.25 percent.

These results show that K solution pH has an important role in correcting

phytotoxic effects of foliar K applications. Leaf burn can disrupt cell membrane integrity and photosynthesis, resulting in decreased carbon fixation and dry matter accumulation, lower boll weights and decreased yield (data not presented).

The leaf area of the top five leaves was considerably reduced from 390 cm^2 in the untreated control to 304, 318 and 325 cm^2 in the KOH, K_2CO_3 and $K_2S_2O_3$ treatments, respectively, at standard solution pH values. That means that foliar treatments with high phytotoxic effects also reduced the growth of upper canopy leaves which would further contribute to decreased production of photosynthates necessary for boll development and high yields.

Large quantities of Xtra Strength buffer were required to adjust the pH values of K_2CO_3 , KOH, $KHCO_3$, and CH_3COOK . The K_2CO_3 solution required about 15 percent volume/volume (v/v) of the buffer to adjust its pH value to 7. The KOH and $KHCO_3$ solutions required about 25 percent v/v of the buffer to adjust their pH values to 7. The buffered solution of $KHCO_3$ was not stable. Its pH increased to 7.4 after 2 hours of storage at 77°F (25.0°C). The CH_3COOK solution required about 52 percent v/v of the buffer to adjust its pH to 4, which also was not stable and increased to 4.3 after 2 hours of storage. Therefore, $KHCO_3$ and CH_3COOK were applied only at their standard pH levels.

Table 2. Potassium concentration (as percent above the untreated control) in cotton leaves, petioles and bolls 48 hours after the fourth foliar application of various K compounds with standard or adjusted solution pH.

K compound	K concentration, % above untreated control					
	Leaves		Petioles		Bolls	
	Standard	Adjusted	Solution pH		Standard	Adjusted
			Standard	Adjusted		
KNO_3	38.8	31.7	28.2	18.4	10.1	3.9
KCl	69.4	75.5	46.6	59.8	11.8	11.2
K_2SO_4	19.5	23.4	16.7	22.5	3.2	0.0
$K_2S_2O_3$	86.2	92.3	62.8	53.4	11.3	13.4
K_2CO_3	143.0	121.7	68.0	64.0	12.0	35.8
KOH	182.9	134.0	115.0	82.4	21.1	52.8
$KHCO_3$	178.6	— ¹	82.3	—	18.9	—
CH_3COOK	91.8	—	50.7	—	10.0	—

¹ Not adjusted due to excessive volume of buffer needed.

Table 2 shows that K treatment increased K concentration in the leaves and petioles while lowering the pH had no significant effect. The largest increases in leaf K were caused by KOH, KHCO_3 , and K_2CO_3 , followed by CH_3COOK , $\text{K}_2\text{S}_2\text{O}_3$ and KCl treatments at their standard as well as adjusted pH levels. Potassium nitrate and K_2SO_4 showed the lowest absorption compared to other K compounds.

All foliar-applied K treatments increased boll K concentration, except for K_2SO_4 adjusted to pH 4. Lowering pH of KOH and K_2CO_3 dramatically increased the K accumulation in the boll by 53 percent and 36 percent, respectively, compared to their standard pH values. These results indicate that when leaf burn was corrected by adjusting the pH of these K solutions, the movement of K from leaves to the boll sink was more efficient.

Lowering solution pH increased lint yield compared to the standard pH treatments for KNO_3 , K_2SO_4 , $\text{K}_2\text{S}_2\text{O}_3$ and KOH, **Figure 1**. Lowering the solution pH had no effect on yield for KCl or K_2CO_3 . The largest yield increases from lowering solution pH occurred with KOH and K_2SO_4 .

Summary

Foliar applications of K_2SO_4 , KNO_3 and KCl caused either none or minimal leaf burn at high or low pH. The highest leaf burn was caused by the applications of KOH, K_2CO_3 , $\text{K}_2\text{S}_2\text{O}_3$, KHCO_3 and CH_3COOK when applied at their standard pH values. When pHs of KOH and K_2CO_3 were adjusted to 7, leaf burn was reduced to about 3.5 percent. The growth of the upper canopy was also severely affected by the phytotoxic effects of KOH, K_2CO_3 and $\text{K}_2\text{S}_2\text{O}_3$ when applied at their standard solutions pH values. Lowering the pH increased the lint yield for KNO_3 , K_2SO_4 , $\text{K}_2\text{S}_2\text{O}_3$, and KOH, but not for KCl or K_2CO_3 .

The pH of the foliar fertilizer solution has an important role in altering phytotoxic effects as well as on absorption and translocation of K to the bolls. Further research is needed to evaluate the optimum pH for maximum foliar absorption and movement to the bolls of various K sources. There is also a need to explore suitable buffer solutions for adjusting the pH of the K solutions because a specific buffer solution may not be ideally suitable for all nutrient solutions. ■

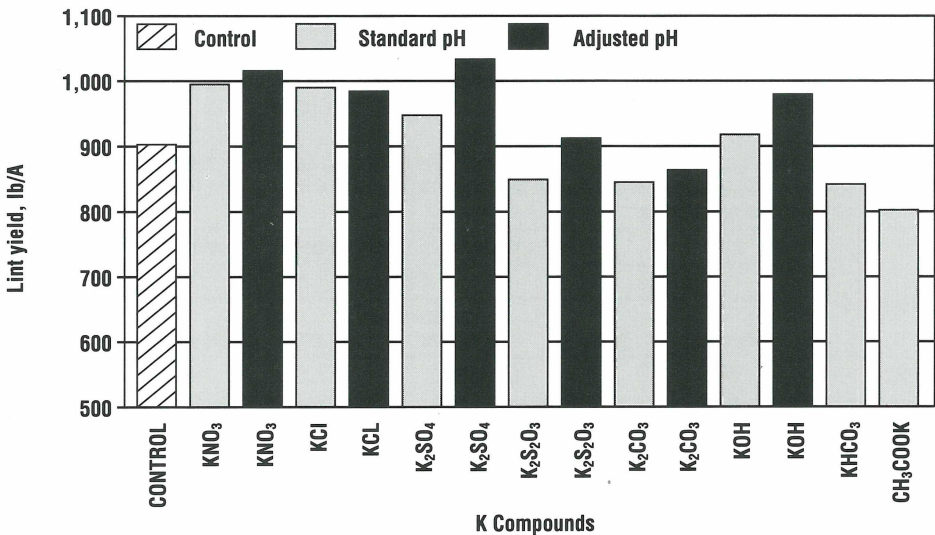


Figure 1. Cotton lint yields were improved by adjusting solution pH in foliar application of several K sources.