FOLIAR FERTILIZATION

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Abstract

Foliar fertilization is a widely used method used to supplement soil applications to improve the yield and quality of cotton. It has the advantages of low cost and a quick plant response, and it is particularly important when soil problems occur and root growth is inadequate. On the other hand, it has disadvantages of possible foliar burn, solubility problems, and only a small amount of the nutrient can be applied at any one time. Variable yield responses to foliar fertilization have been reported. These are probably associated with incorrect timing of applications, the use of inappropriate fertilizer materials, and insufficient attention to soil available nutrients, the size of the boll load, and environmental conditions. The efficiency of foliar fertilization can be influenced by the type of fertilizer, concentration and pH of the solution, the use of adjuvants, and compatibility with other agrochemicals. Attention also needs to be given to the ideal method and timing for incorporation of foliar fertilization into existing production practices.

What Is Foliar Feeding?

The application of mineral nutrients to the aerial portion of plants to alleviate deficiencies and *supplement* traditional soil application methods. Foliar feeding is particularly important when soil problems occur and root growth is inadequate.

Why Is Foliar Fertilizer Used?

Foliar fertilization is a method used to improve the efficiency and rapidity of utilization of a nutrient urgently required by the plant for maximum growth and yield. Foliar application of nutrients is used to correct low soil nutrient availability, to correct low plant nutrient status, particularly when root growth and nutrient uptake are inadequate, or when a heavy fruit load and large nutrient uptake requirement occurs.

How Does it Work?

The basis for this is that certain fertilizer nutrients are soluble in water and may be applied directly to the aerial portions of plants. The nutrient enters the leaf either by penetrating the cuticle or entering through the stomata before entering the plant cell where be used in metabolism. For successful foliar fertilization, nutrients must be successfully applied to the leaf, penetrate the cuticle or stomata into the leaf and enter cells and metabolic pathways.

Advantages of Foliar Fertilization

Advantage of foliar feeding are:

- low cost
- quick plant response
- can respond immediately to plant conditions
- lack of soil fixation
- independent of root uptake
- use much less chemical
- can incorporate with other agrochemicals.
- increased quality
- increased yields

Disadvantages of Foliar Fertilization

Disadvantages of foliar feeding are:

- the possible occurrence of foliar burn
- solubility problems
- the requirement for correct weather conditions for application
- pH of solution is often high (boron, potassium)
- incompatibility with certain chemicals
- can't put on sufficient chemical if deficiency is severe
- possibility of inefficient absorption (leaf age, crop stage, drought)

Practical Problems

Practical problems associated with foliar fertilization include the detrimental effects of drought and increased leaf wax (Oosterhuis et al., 1991), the possibility of foliar burn, optimal timing of the application foliar during the day, and effects of various plant organs and organ age on absorption (Zhu, 1989). Nutrient absorption can also be affected by environmental conditions weather (wind, temperature, humidity) , the correct location of the spray in the canopy (Oosterhuis et al., 1989), leaf age (physiological activity) (Bondada et al., 1996), the crop fruit load (Bondada et al., 1994). The efficiency of foliar fertilization can also be affected by such practical factors as the choice of salt (Miley et al., 1992), concentration of salt, the pH of solution (Chang and Oosterhuis, 1995), the use of adjuvants (Oosterhuis, 1998), and compatibility with other chemicals (Baker et al., 1994). Attention also needs to be given to the ideal method and timing for incorporation of foliar fertilization into existing production practices.

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Research Highlights

The Leaf Cuticle

The surface morphology and cross section form of the leaf cuticle has been shown using electron microscopy (Plate 1). Water deficit increased cuticle thickness 33% and also changed the composition of the lipid constituents to more long-chain hydrophobic lipids (Oosterhuis et al., 1991) (Table 1). Plate 2A shows a schematic representation of the surface wax formation from epidermal cells in the stomatal-cuticle complex of a leaf (Bondada et al., 1996). Note the wax precursors in the epidermal cells and the build up of epicuticular wax on the leaf surface. Also note the complex nature of the cuticle. The anatomy of the boll wall is illustrated in Plate 2B showing the stomata with reduced stomatal chamber and cuticular ledges.

The Uptake of Foliar-Applied ^{15}N Urea

Results of recent research clearly demonstrated the uptake of foliar-applied ^{15}N urea by the leaves and translocation to the developing bolls (Fig. 1). Foliar-applied ^{15}N was rapidly absorbed by the leaf to which it was applied (30% within one hour!) and translocated into the closest boll within 6 to 48 hours after application. The N moved progressively into adjoining bolls for the next few days with no translocation to other leaves (Zhu, 1989; Miley and Oosterhuis, 1989).

Effect of Water Deficit and Time of Day on ^{15}N Absorption

The uptake of foliar-applied ^{15}N was highest in the early morning and late afternoon, and lowest at midday (Fig. 2). Water deficit (drought) significantly reduced the absorption of foliar-applied N (Zhu, 1989).

Change in the Leaf Cuticle with Age and Effect on the Uptake of Foliar-Applied ^{15}N

Total leaf wax of field-grown cotton increased with increase in leaf age (Fig. 3A) and this was associated with a significant decrease in ^{15}N from foliar application (Fig. 3B) (Bondada et al., 1996). This may account for the decrease in yield response to foliar-applied urea three weeks after flowering as reported by Keisling et al., (1992) and may warrant the use of increased rates or frequency of application of N and the use of adjuvants.

The Effect of pH on the Efficacy of Foliar-Applied K Fertilizers

Research has shown the importance of pH on the efficacy of foliar-applied K fertilizers (Chang and Oosterhuis, 1995) (Fig. 4). Potassium fertilizers have a high pH in solution, and adjusting the solution to a pH of 4 to 6 significantly increased uptake and yield. Furthermore, KNO_3 and K_2SO_4 were superior to the other K fertilizers tested, whereas K_2CO_3 and KOH gave the poorest results.

Soil and Foliar Application of K (A Beltwide Study)

The potential benefit of foliar K fertilizer was demonstrated in a three-year, twelve location (Beltwide) study in which foliar fertilizer was applied in addition to soil applied K (Fig. 5).

Conclusions

Proper plant nutrition for optimal crop productivity in cotton requires that nutrient deficiencies be avoided. However, nutrient deficiencies often occur for a variety of reasons, and can be rectified by timely application of the deficient nutrient. This usually entails some sort of soil application but after canopy closure, foliar application may be more appropriate. Foliar fertilization can be used to improve the efficiency and rapidity of utilization of a nutrient urgently required by the plant for maximum growth and yield. In this way the foliar fertilization supplements soil applications for a more efficient supply of nutrients to the developing cotton plant for optimum yields and fiber quality. In general, foliar applications should be made either early morning or late evening for maximum efficiency, and no foliar applications should be made to water-stressed plants. Foliar fertilization of cotton is a viable means of applying certain fertilizers that can supplement traditional soil methods. Foliar fertilization can result in yield increases. Foliar fertilization can cause improved fibre quality. Certain precautions should be observed.

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References

Baker, W.H., McConnell, R., McConnell, S.J., Varvil, J.J., Bagwell, R. and Tugwell, N. 1994. The physical stability of insecticide mixed with foliar urea nitrogen and potassium nitrate fertilizers. p. 48-55. In D.M. Oosterhuis (ed.) Proc. 1993 Cotton Research Meeting and Summaries of Research in Progress. Arkansas Agric. Exp. Sta., Special Report 162.

Bondada, B.R., Oosterhuis, D.M. and Norman, R.J. 1996. Cotton leaf age, epiculticular wax, and nitrogen-15 absorption. Crop Sci. 37:807-811.

Bondada, B.R., Oosterhuis, D.M., and Tugwell, N.P. 1994. Late-season foliar nitrogen fertilization of cotton. 1993 Summaries of Cotton Research in Progress. Arkansas Agric. Exp. Sta. Special Report 162:176-179.

Chang, A.M. and Oosterhuis, D.M. 1995. Differential response of cotton to foliar application of various compounds at different pH levels. Proc. Beltwide Cotton Conf., San Antonio, TX pp 1364-1366.

Keisling, T. C., Mascagni, H. J., and Maples, R. C. 1992. Nitrogen response curves based on tissue analysis and yield. Proc. Beltwide Cotton Conf., National Cotton Council, Memphis, TN. pp 1178.

Miley, W.N. and Oosterhuis, D.M. 1989. Cotton nitrogen and carbohydrate nutrition. University of Arkansas, Coop. Ext. Ser., Fact Sheet No. 2045.

Miley, W.N., Oosterhuis, D.M., Baker, W.H., Varvil, J., and Batchelor, T.J. 1992. Effects of foliar application of five potassium fertilizers on cotton yield and leaf burn. Proc. Beltwide Cotton Conf., Nashville, TN. p. 1164-1165.

Oosterhuis, D.M., Zhu, B., and Wullschleger, S.D. 1989. Uptake of foliar-applied nitrogen by cotton. p. 23-26. In, D.M. Oosterhuis (ed.) Proc. 1989 Cotton Research Meeting, Arkansas, Agric. Exp. Sta., Special Report 138.

Oosterhuis, D.M. Hampton, R.E., and Wullschleger, S.D. 1991. Water deficit effects on cotton leaf cuticle and the efficiency of defoliants. J. Agron. Prod. 4:260-265.

Oosterhuis, D.M. 1998. The cotton leaf cuticle and absorption of foliar applied agrochemicals. Proc. Fifth International Symposium on Adjuvants for Agrochemicals. Vol. 2. Memphis, TN, August 17-21, 1998.

Oosterhuis, D.M., Abaye, O., Albers, D., Baker, W.H., Burmiester, C., Cothren, J.T., Ebelhar, M.W., Guthrie, D.S., Hickey, M.G., Hodges, S.C., Howard, D.D., Hutchinson, R., Janes, L.D., Mullins, G., Roberts, B.A., Silvertooth, J., Tracy, P., and Wier, B. 1994. A three-year summary of a Beltwide study of soil and foliar potassium fertilization with potassium in cotton. Proc. Beltwide Cotton Conf., San Diego, CA. p. 1532-1533.

Zhu, B. 1989. Absorption and translocation of foliar-applied nitrogen in cotton. M.S. Thesis, University of Arkansas, Fayetteville.

Table 1. Composition of adaxial cuticle of well-watered and water-stressed leaves (Oosterhuis et al., 1991).

Epicuticular Composition	Molecular Composition	Epicuticular Wax Composition Well-watered	Water-stressed
Tricosane	$C_{23}H_{48}$	+	-
n-Tetracosane	$C_{24}H_{50}$	+	-
Pentacosane	$C_{25}H_{52}$	+	+
Hexacosane	$C_{26}H_{54}$	+	tr
Octocosane	$C_{28}H_{58}$	+	++
n-Nonacosane	$C_{29}H_{60}$	tr	++
Decasane	$C_{30}H_{62}$	tr	++
Octocosanol	$C_{28}H_{58}O$	+	++
Fucosterol	$C_{29}H_{48}O$	+	0

'-' wax absent, '+' wax present, '++' increased quantity, 'tr' trace present

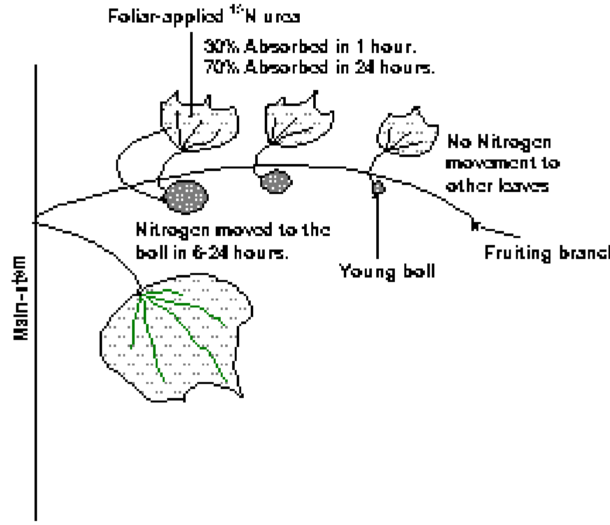


Fig. 1. The uptake of foliar-applied ^{15}N labeled urea by cotton and movement to the closest developing boll (Redrawn from Miley and Oosterhuis, 1989)

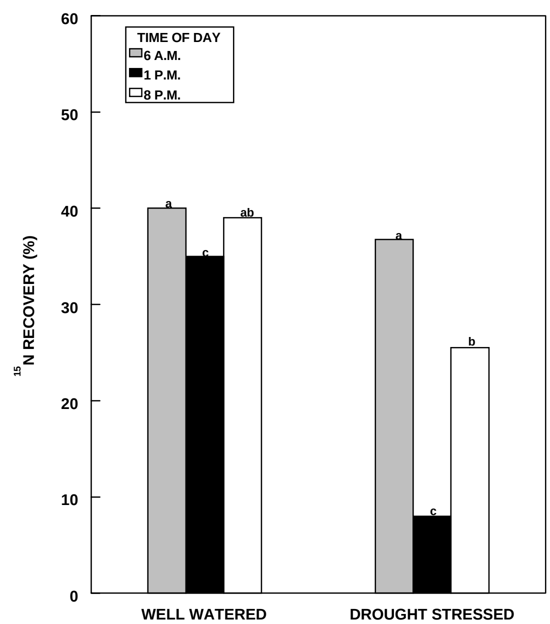


Fig. 2. The uptake of foliar-applied ^{15}N labeled urea as affected by water deficit stress and diurnal timing of application. Values within the same treatment with the same letter are not significantly different (P>0.05). Redrawn from Zhu (1989).

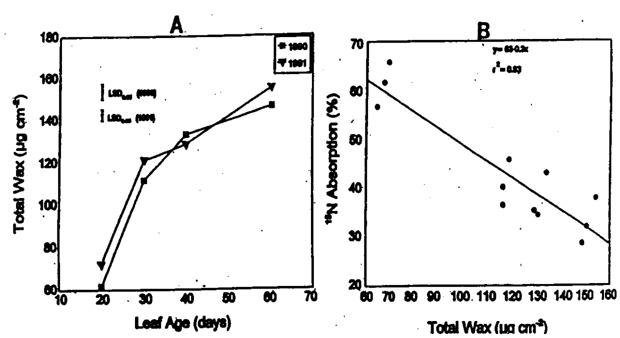


Fig. 3. A. Change in total leaf epicuticular wax content with increase in leaf age of field-grown cotton. B. Relationship between leaf ^{15}N absorption and total wax content during leaf ontogeny for field-grown. From Bondada et al. (1996).

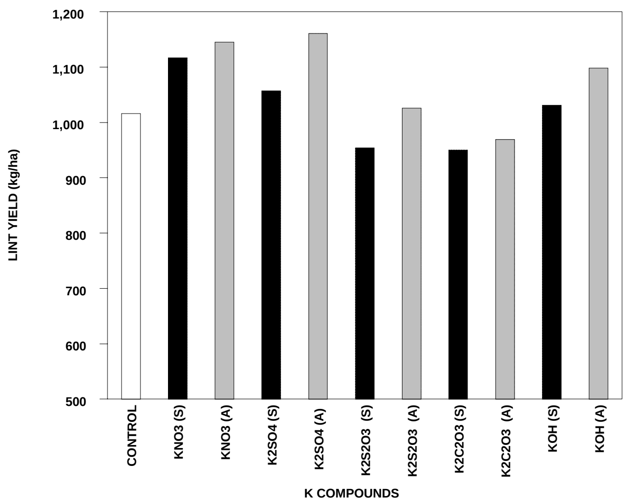


Fig. 4. Effect of pH of foliar-applied potassium fertilizers on cotton lint yield. (S=Standard pH of solution; A=adjusted pH to 4.0 with buffer). From Chang and Oosterhuis (1995).

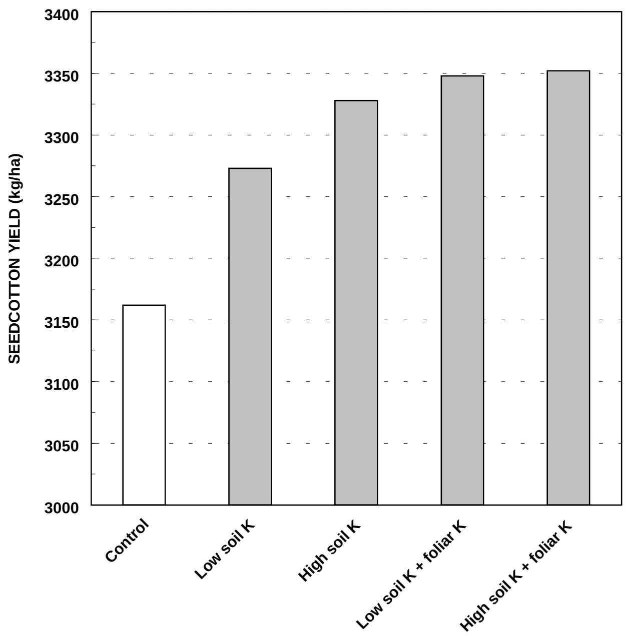
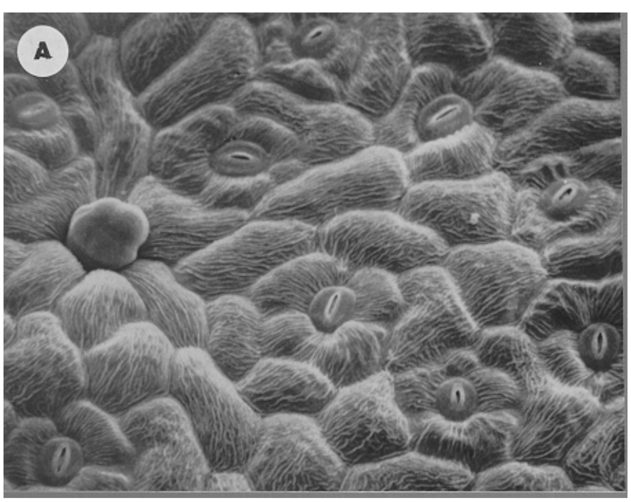
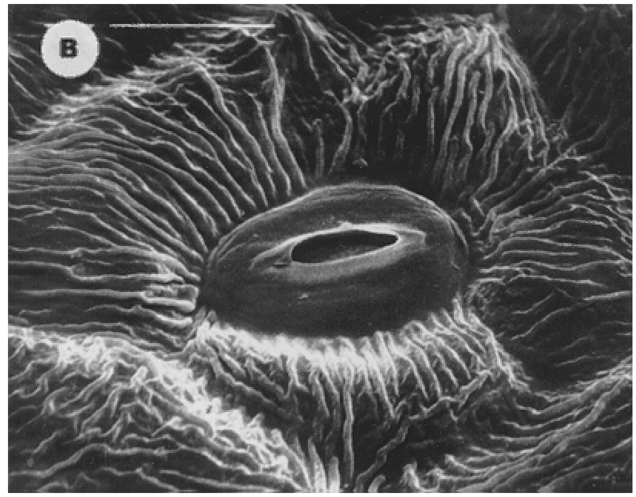


Fig. 5. Comparison of soil-applied and foliar-applied potassium fertilizers to seedcotton yields averaged over 12 sites for the Beltwide Foliar Potassium Study (1991-1993). From Oosterhuis et al. (1994).





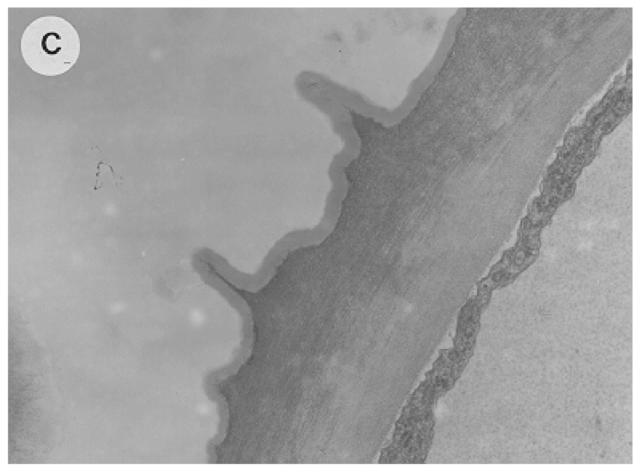


Plate 1. (A) Schematic representation of surface wax formation from the epidermal cells in the stomatal-cuticle complex of a leaf. Note the wax precursors in the epidermal cells and the build-up of epicuticular wax on the leaf surface. Also note the complex nature of the cuticle.
(B) Light micrograph of the boll wall showing stomata with reduced stomatal chamber and cuticular ledges.

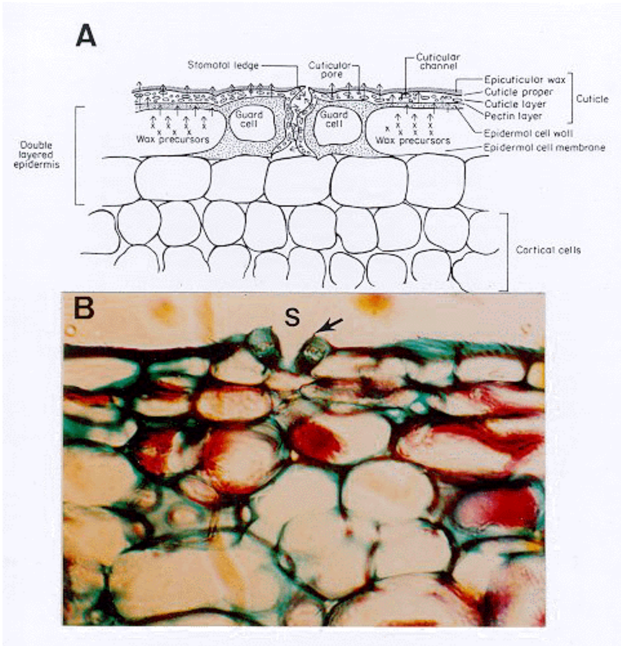


Plate 2. (A) Schematic representation of surface wax formation from the epidermal cells in the stomatal-cuticle complex of a leaf. Note the wax precursors in the epidermal cells and the build-up of epicuticular wax on the leaf surface. Also note the complex nature of the cuticle. (B) Light micrograph of the boll wall showing stomata with reduced stomatal chamber and cuticular ledges.