SUMMARY OF COTTON YIELD RESPONSE TO FOLIAR APPLICATIONS OF POTASSIUM NITRATE AND UREA

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Abstract

Potassium (K) deficiency symptoms have been observed in fast-fruiting, early- maturing cotton (***Gossypium hirsutum* L.**) cultivars across the Cotton Belt. Research was conducted across the Cotton Belt to evaluate foliar K applications for increasing cotton lint production. Several factors including the interaction of foliar potassium nitrate (KNO_3) and urea at different levels of soil-applied K were evaluated at various locations and many continue to be researched in some areas. In Mississippi, along with the Beltwide protocol, additional treatments were included in subsequent years to examine the interaction of plant growth regulators with foliar KNO_3 and urea. The objectives of these studies were 1) to determine lint yield response to foliar KNO_3 and urea with different levels of soil-applied K and 2) to evaluate the interaction of foliar KNO_3 and urea applications with plant growth regulators (mepiquat chloride and PGR-IV). A 3-year study was conducted from 1991 to 1993 on a Dundee silt loam at the Delta Research and Extension Center at Stoneville, MS. Treatments included 0, 50, 75, and 100 lb K/A soil-applied with either foliar-applied KNO_3 or urea. There were no significant yield difference with either foliar-applied KNO_3 or urea in any of the three years. No K deficiencies were evident, and maturity was unaffected by treatment. In 1994, a 2-year study was begun to continue the evaluation of foliar K and also introduced plant growth regulators into the system. There was no significant interaction between the main effect factors (foliar-applied nutrients, mepiquat chloride and PGR-IV). When averaged across foliar systems, there was no significant lint yield increase with PGR-IV in either year. When averaged across years and foliar systems, mepiquat chloride increased lint yields by 4% (33 lb lint/A). The foliar systems had no significant effect on lint yield in either 1994 or 1995 but when averaged across years and plant growth regulators, both foliar-applied urea and foliar-applied KNO_3 increased lint yields by 5 to 6% (47 and 42 lb lint/A, respectively).

Introduction

The development and adoption of fast-fruiting and early-maturing cotton (***Gossypium hirsutum* L.**) cultivars with high yield potential across the Cotton Belt increased the occurrence of potassium (K) deficiency symptoms across the Cotton Belt that had not been evident with full-season cultivars. Although common in older leaves, the deficiencies were also observed in younger leaves, especially when heavy fruit loads were present on plants. Researchers across the Cotton Belt developed research programs to determine the cause of this widespread K deficiency. Results from these studies have been presented at the Beltwide Cotton Conference all through the 1990's, and many studies are cited (Abaye et. al., 1996: Hodges, 1994; Knowles et. al., 1995; Mitchell et. al., 1994; Mitchell et. al., 1995; Roberststs and Howard, 1995; Snyder et. al., 1995a: Snyder et. al., 1995b, Weir et. al., 1996) in the references accompanying this paper. Several scientist were involved in a Beltwide study to evaluate the use of potassium nitrate (KNO_3) as a foliar source of supplemental K which could be applied after flowering was initiated. As expected, the soil K levels varied across the Cotton Belt as reported by Oosterhuis et. al., 1994, in the summary of the 3-year study. The yields from these same studies were just as variable. Therefore, yield responses to soil applications of K were evident in some areas but results were inconsistent in tests across the Cotton Belt. Moreover, the yield responses to foliar applications of KNO_3 potassium nitrate were just as variable and relatively unpredictable.

The Beltwide evaluation of foliar applications of KNO_3 ended in 1993, but several states including Mississippi continued studies with foliar K applications. The demand for K during peak fruiting continued to be great and large amounts of soil-applied K were being used and continues to be used today. To continue the studies in Mississippi, a 2-year study was begun which incorporated the foliar application of urea and KNO_3 with the applications of PGR-IV and mepiquat chloride. Variable results with mepiquat chloride had been observed through the mid-South and in some studies even significant yield reductions had been observed with low levels of growth regulator. Additional studies were conducted across the Cotton Belt with many different factors related to foliar K applications under investigation. Areas of interest included evaluations of pH and buffer relationships with respect to foliar K applications (Howard, 1995; Howard, 1995; Howard and Gwathmey, 1996), different K sources including KNO_3 (Howard, 1995; Miley and Oosterhuis, 1994; Mullins and Burmester, 1994; Mullins and Burmester, 1995), and interactions with other materials and other nitrogen (N) sources (Lege and Lippert, 1997; Stichler, 1995; Wallace et. al., 1996). Further work is underway to evaluate the K buffering capacity of soils in order to predict possible response to added K whether from soil-applied sources or from foliar applications (Davis et. al., 1996). This study also involves a Beltwide cooperation among scientist from several disciplines.

In Mississippi, the yield response to foliar applications of nutrients of all types was measured in replicated field trials conducted at the Delta Research and Extension Center in

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:684-688 (1998)
National Cotton Council, Memphis TN

the 1980's where no significant response was observed at any rate of nutrient applied. As part of the Beltwide evaluation of KNO_3, a study was conducted from 1991 to 1993 with additional interest in evaluating combinations of foliar nutrients and plant growth regulators. Mepiquat chloride had been in the production systems for several years with variable results. Lint yields sometimes increased or even decreased, but in most years there was no significant yield response to using the mepiquat chloride. PGR-IV was also being promoted in popular press advertisements as a plant growth regulator which stimulated root growth and thus, resulted in increased productivity.

This manuscript summarizes the data from the Mississippi Delta, with respect to foliar applications of KNO_3 (Study I) and interactions of foliar KNO_3 and urea with mepiquat chloride and PGR-IV (Study II). The objectives of these studies were to 1) determine lint yield response to supplemental foliar applications of urea and KNO_3 at various levels of soil- applied K, and 2) determine the interactive effects of foliar nutrients and plant growth regulators.

Materials and Methods

Study I

A 3-year study was initiated in 1991 on a Dundee silt loam (Aeric Ochraqualf) at the Delta Research and Extension Center at Stoneville, MS. The study consisted of 10 treatments involving four rates of potassium (0, 50, 75, and 100 lb K/A) applied to the soil surface as muriate of potash and incorporated prior to planting, two foliar materials, 40 lb KNO_3 applied in four 10-lb/A applications beginning one week after first bloom, and urea applied at an equivalent rate of N (1.38 lb N/A/application) as compared to the KNO_3. An untreated control receiving no soil-applied K or foliar nutrients, and a tenth treatment which added the supplemental N (5.52 lb N/A) to the soil only. An N rate of 120 lb/A was "knifed-in" on either side of the row prior to planting as a 32% N solution of urea-ammonium nitrate. Cultural practices such as pest control, cultivation, irrigation and, defoliation were maintained uniformly across all treatments throughout the growing season in an effort to optimize yields. Treatments were arranged in a randomized complete block (RCB) design with four replications each year. Four-row plots (82 ft long) were used and maintained in the same location throughout the study.

Leaf samples were taken to determine leaf N and K and petiole nitrate concentrations and the foliar applications were made every two weeks beginning one week after first bloom. After defoliation, two harvests were made utilizing a 2-row spindle picker adapted for plot harvest. The two center rows of each plot were harvested for yield determination. A subsample was taken from each plot at harvest and ginned on a 10-saw sample gin to determine lint percent. All results were analyzed statistically using the analysis of variance procedure (Statistical Analysis System, SAS) and Fisher's Protected LSD (least significant difference). Where appropriate means over years were averaged .

Study II

A 2-year study was initiated in 1994 on a Dundee silt loam (Aeric Ochraqualf) at the Delta Research and Extension Center at Stoneville, MS. This study consisted of 12 treatments arranged in a randomized complete block (RCB) design with four replications. The treatments were a factorial arrangement (2x2x3) of plant growth regulators (2x2 factorial), PGR-IV (O oz/A and 1+2+4 oz/A applied 1 oz/A [5/13/94, 6/05/95] + 2 oz/A [6/07/94, 6/15/95] + 4 oz/A [7/01/94, 6/29/95] according to company protocol), and mepiquat chloride (0 oz/A and 8 oz/A applied 2 oz/A [6/07/94, 6/15/95] + 2 oz/A [7/07/94, 6/29/95] + 2 oz/A [8/02/94, 7/13/95] + 2 oz/A [8/16/94, 7/29/95] for a total of 8 oz/A), and foliar nutrients (no foliar material, urea at 5.52 lb N/A applied in 1.38- lb N/A increments (7/07/94, 8/01/94, 8/11/94, 8/19/94 and 7/11/95, 7/25/95, 8/08/95, 8/22/95) and KNO_3 applied at 40 lb product/A applied four times at a rate of 10 lb/A/application at the same date as urea applications. All cultural practices were maintained in an effort to optimize yields.

The foliar nutrient applications were made every two weeks beginning one week following first bloom. After defoliation, two harvests were made utilizing a 2-row spindle picker adapted for plot harvest. The two center rows of each plot were harvested for yield determination. A subsample was taken from each plot at harvest and ginned on a 10-saw sample gin to determine lint percent. All results were analyzed statistically using analysis of variance procedures (Statistical Analysis Systems, SAS) and Fisher's Protected LSD. Where appropriate (no treatment interaction) main effect means and means over years are presented .

Results and Discussion

Study I

Lint yields are summarized in Tables 1 through 3 for the individual years 1991 through 1993, respectively. In 1991 (Table 1), the total lint yield ranged from 1383 to 1461 lb lint/A, with no significant difference between any of the treatments. Most of the cotton (>95%) was harvested at the first harvest, with no apparent difference in maturity. Potassium deficiency symptoms were not evident even on the plots receiving no soil-applied or foliar-applied K.

In 1992 (Table 2), total lint yields ranged from 796 to 1011 lb lint/A, with the average (895 lb lint/A) 37% lower than yields measured in 1991 (1414 lb lint/A). There were significant reductions in total lint yields where the high rates (100 lb/A) of K were applied with either foliar nutrient. Reductions were possibly related to higher salt levels associated with applications of muriate of potash (KCl) especially in the dry years such as 1992. These yields with

100 lb K/A of soil-applied K were approximately 15% lower compared to the untreated control. There was no significant increase in total lint yield when foliar KNO_3 or urea was included in the system, even though the total lint yield with foliar urea was 7% higher than the control. In general with both foliar K and N, the total yield decreased with increasing soil-applied K indicating the possible salt problem with the higher levels of soil applied K. In dry years, excess salts could limit production especially if roots are concentrated in the higher salt areas.

The lint yields in 1993 (Table 3) were even lower than those observed in 1992. There was no significant difference between any of the treatments in the study in 1993. The yield ranged from a low of 625 to a high of 779. Lint cotton yields were generally low in 1993 due to several environmental stresses during the growing season and an unusually high level of insect pressure.

Study II

No significant (5% level) treatment effects were found when the analysis included all treatments in either year. However, when the years were combined (Table 4), some treatment differences were detectable. The lint yield ranged from 748 to 856 lb lint/A with the highest yield obtained with mepiquat chloride and foliar-applied urea.

There were no significant interactions between main effect factors so main effect means are presented in Table 5. When averaged across the other factors, PGR-IV had no significant effect on lint yields in either of the two years. Pix applications did significantly increase lint yields in 1994 (7%) but had no effect in 1995. When averaged across the two years the mepiquat chloride treatment increased total lint yields an average of 4% e (33 lb lint/A). Although some significant responses were detected, an economic evaluation (data not presented) makes the applications of a plant growth regulator a breakeven input at best. The foliar systems had no significant effect on lint yields in either 1994 or 1995 but when average across years and growth regulators, both foliar-applied urea and foliar- applied KNO_3 increased total lint yields by 5 to 6% (47 and 42 lb lint/A, respectively).

Summary

Foliar applications of KNO_3 and urea have not proven to be a consistent treatment for K deficiency in the Mississippi Delta. Soil applications of K provide the basis for having an ample supply of plant-available K during the peak fruiting period for cotton. Where any type of stress such as water stress or carbohydrate stress occur the uptake of K through the leaves is greatly reduced so that the chances of K actually getting into the plant through foliar applications of K are also greatly reduced. With fast-fruiting and early-maturing cotton cultivars, the best method for increasing plant-available K is to add supplemental soil-applied K keeping in mind that too much soil-applied K can lead to possible salt injury in extremely dry years.

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Table 1. Lint yield response of cotton plants to various foliar applications of KNO_3 and urea with different levels of soil-applied K. MAFES-DREC, Stoneville, MS. 1991

Applied treatment[§]			First	Second	Total
Soil K	K-N	Urea	Harvest	Harvest	Harvest
(lb K/A)	----(lb/A)----		-----------------lb lint/A	-----------------	
0	0	0	1392	53	1445
0	0	5.52	1406	55	1461
50	0	5.52	1342	41	1383
75	0	5.52	1364	45	1409
100	0	5.52	1347	41	1388
0	40	0	1347	52	1399
50	40	0	1359	62	1421
75	40	0	1360	60	1420
100	40	0	1332	53	1385
0	0	5.52[a]	1387	42	1429
LSD (0.05)[¶]			NS	NS	NS

§ Treatments: Preplant N (120 lb/A) and K applied 4/24/91. Cotton planted 5/13/91 and emerged 5/18/91. Harvests: 10/02/91 and 10/21/91 Potassium nitrate (K-N) applied 10 lb product/A on 7/15/91, 7/29/91, 8/12/91, and 8/26/91. Urea (46-0-0) applied as foliar spray at 1.38 lb N/A per application and applied on same dates as potassium nitrate

a 5.52 lb N/A as Urea applied PP at the time of UAN application

¶ Least Significant Difference at the 5% level of probability

Table 2. Lint yield response of cotton plants to various foliar applications of KNO_3 and urea with different levels of soil-applied K. MAFES-DREC, Stoneville, 1992.

Applied treatment[§]			First	Second	Total
Soil K	K-N	Urea	Harvest	Harvest	Harvest
(lb K/A)	----(lb/A)----		-----------------lb lint/A	-----------------	
0	0	0	856 ab	85 d	942 ab
0	0	5.52	891 a	121 ab	1011 a
50	0	5.52	724 bc	100 a-d	824 b
75	0	5.52	784 abc	116 abc	900 ab
100	0	5.52	705 c	91 cd	796 b
0	40	0	814 abc	104 a-d	918 ab
50	40	0	834 abc	100 a-d	933 ab
75	40	0	770 abc	124 a	894 ab
100	40	0	702 c	107 a-d	810 b
0	0	5.52[a]	831 abc	93 bcd	924 ab
LSD (0.05)[¶]			143	29	155

§ Treatments: Preplant N (120 lb/A) and K applied 4/08/92. Cotton planted 5/05/92 and emerged 5/12/92. Harvests: 10/06/92 and 10/26/92 Potassium nitrate (K-N) applied 10 lb product/A on 7/20/92, 8/03/92, 8/17/92, and 8/31/92. Urea (46-0-0) applied as foliar spray at 1.38 lb N/A per application and applied on same dates as potassium nitrate

a 5.52 lb N/A as Urea applied PP at the time of UAN application

¶ Least Significant Difference at the 5% level of probability

Table 3. Lint yield response of cotton plants to various foliar applications of KNO_3 and urea with different levels of soil-applied K. MAFES-DREC, Stoneville, 1993

Applied treatment[§]			First	Second	Total
Soil K	K-N	Urea	Harvest	Harvest	Harvest
(lb K/A)	---(lb/A)----		-----------------lb lint/A	-----------------	
0	0	No	681	65	746
0	0	5.52	564	60	625
50	0	5.52	678	65	743
100	0	5.52	636	65	701
50+50	0	5.52	636	61	697
0	40	0	662	60	722
50	40	0	715	64	779
100	40	0	629	69	698
50+50	40	0	713	63	776
0	0	5.52[a]	600	63	663
LSD (0.05)[¶]			NS	NS	NS

§ Treatments: Preplant N (120 lb/A) and K applied 4/23/93. Cotton planted 4/28/93 and emerged 5/06/93. Sidedress K (50 lb K/A) applied 7/21/93. Harvests: 10/01/93 and 10/27/93. Potassium nitrate (K-N) applied 10 lb product/A on 7/20/93, 8/03/93, 8/18/93, and 9/03/93. Urea (46-0-0) applied as foliar spray at 1.38 lb N/A per application and applied on same dates as potassium nitrate

a 5.52 lb N/A as Urea applied PP at the time of UAN application

¶ Least Significant Difference at the 5% level of probability.

Table 4. Summary of lint cotton yield from foliar applications of nutrients and/or growth regulators. MAFES-DREC, Stoneville, MS 1994-1995.

Treatment[§]				1994	1995	Mean
PGRIV	MC	K-N	Urea	Total Lint	Total Lint	Total Lint
				-----------------lb lint/A	-----------------	
0	0	No	No	680	817	748 c
0	0	Yes	No	773	843	808 abc
0	0	No	Yes	737	805	771 bc
7	0	No	No	711	818	764 bc
7	0	Yes	No	738	814	776 bc
7	0	No	Yes	746	829	788 bc
0	8	No	No	782	798	790 bc
0	8	Yes	No	796	830	813 ab
0	8	No	Yes	823	889	856 a
7	8	No	No	723	777	750 c
7	8	Yes	No	791	856	824 ab
7	8	No	Yes	782	868	825 ab
LSD (0.05)[¶]				NS	NS	61[‡] **

§ Treatments: PGR-IV applied at 1 oz/A (5/13/94, 6/05/95), 2 oz/A (6/07/94, 6/15/95) and 4 oz/A (7/01/94, 6/29/95). Mepiquat chloride (MC) applied 2 oz/A (6/07/94, 6/15/95), 2 oz/A (7/07/94, 6/29/95), 2 oz/A (8/02/94, 7/13/95) , 2 oz/A (8/16/94, 7/29/95). Potassium nitrate (K-N) applied 10 lb product/A (7/07/94, 8/01/94, 8/11/94, 8/19/94; 7/11/95, 7/25/95, 8/08/95, 8/22/95). Urea (46-0-0) applied as foliar spray at 1.38 lb N/A per application and applied on same dates as KNO_3.

¶ Least Significant Difference at the 5% level of probability

‡ LSD calculated from pooled error (year*treatment + residual)

Table 5. Summary of main effects for lint cotton yield from foliar applications of nutrients and/or growth regulators. MAFES/DREC, Stoneville, MS. 1994-1995.

Treatment[§]				1994	1995	Mean[†]
PGRIV	MC	K-N	Urea	Total Lint	Total Lint	Total Lint
				-----------------lb lint/A	-----------------	
0	----	----	----	765	830	798
7	----	----	----	748	827	788
LSD (0.05)[¶,‡]				NS	NS	NS
----	0	----	----	731 b	821	776 b
----	8	----	----	783 a	836	809 a
LSD (0.05)[‡‡]				41	34	20
Foliar Nutrient						
----	----	0	0	724	802	763 b
----	----	40	0	774	836	805 a
----	----	0	5.52	772	848	810 a
LSD (0.05)[‡‡‡]				NS	NS	25

§ Treatments: See Table 4 for complete listing.

¶ Least Significant Difference at the 5% level of probability

‡ Means across Pix rate (2), foliars (3), and reps (4) [n = 24]

‡‡ Means across PGR-IV rate (2), foliars (3), and reps (4) [n = 24]

‡‡‡ Means across PGR-IV rate (2), Pix rate (2), and reps (4) [n = 16]

† Means across years (2). For PGR-IV, [n = 48]; for Pix, [n = 48]; and for foliars [n = 32].