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FOLIAR FERTILIZATION OF NUTRIENTS

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Introduction

Foliar feeding is a technique of feeding plants by applying liquid **fertilizer** directly to their leaves. Plants are able to absorb essential elements through their leaves. The absorption takes place through their stomata and also through their epidermis. It is the application of fertilizers to foliage of the crop as spray solution is known as foliar spray. This method is suitable for application of small quantities of fertilizers, especially micronutrients. Major nutrients can also be applied by this method when there is no adequate moisture in top layer of soil. Foliar application is not substitute for soil application, but only a supplement to it, Kannan, 2010.

More recently, foliar feeding has been widely used and accepted as an essential part of crop production, especially on horticultural crops. Although not as widespread on agronomic crops, the benefits of foliar feeding have been well documented and increasing efforts have been made to achieve consistent responses.

Mechanism of Foliar Fertilization

- In order for a foliar fertilizer nutrient to be utilized by the plant for growth, it must first gain entry into the leaf prior to entering the cytoplasm of a cell in the leaf.
- To achieve this nutrient must effectively penetrate the outer cuticle and the wall of the underlying epidermal cell.
- Once penetration has occurred, nutrient absorption by the cell is similar to absorption by the roots.
- Of all the components of the pathway of foliar-applied nutrients, the cuticle offers the greatest resistance.

The purpose of foliar feeding is not to replace soil fertilization. Supplying a plant's major nutrient needs (nitrogen, phosphorus and potassium) is most effective and economical via soil application. However, foliar application has proven to be an excellent method of supplying plant requirements for secondary nutrients (calcium, magnesium and sulphur) and micronutrients (zinc, manganese, iron, copper, boron, and molybdenum), while supplementing N-P-K needs for short and/or critical growth 3 stage periods. Primarily, foliar feeding is intended to delay natural senescence processes shortly after the end of reproductive growth stages . Foliar feeding targets the growth stages where declining rates of photosynthesis and levelling off of root growth and nutrient absorption occur, in attempts to aid translocation of nutrients into seed, fruit, tuber or vegetative production. Secondarily, foliar feeding can be an effective management tool to favourably influence pre-reproductive growth stages by compensating for environmentally induced stresses of adverse growing conditions and/ or poor nutrient availability. Early foliar applications can make an already good crop better, either by stimulating more vigorous regrowth or maximizing the yield potential growth stage period. The advantages of foliar feeding in accomplishing the desired crop responses are two-fold.

1. It is a highly efficient and timely method of applying needed and/or critical plant nutrients.
2. It is a means of compensating for soil or environmentally induced nutrient deficiencies.

Proper Timing of Foliar Applications

Proper Growth Stage: This is one of the most critical aspects of a foliar feeding program. Foliar applications should be timed to provide needed nutrients during the yield potential determining time frame of plant development, which will in turn favourably influence the post-reproductive development stages. Multiple, low rate applications may show the most favourable responses within these time frames, whether a crop is nutritionally sound or not. Careful crop growth stage monitoring on a weekly, and sometimes a daily basis, is essential. A comprehensive plant tissue analysis program taken just prior to the desired application is also essential to establish levels of plant nutrients most limiting to crop growth. DRIS (Diagnosis and Recommendation Integrated System) analysis of tissue tests is the best method of relating tissue nutrient levels to desired plant needs by ranking plant nutrients in order of most limiting to least limiting. See the appendix for timing and rates of foliar applications regarding specific crops.

Proper Crop Condition: Generally speaking, crops that are nutritionally sound will be most likely to respond to foliar feeding. This is due to better tissue quality (allowing for maximum absorption of nutrients into leaf and stem) and better growth vigour (allowing for translocatable nutrients to be rapidly moved to the rest of the plant). Crops under heat or moisture stress show less response to foliar applications due to lower leaf and stem absorption rates and/or poor vigour. However, foliar feeding does benefit crop performance and yield if an application was made prior to heat or moisture stress. Recovery from cold growing conditions and herbicide stress can be hastened with proper foliar applications. Good recovery of corn suffering from light to moderate hail damage has been shown where nitrogen-sulphur solutions were foliar applied. Under most conditions, however, due to the practical and economic limitations on the amount of nutrients that can be foliar applied to give a favourable growth response, foliar feeding has a limited rescue capability.

Proper Meteorological Conditions: Environmental influences, such as time of day, temperature, humidity and wind speed influence the physical and biological aspects of foliar applications. Plant tissue permeability is an important factor in absorption of nutrients into the plant: warm, moist and calm conditions favour highest tissue permeability, conditions found most often in the late evening hours, and occasionally in the early morning hours. Table summarizes meteorological conditions favouring foliar applications.

Table 1: Meteorological condition favouring foliar applications

Time of Day:	Late evening; after 6:00 p.m. Early morning; before 9:00 a.m.
Temperature:	Low temperature 18-19^{0}C (Ideal 21^{0}C)
Humidity:	Greater than 70 % relative humidity
Wind speed:	less than 5 mph
Rainfall:	Within 24 to 48 hours after a foliar application may reduce the application effectiveness, as not all nutrient materials are immediately absorbed into the plant tissue

Table 2: Rates of nutrient absorption into plant tissues

Nutrient	Time for 50 % absorption
Nitrogen (as Urea)	½-2 hours
Phosphorous	5-10 days
Potassium	10-24 hours
Calcium	1-2 days
Magnesium	2-5 days
Sulphur	8 days
Zinc	1-2 days
Manganese	1-2 days
Iron	10-20 days
Molybdenum	10-20 days

Foliar feeding: desirable characteristics

1. Solubility: foliar fertilizers should be able to either dissolve or suspended in water and contain an active ingredient chemical compound as salts, chelates or complexes of mineral nutrients.

2. Molecular weight/size: foliar fertilizer must contain low molecular weight or molecules of smaller size in order to have higher penetration of leaf cuticle, Fageria *et al.*, 2009.

3. Solution pH: solution pH should be adjusted for better activity of nutrient and to prevent the scorching or burning effects.

4. Form: The absorption rate of ammonium ions into the leaves is faster than that for nitrate ions. Urea has higher leaf penetration than other inorganic N fertilizers. KCl fit for use for soil fertilization but unfit for foliar application due to its rapid crystallization over leaf surface.

Types of Fertilizer Materials/Additives/Water

Fertilizer Materials: Not all fertilizers are suitable for use as a foliar spray. The primary objective of a foliar application is to allow for maximum absorption of nutrients into the plant tissue; therefore, foliar fertilizer formulations should meet certain standards in order to minimize foliage damage. Qualifications for fertilizer materials follow:

Low salt index: Damage to plant cells from high salt concentrations can be considerable, especially from nitrates (NO_3^-) and chlorides (Cl^-).

High solubility: Needed to reduce the volume of solution needed for application.

High purity: Needed to eliminate interference with spraying, solution compatibility, or unexpected adverse effects on foliage.

Fertilizer materials:

A) Nitrogen Materials: Urea is the most suitable nitrogen source for foliar applications, due to its low salt index and high solubility in comparison to other nitrogen sources. Urea has been shown to stimulate absorption of other nutrients by increasing the permeability of leaf tissue. However, the urea utilized in foliar sprays should be low in biuret content (0.2 percent or less) to lessen urea foliage burn side effects. Urea formulated in today's urea-containing solutions and feed grade products is low enough in biuret to provide no hazard for plants. Other sources of nitrogen can be obtained from ammonium polyphosphates, ammoniated ortho-phosphates (liquid), ammonium thiosulfate (12-0-0-26S), and fluid ammonium sulphate (8-0-0-9S). These sources, when utilized at low foliar rates, are excellent supplemental nitrogen carriers with no/minimal foliage burn side-effects. A relatively new nitrogen compound, Triazone, which was developed in the late 1970's, has ideal uses in foliar applications due to its low-burn characteristics. Triazone nitrogen has been shown to significantly reduce leaf burn and enhance foliar absorbed nitrogen compared to urea, nitrate, and ammonium nitrogen sources. Triazone is currently sold under the trade names N-Sure®

(28-0-0) and Trisert® (20-0-0-0.5B; 13-3-4; and 13-3-4-0.3B), marketed by Hickson Kerley, Inc., Phoenix, Arizona.

B) Phosphorus Materials: A combination of poly and ortho-phosphates has been shown to lessen leaf burn and aid in leaf phosphate absorption. Secondarily, the polyphosphate advantage may also be due to supplying both ortho and polyphosphate forms simultaneously

C) Potassium Materials: Depending on availability, potassium polyphosphates are an excellent source of low salt index, highly soluble potassium. Potassium sulfate is suitable also, having a low salt index, but a rather low solubility. Potassium hydroxide, potassium nitrate and potassium thiosulfate sources combine both low salt index and high solubility characteristics.

D) Secondary and Micronutrient Materials: Foliar application of these nutrients (secondary: calcium, magnesium and sulfur; micronutrients: zinc, manganese, iron, copper, boron and molybdenum) can be highly effective, but because of difficulties associated with leaf tissue absorption and translocation of some of these nutrients (notably calcium magnesium, iron, boron and molybdenum), choosing the correct fertilizer sources for these nutrients becomes very critical. Chelate sources, while valuable for soil application, have been shown to be generally unfavorable for foliar application, because most chelating agents have a molecular size too large to be effectively absorbed by leaf tissue. Organic chelating agents (including citric and malic acids, amino acids, phenolic acids, glucoheptonate and glucosylgycine) have been shown to enhance secondary and micronutrient foliar absorption, Fernandez *et al*., 2013.

Advantages of foliar nutrition

- It helps in rapid correction of nutrient deficiency
- Foliar spraying can be combined with other sprayings like insecticides
- When the soil is deficient in nutrients foliar application is beneficial
- When a quick growth response is desired foliar application can be sprayed
- It will help during high fixation of P and K
- Foliar spray can be applied when adverse condition like root rot disease, drought condition *etc*. were noticed in field
- Foliar spray can also be given when there is not adequate moisture in top soil to absorb the nutrients by plant roots
- Only use small amounts of fertilizer
- Improved yield and yield quality parameters

Limitations

- It will cause scorching or burning effect if concentration of the spray is high
- It requires sticking agent to get more efficiency
- To obtain good efficiency of spray leaf area should be large
- Only small quantities of fertilizers can be applied through foliar application
- Foliar application efficiency is depends on climatic conditions like temperature, humidity, wind velocity etc.
- Cost of multiple applications can be prohibitive.
- Possibility of foliar burn (with high concentrations).

Conclusion

Foliar feeding today plays an important role in crop production. Some crops are fed almost exclusively through the leaves. In many others absorption by aerial parts constitutes the only practical means for supplying specific nutrients. With almost all crops foliar feeding will eventually play some role in their nutrition at one time or another in their development. Leaf feeding is rapidly being standardized as an insurance against specific deficiencies and the hazards of unpredictable weather which may occur during the growth of some crops. The concept that foliar sprays should be applied only after the appearance of a deficiency disorder is confirmed, since decline in yield and quality usually precedes the appearance of visual symptoms. Nutrient sprays like fertilizers applied to the soil should be used with the objective of maintaining crops at an optimal rather than at a suboptimal or marginal productivity status.

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