FOLIAR FERTILIZATION WITH POTASSIUM: PRINCIPLES AND PRACTICES

Derrick M. Oosterhuis
University of Arkansas
Fayetteville, AR

Abstract

The advent of widespread potassium (K) deficiency across the US Cotton Belt has focused attention on foliar fertilization with K in cotton production systems. However, the yield response to foliar-applied K fertilizer has been inconsistent, partly due a lack of understanding of the fundamentals needed for successful foliar fertilization. The objective of this paper is to review the fundamentals of foliar fertilization with K. Generally, the efficiency of foliar fertilization can be influenced by the type of fertilizer, concentration and pH of the solution, the use of adjuvants, the time the chemical remains on the leaf, and compatibility with other agrochemicals. Attention also needs to be given to the method and timing of foliar applications, and the best way for incorporation of foliar fertilization into existing production practices. Variable yield responses to foliar fertilization are 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. Overall, foliar fertilization 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. A sound knowledge of the fundamentals involved in foliar fertilization will ensure a higher efficiency and enhanced economic returns.

Introduction

Proper plant nutrition for optimal productivity in crops requires that nutrient deficiencies be avoided. However, deficiencies occur for a variety of reasons, most of which can be avoided by the use of soil and tissue tests and the timely application of the required mineral nutrients. Foliar fertilization is a widely used practice to improve the efficiency and rapidity of utilization of a nutrient urgently required by the plant for maximum growth and yield. However, there are still many misconceptions about the practice and method of application that result in poor efficiency and reduced economic returns. The appearance of K deficiency across the Cotton Belt has focused attention on K fertilization and the use of foliar applications of K, but the yield response to foliar-applied K fertilization has been inconsistent. Part of the reason for this is associated with the lack of understanding of the fundamentals needed for successful foliar fertilization.

Foliar Fertilization

There is a wealth of literature about foliar fertilization that was first used as long ago as 1844 to correct plant chlorosis with foliar sprays of iron. The practice has only caught on in cotton production in the last two decades, although there is still considerable speculation about the benefits and correct implementation of this practice. While there are many reports on research with cotton involving soil-applied fertilizer, there are relatively few definitive studies on the usefulness of foliar-fertilization with K in cotton (Oosterhuis, 1999).

Foliar fertilization should only serve as a supplement to traditional soil-applied fertilizer. However, when deficiencies occur, foliar fertilization provides an efficient means of rectifying the problem and ensuring optimal growth and yields. Indiscriminate application of foliar-applied nutrients without due consideration of soil availability and plant nutrient status can be wasteful. A sound soil test as well as accurate tissue analysis is a fundamental requirement for a successful fertilization program. Foliar applications have the advantage of allowing producers to add the necessary nutrient when tissue analysis indicates a pending shortage, and thereby correct the deficiency and prevent yield loss.

Mechanism of Foliar Fertilization

In order for a foliar-applied fertilizer nutrient to be utilized by the plant for growth, the nutrient must first gain entry into the leaf prior to entering the cytoplasm of a cell within the leaf. To achieve this, the nutrient must effectively penetrate the outer leaf cuticle and the wall of the underlying epidermal cell. Once penetration has occurred, nutrient absorption by leaves is probably not greatly different from absorption of the same nutrient by roots, the major difference being the environment in which each of these plant parts exists. Of all the components of the pathway of foliar-applied nutrients, the cuticle offers the greatest resistance.

Originally it was held that movement of solutes occurred in ectodesmata (teikodes) in the cuticle. However, it is now believed that cuticles are traversed by numerous hydrophilic pathways permeable to water and small solute molecules. These pores have a diameter of <1nm, with a density of about 1010 pores/cm, and are readily accessible to low molecular weight solutes such as urea (radius 0.44 nm) but not to larger molecules such as synthetic chelates. These pores are lined with negative charges increasing in density towards the inside, facilitating movement of cations along the gradient. Actual movement through the cuticle depends on the nutrient concentration, molecular size, organic or inorganic form, time as a solution on the leaf surface, and charge density across the cuticle. Following penetration of the cuticle, the uptake of solutes into the cell interior depends primarily on the electrochemical gradient concentration gradient from outside into the cell, but also on the plasma membrane permeability coefficient of the molecule and the degree of cell-mediated active uptake.

The Leaf Cuticle

It is generally accepted that most nutrient uptake occurs through the cuticle. Nutrients do not usually gain entry into the leaf indirectly through the stomata due to the high surface tension of water, the hydrophobicity of leaf surfaces, and the geometry of the stomate. Furthermore, ion uptake rates from foliar sprays are usually higher at night, when the stomata are closed. Surfactants in agrochemical sprays typically provide surface tensions which would usually not be sufficient to enable stomata to be infiltrated. However, organosilicone surfactants can reduce aqueous surface tensions to allow nutrient entry via the stomates. Furthermore, stomatal penetration can occur only in the brief period after application while spray deposits remain liquid, thereafter cuticle penetration remains the sole pathway of uptake. In cotton, it is unlikely that direct penetration of solutes from the leaf surface through open stomata into the leaf tissue plays an important role, because cotton has pronounced stomatal ledges that partly cover the mature stomate, as well as an internal cuticular layer which extends through the stomatal pore and partially covers the mesophyl cells in the sub-stomatal cavity closest to the stomate. The cuticle is generally considered to be the rate-limiting step in the overall process of foliar penetration.

The cuticle constitutes a continuous waxy covering over the underlying epidermis, interspersed with numerous stomates and glandular trichomes. Superimposed on this is the epicuticular layer of predominantly lipid material formed from precursors in the underlying epidermal cells. Water-deficit stress has been shown to increase cuticle thickness by 33% and also change the qualitative composition of cuticular waxes. The leaf wax from water-stressed cuticles contained more long chain molecular waxes of greater hydrophobicity. The thickness of the cotton leaf cuticle has been shown to increase with leaf age from 20 to 60 days after leaf unfolding. This was negatively associated with a decrease in absorption of foliar-applied foliar-applied nutrients such as 15N-urea. Studies showed that the uptake of foliar-applied KNO3 could be increased by the use of adjuvants. The dynamic nature of the leaf cuticle in response to management and environment needs to be taken into consideration for efficient foliar application of fertilizers.

Factors Affecting the Efficiency of Foliar fertilization

There are various fates of foliar-applied fertilizer nutrients including volatilization and loss to the atmosphere, crystallization and retention on the outer plant surface, loss in dew dripping from the leaf, as well as absorption and retention inside the treated leaf including in lipoidal layer of the cuticle. Foliar-applied nutrients are transported through the phloem and take the pathway of photosynthetic assimilates. The most important consideration for efficient and profitable foliar fertilization is that this practice will only be affective if the applied nutrient ultimately reaches the target site for its use, i.e., the growing points in a vegetative cotton plant and the developing fruit in a more mature reproductive plant.

Generally, the efficiency of foliar fertilization can be influenced by the type of fertilizer, concentration and pH of the solution, the use of adjuvants, the time the chemical remains on the leaf, and possible incompatibility when applied together with other agrochemicals. Attention also needs to be given to the ideal method and timing of foliar applications, and the best way for incorporation of foliar fertilization into existing production practices. Variable yield responses to foliar fertilization 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.

Environmental conditions can seriously affect the absorption of a foliar-applied nutrient, particularly temperature, humidity and wind. In general, foliar applications should be made either early morning or late evening for maximum absorption by the plant, and no foliar applications should be made to water-stressed plants. Adjuvants can improve the efficiency of absorption of a foliar-applied nutrient by prolonging the time the nutrient remains in solution on the leaf surface and thereby improving the absorption efficiency. More research is needed to determine the amounts of each specific nutrient that actually reaches the target (e.g., the fruit to be harvested) and how much of the total budget of these organs this constitutes. Information is also needed on the quantification of environmental effects, humidity and temperature in particular, on the absorption of foliar-applied fertilizers

Conclusions

Overall, foliar fertilization 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, foliar applications have disadvantages of possible phytotoxicity, solubility problems, and because only a small amount of the nutrient can be applied at any one time. In general there is a lot of conflicting information about the benefits of foliar fertilization, but the scientific evidence to date and the widespread use of the this practice indicates that it is a viable and useful method for improved crop production. A sound knowledge of the fundamentals involved in foliar fertilization will ensure a higher efficiency and enhanced economic returns.

References

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