[Article ID : 01/I/18/0121]

FOLIAR NUTRITION FOR IMPROVING CROP PRODUCTIVITY AND FERTILIZER USE EFFICIENCY

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Nutrients are essential for healthy and vigorous plants. They initiate all processes vital for crop development. Therefore, plant needs nutrients throughout its life cycle. The elements such as phosphorus, potassium and most of the micronutrients are fixed in soil complex while soluble nutrients such as nitrogen are easily leached down the soil. This leads to pollution of ground water, aquifers, green house gas (GHG) emission and harmful for humans. Granular fertilizers have many positive effects on plant growth, but sometimes they are not enough to provide healthy crop development with respect to its availability to plants. Also with increasing cost of fossil fuel, which provides raw materials for fertilizer manufacture, so there is a need to find innovations in fertilizer usage techniques and foliar application is one such important technique.

When to apply nutrients by foliar sprays

The need for foliar application of plant nutrients occurs when:

- There is a lack of a particular nutrient in the soil and basal soil application not done for that purpose.
- High loss rate of nutrients in soil occur (Coarse quartz sandy soil).
- Plant roots are not able to absorb the required amounts of nutrients needed due to unfavorable conditions.

Foliar fertilization is a simple nutrient corrective technique used in crops during the growth cycle when soil application is ineffective, impossible or expensive. There are various reasons for foliar application of nutrients that are:

Table 1. Reasons for foliar application of macro elements (N, K, P, Ca, Mg, S), micro elements (Fe, Mn, Cu, Zn, Mo, B) and beneficial element (Si)

Macro Element	Reasons for use as foliar application
N	Poor availability
	Asynchronus availability/requirement
	Soil depletion/leaching
	Low root temperature
	Increase uptake of micro elements e.g. Fe
K	Poor availability
	Positive against flattened wheat
	Low root temperature
	Flowering stage of citrus
P	Poor availability due to high pH in soil
	Low root temperature

Ca	Reduce Ca-related disorders, e.g. Blossom end rot (BER) in tomato and sweet pepper, butter pit of apples
	Improve leaf quality
Mg	Improve leaf quality
S	Oilseed rape-possible S deficiency in soil
Micro element	**Reasons for use as foliar application**
Fe, Mn, Zn, Co	Poor availability due to high pH
	Prevent deficiency at emergence
B	Enhance crop growth, number of fruits, fruit size and yield Sugar translocation
Zn	Prevent deficiency at emergence in rice
Fe and Mn	Cure chlorosis due to high pH and insufficient root development in greenhouse crops
Si	Positive effect on rice

Foliar nutrient sprays are often applied as mixtures of plant nutrients with compatible adjuvants. Adjuvant acts as a sticker, thus preventing the leaking and washing off of spray solution from the plant. A spray enhancer can help nutrients stick to the leaf and then penetrate the leaves' cuticle. Foliar application of phosphorus, zinc and iron brings the greatest benefit in comparison with addition to soil where phosphorus becomes fixed in a form inaccessible to the plant and where zinc and iron are less available.

Prior to foliar nutrient application, certain environmental factors need to be considered such as :

- Relative humidity, since it affects the permeability of the plant surface
- Temperature, since it regulates the uptake of applied plant nutrients
- Light intensity: since it affects evaporation thus indirectly affect permeability of nutrients.
- Precipitation: immediate precipitation (high intensity) affects flow down of nutrients from leaves, drizzling improves permeability.

Mechanism of foliar fertilization

- **First :** Entry into the leaf prior to entering the cytoplasm of a cell in the leaf.
- **Second :** Nutrient must effectively penetrate the outer cuticle and the wall of the underlying epidermal cell.
- **Third :** 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.

Plants are able to absorb essential elements through their leaves. Absorption takes place through their stomata and also through their epidermis. Transport is usually faster through the stomata, but total absorption may be as great through the epidermis. Plants are also able to absorb nutrients through their bark. Since plants take in nutrients more efficiently through stomata on their leaves than through the root, foliar fertilization is a great way to rapidly boost plant growth.

Advantages of foliar nutrient application

The foliar spray may contain supplemental doses of macro- and micronutrients, plant hormones, stimulants, and other beneficial substances.

- 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.
- 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 poor nutrient availability. Plants show very positive effects with this type of fertilization. Those effects include:
- It is a means of compensating for soil or environmentally induced nutrient deficiencies.
- Higher resistance to diseases and insect pests
- Improved drought tolerance
- Improved soil salinity tolerance
- Higher resistance to physiological disorders
- Rapid utilization of applied nutrients and therefore rapid correction of observed deficiencies
- Being highly effective for the immobilized nutrients in the soils, such as iron
- Providing faster responses with applied crop nutrients, only 3-4 days required
- Better plant nutrient absorption at early crop growth stages, when plant roots are not well developed.

Table 2. 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 3. Rates of nutrient absorption into plant tissues

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

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 as 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 : Reduce the volume of solution needed for application.

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

Disadvantages of foliar nutrient application

Despite many positive effects, foliar application as a good farm practice can also have certain disadvantages. Therefore, farmers have to take precautions prior to using this type of fertilization, otherwise, the following effects may occur:

- The foliar applied nutrients will have a reduced influence on plant growth, unlike soil applied.
- The wind has a major influence on the uniformity of distribution of the nutrient solution. Hence, on a windy day care should be taken to avoid spraying.
- The foliar application is most successful for micronutrients, whereas soil application is effective for both macro and micronutrients.
- Plant response to the foliar application is often only temporary. In cases of severe nutrient deficiency, several foliar applications are needed.

Farm practices to get the best out of foliar fertilization

The effect of foliar application on the plant is dependent upon species, fertilizer form, concentration and frequency of application, as well as the stage of plant growth. A common farm practice is to apply plant nutrients at specific plant growth stages, *i.e.* at vegetative (root development, shoot development) and generative stages (flowering, fruit setting). Foliar fertilization is also used in plant recovery from transplant shock, hail damage, and other bad weather conditions which may affect the plant. This is a desirable farm measure due to its positive effects on the entire crop production. It will not only increase the efficiency of plant nutrient uptake and reduce soil pollution but also maximize the crop yield and decrease the total cost of crop production.

Conclusion

Foliar feeding could be used in delivering different agro-chemicals including fertilizers, pesticides, biostimulators and some soil amendments as well as nano-agro-chemicals (nanofertilizers, nanopesticides, etc.). The efficiency of foliar process is mainly controlled with the characterization of plant leaves, the agro-chemicals and the environmental conditions including weather factors. In many crops absorption by aerial parts constitutes the only practical means for supplying specific nutrients. 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. 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.