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ECONOMICS AND MARKETING

Economics of Using an Adjuvant with Foliar Potassium Nitrate (KNO_3) on Cotton

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INTERPRETIVE SUMMARY

Foliar applying K to cotton plants at or shortly after bloom can correct late season K deficiencies and enhance lint yields in low-K soils. Yields from cotton produced on high-K soils have not responded as well to foliar K treatments. Adding an adjuvant to the foliar K solution may promote absorption of foliar-applied nutrients into leaves and further enhance yields. The objective of this study was to determine if applying an adjuvant with foliar potassium nitrate (KNO_3) on medium-to-high-K soils is economically beneficial to cotton producers.

Experiments were conducted between 1992 and 1995 on no-tillage cotton produced on a high-K Collins silt loam soil at Jackson, TN, and between 1993 and 1994 on conventional- and no-tillage cotton produced on a medium-K Loring silt loam soil at Milan, TN. Treatments for each experiment were a non-foliar check, a foliar KNO_3 treatment, and a foliar KNO_3 plus adjuvant treatment. Foliar treatments were applied four times at 10 lb KNO_3 acre^{-1} in 10 gal of water starting at flowering to 14 d after flowering on a 9-to-14-day interval. The cultivar D&PL 50 was planted by mid-May each year.

The results suggest that farmers producing cotton on these medium-to-high-K soils who are already applying foliar KNO_3 can increase their net revenue substantially by adding the adjuvant to the foliar fertilizer. On the other hand, negative net revenue increases when comparing the foliar KNO_3 treatment with the check suggest that farmers of these medium-to-high-K soils would simply incur economic losses by foliar applying KNO_3 without the adjuvant. The high break-even cotton lint prices for conventional-tillage cotton produced at Jackson and for conventional- and no-tillage cotton produced at Milan (\$2.28 lb^{-1}, \$1.34 lb^{-1}, and \$2.28 lb^{-1}, respectively) suggest that applying foliar KNO_3 without the adjuvant would be unprofitable across a wide range of prices expected to prevail in the near future.

ABSTRACT

Foliar potassium nitrate (KNO_3) applications can correct late season K deficiencies. Adjuvants may promote absorption of foliar-applied nutrients, reducing nutrient loss and enhancing yield. The objective was to determine if applying an adjuvant with foliar KNO_3 on medium-to-high-K soils is economically beneficial to cotton producers. Experiments were conducted between 1992 and 1995 on no-tillage cotton produced on a high-K Collins silt loam soil at Jackson, TN, and in 1993 and 1994 on conventional- and no-tillage cotton produced on a medium-K Loring silt loam soil at Milan, TN. Treatments were non-foliar check, foliar KNO_3, and foliar KNO_3 plus adjuvant. Foliar treatments were applied four times at 4.1 kg K ha^{-1} (11.2 kg KNO_3 ha^{-1}) in 94 L H_2O starting at flowering to 14 d after flowering on a 9-to-14-d interval. The adjuvant was added to the foliar solutions at 1.25% (v/v). Partial budgeting was used to estimate net revenue differences (\$ ha^{-1}) among the treatments. Cost of KNO_3 was \$27.33 ha^{-1}, the adjuvant, \$17.34 ha^{-1}, and machinery and labor costs for foliar application summed to \$22.95 ha^{-1}. Yields did not increase sufficiently to cover the higher cost of the foliar KNO_3 treatment compared with the check. The foliar KNO_3 plus adjuvant treatment, compared with the check, increased yields 70 kg ha^{-1} for Jackson, 52 kg ha^{-1} for the conventional-tillage at Milan, and 112 kg ha^{-1} for the no-tillage treatments at Milan, causing net revenues to increase \$35.98 ha^{-1} at Jackson, \$9.34 ha^{-1} for conventional till at Milan, and \$98.14 ha^{-1} for no-till at Milan. Results indicated that no-tillage cotton producers who farm medium-to-high-K soils could increase net revenue by applying foliar KNO_3, but

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only if the adjuvant is applied with it. Results were less convincing for conventional-tillage cotton.

Foliar fertilizers are used to supplement soil-supplied nutrients with the hope that they may enhance yields. Foliar KNO_3 applications can correct late-season K deficiencies when soil applications may not be effective (Oosterhuis et al., 1993). Increased leaf and petiole K concentrations, accompanied by higher yields and net revenues, have been reported from foliar applications of KNO_3 to a soil low in Mehlich I-extractable K (Howard et al., 1998; Roberts et al., 1997). Yields from cotton produced on high-K soils have not responded as well to foliar KNO_3 applications (Howard et al., 1997).

The use of adjuvants may promote absorption of foliar-applied nutrients into leaves compared with solutions without adjuvants (Howard et al., 1993), reducing nutrient loss and enhancing yield. Agronomic analyses exist comparing the effects on yields of using adjuvants to enhance K absorption by cotton leaves (Chang and Oosterhuis, 1995; Howard, 1993; Howard and Gwathmey, 1995; Howard et al., 1998; Oosterhuis et al., 1993), but the economics of using an adjuvant with foliar KNO_3 has not been analyzed. The objective of this study was to determine if applying an adjuvant with foliar KNO_3 on medium-to-high-K soils is economically beneficial to cotton producers.

MATERIALS AND METHODS

Field experiments were conducted in 1992 through 1995 evaluating foliar KNO_3 applications to no-tillage cotton produced on a high-K (222 kg ha^{-1} Mehlich I-extractable K) Collins silt loam soil (coarse-silty, mixed, acid, thermic, Aquic Udifluvent) at the West Tennessee Experiment Station, Jackson, TN. A second set of experiments was conducted in 1993 and 1994 on conventional- and no-tillage cotton produced on a medium-K (175 kg ha^{-1} Mehlich I-extactable K) Loring silt loam soil (fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs) at the Milan Experiment Station, Milan, TN.

Three treatments were analyzed in each experiment, including non-foliar check, foliar KNO_3, and foliar KNO_3 plus the adjuvant Penetrator Plus (light to mid range paraffin oil, polyol fatty acid esters, polyethoxylated esters of polyol fatty acids, and ethoxylated allkylarly phosphate ester, buffering crop oil concentrate), manufactured by Helena Chemical Co. of Memphis, TN. The adjuvant was added to the foliar solutions at 1.25% (v/v). Foliar treatments were applied four times at a rate of 4.1 kg K ha^{-1} (11.2 kg KNO_3 ha^{-1}) in 94 L H_2O starting at flowering to 14 d after flowering on a 9-to-14-d interval.

The cultivar D&PL 50 was planted by mid-May each year. Plots were 9.1 m long and four rows wide with cotton planted in 0.97-m rows at Jackson and 1.02 m rows at Milan. Soil fertilizer applications were 90 kg N ha^{-1} as NH_4NO_3, 15 kg P ha^{-1} as triple super phosphate, and 28 kg K ha^{-1} as KCl. Conventional plots were disked several times before planting while the fertilizers were surface applied to the no-tillage plots. Recommended cotton production practices were used at both locations (Shelby, 1996).

Partial budgeting was used to estimate net revenue differences (\$ ha^{-1}) for the foliar KNO_3 and foliar KNO_3 plus adjuvant treatments from each other and from the check. Partial budgeting provided a method for calculating the expected change in net revenue by considering only those revenue and cost items that changed from treatment to treatment (Boehlje and Eidman,1984). Expected gross revenue differences were calculated by multiplying the Tennessee annual average cotton lint price between 1993 and 1997 of \$1.48 kg^{-1} (Tennessee Department of Agriculture, 1998) by the treatment differences in mean annual lint yields. Differences in seed revenue were assumed to cover differences in ginning cost. Material cost differences were calculated by multiplying the quantities of foliar KNO_3 and the adjuvant applied by their respective prices. Prices of KNO_3 and the adjuvant were \$0.61 kg^{-1} (John Duke, Tennessee Farmers' Cooperative, February1999, personal communication) and \$3.69 L^{-1} (Mike Powell, Helena Chemical Co., May 1999, personal communication). Additional machinery costs for the foliar treatments included the variable costs of fuel, oil, filter, and repair and the fixed costs of depreciation, interest, insurance, and storage. These costs were calculated by multiplying the cost per hour of operation by the fraction of an hour required per hectare for foliar application. Foliar application was assumed to be performed using a self-propelled sprayer with an 18-m boom, a purchase price of \$63,000, a 14-yr useful life, and the ability to cover a hectare in 4.4 min (0.07 h ha^{-1}). A wage rate of \$6.75 h^{-1} was assumed in calculating the labor cost of foliar application and labor hours were assumed to be 1.25 times machine hours, or 5.5 min ha^{-1} (0.088 h ha^{-1}). This method of allocating machinery costs implicitly assumed the sprayer was fully employed on the farm, but not necessarily in cotton production (Gerloff and Maxey, 1999).

Sensitivity analysis was performed on cotton lint yield differences and on cotton lint prices. Given a cotton lint price of \$1.48 kg^{-1}, break-even yield differences between treatments were found that made gross revenue differences equal to cost differences. Similarly, given the yields obtained from the experiments, cotton lint prices were calculated that made gross revenue differences between treatments equal to cost differences.

RESULTS AND DISCUSSION

The costs presented in Table 1 represent those costs that change from the check to the foliar KNO_3 plus adjuvant treatment. Budgeted material cost for KNO_3 was \$27.33 ha^{-1} and for the adjuvant it was \$17.34 ha^{-1}. The budgeted cost of foliar application was \$22.95 ha^{-1}, which was the sum of machinery variable (\$5.64 ha^{-1}) and fixed (\$14.95 ha^{-1}) costs and the cost of labor (\$2.36 ha^{-1}) (Gerloff and Maxey, 1999, p. 2). Summing these costs gave a difference in cost from the check for the foliar KNO_3 plus adjuvant treatment of \$67.62 ha^{-1}. For the foliar KNO_3 plus adjuvant treatment to be as profitable as the check, yield would have to increase 46 kg ha^{-1} (\$67.62 ha^{-1} / \$1.48 kg^{-1}) for the increased gross revenue to offset the higher cost. Subtracting the \$17.34 ha^{-1} cost of the adjuvant from \$67.62 ha^{-1} gave a cost difference between the foliar KNO_3 treatment and the check of \$50.28 ha^{-1}. For the foliar KNO_3 treatment to be as profitable as the check, yield would have to increase 34 kg ha^{-1} (\$50.28 ha^{-1} / \$1.48 kg^{-1}). Also, for the foliar KNO_3 plus adjuvant treatment to be as profitable as the foliar KNO_3 treatment, its yield would have to increase 12 kg ha^{-1} (\$17.34 ha^{-1} / \$1.48 kg^{-1}) to offset the \$17.34 ha^{-1} cost of the adjuvant.

Tables 2 and 3 present the overall and annual cotton lint yield means for the experiments

Table 1. Budgeted costs of foliar applying KNO_3 with an adjuvant.

Cost item	\$ ha^{-1}
KNO_3 = \$0.61 kg^{-1} × 11.2 kg ha^{-1} × 4 applications	27.33
Adjuvant = \$3.69 L^{-1} × 94 L ha^{-1} × 0.0125 × 4 applications	17.34
Variable machinery = fuel, oil, filter, and repair of \$20.13 h^{-1} × 0.07 h ha^{-1} × 4 applications	5.64
Fixed machinery = depreciation, interest, insurance, and storage for a self-propelled sprayer of \$53.41 h^{-1} × 0.07 h ha^{-1} × 4 applications	14.95†
Labor = \$6.75 h^{-1} × 0.07 h ha^{-1} × 1.25 × 4 applications	2.36
Total cost	67.62

† Machinery fixed costs are calculated on a machine-hour basis. This method of calculation implicitly assumes the machinery is fully employed on the farm, but not necessarily in cotton production (Gerloff and Maxey, 1999).

Table 2. No-tillage cotton lint yield means for the check and foliar treatments, 1992–1995, Jackson, TN.

Treatment	Overall mean	1992	1993	1994	1995
	..............kg ha^{-1}..............				
Check	1,185 b†	1,129 a	949 a	1,383 a	1,276 a
Foliar KNO_3	1,195 b	1,148 a	944 a	1,395 a	1,293 a
Foliar KNO_3 + Adjuvant	1,255 a	1,195 a	1,038 a	1,482 a	1,303 a

† Within a column, means followed by the same letter are not significantly different (LSD, $\alpha = 0.05$).

Table 3. Conventional- and no-tillage cotton lint yield means for the check and foliar treatments, 1993 and 1994, Milan, TN.

	Conventional-tillage means			No-tillage means		
Treatment	Overall mean	1993	1994	Overall mean	1993	1994
	..............kg ha^{-1}..............					
Check	1,313 a†	1,182 a	1,445 b	1,143 b	915 ab	1,371 b
Foliar KNO_3	1,330 a	1,159 a	1,501 ab	1,153 b	839 b	1,466 ab
Foliar KNO_3 + adjuvant	1,365 a	1,130 a	1,601 a	1,255 a	1,014 a	1,496 a

† Within a column, means followed by the same letter are not significantly different (LSD, $\alpha = 0.05$).

conducted at Jackson and Milan, respectively. In no case did the foliar KNO_3 treatment produce a mean yield that was significantly higher than the check. The overall mean yield increases for Jackson and the conventional- and no-tillage treatments at Milan were 10 kg ha^{-1}, 17 kg ha^{-1}, and 10 kg ha^{-1}, respectively. These yield increases were substantially less than the break-even yield increase of 34 kg ha^{-1} mentioned above. The unprofitability of foliar KNO_3 compared with the check was not

Table 4. Differences in gross revenues, costs, and net revenues among the check and foliar treatments for Jackson and Milan, TN, Using 4-yr and 2-yr mean yields, respectively.

Treatments	Jackson No-tillage	Milan	
		Conv-tillage	No-tillage
	................................$ ha^{-1}		
Foliar KNO_3 + adjuvant vs. foliar KNO_3			
Gross revenue increase	88.80	51.80	150.96
Cost increase	17.34	17.34	17.34
Net revenue increase	71.46	34.46	133.62
Break-even lint price ($ kg^{-1})†	0.29	0.50	0.17
Foliar KNO_3 versus check			
Gross revenue increase	14.80	25.16	14.80
Cost increase	50.28	50.28	50.28
Net revenue increase	-35.48	-25.12	-35.48
Break-even lint price ($ kg^{-1})†	5.03	2.96	5.03
Foliar KNO_3 + adjuvant versus check			
Gross revenue increase	103.60	76.96	165.76
Cost increase	67.62	67.62	67.62
Net revenue increase	35.98	9.34	98.14
Break-even lint price ($ kg^{-1})†	0.97	1.30	0.60

† Break-even lint prices were calculated by determining the lint price that made the gross revenue increase equal to the cost increase, giving a net revenue increase equal to zero.

surprising given the medium-to-high levels of extractable K in the soils when the experiments began and the results from previous research that showed little yield response to foliar KNO_3 on high-K soils (Howard et al., 1997).

Overall mean yield increases for the foliar KNO_3 plus adjuvant treatment compared with the check were 70 kg ha^{-1} for Jackson, 52 kg ha^{-1} for conventional till at Milan, and 112 kg ha^{-1} for no-tillage treatments at Milan. These yield increases were greater than the 46 kg ha^{-1} yield increase required for the foliar KNO_3 plus adjuvant treatment to break even with the check. Although the yield increase was greater than the break-even yield increase for conventional-tillage cotton at Milan, the overall means for the foliar KNO_3 plus adjuvant and check treatments were not significantly different.

Overall mean yield increases for the foliar KNO_3 plus adjuvant treatment compared with the foliar KNO_3 treatment were 60 kg ha^{-1} for Jackson, and 35 kg ha^{-1} and 102 kg ha^{-1} for the conventional- and no-tillage treatments at Milan. These yield increases were substantially higher than the 12 kg ha^{-1} required to break even with the foliar KNO_3 treatment. Increased uptake from adding the adjuvant may have been related to solution pH being adjusted from 9.0 to 5.5 or lower (Howard et al., 1998). Again, for conventional-tillage cotton at Milan, the overall mean yields for the foliar KNO_3 plus adjuvant treatment and the foliar KNO_3 treatment were not significantly different.

Differences in net revenue between treatments and break-even cotton lint prices are presented in Table 4. Estimates of net revenue increases for the foliar KNO_3 plus adjuvant treatment compared with the foliar KNO_3 treatment were $71.46 ha^{-1} for Jackson, $34.46 ha^{-1} for the conventional treatments at Milan, and $133.62 ha^{-1} for the no-tillage treatments at Milan. These net revenue increases became zero for break-even cotton lint prices of $0.29 kg^{-1}, $0.50 kg^{-1}, and $0.17 kg^{-1}, suggesting that net revenue increases would likely remain positive within a wide range of prices expected to prevail in the near future.

The implication from these results is that farmers producing cotton on these medium-to-high-K soils who are already applying foliar KNO_3 can increase their net revenue substantially by adding the adjuvant to the foliar fertilizer. On the other hand, negative net revenue increases when comparing the foliar KNO_3 treatment with the check suggest that farmers of these medium-to-high-K soils would simply incur economic losses by foliar applying KNO_3 without the adjuvant (Table 4). The high break-even cotton lint prices of $5.03 kg^{-1}, $2.96 kg^{-1}, and $5.03 kg^{-1} suggest that applying foliar KNO_3 without the adjuvant would be unprofitable across a wide range of prices expected to prevail in the near future.

More important, however, are the positive net revenue increases when the foliar KNO_3 plus adjuvant treatment is compared with the check. The estimated net revenue increases were \$35.98 ha^{-1} for Jackson, \$9.34 ha^{-1} for conventional treatments at Milan, and \$98.14 ha^{-1} for no-tillage treatments at Milan. These results indicate that no-tillage cotton producers who farm medium-to-high-K soils may be able to increase their net revenue by applying foliar KNO_3 if the adjuvant is applied with it. For instance, farmers who grow cotton in the same areas and using the same treatments described above can increase net revenue by foliar applying KNO_3 with the adjuvant if they receive cotton lint prices above \$0.97 kg^{-1}, \$1.30 kg^{-1}, and \$0.60 kg^{-1}, respectively. These break-even prices were 34, 12, and 59 % lower than the 1993-to-1997 annual average cotton lint price received by Tennessee farmers of \$1.48 kg^{-1}, but 25, 0, and 54 % lower than the May 1999 Tennessee cotton lint price of \$1.30 kg^{-1} (Tennessee Department of Agriculture, 8 July 1999). These results suggest that foliar applying KNO_3 with the adjuvant on no-tillage cotton may be profitable compared with the check for a wide range of lint prices; however, the same conclusion cannot be drawn for conventional-tillage cotton because the overall mean yields for the foliar KNO_3 plus adjuvant and check treatments were not significantly different for conventional-tillage cotton at Milan.

CONCLUSIONS

Although using an adjuvant with foliar KNO_3 may appear costly to the typical cotton producer, foliar KNO_3 with the adjuvant may increase no-tillage cotton lint yields sufficiently to offset the \$67.62 ha^{-1} higher cost. Also, on medium-to-high-K soils (Mehlich I), foliar KNO_3 may not increase net revenue without the use of the adjuvant; but with the adjuvant, foliar KNO_3 potentially can increase net revenue substantially. The results for conventional-tillage cotton are less convincing because mean yields were not significantly different among treatments.

Considerable research has been conducted to determine the timing of foliar KNO_3 application, but little has been done to determine the optimal frequency and quantity of application (Weir et al., 1993). Research to determine the optimal frequency and quantity of application is important given that reducing the frequency of application by one trip can save cotton producers \$5.74 ha^{-1} in machinery and labor costs [(\$5.64 + \$14.95 + \$2.36) / 4 applications, Table 1], and if the quantity of KNO_3 and the adjuvant could be reduced commensurately without affecting yield, additional savings of \$6.83 ha^{-1} (\$27.33 / 4 applications, Table1) and \$4.34 ha^{-1} (\$17.34 / 4 applications, Table 1) could result. Total potential savings for cotton producers from reducing the number of trips across the field from four to three would be \$16.91 ha^{-1}, which is reason enough for conducting additional research into determining the optimal frequency and quantity of foliar application.

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REFERENCES

Boehlje, M.D., and V.R. Eidman. 1984. Farm management. John Wiley & Sons, New York.

Chang, M.A., and D.M. Oosterhuis. 1995. Efficacy of foliar application to cotton of potassium compounds at different pH levels, Vol. 3:1364–1366. Proc. Beltwide Cotton Conf., Natl. Cotton Counc. Am., Memphis, TN.

Gerloff, D.C., and L. Maxey. 1999. Field crop budgets for 1999. AE & RD no. 22.. Univ. of Tennessee Dep. of Agric. Econ. and Res. Dev.

Howard, D.D. 1993. Foliar fertilization of cotton as affected by surfactants and foliar solution pH. p. 77–90. *In* L.S. Murphy (ed.) Foliar fertilization of soybeans and cotton. PPI/FAR Tech. Bull. 1993-1. Potash & Phosphate Inst. and Found. for Agronomic Res., Norcross, GA.

Howard, D.D., and C.O. Gwathmey. 1995. Influence of surfactants on potassium uptake and yield response of cotton to foliar potassium nitrate. J. Plant Nutr. 18:2669–2680.

Howard, D.D., C.O. Gwathmey, and C.E. Sams. 1998. Foliar feeding of cotton: Evaluating potassium sources, potassium solution buffering, and boron. Agron. J. 90:740–746.

Howard, D.D., C.O. Gwathmey, R.K. Roberts, and G.M. Lessman. 1997. Potassium fertilization of cotton on two high testing soils under two tillage systems. J. Plant Nutr. 20:1645–1656.

Howard, D.D., C.O. Gwathmey, R.K. Roberts, and G.M. Lessman. 1998. Potassium fertilization of cotton produced on a low K soil with contrasting tillage systems. J. Prod. Agric. 11:74–79.

Howard, D.D., P.E. Hoskinson, and P.W. Brawley. 1993. Soil and foliar applied K for conventional- and no-tillage cotton in Tennessee, Vol. 3:1382. Proc. Beltwide Cotton Conf., Natl. Cotton Counc. Am., Memphis, TN.

Oosterhuis, D.M., D.W. Albers, W.H. Baker, C.H. Burmiester, J.T. Cothren, M.W. Ebelhar, D.S. Guthrie, M.G. Hickey, S.C. Hodges, D.D. Howard, L.D. Janes, G.L. Mullins, B.A. Roberts, J.C. Silvertooth, P.W. Tracy, and B.L. Weir. 1993. A beltwide study of soil and foliar fertilization with potassium nitrate in cotton, Vol. 3:1351. Proc, Beltwide Cotton Conf., Natl. Cotton Counc. Am., Memphis, TN.

Roberts, R.K., D.C. Gerloff, and D.D. Howard. 1997. Economics of foliar-applied potassium for conventional and no-till cotton. J. Prod. Agric. 10:585–589.

Shelby, P.P. 1996. Cotton production in Tennessee. P. 3–7. PB1514. Univ. Tenn. Agric. Ext. Serv. Pub. Knoxville, TN.

Tennessee Department of Agriculture. 1998. Tennessee agriculture, 1998. Tennessee Agric. Statistics Serv., Nashville.

Tennessee Department of Agriculture. 8 July 1999. Farm facts, Vol. 99, No. 13. Tennessee Agric. Statistics Serv., Nashville.

Weir, B.L., B.A. Roberts, and T.A. Kerby. 1993. Effect of water-run and foliar K on cotton yields, Vol. 3:1338. Proc. Beltwide Cotton Conf., Natl. Cotton Counc. Am., Memphis, TN.