

18. FOLIAR FERTILIZATION

Foliar nutrient sprays have been used in agriculture for a long time. If they did not have merit, they would not have lasted this long.

Foliar sprays are used for 3 main purposes:

1. To correct a deficiency

When a deficiency of a particular nutrient is spotted in the field, waiting for a soil application to take effect can mean crop dollars lost. Foliar sprays can give fast correction of nutrient deficiencies; zinc sprays have been widely used in this regard.

2. To maintain optimum nutrition of a particular nutrient

Vigorously growing plants can grow faster than the ability of their roots to supply the tops and fruit with a needed nutrient. Zinc deficiency on vigorously growing young almond trees is an example. One or more zinc sprays during the growing season can help to maintain optimum zinc nutrition of crops.

Calcium sprays are used to prevent disorders on crops that do not have the ability to supply calcium to fruiting parts that have a need for calcium.

When soil temperatures are unseasonably cool, as can occur during some springs, the adsorptive efficiency of a plant's root system is impaired. Foliar nutrient sprays can help plants through such periods.

3. To give a crop a nutritional boost at a critical juncture in its life

On tree fruit crops, a critical growth stage occurs immediately after pollination when a large number of small fruits (or nuts) compete for a limited amount of nutrients; those that don't survive the competition drop. On other crops, the period of seed set and pod filling is a critical one. For cotton, the period of heavy boll set is critical. Providing a nutritional boost with a foliar spray can help crops make it through these critical periods with minimal crop loss.

On citrus in California, a urea-zinc spray near the time of fruit set has become an accepted and University recommended practice.

Fall-applied boron sprays on prunes can strengthen next years developing flowers so that they set much better the following spring; this effect occurs even though boron levels in soil and leaves are in an optimum range.

Recent work in soybeans in Iowa has shown increased seed set from foliar nutrient sprays.

Mechanism of Foliar Absorption

There are 2 main paths of entry for foliar nutrients: the cuticle and the stomata. These are discussed separately:

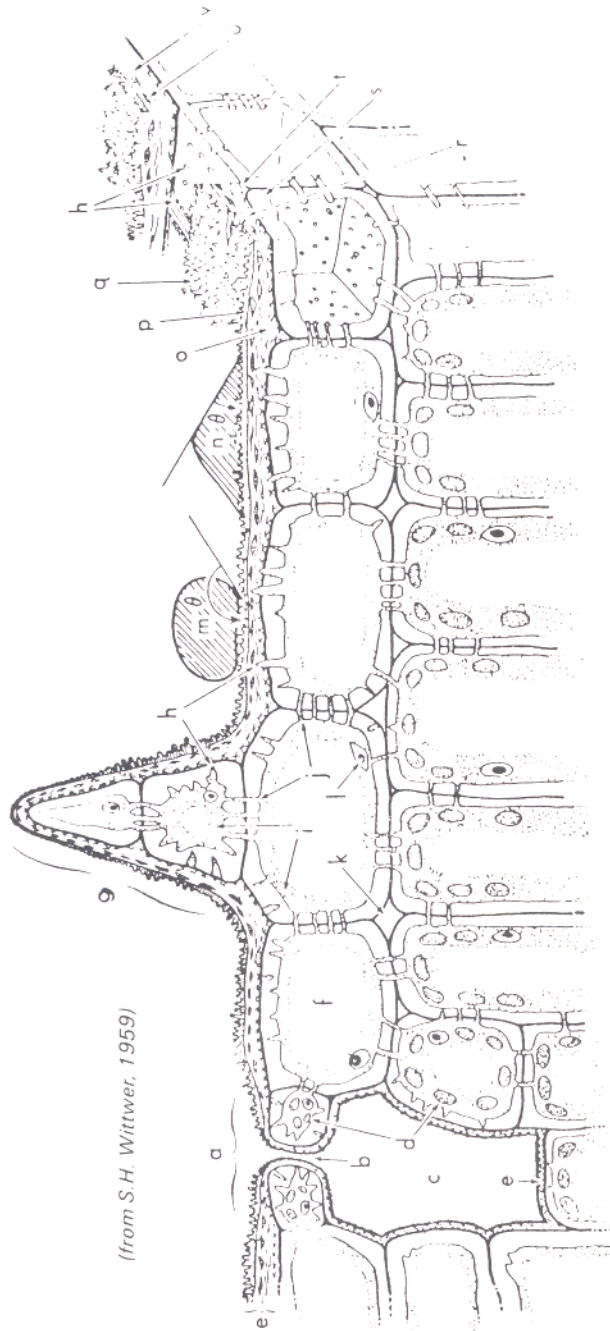
Cuticle entry

The cuticle is a waxy layer covering leaves, flower petals and fruits. It's primary function is to prevent moisture loss from plants and to protect the plant from injury. It is typically thicker on upper leaf surfaces than on lower leaf surfaces and is impermeable to

aqueous (water) solutions; oily solutions will penetrate the cuticle more readily. Cracks can occur in the cuticle and can serve as a port of entry for foliar sprays. On young, immature leaves the cuticular layer is not as well developed as an older leaves.

Stomatal Entry

The stomata of plants are located almost exclusively on the leaves. These pores are only a few millionths of an inch in diameter and their primary function is to breathe for the plant. They allow carbon dioxide, the building block of plants, to pass into the leaf and here the chlorophyll molecules, using sunlight for energy, convert the carbon dioxide molecules into simple sugars. The stomata also allow the by-product of this reaction, oxygen, to escape from the plant. A third function of the stomata is to allow the escape of water vapor that evaporates from the inside of the leaves to cool the plant.



Diagrammatic representation of leaf epidermal cells and cuticle.

LEGEND:

- | | | | |
|---------------------|------------------------|------------------------|------------------------|
| a: Stoma | g: Hair | m: Non-wetting Droplet | s: Cellulose Cell Wall |
| b: Stomatal Opening | h: Ectodesma | n: Wetting Droplet | t: Pectic Lamella |
| c: Stomatal Cavity | i: Protoplasm | o: Cutin | u: "Wax" Lamella |
| d: Chloroplasts | j: Plasmodesma | p: "Wax" Layer | v: Cellulose Lamella |
| e: Cuticle | k: Intercellular Space | q: "Wax" Rodlet | θ: Contact Angle |
| f: Vacuole | l: Nucleus | r: Crack in Cuticle | |

Stomata are usually closed at night, and can close during the hottest part of the day.

The distribution and occurrence of stomata, as well as their size and shape, varies widely from one plant species to another. Broadleaf crops and tree crops commonly have most of their stomata on the lower leaf surface while grass species may have about the same number on both surfaces. As examples, small white beans commonly have 40,000 stomata per square centimeter on their lower surface and only 3,000 on their upper surface, while sorghum has 1 6,000 on the lower surface and 1 1,000 on the

upper surface. In addition, the sorghum stomata are four times as large as the bean stomata.

The accompanying diagram depicts the cuticle and a stoma of a leaf.

Timing of Foliar Sprays

Timing of foliar sprays can be critical, both in regard to time of season and time of day:

Optimum time of season

As indicated previously, foliar sprays may be effective only during "critical stages" of a plant's growth cycle and must be applied during or shortly before the critical period to be effective. For example, zinc deficiency on grapes causes shattering (berry drop) of clusters; pre-bloom foliar zinc sprays can prevent shattering, post bloom sprays will not.

Since immature foliage does not have a well developed cuticular layer, application of nutrient sprays when there is a significant amount of young foliage present will enhance cuticular entry.

Optimum time of day

For maximum stomatal entry, nutrient sprays must be applied when the stomata are open. Since stomata can close at night and during mid-day, early morning applications are the best. Also, there is less evaporation during the early morning thus giving a better chance for maximum uptake by leaves. High relative humidity during the time of application will also enhance uptake by minimizing evaporation.

Methods of Application

For crops having most of their stomata on the underside of leaves (most broadleaf and tree crops) ground rig application is preferred. For crops having significant stomata on the upper leaf surface (most grasses) either ground or aerial application is satisfactory.

Surfactants

Use of surfactants or wetting agents is important to get maximum benefit from foliar applied nutrients. Surfactants lower the contact angle of spray droplets on the leaves (see diagram) thus enhancing absorption.

New chemicals are being tested that have the ability of penetrating or breaking down the waxy cuticular layer of leaves. Advances here would greatly widen the scope of foliar fertilization.

Individual Nutrient Sprays

Individual nutrient sprays are discussed in four categories following:

Nitrogen sprays

When foliar nitrogen is needed, urea is the material usually selected. Other material can be used, but have an increased phytotoxicity hazard except at very low rates. Tolerance of various plants species to foliar applied urea is given in the following table:

Biuret is an impurity in many urea formulations and is toxic to many plant species at high concentrations. Urea with a low biuret content is available (Lo-Bi urea) and should be used for foliar sprays.

Tolerances of plant foliage to repeated applications of urea sprays †	
CROP	Tolerances—no leaf scorch* (Lbs/100 gal. water)
VEGETABLE	
Cucumber, bean, tomato, sweet corn	4-6
Carrots, celery, onions, potatoes	15-20
FRUIT	
Apple, grape, brambles, strawberry	4-6
Cherry, peach, plum, currants	10-20**
FIELD CROPS	
Sugar beets, alfalfa, corn, wheat	5-10
Oats, barley, brome grass, ryegrass	20-50
PLANTATION AND TROPICAL	
Tobacco, citrus, cacao	5-10
Sugarcane, banana, mango, tea, coffee	10-25
Cotton, hops, pineapple	20-50
* Higher concentrations may be used with lower volume spraying.	
** Leaves are tolerant at this level as measured by scorch, but severe chlorosis may occur at these and even lower concentrations.	

t from **Foliar Application of Nutrients** by S.H. Wittwer. Plant Food Review, No. 2, 1967.

When applied in conjunction with zinc, urea can enhance the up- take of zinc by leaves. Zinc-urea combinations are common for foliar application.

Application of urea will often "green up" a plant (as can some other nutrients). This greening does not always mean that an economic yield increase has (or will) occurred. Crop yield measurements are the best method of evaluating the efficacy of a foliar spray.

Urea sprays have not been effective on stone fruits.

Other major nutrient (or macronutrient) sprays

Phosphorus (P) and potassium (K) are not commonly applied as foliar sprays but have been used successfully on some crops. Heavy cropping of prunes creates a temporary potassium deficiency that is alleviated by potassium nitrate sprays at bi-weekly intervals.

Calcium sprays are often the only method of correcting calcium related disorders. Both calcium nitrate and calcium chloride are used to correct bitter pit in apple.

Magnesium sprays, usually magnesium sulfate, are not common but have been successfully applied. Sulfur sprays are rare.

Micronutrient sprays

One of the first uses of foliar sprays was in the correction of zinc deficiency. Foliar zinc sprays are widely used today and will be in the future. Deficiencies of the other metallic micronutrients (copper, iron, manganese) can also be alleviated by foliar sprays. Both inorganic and chelated materials have been used for correction. Chelates, though more costly, have outperformed the in- organic materials in some tests.

Boron sprays are common on orchard crops in the pacific northwest and are also used on crops in other areas. Molybdenum sprays have been used to correct Mo deficiency.

Carbohydrate sprays

Although not always considered as such, carbon, hydrogen and oxygen are major, essential plant nutrients. Fruit drop at the critical fruit setting stage on some crops is felt by some to be related to carbohydrate shortage (the definition of carbohydrate is a material that contains carbon, hydrogen and oxygen). Some cotton growers feel that sugar sprays during the bloom period increase boll set, but there is no hard data on this. Some greenhouse growers have shown definite benefits from CO₂ enrichment of greenhouses.

Interestingly, urea is a carbohydrate-formula CO(NH₂)₂. Probably most of the carbon in urea is converted to CO₂ shortly after being sprayed but detailed studies on the fate of the carbon in urea would be of interest.

Summary

Foliar nutrient sprays have a definite place in agriculture and will see more use in the future. Fieldmen should be alert to the possibility of mixing foliar nutrients with insecticides and thus giving them a free ride. Where fruit or crop spotting is a concern, obtain experience with a particular nutrient formulation before using it on a large scale.

Shot gun mixes of nutrient sprays should be avoided; the rifle approach is better. Discover what nutrient is the most limiting and concentrate on it. Beware of the many foliar nutrient formulations on the market. Many of them carry a fancy price tag but are little, if any, better than the cheaper inorganic, non-proprietary materials.

General Reference

Wittwer, S.H. and F.G. Teubner. Foliar absorption of mineral nutrients. Annual Rev. of Plant Physiol. 10:13-32. 1959.