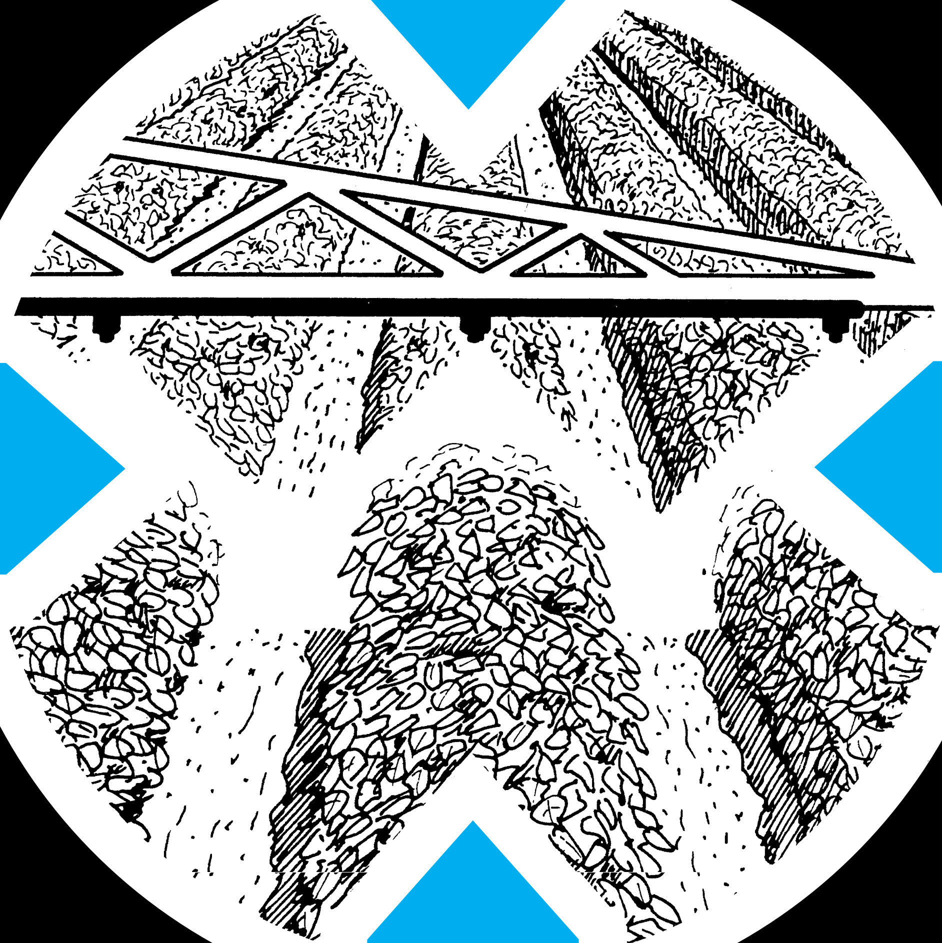
FOLIAR NUTRITION



Midwest Laboratories℠

MIDWEST LABORATORIES, INC. • 13611 B STREET • OMAHA, NE 68144 • 402-334-7770 • FAX 402-334-9121

TABLE OF CONTENTS

LIMITATION OF LIABILITY

The information in this publication is based on the best information available to the author at the time of publication. It is not intended to be used in place of instruction issued by the manufacturer of any product. All agricultural materials should be used in strict compliance with label directions, and the user assumes all liability for results of deviation from such directions.

ACKNOWLEDGEMENTS

The following people have lent considerable time and effort into making this resource handbook both understandable and credible. Their efforts and contributions are sincerely appreciated.

Steve Curley; C.P.Ag./S.S.
Midwest Laboratories Agronomist
Editor

Richard D. Curley; C.P.Ag. (contributing editor)
Fremont, Nebraska

David DeGrood
Shakopee, Minnesota

Richard Goff; C.P.Ag. (contributing editor)
Midwest Laboratories Agronomist
New Ulm, Minnesota

Eldon Hart
Shield Brite/Pace International
Phoenix, Arizona

Robert Hecht; C.P.Ag. (contributing editor)
Midwest Laboratories Agronomist
Seneca, Kansas

Don Johnson
Arcadian Corporation

Ed Krysl
Hickson Kerley, Inc.
Phoenix, Arizona

John Menghini; C.P.Ag. (contributing editor)
Midwest Laboratories Agronomist
Omaha, Nebraska

Kennard Pohlman; C.P.Ag./S.S.
Midwest Laboratories, Inc.
Omaha, Nebraska

Ned Van Buren
Greensboro, North Carolina

FOLIAR APPLIED PLANT NUTRITION

Foliar feeding, a term referring to application of essential plant nutrients to above-ground plant parts, has been documented as early as 1844 (21), when an iron sulfate solution was sprayed as a possible remedy for “chlorosis sickness.” More recently, foliar feeding has been widely used and accepted as an essential part of crop production, especially on horticultural crops (21). 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 (24).

Table 1.

Common Nutrient Element Deficiency Disorders in Crops Corrected by Foliar Applications of the Deficient Nutrient (26)

Nutritional Deficiency	Corrective Nutrient	Foliar Spray Recom. Lbs/Acre	Lbs/100 gal.
Nitrogen	Nitrogen as urea	(Table 2)	
Potassium	Potassium sulfate		5-10
Citrus	Potassium nitrate		25-100
Phosphorus	Orthophosphoric acid	5 - 25	2-3
Sugar Cane	Ammonium phosphates	5 - 25	3-15
Sugar Cane	Potassium phosphates	5 - 25	3-15
Calcium			
Blossom-end rot of tomatoes	Calcium chloride	10 - 20	5-20 $CaCl_2$
Blackheart of celery	Calcium nitrate or Calcium chloride	5 - 10 $CaCl_2$	15-20 $Ca(NO_3)_2$
Magnesium Celery, tomatoes, apples and oranges	Magnesium sulfate or Magnesium nitrate	10 - 20	10-20 $MgSO_4$ or 15 $Mg(NO_3)_2$
Iron--pineapple, and grain sorghum	Iron sulfate	10 - 15	5-25
Manganese--beans, soybeans, celery, tomatoes, citrus, etc.	Manganese sulfate	5 - 10	3-6
Zinc--row crops, corn, tomatoes, beans	Zinc sulfate or Zinc oxide	1 - 2	2-3
Zinc--fruit crops, ("little leaf") peaches, pears, apricots, grapes	Zinc sulfate (dormant)		10-25
	Zinc oxide (cover, post-harvest)		5-6
Copper--vegetable and fruit crops	Bordeaux mixture		10-10-100
	Basic copper sulfate	1 - 3	-2
Boron--alfalfa, beet, celery, cruciferae, fruit trees	Borax or other soluble borates	1/2 - 2	1-3
Molybdenum--yellow spot in citrus, Whiptail in cauliflower	Sodium molybdate or Ammonium molybdate	2 - 4 (oz.)	1-2 (oz.) 1/2-1 (lb.)

Table 2.

Tolerances of Plant Foliage to Urea Sprays in Pounds per 100 Gallons of Water (27)

Vegetable Crops		Plantation or Tropical Crops		Deciduous Tree and Small Fruit Crops		Agronomic Crops	
Crop	**Tolerance**	**Crop**	**Tolerance**	**Crop**	**Tolerance**	**Crop**	**Tolerance**
Cucumber	3-5	Pineapple	20-50	Grape	4-6	Potatoes	20
Bean	4-6	Cacao	5-10	Raspberry	4-6	Sugar beets	20
Tomato	4-6	Sugar cane	10-20	Apple	4-6	Alfalfa	20
Pepper	4-6	Banana	5-10	Strawberry	4-6	Corn	5-20
Sweet corn	4-6	Cotton	20-50	Plum	5-15	Wheat	20-800
Lettuce	4-6	Tobacco	3-10	Peach	5-20	Bromegrass	20-800
Cabbage	6-12	Citrus	5-10	Cherry	5-20		
Carrots	20	Hops	40-50				
Celery	20						
Onions	20						

Table 3.

Tolerances of Plant Foliage to Repeated Applications of Mineral Nutrient Sprays (28)

Nutrient	Formulation or salt	Tolerances--no leaf scorch* (Lbs/100 gal. water)
Nitrogen	Urea	(See Table 1)
	NH_4NO_3, $(NH_4)_2$ HPO_4, $NH_4H_2PO_4$, $(NH_4)_2SO_4$ and NH_4Cl	4-6
Phosphorus	H_3PO_4	3-5
	Others (see nitrogen above)	
Potassium	KNO_3, K_2SO_4, KCl	6-10
Calcium	$CaCl_2$, Ca $(NO_3)_2$	6-12
Magnesium	$MgSO_4$, Mg $(NO_3)_2$	8-24
Iron	$FeSO_4$	4-24
Manganese	$MnSO_4$	4-6
Zinc	$ZnSO_4$	3-5
Boron	Sodium borate	0.5-2
Molybdenum	Sodium molybdate	0.2-0.3

*Higher concentrations may be used with lower volume spraying.

The purpose of foliar feeding is not to replace soil fertilization. Supplying a plant's major nutrient needs (nitrogen, phosphorus, 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, sulfur) and micronutrients (zinc, manganese, iron, copper, boron, and molybdenum), while supplementing N-P-K needs for short and/or critical growth stage periods. Primarily, foliar feeding is intended to delay natural senescence processes shortly after the end of reproductive growth stages (29). Foliar feeding targets the growth stages where declining rates of photosynthesis and leveling 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 favorably 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 (18):

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.

In order to achieve the benefits of foliar feeding, combining proper methods of application and the best suited nutrient materials related to specific crops is essential.

METHODS

I. 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 favorably influence the post-reproductive development stages.

Multiple, low rate applications may show the most favorable responses within these time frames (9, 10), 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 vigor (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 vigor. 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 (19). Good recovery of corn suffering from light to moderate hail damage has been shown where nitrogen-sulfur solutions were foliar applied (30). Under most conditions, however, due to the practical and economic limitations on the amount of nutrients that can be foliar applied to give a favorable 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 favor highest tissue permeability, conditions found most often in the late evening hours, and occasionally in the early morning hours. Table 4 summarizes meteorological conditions favoring foliar applications.

Table 4.

Meteorological Conditions Favoring Foliar Applications

Time of Day:	late evening; after 6:00 p.m. early morning; before 9:00 a.m.
Temperature:	65-85½F; 70½ideal
Humidity:	greater than 70% relative humidity
Temperature/Humidity Index:	140-160
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 5 gives rates of absorption or entry into the leaf tissue for various nutrients.

Table 5.

Rates of Nutrients Absorption into Plant Tissue (9, 10, 18, 27)

Nutrient	Time for 50% Absorption
Nitrogen (as urea)	1/2 - 2 hours
Phosphorus	5 - 10 days
Potassium	10 - 24 hours
Calcium	1 - 2 days
Magnesium	2 - 5 hours
Sulfur	8 days
Zinc	1 - 2 days
Manganese	1 - 2 days
Iron	10 - 20 days
Molybdenum	10 - 20 days

II. 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:

A. Low salt index: Damage to plant cells from high salt concentrations can be considerable, especially from nitrates (NO_3^-) and chlorides (Cl^-). Table 6 lists the salt index of fertilizer materials considered for foliar application.
B. High solubility: Needed to reduce the volume of solution needed for application.
C. High purity: Needed to eliminate interference with spraying, solution compatibility, or unexpected adverse effects on foliage.

Table 6.

Salt Indexes of Some Fertilizer Materials [1]

Materials and Analysis	SALT INDEX Per Equal Weights of Materials Basis: Sodium Nitrate = 100	Per Unit (20 lbs.) of Plant Nutrients [2]
NITROGEN		
Calcium nitrate, $Ca(NO_3)_2$, $_4H_2O$ 11.9% N	52.5	4.409
Calcium nitrate, com. grade, 15.5% N	65.0	4.194
Urea, 46.6% N	75.4	1.618
Natural organic, 5% N	3.5	0.702
Natural organic, 13% N	3.5	0.270
PHOSPHATE		
Ammonium phosphate (11-48-0)	26.9	2.442
Normal superphosphate, 20% P_2O_5	7.8	0.390
Concentrated superphosphate, 45% P_2O_5	10.1	0.224
Concentrated superphosphate, 48% P_2O_5	10.1	0.210
POTASH		
Potassium sulfate, 54% K_2O	46.1	0.853
Monopotassium phosphate, 52.2% P_2O_5, 34.6% K_2O	8.4	0.097

Data for Calculating the Salt Indexes of Mixed Fertilizers Formulated with Acids:

Type	Acid Description	Degree of Ammoniation (lbs. NH_3/unit P_2O_5)	Salt Index Contributed by 100 lbs. of acid
Sulfuric	100% H_2SO_4	35[3]	4.652
	66½Be, 93% H_2SO_4	3	4.326
	63½Be, 84% H_2SO_4	29[3]	3.871
	60½Be, 78% H_2SO_4	27[3]	3.611
Phosphoric	72.4% P_2O_5	4.8	1.754
		7.2	2.028
		9.6	2.303
	54% P_2O_5	4.8	1.303
		7.2	1.613
		9.6	1.715

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 (9). However, the urea utilized in foliar sprays should be low in biuret content (0.2 perent or

[1]Farm Chemicals Handbook (1985); Western Fertilizer Handbook (seventh edition)
[2]Based on plant nutrients shown in column 1.
[3]Pounds of ammonia per 100 pounds of the respective sulfuric acid.

less) to lessen urea foliage burn side effects (6, 7, 9). Urea formulated in today's urea-containing solutions and feed grade products is low enough in biuret to provide no hazard for plants (7). Other sources of nitrogen can be obtained from ammonium polyphosphates, ammoniated ortho-phosphates (liquid), ammonium thiosulfate (12-0-0-26S), and fluid ammonium sulfate (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 tradenames 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.

Phosphorus Materials: A combination of poly and ortho-phosphates has been shown to lessen leaf burn and aid in leaf phosphate absorption (2, 3). Secondarily, the polyphosphate advantage may also be due to supplying both ortho and polyphosphate forms simultaneously.

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.

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) (27), 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 (25, 26) because most chelating agents have a molecular size too large to be effectively absorbed by leaf tissue.

Chelated zinc preparations were no better than inorganic sources for grapes, and not as effective as $ZnSO_4$ for vegetable crops. The relative ineffectiveness of iron sprays has not been improved by using chelated sources. Copper chelate sprays were not found as effective as (Bordeaux on almonds, and chelated Mg was inferior to $MgSO_4$ on apples. Chelated iron was as effective as ferrous sulfate for grain sorghum but the cost was much greater.

However, 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 (1, 26).

Table 7.

Effectiveness of Iron Carriers for Foliar Application (4)

Treatment	Iron Concentration of Solution (ppm Fe)	Iron Content of fruit [1] (ppm dry matter)	Leaf Greenness [2]
Control		100	0.6
(Foliar Spray)			
Fe-EDDHA	30	107	3.3
	60	112	3.6
Fe-citrate	250	163	3.2
Fe-glucoheptonate	800	485	4.8
	1600	655	5.4
(Soil Treatment)			
Fe-glucoheptonate	1600	99	0.4

Excellent sources for supplying many of the secondary and micronutrient elements are the sulfate sources, obtained either in highly soluble dry or wettable powder formulations or in solution form. The overall effectiveness of secondary, and especially micronutrient foliar applications, depends on multiple (2-4) applications of low rate spray solutions containing nitrogen (3-8%N).

See the appendix for plant nutrient functions and fertilizer nutrient sources suitable for foliar application.

Base Fertilizer Formulations: In order to enhance the effectiveness of any foliar application, certain base solutions should be applied. Nitrogen should always be present in any base solution. N-P, N-S or N-P-S base solutions are influential during early stages of growth utilizing a 1 : 2 or 1 : 3 N-P_2O_5 ratio. N-P-K-S base solutions are suggested to influence the seed/grain fill growth stages, utilizing a 2 : 1 : 1 N-P_2O_5-K_2O ratio.

Micronutrients should be applied according to need as determined by a tissue test, and should always be applied along with nitrogen in the solution. Combinations of certain nutrients may pose solution solubility problems, especially where nutrient solutions are combined with fungicides and pesticides. Generally speaking, unless compatibility with fungicides and pesticides is known, nutrient sprays should be applied separately (27). Urea is compatible with most pesticides, exceptions being lime, sulfur, Karathane, Glyodin, Phygon, Phosdrin and Sevin. Magnesium sulfate is not compatible with arsenicals or copper sprays. Dormancy zinc sprays are not compatible with oil. Manganese solutions should not be mixed with phosphate, iron sulfate or with Nabam. Lead arsenate should not be mixed with any nutrient solution.

Additives: Agents added to the foliar fertilizer solution which buffer the pH of the solution (preferably between pH of 5.0 and 6.0) and provide for quick and uniform coverage of the spray

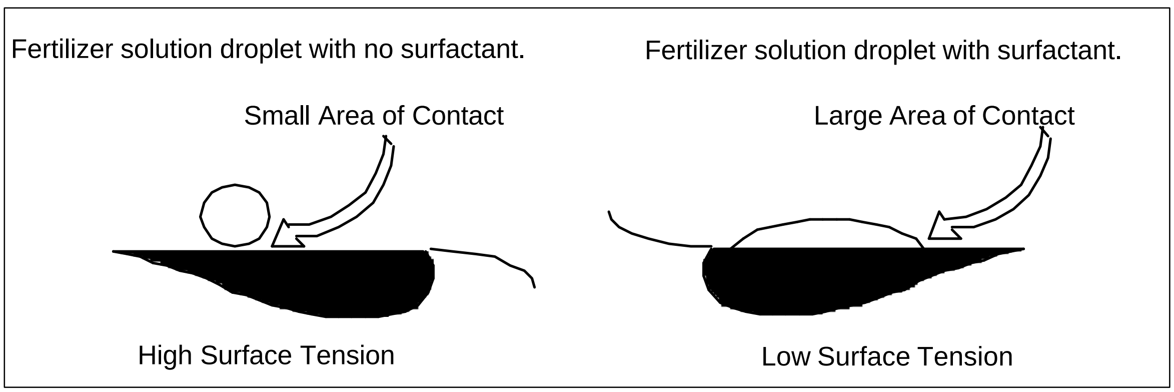
[1/]Conference pear trees (20 yrs. old) grown on calcareous soils showing marked symptoms of iron deficiency.
[2/]On scale 0 = white to 5 = green.

droplets are highly recommended. Foliage burn is caused by a high concentration of fertilizer salts (i.e., nitrate and chloride) rather than low pH in the fertilizer solution. Low pH fertilizer foliar solutions have been shown to increase the absorption rate of fertilizer materials (18). Leaf and stem tissues can inhibit initial nutrient absorption by means of waxy substances in the cuticle (outer layer of plant cells), pubescence (fine hairy growths) and drooping leaf angles. To achieve maximum nutrient absorption via foliar applications, a fine mist application with spreading and wetting agents is desired. These agents provide quick wetting of plant tissue and more uniform coverage with increased spray retention by reducing the surface tension of the spray droplets. Effective foliar applications depend on maximum absorption of soluble nutrients, avoiding losses due to evaporation and/or runoff as much as possible.

Figure 1 illustrates the beneficial effect surfactants can have in enhancing foliar fertilizer adsorption.

figure 1.

Leaf Surface



There are currently available a large number of adjuvants (additives) encompassing a wide range of properties and uses. Following is an excerpted article reviewing properties, uses and efficacies of adjuvant materials[1/].

A start to understanding the adjuvant story is an examination of the characters. What does what? Adjuvants (broadly defined as any substance added to the spray tank, separate from the pesticide formulation, that improves a pesticide's performance) may be grouped into two categories: activators and special-purpose adjuvants. In this way, James Witt, an adjuvant expert at Oregon State University, simplifies the task of identifying what the many products do.

The activator category consists of the following wetter-spreaders, stickers, (e.g., builders and extenders), emulsifiers (dispersants and suspending agents), emulsifiable oils (activators), and plant penetrants (translocators).

Special-purpose adjuvants would include foliar nutrients, compatibility agents, drift retardants, foam retardants, buffers, inverting agents, soil penetrants, stabilization agents (UV filters), feeding stimulants, washing agents, sinking agents, and protectant binders.

Here are definitions that might clear up some of the confusion surrounding adjuvants and their uses.

[1/]***Agrichemical Age***/*April, 1985*

Surfactant. A surfactant is a "surface active agent" and is the active ingredient in most adjuvants. Surfactants are either nonionic (do not ionize, but will have a slight electrostatic charge due to the polarity of dissimilar atoms in the molecule), anionic (ionized, with a strong negative charge), or cationic (ionized, with a strong positive charge).

Adjuvants usually contain one or two surfactants, most often nonionics but occasionally anionics. There are sometimes other chemicals included, depending on the purpose. In wetter-spreaders (see below), the most common surfactants fall in either an *alkylaryl poly oxy ethylenate* (AAPOE) group or an *alcohol poly oxy ethylenate* (APOE) group; two types of nonionic surfactants. About 10 percent of wetter-spreaders contain an anionic surfactant, usually a fatty acid (FA) or a linear alkyl sulfonate (LAS). Stickers (see below) most often contain AAPOE, but also contain an FA or LAS.

It is safe to assume that products with similar surfactants will perform alike in proportion to the amount of active ingredient they contain. For instance, two products may both contain an FA, but one may contain a 12-carbon FA, the other an 18-carbon FA. These differences can affect how the surfactant acts but are not likely to affect efficiency within a 'type' of surfactant when used for the same function.

Wetter-Spreader. Ortho's X-77 is an example of a wetter-spreader, providing quick wetting and more uniform coverage by reducing surface tension of the spray droplets. A spray drop must be able to wet the foliage and spread out or cover an area of the leaf for the pesticide to perform its function. With very waxy or hairy leaves or with insufficient surfactant in the pesticide concentrate, additional adjuvant is needed for good coverage. Too much surfactant may permit runoff or loss of deposit rather than increasing coverage. The surfactant acts here by reducing the surface tension of the water on the surface of the spray drop and by reducing the interfacial tension between the spray drop and surface of the leaf. This may not be done effectively by the surfactants that form and stabilize the oil-water emulsion from the concentrate formulation.

Stickers. A sticker, like Loveland's Bond, can perform three functions. It can increase the adhesion of solid particles that might be easily dislodged from a leaf surface—sort of gluing them on. It can also reduce evaporation of the pesticide. Finally, a sticker may provide a waterproof coating for the pesticide.

If a pesticide is fairly water soluble, it may be washed off the leaf during heavy rainfalls that follow deposition. If the sticker is not water soluble, it can provide a degree of protection from this.

Many stickers contain AAPOE, and are sold as *spreader-stickers*, which provide both sticker and wetter-spreader functions. But since the surfactants that provide wetter-spreader action must be somewhat water soluble, they may not provide good protection from rain. This will be provided by products that contain latex (rubber), polyethylene (plastic), resins (rosin), polymenthenes (rosin-like), or other waterproofing agents.

Emulsifiers. There are few emulsifiers on the market and few growers need to be concerned with these agents. Most often, the manufacturer includes an emulsifier (*dispersant or suspending agent*) in the pesticide (emulsifiable concentrate) to enhance the dispersion of particles from one phase into another--for example, from oil into water. For this reason, you hardly see these products on the market.

Emulsifiable Oil Activators. Petroleum oils will enhance the penetration of some pesticides through the waxy layer of cuticle on a leaf surface, increasing the rate of penetration. This is why brush is sometimes sprayed with diesel oil as a carrier or diluent instead of water. The same effect can be gained in part with the addition of small amounts of a petroleum oil like a summer spray oil. Most herbicide activators are emulsifiable light oils containing variable amounts of surfactants to emulsify the oil.

Plant Penetrants (translocators). Surfactants in plant penetrators like Kalo Lab's Regulaid, enhance penetration of some pesticides into plants, and may be found on wetter-spreader labels as *plant penetrators* or *translocators.* This action is not related to the surfactant's ability to reduce the surface tension of water, as is its wetter-spreader action. It is a function of its specific molecular makeup.

A surfactant may increase penetration for a pesticide on one species of plant but not another, or for one pesticide but not another. It is best to consider specific data on each surfactant/ pesticide/plant combination. Systemic herbicides, auxin herbicides and some other types, and translocatable fungicides can have their activity increased as a result of increased penetration. However, too much increase may result in loss of specificity between the weed and the crop from the action of herbicides.

The following definitions for special-purpose adjuvants are also helpful:

Foliar Nutrients. Foliar nutrients, for instance Chevron's Nutrient Buffer Spray 8-8-2Zn Mn, may contain plant nutrients like N, P, K, minor nutrients like sulfur and zinc, and a variety of trace elements. They also contain a relatively small amount of surfactant. It is beyond the scope of most discussions on pest control to consider the relative effectiveness of foliar plant nutrients. The surfactant concentration is usually near 2 percent. Since this is one-tenth to one-forty-fifth of the surfactant concentrations in wetter-spreaders, it is clear that these adjuvants will not be nearly as effective as wetter-spreaders in enhancing coverage by pesticides.

Compatibility Agents. Pesticides can sometimes be combined with liquid fertilizers for application, saving a trip through the field. But an applicator must guard against unequal distribution of the pesticide and the pesticide formulation breaking under the influence of the strong salt solutions in liquid fertilizers. *Compatibility agents or pesticide—liquid fertilizer emulsification adjuvants* are designed to prevent formulations from breaking down when combined with liquid fertilizers. One example of a compatibility agent is Precision Lab's Complement.

Unless the pesticide concentration formulation specifically states that it is compatible with liquid fertilizers, it will probably be necessary to add a compatibility agent to ensure that the pesticide will not either cream or sink and leave a high treatment rate and low treatment rate in opposite parts of the run. If you lack experience with the pesticide/liquid fertilizer/ compatibility agent mixture in question, try small-scale tests in quart jars to determine stability before mixing in a spray tank.

Drift Retardants. Drift is a function of drop size. Drops with diameters of 100 microns or less contribute the bulk of the drift off-site from the treated fields. Chemicals that increase the viscosity and the tensile strength of water, for instance those in Nalcotrol, will decrease the proportion of these smaller drops in a spray and increase the average drop size. This will result in fewer drops per square inch of leaf surface, but it will still be the same rate of deposit of pesticide in pounds per acre. This may or may not affect the level of pest control and resulting crop yield. The need to reduce drift, particularly near sensitive sites, may very well take precedence over small reductions in efficacy.

Foam Retardants. Some formulations will create foam or a frothy head in some spray tanks. This is usually a result of both the surfactants used in concentrate formulation and the type of spray tank agitation. The foam can usually be reduced or eliminated by a small amount of foam inhibitor. Foam is an emulsion of air in water and forms when the surfactant has a preferential air-water interface and good tensile strength. A variety of surfactants will destabilize these air-water emulsions, but the most common one is a silicone-carbon polymer known as dimethylpolysiloxane. This is sometimes included in wetter-spreader formulations, but is also available as a separate product that is squirted directly into the foam.

Buffers. Some water used for diluting pesticide formulations is alkaline, having a high pH. If the pH is high enough and the pesticide is subject to degradation by alkaline hydrolysis, it may be necessary to lower the pH of the mix water with buffers. Buffers contain phosphoric acid or a salt of phosphoric acid, that will lower the pH of the water and tend to stabilize the pH as an acceptable value. How well any buffer product works depends on its concentration of phosphoric acid and the degree of alkalinity, or hardness of the mixing water. Some products give directions indicating the amounts of buffering agent needed with water of different alkalinity, but not all do.

Some buffers have sufficient surfactant present to also perform as wetter-spreaders. The concentration of surfactant and phosphoric acid are usually lumped together and it is not possible to determine the concentration of either and thus predict their efficacy. Some foliar nutrients that contain phosphorous are also labeled as buffers because the phosphorous nutrient present can also act as a buffering agent.

Inverting Agents. These are special emulsifiers that can invert an oil/water emulsion (the usual type in pesticide formulations) to a water/oil emulsion, which is very “mayonnaise-like.” This requires special application equipment and is effective in reducing drift.

Minor Purpose Adjuvants. A number of adjuvants for various special purposes exist for which there are only a few products available in each category, for instance, stabilizing agents, washing agents, sinking agents, and feeding stimulants. For some of these, there is disagreement among researchers as to their effectiveness, circumstances under which they will be effective, and the concentration that may be needed to be effective. Contacting the manufacturer and requesting data that support their claims before making a decision is recommended.

Much of the confusion surrounding adjuvant use centers around lax labeling requirements and manufacturers making vague claims not based on submitted data claiming: "It makes water wetter." All of these work, but the need may not always be warranted.

All pesticides should be formulated with the adjuvant included, but manufacturers don't do it. Chevron recommends the use of a surfactant with paraquat, usually X-77, since they manufacture it. On the other hand, glyphosate (Roundup) originally had a surfactant built in, but farmers added some anyway for more control. Later, Monsanto agreed with the grower and recommended a nonionic surfactant.

Individuals must rely on their own observation to determine their adjuvant needs. If you want to know if you need a wetter-spreader, after you apply a row, get off the tractor, get down on your hands and knees with a hand lens, look at a leaf or two and try to make a decision.

Still, empirical data on adjuvant efficacy can be elusive.

The effects of adjuvants on insecticide efficiency are difficult to determine. It is such a subtle effect and there are so many variables, even researchers who set up test plots sometimes throw their hands up. In some of the testimonials you see based on users' satisfaction, I'm sure that is how the person feels, but it may or may not be what actually took place.

Still, it is possible to determine general situations where an adjuvant is likely to draw a better performance out of your pesticide. These include:

- When the directions of the pesticide formulation call for an adjuvant.
- When you examine your crop after spraying and can see you are getting poor coverage from poor wetting.
- When the crop or weed you are spraying has very waxy or hairy leaves.
- When you are mixing pesticides with liquid fertilizers.
- When you are spraying near a sensitive site (water, homes, school, sensitive crops). You may need a drift retardant—but you may get poorer coverage.
- When your pesticide is formulated as a water solution. Check the label on this. In the past, many formulations of water-soluble pesticides did not contain adequate surfactant.
- When using systemic pesticide. But be careful! Most surfactants will increase plant penetration, but not for all pesticides, or on all plants. You could end up with no effect or kill your crop if you increase penetration too much.

Above all, don't use an adjuvant just because it only costs a dollar and you hope it might do some good.

Trying to pick the best adjuvant buy involves more than comparing price tags. Use the "pickle test"—going through the same steps you would take if buying pickles in the supermarket.

If you find two jars with different amounts of pickles and at different prices, how do you decide which is the best buy? If jar A has 46 ounces at $1.89 and jar B has 22 ounces at $1.19, which is the cheapest? Jar A is 4.1 cents per ounce and jar B is 5.4 cents per ounce.

The same reasoning can be used to determine the best adjuvant buy, when comparing cost on the basis of active ingredient content.

It is reasonable to assume that similar surfactants are similar in their activity and efficiency with regard to wetting, spreading, or sticking. This also assumes that the content of IPA (iso propyl alcohol), for those products that include it in their active ingredients statement, is low and does not significantly reduce the apparent percentage of surfactant.

If the cost of all products in Table 8 is assumed to be $11 per gallon, the range of costs for a gallon of active ingredient for each product is (1) $12.22, (2) $12.22, (3) $44.00, and (4) $35.03.

Table 8.

Wetter-Spreader Ingredients Statements Abstracts

Product	Ingredients	Concentration
1. X-77 Spreader	a.i.--AAPOE[1/], FA, IPA	90.0%
	inert ingredients	10.0%
2. R-11 Spreader-Activator	a.i.--AAPOE, IPA[2/], Si[3/]	90.0%
	inert ingredients	10.0%
3. No Foam 8	a.i.--AAPOE, IPA, LAS	25.0%
	inert ingredients	75.0%
4. Wex	a.i.--APOE[4/], PG, Si	--
	inert ingredients	88.6%

AAPOE - Alkylaryl poly oxy ethylenate
APOE - Alcohol poly oxy ethylenate
FA - Fatty Acid
IPA - Iso propyl alcohol
LAS - Linear alkyl sulfonate (anionic surfactant)
PG - Propylene glycol
Si - A poly sioxane foam retardant

[1/]Included in this group are such specific surfactants as octyl phenoxy poly ethoxy ethanol and alkyl phenoxy poly ethoxyethanol.
[2/]Specifically, iso propanol.
[3/]Specifically, compounded silicone.
[4/]Specifically, alcohol ethoxylates.

Most other adjuvants can be similarly compared by carefully reading the label and looking for similar chemical names in the active ingredients statement. Comparing label claims, however, is more subjective.

Generally, all of the label claims will be correct, but they may not all be relevant and they may not all be significant. You'll have to judge for yourself. Give preference to products whose labels are relevant to specific agricultural uses rather than general, fuzzy, and do-it-all.

Remember, if the pesticide you are using is formulated adequately for your crop, using a wetter-spreader may not give better spreading or coverage, but rather runoff and less deposit. If the insecticide you are using is a systemic, you may get less pest control with a sticker, rather than more. If you are applying a pesticide close to harvest with a sticker, you may get better residual action and also end up over tolerance.

Correct use of adjuvants, then, does require some homework. By knowing your needs and a product's potentials, and by reading adjuvant labels with a critic's eye, adjuvants can be a profitable addition to the spray tank.

Water: Water is taken for granted in formulating fertilizer solutions, but the quality as well as the amount of water used must be considered. Water quality, especially pH, hardness, and possible excess in sulfates, nitrates, carbonates and iron, should be determined before a water source is used for foliar fertilizer formulations. Where water is needed as a part of the fertilizer solution, usually 10 to 20 gallons of water per acre is required, with lower nutrient concentrations and early growth stage applications requiring lesser amounts of water in the formulation.

Postemergence Applications of Fertilizer-Herbicide Mixes

While specific labels allowing use of certain fertilizer materials (UAN 28 percent solution, both dry and liquid formulations of ammonium sulfate, and ammonium polyphosphate: 10-34-0) as adjuvants in herbicide tank mixes have only recently met EPA approval (See Table 9), the practice and beneficial effects of postemergence applications of fertilizer-herbicide mixes have been known for quite some time.

Table 9.

EPA Approved Fertilizer Adjuvants + Postemerge Herbicide Combinations (as of June, 1986)

Fertilizer Material	Herbicide
Ammonium Polyphosphate (10-34-0)	Blazer[1/] + Basagran [2/] tank mix
Ammonium Sulfate (21-0-0-24S)	Landmaster[3/]
Ammonium Sulfate Spray Grade (8-0-0-9S)	Poast[2/]
	Roundup[3/] and other glysophate based products
Urea Ammonium Nitrate (UAN: 28 percent solution)	Basagran[2/] Basagan [2/] + Blazer [1/] tank mix

Fertilizer materials listed in Table 9 can enhance the effectiveness of the herbicides through a variety of interactions (14, 17, 22). One such interaction is through fertilizer adjuvant action. Certain fertilizer materials added to herbicide solutions can provide for better wetting of plant tissue and more uniform coverage than solutions without adjuvants. Increased spray retention on plant tissue results from fertilizer adjuvant action, and effectiveness of the herbicide is enhanced by decreasing losses due to evaporation and/or runoff, increasing the amount and time of contact of herbicide/tissue exposure.

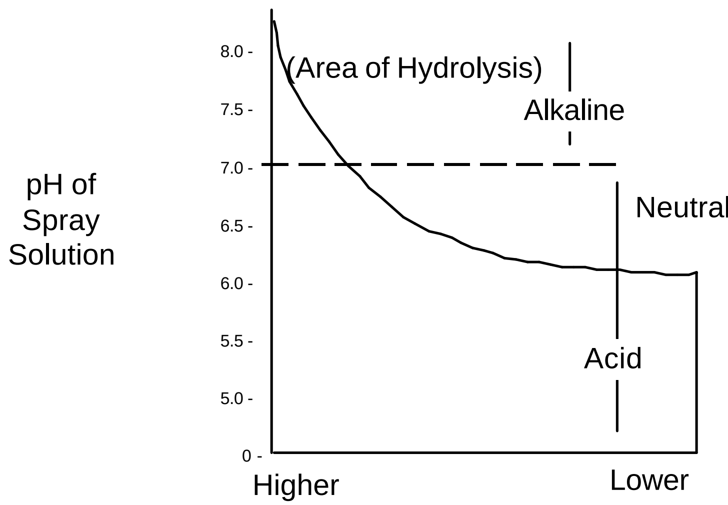
Another positive interaction effect of fertilizer adjuvants is increasing leaf-tissue permeability, accomplished both by enhanced spray coverage on tissue surfaces and utilization of nitrogen containing fertilizer material (9). Plant cell absorption capacities for herbicides are, therefore, enhanced. Additionally, slightly acidic properties of 10-34-0 and ammonium sulfate (21-0-0-24S), (or ammonium sulfate solution: 8-0-0-9S) also enhance leaf permeability (17).[4/]

The slightly acidic fertilizer properties of the fertilizer adjuvants just mentioned perform an additional role of reducing herbicide hydrolysis in the spray tank and on the leaf surface. A majority of spray tank water is naturally neutral to alkaline in pH (ž pH 7.0). These pH ranges favor herbicide hydrolysis, reducing herbicide efficacy by decreasing herbicide solubility in the spray tank and/or on the leaf surface (14, 23). Figure 2 illustrates the relationship between spray tank water pH and herbicide hydrolysis.

[1/] Product of Rhone Poulenc
[2/] Product of BASF Wyandotte Corporation
[3/] Product of Monsanto Agricultural Products Company
[4/] Consult labeled rates.

figure 2.

pH of Spray Solution vs. Rate of Herbicide Hydrolysis[1]



Amount of herbicide hydrolysis in solution (based on acidification rate of 1.5 milliequivalents per milliliter). Lower herbicide hydrolysis = increased herbicide efficacy.

A three-way interaction among enhanced spreader-sticker action, increased leaf permeability, and reduced herbicide hydrolysis all contribute to the possibility of favorable responses of adding fertilizers as adjuvants to postemerge herbicide applications. Increased responses are noted, especially when reduced labeled rates of herbicides are applied, and/or when the weather/climatic conditions are detrimental to herbicide activity (notably excessive cool, wet, or dry conditions) (15). Tables 10 and 11 help illustrate results of the principles involved with fertilizer adjuvants in postemerge herbicide applications.

Table 10.

Velvet Leaf Growth Stage Response and Other Weed Activity with Blazer[2]/Basagran[3]/Adjuvant Combinations (22)

	% Weed Control			
	Velvet Leaf		Pigweed	Black Nightshade
Herbicide/Treatment	**1-4** Leaf Stage	**4-6** Leaf Stage	**1-4** Leaf Stage	**1-4** Leaf Stage
Blazer + Basagran + 10-34-0 (1 pt + 1pt + 1 qt/A)	95	85	91	62
Blazer + Basagran + 10-34-0 (1.5 pt + 1 pt + 1 qt/A)	95	90	98	85
Blazer + Basagran + COC (1 pt + 1 pt + 1pt/A)	88	73	98	70
Basagran + COC (1 qt + 1 qt/A)	95	76	18	13
No. of Trials	(8)	(12)	(3)	(3)

[1]Reprinted from Product Manual and Nutrient Deficiency Guide, Fourth Edition; Stoller Chemical Company, Houston, Texas.
[2]Product of Rohm and Haas Company
[3]Product of BASF Wyandott Corporation

Table 11.

Velvet Leaf Control at 14 Days
Following 2, 4 and 24 Rain-Free Hours After Treatment (17)

Herbicide/Treatment	% Velvet Leaf Control Rain-Free Period (Hours)		
	2	4	24
Blazer + Basagran + 10-34-0 (1 pt + 1 pt + 1 qt/A)	55	64	95
Blazer + Basagran + Crop Oil (1 pt + 1 pt + 1 pt/A)	18	20	71
Basagran +Crop Oil (1 qt + 1 qt/A)	16	14	78

IMPORTANT:

Addition of fertilizer adjuvant materials to postemergence herbicide solutions should be added before the herbicide is mixed into the tank. A compatibility test for solubility of the mix is highly recommended prior to final mixing.

Caution should be used, however, when spraying liquid nitrogen-herbicide mixes on corn as a postemergence application. While several preemergence herbicide tank mixes are labeled for postemergence application on corn, these labels do not allow for fluid fertilizer in the application, due to resulting corn injury from enhanced herbicidal activity. Experiments in Minnesota have shown that atrazine + 60 pounds of N per acre from UAN 28 percent solution applied at the 4-leaf stage of corn caused heavy burning with significant necrosis on the second, third, and fourth leaves (20). While recovery from the application was noted, yield potential may have been significantly reduced as the developing ear and number of rows of grain on that ear are determined at the three to four leaf stage of corn. Consult herbicide label information regarding early postemergence herbicide/fluid fertilizer applications.

III. Equipment

Nozzles[1/]: Nozzles have to be considered the most important part of a fertilizer sprayer. The four functions of nozzles are: (1) to meter liquids for proper application rates; (2) to atomize or break up liquids into droplets for coverage of the target area; (3) to disperse these droplets in specified patterns so that coverage across a spray boom can be uniform; and (4) to provide hydraulic momentum or impact so that spray from a nozzle will reach the target area.

Correct pressure at the nozzle for a given application involving specified sprayer speed and nozzle spacing is all that is required for accurate application. Reduction of that pressure, or starving the nozzle, causes less flow to pass through the nozzle with a resultant decrease in application rate (and possible distortion of the spray pattern and change in droplet size).

When decreased pressure occurs at the nozzle, the first factor to be considered is pump capacity—is it big enough to produce a given output at a given pressure required for a spray

[1/]Reprinted in part from April, 1977, Agrichemical Age by B. C. Brandenberg: Delavan Manufacturing Company application? As an example, a sprayer moving at 4 mph with a 40-foot boom and a 20-inch nozzle spacing at 40 psi requires pump capacity of 3.38 gallons per minute for a 10-gallon per acre application. This is well within the capacity of most standard pumping systems. However, this same sprayer increased to a speed of 7 mph and a spray volume increased to 20 gallons per acres requires total nozzle output of 11.78 gallons per minute. This is approaching the maximum capacity of most roller type pumps so a larger pump would be required to maintain adequate pressure at the nozzle.

Assuming that a sprayer has adequate pumping capability, there are other factors that can cause insufficient flow and pressure so that the nozzles are starved. The most obvious is pressure drop through the plumbing system that delivers the spray solution to the nozzles. There are many points in this plumbing system that can cause flow restrictions. One of the first in the system between the pump and the nozzles is the boom control valve. It is quite common for the sprayer pressure gauge to be mounted at the boom control valve; this gives the pressure reading at the valve, but is not a true measure of pressure at the nozzles.

Between the boom and control valve, spray solution usually passes through three lines—one to each section of the boom. In these three lines pressure drop occurs as a result of friction resulting from flow moving through the hose. For example, 5 gallons per minute of flow passing through 10 feet of 1/2-inch I.D. hose will have a friction loss of 1.2 psi. The same flow through 3/4-inch hose of the same length will drop only 0.28 psi. But remember, there are fittings that the hose is attached to, such as hose barbs, and significant pressure drops can result in each of these. For example, each fitting used for 1/2-inch plumbing will cause approximately one psi drop in addition to friction loss within the hose. If a 3/4-inch I.D. hose is used, each fitting will cause about 1/2 psi drop for the 5 gpm of flow. There can be additional pressure drops in each section of the boom; there is a friction loss as well as pressure drop through each nozzle outlet.

Another factor that must be considered that affects spraying pressure is the density of the spray solution. All agricultural nozzle flow rates are based on water which weighs 8.34 pounds per gallon at 60½ F and has a specific gravity of 1. A liquid fertilizer that weighs 10.0 pounds per gallon has a specific gravity of 1.2. This means that a nozzle which will spray 0.3 gallons of water per minute at 40 psi will only spray 0.27 gallons per minute of the 10-pound fertilizer at the same pressure. (Check spray charts to determine if they are calibrated for water or the product being applied).

Another factor in the starving of a nozzle is plugging or partial plugging of its orifice. To reduce plugging, use strainers throughout the system from the tank to the nozzle. A suction strainer between the tank and the pump gives the added benefit of reduced pump wear.

Deviation from an accurate and uniform application can result in poor crop response to the fertilizer being applied and even in injury to the growing plants. It is the nozzle that performs the function of delivering the proper amount of spray solution applied uniformly to the target area. Check each nozzle for output as you calibrate, and space them properly. A nozzle that does not spray according to its rating could possibly be starved because of an undersized pumping or plumbing system. Additional guidelines and information can be obtained in theappendix for calibration of field sprayers, calibration check list, cleaning spray equipment, and particle size information.

Obtaining Uniform Coverage on Foliar Sprays[1/]: To obtain uniform application across the entire swath of a spray boom, the spray solution must be dispersed into droplets in a specific pattern. The boom height above the target area must be adjusted to the spray angle from each nozzle so that the same volume of spray is obtained all along the area covered by the boom. With a side angle (120½), hollow cone nozzle single coverage is obtained at a height of 6 to 8 inches above the target area and double coverage at a height of 12 to 16 inches. It is suggested that the spray nozzle be position at an angle of 90½ straight down from the spray boom (31). Nozzle spacing should be aligned to allow for maximum foliage interception of the spray pattern.

Once the type of nozzle has been selected to give the desired spray pattern and droplet size, a spray chart should be consulted for that particular nozzle to determine what nozzle size is most adaptable to the applicator being used. Correlate desired nozzle spacing with effective ground speed to determine pressure required to obtain desired per acre application rate. **Caution**, do not select a nozzle size which will require a pressure which cannot be maintained by the applicator pump. Conversely, avoid low pressure settings (less than 20 psi on cone nozzles) which may result in distorted spray patterns with some liquids.

Equal volume output by each spray nozzle is also critical to obtaining uniform coverage. Each nozzle should be checked individually for volume uniformity before the applicator is calibrated for field use. This can be easily accomplished by a time-volume measurement (seconds required to collect 1 pint or 1 quart) at a constant pressure. (Use a pressure setting comparable with that needed for rate of application desired).

If it is determined that a given nozzle produces too little or too much volume, replace the nozzle with one which has already been checked for accuracy at a different point on the boom. If an inconsistency still exists, check the boom nozzle outlets for starving caused by reduction in pressure.

Pressures: When using high clearance ground sprayers (boom-type), pressures should range from 80-120 pounds per square inch. Aerial spraying pressures should be 75 pounds per square inch as a minimum.

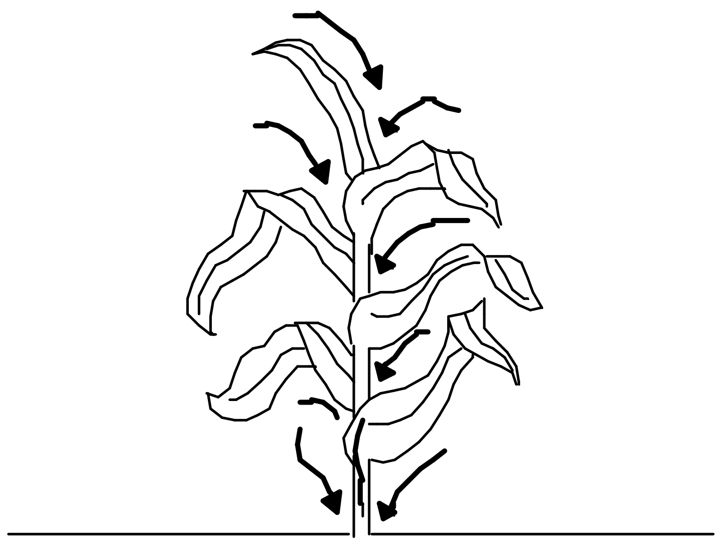
Using Center Pivot/Solid Set Irrigation Systems: The benefits of sprinkler system foliar applications of micronutrients are not always evident. Nutrient concentrations in irrigation water are generally at such a low level that foliar feeding through sprinkler systems is not effective. Generally, irrigation supplies one-half to one inch of water per application, while lower limits can be as low as one-fourth to one-third inch of water equaling an application of 7,000 to 9,000 gallons per acre (11). A 30-pounds per acre nitrogen application of urea ammonium nitrate (UAN 28) in one-third inch of water equals a concentration of 200 ppm urea nitrogen, 100 ppm ammonium nitrogen, and 100 ppm nitrate nitrogen. Normally, foliar feeding rates of 10 to 20 gallons per acre of concentrated fertilizer solution are applied, making the concentration of nutrients in irrigation water quite low in comparison, especially considering proportional amounts of micronutrients.

Responses to micronutrient fertigation cannot be entirely written off; however, quick-fix or rescue treatments in severe cases utilizing fertigated micronutrients may show favorable results. Figure 3 lends a possible explanation. Sprinkler application will thoroughly wet the

[1/]Reprinted in part from April, 1977. Agrichemical Age by B. C. Brandenberg: Delavan Manufacturing Company.

entire plant increasing the probability of foliar absorption of nutrients. Additionally, water flowing off the leaf surface would tend to be directed downward and concentrate at the base of the stem, concentrating nutrients for root uptake. The positive interaction of moist soil, concentrated nutrients, and nitrogen present in the solution contribute to the possibility of response to fertigated micronutrients.

figure 3.



Advantages and Limitations of Foliar Applications (27)

Several factors have contributed to the current widespread interest and potentialities in foliar feeding. With continuous cropping on the same soils and with tree fruits and other perennial plants, deficiency disorders are becoming more frequent and foliar sprays are often the most effective and at times the only practical means of correction and control. Soil imposed problems of dilution, penetration, and fixation are circumvented. Thus a greater response per unit of applied nutrient is realized. A plant's entire requirement for many trace elements may often be supplied by one or two foliar applications. Quantities needed are small, and tolerances for the applied materials, and rates of uptake are adequate. For the macro-elements used in large quantities, however, only a part of the nutrient needs for most crops are satisfied, but the contribution can still be significant. There is no sharp line of demarcation between benefits derived from foliar sprays of nutrients required in trace amounts by plants and those needed in larger quantities. Rates of leaf absorption and extent of transport from sprayed leaves generally favor the major nutrients (N, P, K). Their contribution to total requirement through foliar feeding can be appreciable though not usually as dramatic as with the trace elements.

Favorable results from foliar feeding are most likely to occur when the total leaf area is large as with tree fruits, shade trees, ornamentals, small fruits, plantation crops, and vegetable and agronomic crops during flowering and fruit setting. Conversely, on many row crops in spring and early summer when fertilizer needs are also great and root absorption limited, the leaves are also small and few in number and leaf surface areas limited for absorption of nutrients.

Foliar feeding is often effective when roots are unable to absorb sufficient nutrients from the soil. Such a condition could arise from an infertile soil, a high degree of soil fixation, losses from leaching, cold soil temperatures, a lack of soil moisture, or a restricted, injured, or diseased root system. Workers in the USSR have repeatedly emphasized the importance of foliar feeding in the arctic regions where perma-frost retards root growth and nutrient uptake by roots. Foliar feeding has proven of great benefit with new improved selections of some crops in which the roots have lost their inherent capacity to absorb sufficient amounts of some nutrients. The failure of the roots of certain green Pascal-type celery cultivars to absorb sufficient Mg is a good example.

Crop response to nutrient sprays is more rapid but also more temporary than from soil treatments. This offers a quick recovery from deficiencies and more precise control over the equilibrium between vegetative growth and fruit production. As a supplement to the usual soil fertilizer treatments during the early life of a crop, favorable responses from foliar fertilization have been observed during periods of slow growth and during flowering. At flowering many crop plants, having achieved their maximum leaf surface, show a marked depression in general overall metabolic activity, including nutrient uptake by the roots. Foliar applications of nutrients should be especially beneficial under such conditions.

The future for foliar feeding does not lie entirely, although it does in part, in achieving growth and yield responses above those that could be procured from the most effective soil fertilization program. The added convenience of applying nutrients in an all-purpose spray is a most attractive consideration. Precision control of nutrient levels independent of soil-imposed variables is another. There are also many quality factors, some real, others perhaps imaginary, associated with foliar feeding, of horticultural and plantation crops. Color transitions and greening of the foliage can occur within hours. Even though these color differences cannot always be translated immediately into yields, the improved appearance of the foliage is justification enough for many growers to continue with the practice. Results from foliar feeding may also be evidenced in the more difficult to define factors of fruit firmness, flavor, and coloration. There are reports of pickling cucumbers darker green in color, cherries with less cracking, strawberries that retain their size through the picking season, and black raspberries that do not dry up and crumble—resulting from the regular foliar application for soluble (NPK + Mg) fertilizers.

Some quality improvement factors are well defined. In sugar cane, quality is equivalent to the sucrose content and this has been increased significantly by preharvest sprays of KH_2PO_4; and regrowth of the ratoon crop was increased by 40 percent. Potato tubers harvested from plants sprayed with certain metal chelates did not darken on boiling. Foliar applications of KNO_3 to roses resulted in more richly colored blossoms, dark green foliage with a glossy sheen, and improved winter hardiness. All fertilizer during the growing season was applied through the foliage, and as a part of the all-purpose spray solution applied weekly. Sprays of $MgSO_4$ and borax applied at critical intervals during the growth and fruiting of cantaloupes and tomatoes in Maryland increased the percent soluble solids, and yield of U.S. No. 1 fruit, respectively.

In contrast to the numerous examples of positive responses to foliar applications of mineral elements cited, herein, there are also many instances of little or no benefit from foliar feeding. Negative results from foliar fertilization have also been reported for wheat, corn, soybeans, oats and alfalfa. Field crops grown in soils with adequate fertility failed to respond to foliar sprays containing N, P, and K. It is significant, however, that in some of these tests no marked response was likewise observed with fertilizer applications to the soil.

There is little question of the value of foliar nutrient sprays for the prevention or correction of trace element deficiency disorders or for the alleviation of some major element deficiencies. The true value of foliar feeding, however, in supplementing standard soil fertility programs remains to be resolved.

Conclusions

From a small beginning of over 100 years ago where iron sprays were used to correct leaf chlorosis on crops grown in alkaline soils, 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 unsound, since depressions in yield and quality usually precede 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.

Foliar feeding of crop plants has not been satisfactorily evaluated. Results from isotopic tracer experiments have been suggestive but not conclusive. Carefully designed, long-time greenhouse and field experiments have yet to be conducted. A consideration of the crop, the variety, leaf area and morphology, stage and rate of growth, soil moisture, soil nutrient level, and prevailing weather conditions must be included. Even then important variables relating to the nature of the applied substance can be introduced. Studies of foliar feeding will be besieged by all the problems encountered in an evaluation of crop response from soil-applied nutrient elements. In addition, the absorbing surface constitutes a complex about which little is known.

Scientists have often through poorly designed experiments and faulty observations been as unscientific in their appraisals of foliar feeding as have liquid fertilizer manufacturers and salesmen in promoting the use of an expensive commodity that will often fall short of the claims for improved crop performance. The same criticisms frequently leveled against the use of the complete package liquid fertilizer formulations for foliar feeding, apply with equal force to the use of complete dry or liquid formulations on the soil. The approach in both instances should be addition of only needed nutrients as revealed by soil and tissue tests and past crop performance.

APPENDIX

Subject **Page**

PLANT NUTRIENT FUNCTIONS AND FERTILIZER NUTRIENT SOURCES SUITABLE FOR FOLIAR APPLICATIONS [1/]

NITROGEN

Stimulates growth through protein formation; stimulates absorption of other nutrients by increasing leaf surface permeability. Higher percentage in foliar applications during early growth stages (10-18% N). Lower percentage at later growth stages (3-8% N). Should be present in every foliar application, especially when applying micronutrients (3-8% N).

Source	% N
Biruet free urea: [Less than 0.2% (6, 7, 9)] (i.e., Feed-grade urea/LB urea)	21-44
Ammonium polyphosphates	10-21
Orthophosphates (liquid)	3-16
Calcium Nitrate	15
Potassium Nitrate	13.75
Ammonium thiosulfate	12
Ammonium sulfate solution	8

Avoid large amounts of UAN solutions.

PHOSPHORUS

Supplies energy for growth; higher percentages beneficial during early growth stages (8-16% P_2O_5); lower percentages required at later growth stages (4-8% P_2O_5). Absorption rate into leaf tissue is greatest when pH of the solution is 5.0 to 6.0 (19).

Source	% P_2O_5
Ammonium polyphosphates	33-52
Orthophosphates (liquid)	4-18

POTASSIUM

Aids in maturity and seed/fruit set. Sufficient percentages in fertilizer solutions range from 6-14% K_2O.

Do not use liquid solutions of potassium chloride; chloride (Cl^-) will cause foliage burn.

Source	% K_2O
Potassium Nitrate	44.5
Potassium Thiosulfate [2/]	25
Liquid solutions involving potassium hydroxide	6-18
Potassium sulfate (17.6% sulfur)	54
Urea Potassium - Polyphosphate	10-20

[1/] Where specific product names and producing companies are mentioned, no specific endorsement or claim to product performance is intended.
[2/] Product of Hickson Kerley, Inc., Phoenix, AZ

Fertilizer Formulation Guidelines Utilizing Potassium Nitrate

Work with Weight and not Volume

To calculate the required weight of K-power to prepare one (1) ton of solution, at a desired K_2O level, is as follows:

$$Y + \frac{2000}{Z} * X$$

Z = 46 when 13-0-46 or 44.5 when 13-0-44
Y = required amount (lbs.) KNO_3
X = desired K_2O level

For example, if 8 units of K_2O are desired, and you use Potassium Nitrate as 13-0-46, it will require:

$$348 \text{ lbs. } KNO_3 = \frac{2000}{46} * 8$$

Potassium nitrate also supplies nitrogen as nitrate, 13.0% N from 13-0-46 or 13.75% N from 13-0-44, as presented in Table A-1.

Table A-1.

The Required Amount of KNO_3 to Prepare One Ton Solution at Different K_2O Levels and the Additional Supplied N

Desired K_2O Level	Required KNO_3		Supplied N		Added Water				13-0-46 Solution	13-0-44 Sollution
	13-0-46	13-0-44	13-0-46	13-0-44	13-0-46	13-0-44	13-0-46	13-0-44	$N-P_2O_5-K_2O$	$N-P_2O_5-K_2O$
-lbs-	-----lbs-----		------lbs------		------lbs------		------gal------		----%----	----%----
1	44	45	0.28	0.30	1956	1955	233	233	0.28-0-1	0.30-0-1
2	87	90	0.56	0.61	1913	1910	228	228	0.56-0-2	0.61-0-2
3	130	135	0.84	0.92	1870	1865	223	223	0.84-0-3	0.92-0-3
4	174	180	1.13	1.23	1826	1820	218	218	1.13-0-4	1.23-0-4
5	218	225	1.41	1.54	1782	1775	213	212	1.41-0-5	1.54-0-5
6	261	270	1.69	1.85	1739	1730	207	207	1.69-0-6	1.85-0-6
7	305	315	1.97	2.16	1695	1685	202	201	1.97-0-7	2.16-0-7
8	348	360	2.26	2.47	1652	1640	197	196	2.26-0-8	2.47-0-8
9	392	405	2.54	2.78	1608	1595	192	191	2.54-0-9	2.78-0-9
10	435	450	2.82	3.09	1565	1550	187	185	2.82-0-10	3.09-0-10
11	479	494	3.10	3.39	1521	1506	182	180	3.10-0-11	3.39-0-11
12	522	539	3.39	3.70	1478	1461	176	175	3.39-0-12	3.70-0-12

Mix with Compatible Fertilizers

When preparing N-P-K solution, a chemical reaction may occur and result in insolubles or reduced solubility and will cause no end of problems. The following compatibility of potassium nitrate with other fertilizers is summarized in Table A-2.

Table A-2.

Potassium Nitrate Compatibility with Other Water Soluble or Liquid Fertilizers

Fertilizer	Potassium Nitrate	Fertilizer	Potassium Nitrate
Urea	C	Chelates of: Iron, Zinc, Copper, Manganese	C
255 Solution	R	Magnesium Sulfate	R
N-32 Solution	C	Magnesium Nitrate	C
Ammonium Nitrate	C	Phosphoric Acid	C
Ammonium Sulfate	R	Nitric Acid	C
Calcium Nitrate	C	10-34-0 Solution (Clear)	C
CAN-17 Solution	C	Water Soluble N-P-K: 20-20-20, etc.	C
Ammonium Phosphate	C		
Sulfates of: Iron, Zinc Copper, Manganese, Magnesium	R		

C = Compatible R = Reduced Solubility I = Incompatible

It should be noted that when a third fertilizer is added to the solution, the compatibility should be checked. For example, calcium nitrate will react with any soluble phosphate or sulfate and produce insoluble materials.

Prepartion of 1:0:2, 2:0:1 and 1:0:1 Solutions

More concentrated solutions tend to salt out at lower temperatures than low concentrated solutions. Therefore, when low temperatures prevail, lower concentrated solutions are preferred, like 4-0-8 rather than 5-0-10 at the same 1:0:2 ratio. An example of preparation of 1:0:2, 2:0:1 and 1:0:1 solutions, with ammonium nitrate or calcium nitrate, are shown in Table A-3.

Table A-3.

Example of Preparation of One Ton of 1:0:2 and 2:0:1 Ratio Solutions

Desired Ratio	Solution $N\text{-}P_2O_5\text{-}K_2O$ (%)	Potassium Nitrate (lbs)		Additional Ammonium Nitrate (lbs)		+ Water (gal)	or Additional Calcium Nitrate (lbs)		+ Water (gal)
		13-0-44	13-0-46	With 13-0-44	With 13-0-46		With 13-0-44	With 13-0-46	
1:0:2	4-0-8	360	348	91	103	185	197	225	170
1:0:2	5-0-10	450	435	114	129	172	246	282	153
2:0:1	8-0-4	180	174	404	405	170	873	887	112
2:0:1	10-0-5	225	218	504	508	152	1091	1108	82
1:0:1	7-0-7	315	305	289	300	167	624	648	142
1:0:1	8-0-8	360	348	330	343	157	713	741	109

CALCIUM

Aids in maturity and seed/fruit set. Essential element in plant cell wall structure. Foliar applications delay senescence/breakdown of plant tissue.

Source	**% Ca**
Calcium sulfate	23
Calcium nitrate	21
Promesol 30[1/]	8
Metalosates®[2/] (Amino Acid)	5.0

Calcium for the control of blackheart is directed into the hearts of the celery stalks by special spray equipment with a single nozzle producing a coarse spray over the center of each row. Usually nutrient sprays for celery are combined in the sprayer with other materials that are applied for disease and insect control.

MAGNESIUM

Central element around which chlorophyll is manufactured; participates in the activity of enzymes (proteins) and in phosphorus translocation. Forage plants containing less than 0.2% magnesium prodiuce high incidences of grass tetany in ruminant animals (Hypomagnesemia).

Source	**% Mg**
Magnesium sulfate	10
Magnesium nitrate (Low rates allow the nitrate concentrations to be low enough in this formulation to allow application without foliage burn.)	6-3

Green Pascal celery varieties susceptible to Mg deficiency in Michigan and other areas in the eastern USA, Canada, and California are sprayed at approximately 10-day intervals with 10 pounds of Epsom salts per acre or the equivalent of 1 pound per acre per day. The 10 to 25 pounds of $MgSO_4$ are added to 100 to 150 gallons of water with spray applications beginning 4 weeks after transplanting and continuing throughout the remainder of the growing season. Urea at the rate of 10 to 20 pounds per 100 gallons of water is also added by some growers.

SULFUR

Necessary for protein formation and sugar metabolism. Beneficial for both early and later growth stages.

Source	**% S**
Ammonium thiosulfate	26
Ammonium sulfate solution	9
Potassium thiosulfate[3/]	17
Potassium sulfate	17-18
Magnesium sulfate	12-13
Calcium sulfate	15-18
Zinc sulfate	18
Manganese sulfate	13-18
Iron sulfate	19
Copper sulfate	13

[1/]Product of Carpenter Sales, Bondurant, IA
[2/]Product of Albion Laboratories; Clearfield, UT
[3/]Hickson Kerley, Inc., Phoenix, AZ

ZINC

Catalyst for plant growth regulators; important for plant maturity.

Source	**% Zn**
Zinc sulfate	36
Metalosates®[1/] (Amino Acid)	6.8
Various organic chelate sources (i.e., phenolic acids, fulvic acids, ligninsulfonates, glucoheptonate)	

Concentrated solutions of Zn salts, 1/2 to 2 pounds of $ZnSO_4$ per gallon, are currently used for swabbing on fresh pruning wounds of spur-pruned grape vines. Similarly, late dormant concentrated sprays of $ZnSO_4$, 25 to 40 pounds per 100 gallons of water, are standard current recommendations for peaches, nectarines, almonds, apricots, pears and peaches in the western states where Zn deficiency ("little leaf") is prevalent. Twenty to 30 pounds of actual Zn per acre is applied whether by ordinary types of spray equipment or by airplaine. Fall sprays of Zn, 10 to 20 pounds per 100 gallons of water, just before leaf fall have given good results on apricots and Golden Delicious apples. The spray burns the foliage but sufficient Zn is absorbed to correct its deficiency. Tree fruits deficient in Zn respond to foliar sprays of this nutrient, with Zn deficiency in the cherry being the most difficult to correct. Foliage sprays of Zn are especially effective on pears. Usual recommendations call for 5 pounds of $ZnSO_4$ plus 3 pounds of spray lime (hydrated) or 5 pounds of ZnO in 100 gallons of water. These materials are compatible with most insecticides and fungicides and are generally used together. Zinc deficiency on sweet corn and tomatoes grown in the desert soils in California has been described. Foliage sprays of $ZnSO_4$ or ZnO as well as soil treatments have been effective.

MANGANESE

Involved in protein manufacture, respiration and enzyme function. Acidic fertilizer solution (pH of 5.0 to 6.0) without phosphate works the best.

Source	**% Mn**
Manganese sulfate	25-28
Metalosates®[1/]	5.0
Various organic chelate sources (i.e., phenolic acids, fulvic acids, ligninsulfonates, glucoheptonate)	

Many crops have responded to foliar feeding with Mn. Soil applications to fruit trees are generally ineffective, and the response to $MnSO_4$ sprays has always been marked. Dormant sprays of a 5% $MnSO_4$ solution effectively control Mn deficiency on peaches and plums. Manganese deficiencies on California walnuts are controlled by spraying young leaves before they are mature with $MnSO_4$ at the rate of 5 pounds per 100 gallons of water. Thorough coverage of the foliage is important. Airplane dusting with Mn-bearing dust has been effective in coastal districts if done while leaves were wet from fog. Foliar sprays are an effective means of correcting Mn deficiencies on bean, and are a part of the regular spray program for this crop grown on the more alkaline muck soils in Michigan and other northern states.

IRON

Directly involved in manufacture of chlorophyll; important during early growth stages, especially in corn, grain sorghum, wheat and soybeans.

Source	**% Fe**
Iron sulfate	20
Ferrous Ammonium Sulfate (17% S, 10% N)	14
Various organic chelate sources (i.e., phenolic acids, fulvic acids, ligninsulfonates, glucoheptonate)	

[1/]Product of Albion Laboratories; Clearfield, UT

Iron sprays, while indespensible for growth and production of pineapple and grain sorghum in some areas, have generally been disappointing when used on fruit trees. Iron chlorosis was the first deficiency disorder to be recognized on tree fruits, and investigations have continued over 40 years, but the best spray treatments are only partially successful. Sprays are most effecive if applied early in the season and when applied with organic chelate carriers (i.e., citric acid, malic acid, fulvic acid, phenolic acid, or glucoheptonate) (27).

COPPER

Important for a photosynthesis enzyme function; also important during reproductive stages.

Source	% Cu
Bordeaux mixtures	
Copper sulfate (Monohydrate: 12% S)	35
Copper sulfate (Pentahydrate)	25
Various organic chelate sources (i.e., phenolic acids, fulvic acids, ligninsulfonates, glucoheptonate)	

Foliar feeding of crop plants with Cu has probably been as extensive and continuous as with any trace element. The purpose, however, has been mainly for disease control. Thus, Cu deficiencies on fruit trees are extremely rare and equally rare with row crops grown on muck soils, even though Cu deficiencies in the absence of Cu sprays or dusts are easily demonstrated (27).

BORON

Essential for actively growing new tissue, necessary for pollen viability and good seed set. Alfalfa most sensitive crop; critical for seed crops. Narrow range between deficiency and toxicity.

Source	% B
Solubor	20.5

Boron deficiencies of apples, almonds, pears and prunes are also corrected by foliar applications of 1 to 2 pounds of sodium pentaborate or boric acid in 100 gallons of water anytime during the spring or summer. Application of B during flowering appears helpful for control of bitter pit in York Imperial apples in Maryland. Van Alphen has summarized the results of spraying B on a wide variety of crops all of which indicate rapid uptake of this nutrient through the leaves (27).

MOLYBDENUM

Essential for nitrogen fixation by nodule bacteria in legumes; also essential in all crops for conversion of nitrate to amine for protein manufacture. Increased probability of response for plants growing in acid soils (pH's less than 6.0).

Source	% Mo
Ammonium Molybdate	54
Sodium Molybdate	
COMO[1/] A fluid cobalt/molybdenum complex	

[1/]Product of Stoller Chemical Company, Houston, TX

Examples of Currently Available Multinutrient Foliar Spray Fertilizer Formulations

SHIELD-BRITE NUTRITIONAL FOLIAR SPRAYS[1/]

Spray Dried Wettable Powder Formuations

NUTRA-PHOS® PRODUCTS	% N	% P_2O_5	% K_2O	% Ca	% Mg	% S	% Zn	% Mn	% Fe	% Cu	% B
Nutra-Phos® 10	--	10.0	--	10.0	--	--	14.0	7.0	--	--	--
Nutra-Phos® 12	--	12.0	--	11.0	--	--	25.0	--	--	--	--
Nutra-Phos® 24	--	24.0	--	20.0	--	6.0	12.0	--	--	--	--
Nutra-Phos® 28	--	24.0	--	28.0	--	4.0	3.0	--	--	--	--
Nutra-Phos® 3-15	--	15.0	--	7.5	--	3.0	15.0	15.0	--	--	--
Nutra-Phos® K	--	16.0	16.0	--	--	--	31.0	--	--	--	--
Nutra-Phos® Fe	3.0	27.0	--	--	--	3.0	--	--	21.0	--	--
Nutra-Phos® Super-K	7.0	13.0	34.0	--	--	--	12.5	--	--	--	--
Nutra-Phos® Mg	--	25.0	--	10.0	5.5	--	5.5	--	--	--	--
Nutra-Phos® ZMC	--	4.0	--	9.0	--	8.0	10.0	10.0	--	6.0	--
Nutra-Phos® N	16.0	12.0	--	4.0	1.5	--	2.0	--	1.0	--	1.0
Nutra-Phos® 40	--	40.0	--	--	--	--	14.0	--	--	--	--

NUTRA-SPRAY® PRODUCTS	% N	% P_2O_5	% K_2O	% Ca	% Mg	% S	% Zn	% Mn	% Fe	% Cu	% B
Nutra-Spray® Mn 35	--	--	--	--	--	--	--	35.0	--	--	--
Nutra-Spray® ZMC171/2-4-4	--	--	--	--	--	--	17.5	4.0	--	4.0	--
Nutra-Spray® ZM181/2-7	--	--	--	--	--	--	18.5	7.0	--	--	--
Nutra-Spray® ZM25-25	--	--	--	--	--	--	25.0	25.0	--	--	--
Nutra-Spray® Zinc 50	--	--	--	--	--	6.5	50.0	--	--	--	--
Nutra-Spray® COPOPHOS™	--	10.8	--	--	--	--	5.4	--	--	14.5	--
Uniflow® Zinc	--	--	--	--	--	1.4	25.0	--	--	--	--
Uniflow® Sulfur	--	--	--	--	--	52.4	--	--	--	--	--

Liquid Formulations

SORBA SPRAY® PRODUCTS	% N	% P_2O_5	% K_2O	% Ca	% Mg	% S	% Zn	% Mn	% Fe	% Cu	% B
Sorba-Spray® Ca	6.0	--	--	8.0	--	--	--	--	--	--	--
Sorba-Spray® CaB	3.0	--	--	5.0	--	--	--	--	--	--	0.5
Sorba-Spray® Cu	--	10.0	--	--	--	1.0	1.0	--	--	4.0	--
Sorba-Spray® Mg	--	10.0	--	--	3.0	3.0	1.0	--	--	--	--
Sorba-Spray® Mn	--	12.0	--	--	--	2.0	2.0	2.0	--	--	--
Sorba-Spray® ZBK	1.0	--	6.0	--	--	--	1.0	--	--	--	1.0
Sorba-Spray® ZIP	--	8.0	--	--	--	2.0	1.0	--	3.0	--	--
Sorba-Spray® ZKP	--	16.0	9.0	--	--	--	1.0	--	--	--	--
Sorba-Spray® ZNP	10.0	12.0	--	--	--	1.0	2.0	----	--	--	--
Sorba-Spray® MIP	--	10.0	--	--	--	2.5	--	2.0	2.0	--	--

NUTRIMIN™ PRODUCTS	% N	% P_2O_5	% K_2O	% Ca	% Mg	% S	% Zn	% Mn	% Fe	% Cu	% B	% Mo
BORTAC	--	--	--	--	--	--	--	--	--	--	10.9	--
FOLIAMAG	--	--	--	--	15.0	--	--	--	--	--	--	--
HYDROPHOS	--	29.0	--	--	4.2	--	--	--	--	--	--	--
SENIPHOS	--	23.0	--	3.0	--	--	--	--	--	--	--	--
STOPIT	--	--	--	12.0	--	--	--	--	--	--	--	--
ZINPHOS	--	28.0	--	--	--	--	9.4	--	--	--	--	--
ZINTRAC	--	--	--	--	--	--	40.0	--	--	--	--	--
MANTRAC 500	--	--	--	--	--	--	--	27.0	--	--	--	--
MOLYTRAC	--	--	--	--	--	--	--	--	--	--	--	15.0

Soluble Formulations

SOLU-SPRAY™ PRODUCTS	% N	% P_2O_5	% K_2O	% Ca	% Mg	% S	% Zn	% Mn	% Fe	% Cu	% B
Solu-Spray™ 10-45-10	10.0	45.0	10.0	--	--	3.0	0.05	0.05	0.10	0.05	0.02
Solu-Spray™ 10-55-10	10.0	55.0	10.0	--	--	--	0.05	0.05	0.05	0.05	0.02
Solu-Spray™ 15-20-20	15.0	20.0	20.0	--	--	2.0	1.0	0.10	0.10	0.25	0.08
Solu-Spray™ 12-26-26	12.0	26.0	26.0	--	--	--	--	--	--	--	--
Solu-Spray™ 20-20-20	20.0	20.0	20.0	--	--	1.0	0.05	0.05	0.10	0.05	0.02
Solu-Spray™ 9-15-32	9.0	15.0	32.0	--	--	5.0	0.05	0.05	0.10	0.05	0.02
Solu-Spray™ 7-5-44	7.0	5.0	4.0	--	--	7.5	1.0	0.05	0.05	0.05	0.02

[1/] Leffingwell Products, and Shield-Brite: A division of Pace International LP

Examples of Currently Available Multinutrient Foliar Spray Fertilizer Formulations

TRISERT®[1]
Foliar Fertilizer Solutions
(contains Triazone®-Nitrogen)

N-Sure (28-0-0)
TRISERT (13-3-4)
TRISERT-CB (26-0-0-0.5B) for Cotton
TRISERT-PB (13-3-4-0.3B) for Peanuts
TRISERT-SB (13-3-4) for Sugar Beets
TRISERT-N (13-3-4) for Nursery Plants

FEAST FORMULATIONS[2]

9-18-9
3-18-18
16-4-4

PRODUCT[3]	% N	% P	% K	% S	% Mg	% Zn	% Mn	% Fe	% Cu	% B	% Mo
THIS Vegetable Mix	0	0	0	4.0	1.4	1.0	1.25	1.0	0.25	0	0
THIS Soybean/Cotton Mix	0	0	0	4.0	0	2.0	3.0	1.0	0	0	0
CLAW-EL Vegetable Mix	0	0	0	4.0	1.5	0.75	0.75	1.75	0	0	0
SORBA Spray ZNP	10.0	12.0	0	1.0	0	2.0	0	0	0	0	0
Harvest Plus 14-4-6	14.0	4.0	6.0	8.4	1.5	2.0	2.0	1.5	0	0.1	0.02
Harvest Plus 4-18-6*	4.0	18.0	6.0	5.8	1.0	3.0	0.5	0.5	0	0.2	0.05
Bayfolan Plus/Complesal	11.0	8.0	5.0	0	0	0.05	0.05	0.10	0.05	0.02	0.0005
Xylex	12.0	6.0	6.0	0	0	0.05	0.05	0.10	0.05	0.02	0.0005
Fol-i-gro/Foliar Feed II	15.0	10.0	5.0	0	0	0	0	0	0	0	0
Balance 121	9.0	18.0	9.0	1.0	0	0	0	0	0	0	0
Nutra Leaf	20.0	20.0	20.0	0	0	0.05	0.05	0.10	0.05	0.02	0.0005

*Plus 1.00% Calcium.

PRODUCT[4]	% N	% P	% K	% S	% Mg	% Zn	% Mn	% Fe	% Cu	% B	% Mo	% Co
PT-21	21											
Score	0	0	0	3.0	0.5	1.0	0.5			0.25	0.001	0.001
N-Zone	0	0	0	0	0	0	0	0	0	0	3.0	2.0

[1]Hickson-Kerley, Inc., Phoenix, AZ
[2]Conklin Co., Shakopee, MN
[3]Stoller Chemical Co., Inc., Houston, TX
[4]Ag Spectrum Co., Dewitt, IA

TIMING AND RATES
OF FOLIAR APPLICATIONS

Alfalfa (Hay) - Applications should be made as soon as there is enough leaf area available to absorb nutrients.

Foliar Spray Program: ***Alfalfa (Hay)***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1	After each cutting - just as new growth reappears	2.0 to 3.5	1.0 to 3.5	1.0 to 4.5	1.0 to 2.5	1.1 to 2.0	0.5 to 0.75	0.35 to 0.60	0.3 to 1.25	0.1 to 0.2	0.2 to 0.7	0.1 to 0.25	1.0 to 1.5
2	When alfalfa is 6" - 8" High	2.0 to 3.5	1.0 to 3.5	1.0 to 4.5	1.0 to 2.5	1.1 to 2.0	0.5 to 0.75	0.35 to 0.60	0.3 to 1.25	0.1 to 0.2	0.2 to 0.7	0.1 to 0.25	1.0 to 1.5
3	7 - 10 days after spray No. 2	2.0 to 3.5	1.0 to 3.5	1.0 to 4.5	1.0 to 2.5	1.1 to 2.0	0.5 to 0.75	0.35 to 0.60	0.3 to 1.25	0.1 to 0.2	0.2 to 0.7	0.1 to 0.25	1.0 to 1.5

Alfalfa (Seed)

Foliar Spray Program: ***Alfalfa (Seed)***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1	Late Bud Stage	3.5 to 5.0	2.0 to 2.5	2.0 to 2.5	0.5 to 1.0	0.7 to 0.9	0.5 to 1.0	0.12 to 0.25	0.1 to 0.5	0.1 to 0.3	0.1 to 0.13	0.05 to 0.1	0.4 to 0.7
2	10 - 20% Bloom	3.5 to 5.0	2.0 to 2.5	2.0 to 2.5	0.5 to 1.0	0.7 to 0.9	0.5 to 1.0	0.12 to 0.25	0.1 to 0.5	0.1 to 0.3	0.1 to 0.13	0.05 to 0.1	0.4 to 0.7
3 thru 4	14 to 20-day Intervals Starting at Seed Formation	3.5 to 5.0	2.0 to 2.5	2.0 to 2.5	0.5 to 1.0	0.7 to 0.9	0.5 to 1.0	0.12 to 0.25	0.1 to 0.5	0.1 to 0.3	0.1 to 0.13	0.05 to 0.1	0.4 to 0.7

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Base solution of N-P-S-B-Mo are recommended and applied with 10-20 gallons of water per acre.

Almonds - Nutritional foliar feeding programs have been tested on almonds for 20 years with consistent results. Not only have higher yields been obtained, but the nuts are larger and of more uniform maturity. Average yield increases of 15-17% have been recorded. In addition, trees have shown stronger bloom and better set the year following treatment.

Timing of application is important to influence the set of the bloom and the development of the nuts.

APPLICATION RATES PER ACRE AND TIMING

When two applications are possible, recommended timing is at 10% bloom, followed by a subsequent application at petal-fall. If weather conditions or other factors preclude two applications, a single treatment should be made at petal-fall to jacket split.

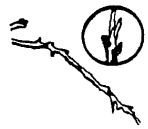
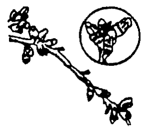
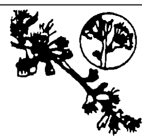
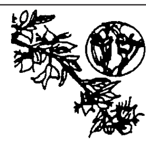
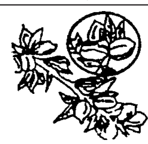
10% bloom (first of two applications)
Dilute solutions of N-P-K-S-Zn-Fe-Mn-B should be applied at early bloom, along with three to five pounds of nitrogen. This tank-mix combination can be included with blossom brown rot sprays. Early applications increase pollen, nectar and flower petal size for bee activity.

Petal-fall (second of two applications)
In a second application, five to ten pounds LoBI Urea should be applied. This treatment can be combined with shot-hole sprays. The second application is designed to increase fruit set, influence the growth of nutmeats and decrease the number of blanks.

Petal-fall to hull split (single application)*
Applications in the interval between petal-fall and hull split if a double application is not possible. The single stage program produces beneficial results in nutmeat size and reduction of blanks.

*Aerial application of dilute solutions of N-P-K-S-Zn-Fe-Mn-B during the bloom stage in 10 to 20 gallons of water has been used successfully to boost set and yield and to augment the simple stage program.

Foliar Spray Program: *Almonds*

Spray No.	Growth Stage		Recommended Nutrients											
			N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
			Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
	Dormant to delayed dormant													
1	Pink bud-- 10% bloom		2.5 to 3.5	0.5 to 1.0	0.5 to 1.0				0.25 to 0.5				0.1 to 0.25	
	Bloom													
2	Post bloom-- petal fall		3.5 to 6.5	0.75 to 1.0	1.0 to 2.0				0.25 to 0.5				0.1 to 0.25	
	Immature nut													
	Mature nut													
3	Hull Split		5.0 to 6.5	1.0 to 1.5	1.0 to 2.0									
	Postharvest													

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Recommended gallonage:

Air: 10-20 gallons per acre
Concentrate: 50-100 gallons per acre.
Dilute Sprays: 100-300 + gallons per acre

Apples - Nutrient sprays of urea, or formulated mixtures containing N, P, K, Mg, and trace elements, may be applied to fruit trees at any time during the growing season along with the regular spray program to improve the appearance of the foliage, and color and quality of the fruit. Fruit growers have adopted these practices based largely upon personal observations. The greatest responses are reported by growers from nutrient sprays that are applied during the growing season from petal fall to within 2 weeks of harvest. Apple orchards in Michigan are especially benefited from urea sprays when ground fertilizer is applied too late in the spring or in insufficient quantitites, when dry weather reduces the availability of soil applied N, and when fruit set is heavy.

Foliar nutrient programs are designed to produce better apple yields and quality than can be obtained from a normal soil fertilization program alone. Used as a suplement to soil fertilizer, foliar programs are most effective when applied to conincide with critical stress periods of the tree.

From the time the tree starts to bloom, to the time it sets and forms fruit, the root system is under tremendous stress to supply all the nutrients needed to produce high quality, profit-bearing fruit.

Timely applications of foliar spray programs specifically designed for most apple varieties, will keep orchards in a healthy condition to withstand both environmental and growth cycle stresses.

Properly designed and time nutritional spray programs can result in the following benefits:

ï Increased fruit set
ï Earlier maturity
ï Better size and fruit color
ï Less bitter pit
ï Better storageability
ï Greater return bloom
ï Reduction or elimination of alternate bearing

These benefits are most consistent when a foliar feeding program is followed for at least a three-year period. A foliar analysis should be conducted each year to help guide recommendations. Careful planning, timing and observation are necessary for successful results.

APPLICATION RATES PER ACRE AND TIMING

Pre-bloom
For increased spur vigor and improved fruit set, spray during the pink bud stage.

Petal-fall to post-petal fall
A second spray should be applied three weeks after the first application, to aid in producing larger, typier fruit. Other benefits can include increased sugar content, improved color and earlier, more uniform maturity.

Alternatve timing may be used where the advantages of an early application are not of paramount importance. This timing would call for a first application at petal-fall to first cover spray with the second application at third cover spray.

Three to four pounds of zinc may be applied with dormant superior oil up to green tip stage to increase zinc levels.

Foliar Spray Program: *Apples*

Spray No.	Growth Stage		Recommended Nutrients											
			N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
			Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1 or	Dormant to Silver Tip								3 to 4					
1 or	Green Tip to Half-Inch Green								3 to 4					
1	Tight Cluster to First Pink		3.5 to 6.5	0.75 to 1.5	1.0 to 2.0				0.25 to 0.5				0.1 to 0.2	
2	Petal Fall		3.5 to 6.5	0.75 to 1.5	1.0 to 2.0									
3 thru 5	Fruit Development		3.5 to 6.5	0.75 to 1.5	1.0 to 2.0	1.5 to 2.0	0.5 to 1.0							

1/ Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
2/ Base solutions of N-P_2O_5-K_2O-S at 2:1:1:0.08 ratios are recommended and applied in 100-300 gallons of water per acre.

Avocados - Foliar programs are used by avocado growers to obtain earlier oil development in heavier, firmer fruit with better keeping quality. Trees respond with healtheir foliage and improved vigor that enables them to better withstand environmental stress from hot, dry wind or cold weather.

A sustained program can help production and reduce alternate bearing tendencies. Where iron chlorosis is a problem, iron should be included in the program.

Avocados

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1	Pre-bloom (mid April)	2.0 to 3.0	2.0 to 2.5	5.0 to 7.0				2.0 to 2.5				0.10 to 0.25	
2	Post bloom May-June	3.0 to 4.0	2.0 to 2.5	3.0 to 3.5	1.0 to 1.5		0.5 to 0.5	1.25 to 1.75	0.50 to 0.75				
3	Post bloom mid July	3.0 to 4.0	2.0 to 2.5	3.0 to 3.5	1.0 to 1.5		0.5 to 0.5	1.25 to 1.75	0.50 to 0.75				

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Recommended gallonage:
Air: 10-20 gallons per acre
Concentrate: 50-100 gallons per acre.
Dilute Sprays: 100-300 + gallons per acre

Blueberries and Caneberries (Raspberries and Blackberries--All Varieties) - Blueberries have responded to foliar feeding programs with increased yields, better fruit quality, greater plant vigor and increased cold hardiness. Increases of 1,000 pounds per acre have been reported.

Various tests with caneberries (including blackberries, raspberries, loganberries and boysenberries) have shown increase in soluble solids, plus yield increases. Foliar programs on blackberries, for example, have produced added returns from $350 to over $600 per acre, for an average 20% greater dollar return to the grower. Raspberries showed an increase in set with firmer berries...resulting in higher quality fruit from mechnically-harvested blocks.

APPLICATION RATES PER ACRE AND TIMING

Caneberries

Pre-bloom (6" to 8" of new growth) — Just prior to bloom to 5%-10% bloom

Blueberries

Pre-bloom — Petal-fall

On caneberries foliar sprays may be applied after harvest to promote post-harvest plant recovery, to strengthen canes for overwintering and to aid bud formation for the following year.

On blueberries a dilute spray of a P-K-Zn solution yield 1.0-0.5-0.05 pounds per acre spray may be applied 2-3 weeks apart during the post season to increase winter hardiness of the bushes, aid recovery from freezes and increase the resistance of buds and flowers to spring frosts.

Foliar Spray Program: ***Blueberries***

Spray No.	Growth Stage	Recommended Nutrients — Suggested Application Rate (Pounds per Acre)[1/ 2/]											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo oz.
1	Pre-bloom	3.5 to 6.5	0.75 to 1.5	1.0 to 2.0				0.10 to 0.25				0.1 to 0.2	
2	Petal Fall	3.5 to 6.5	0.75 to 1.5	1.0 to 2.0				0.25 to 0.5					

Foliar Spray Program: ***Caneberries***

Spray No.	Growth Stage	Recommended Nutrients — Suggested Application Rate (Pounds per Acre)[1/ 2/]											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo oz.
1	Pre-bloom (6"-8" of new growth)	3.5 to 6.0	1.0 to 2.0	1.25 to 2.5				0.10 to 0.25				0.1 to 0.2	
2	Just Prior to Bloom-- (5-10% bloom)	3.5 to 6.0	1.0 to 2.0	1.25 to 2.5				0.10 to 0.25				0.1 to 0.2	

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

Cabbage, Cauliflower, Broccoli - Cole crops respond to foliar nutrition programs with an increase in head size and weight and by developing firmer heads that hold up better during shipment. Plants for transplant should receive foliar sprays seven to ten days prior to transplant and again seven to ten days after transplant.

The first treatment develops healthier plants that are more resistant to transplant shock.

The second treatment promotes root development and helps reestablish vigorous growth.

A third application 10 to 14 days later, promotes development of heavier, firmer heads. For direct seeded crops, the first application should be made five to seven days after thinning, with second and third application following at seven to ten day intervals. A spreader sticker should be used on cole crop applications. Two to three pounds LoBi Urea may also be used as desired.

Foliar Spray Program: ***Cabbage, Cauliflower, and Broccoli (Transplants)***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1	7 - 10 days prior to transplanting	1.0 to 1.3	0.2 to 0.3	0.3 to 0.4									
2	7 - 10 days after transplanting	1.0 to 1.3	0.2 to 0.3	0.3 to 0.4									
3	10 - 14 days after spray No. 2	1.0 to 1.3	0.2 to 0.3	0.3 to 0.4									

Foliar Spray Program: ***Cabbage, Cauliflower, and Broccoli (Direct Seeded)***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1	5 - 7 days after thinning	2.0 to 2.6	0.4 to 0.6	0.6 to 0.8									
2	7 - 10 days after spray No. 1	1.0 to 1.3	0.2 to 0.3	0.2 to 0.4									
3	7- 10 days after spray No. 2	1.0 to 1.3	0.2 to 0.3	0.2 to 0.4									

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

Cherries - Grower reports on virtually all varieties of cherries show excellent results from one or more properly-timed applications.

Foliar feeding benefits can include a heavier crop, with improved yields, as well as a higher sugar content and better color. Grower reports also show foliar feeding programs result in more even maturity, uniform size, and better fruit quality.

An additional benefit is in the form of tree response, with improved tree vigor and better return bloom and fruit set the following year.

APPLICATION RATES PER ACRE AND TIMING

Pink open cluster
For increased set, five to ten days before bloom. Rates vary, depending on program and area.

Petal-fall/shuck fall
Application at petal-fall, or in the period prior to shuck fall, can result in increased size, weight and sugar content. Other advantages include earlier maturity and uniform size.

Rates will vary. Use rates at the higher end of the range if a pre-bloom application is not made.

Postharvest
A postharvest spray will encourage tree vigor, bloom, set and increase yields the following year.

Young tree treatments
One hundred gallons of spray mixture on young, non-bearing cherry trees will greatly enhance their development. First application should be early in the growing season when leaves are about 1/4 grown. A second and subsequent applications should follow at 25-30 days intervals. The most efficient means of treating young trees without waste is with hand spray guns.

Foliar Spray Program: ***Cherries***

Spray No.	Growth Stage		Recommended Nutrients											
			N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
			Suggested Application Rate (Pounds per Acre)[1/] [2/]											oz.
1	Pink to open cluster		5.0 to 6.5	1.0 to 1.5	1.0 to 1.0				0.25 to 0.5				0.25 to 0.25	
2 thru 5	Straw color fruit		5.0 to 6.5	1.0 to 1.5	1.5 to 2.0	1.0 to 1.5								
	(up to) Harvest		5.0 to 6.5	1.0 to 1.5	1.5 to 2.0	1.0 to 1.5								

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 100-300 gallons of water per acre.

Foliar Spray Program: *Cherries (Young Trees)*

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1	Early in season when leaves 1/4 grown	1.0 to 1.3	0.2 to 0.3	0.3 to 0.4									
2 thru 6	2nd and subsequent sprays 25-30 days apart, commencing 25-30 days after No. 1	1.0 to 1.3	0.2 to 0.3	0.3 to 0.4									

Citrus - Nutritional sprays have been used on Florida citrus groves since the early 1930's. They were first used to supply Zn, Mn, and Cu. Since the discovery of yellow spot, Mo sprays have been recommended. Nutritional sprays of trace elements are probably used on more than 80% of the 50 million citrus trees in Florida. Most commercial groves are sprayed with Zn (3 pounds of $ZnSO_4$ plus 1 pound of hydrated lime per 100 gallons of water), once a year or once in 2 years. A dormant or post-bloom spray is recommended. Manganese sprays, as $MnSO_4$, are applied primarily to the 20% of the groves on alkaline calcareous soils. Molybdenum is usually sprayed only on those groves that show some evidence of "yellow spot." Application of the Mo sprays is recommended for spring or summer since sprays applied in October or later will not cause regreening of the yellow spots. Late fall, spring dormant, or post-bloom regreening of the yellow spots. Late fall, spring dormant, or post-bloom sprays will, however, prevent the occurrence of yellow spot the following summer. One or 2 ounces of sodium molybdate per 100 gallons of water incorporated into any spray application will correct a nutritional deficiency of Mo. Boron as borax is sprayed on many groves in lieu of including it in a ground application. Copper and iron sprays are not recommended. Apparently absorption of these nutrients is restricted by the waxy and hard leaf surface. Urea is applied as a spray to some citrus groves, but they are a small proportion of the total acreage.

However, in California foliar nitrogen fertilizer applications provide citrus growers with an option not available to other crops.[3/] With increased legislative interest in ground water quality, it is likely that in the future a combination of soil and leaf nitrogen applications may be the most effective way to meet stricter water pollution enforcement standards. While current interest in ground water quality is concentrated on pesticides and other chemicals, it is considered only a matter of time before nitrates receive more scrutiny. When more than 50 pounds of ntirogen is soil-applied, the amount of nitrates leached as potential ground water pollution increases in "almost a straight line" relationship. Under present practices, if growers apply enough nitrogen to maintain optimum production levels, the nitrate level in the water leached out of the root zone is "at least twice as high as the U.S. standard for ground water. In this respect, citrus growers have a distinct advantage in that they have an alternate fertilization system available. Growers can drastically reduce the amount

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 50-100 gallons of water per acre.
[3/]Tim Heinrichs, *California-Arizona Farm Press*, April 27, 1985.

of nitrate leaching to the ground water by splitting the application between soil and leaves. To reduce the amount of nitrates a light soil application of 50-70 pounds is recommended. Growers should consider how much nitrogen is being carried in their irrigation water and not put on more than 75 pounds total per acre from both sources. With 50 to 70 pounds of nitrogen soil-applied, only two or three supplemental foliar feedings would be required to maintain fertilization levels in the orchard.

Foliar nitrogen application will work with all citrus crops, however, rates may need to be adjusted between cultivars. Since the urea nitrogen sprays can be mixed with other materials, shifting to increase use of foliar applications can be accomplished in many instances with only one additional spray trip through the orchard. It is possible to totally supply the nitrogen requirements of citrus through leaf applications. That would require at least four foliar sprays a year, according to UC Riverside. With a 50 to 70 pounds per acre soil nitrogen application, a minimum of two supplemental sprays will be required and possibly a third, depending on orchard condition. In a vigorous orchard "with a lot of leaf area" growers can get by with the minimum number of sprays while orchards with thinner canopies are likely to need the third. Foliar applications should be made before bloom and after petal fall to provide the highest nitrogen concentration during the most critical period. If the third treatment is required, apply before June drop. The foliar nitrogen sprays should be timed at least a month apart to avoid leaf buildup. Unlike some other foliar-applied materials, notably zinc, the nitrogen will translocate through the tree. This means application of the nutrient before spring shoot development will provide nitrogen for this growth stage.

Growers can apply up to about 10 pounds of low biuret urea per 100 gallons of water with a dilute spray of 300-500 gallons per acre. If more than 35 pounds of nitrogen per acre is applied in one application, your're going to be in trouble and can expect some toxicity symptoms. In trials, when increasing the urea concentration to 12 pounds per 100 gallons, there were no leaf damage symptoms after the first two applications, however, symptoms did appear after the third. Twelve pounds has been shown to be the upper limit. There is some cumulative effect with subsequent treatments and the leaves don't have enough time to translocate the nitrogen between applications resulting in damaging concentrations.

There are also other advantages for foliar nitrogen application. The practice does result in a better quality valencia orange. Some increased quality is also noted for navels although it is not as great. Fruit grade is not improved for lemons. Also, if a grower suddenly realizes that he is short on nitrogen, the materials can be flown on if the orchard is too wet for ground rigs. Foliar nitrogen also is more rapidly absorbed and total nitrogen requirements can be cut by as much as 50 percent in a total foliar program.

Properly applied foliar nutrient programs have shown an increase in production, packout, and quality of citrus. On grapefruit, increases of from 21% to 42% were recorded over a five-year period. On lemons, over a four-year period, an average increase of 21.7% was obtained in one test and 25.5% in another. Fruit has shown increased color, firmness and earlier maturity. Trees have responded with improved vigor, foliage color, greater ability to withstand temperature extremes (including hot, desiccating winds), and a reduction in alternate bearing tendencies.

For best response and to nurture and maintain a healthy grove, a consistent management program is recommended. Up to four applications have been used with incrementally beneficial results.

APPLICATION RATES PER ACRE AND TIMING

Early spring

To increase the set of fruit and to improve fruit quality and leaf size, a program consisting of ten pounds of LoBi Urea should be applied to coincide with the early spring growth cycle.

Late spring, early summer

A second treatment consisting of ten pounds of LoBi Urea should be applied in late spring or early summer to reinforce the benefits gained from the early application and to aid in producing quality fruit of uniform size.

Fall

Separately, or with the fall whiteway sprays, a third application is recommended. Fall treatments have a positive effect on the quantity of fruit set for the following year, as well as increasing the ability of trees to withstand adverse weather conditions. In the instance of navels, fall treatments promote earlier maturity--up to a week to ten days.

Foliar Spray Program: *Citrus*

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/] [2/]											oz.
1	Early spring regrowth	7 to 10	1.0 to 1.5	1.5 to 2.0			0.75 to 1.0	0.75 to 1.0				0.20 to 0.25	1 to 2
2	Late spray early summer	7 to 10	1.0 to 1.5	1.5 to 2.0			0.75 to 1.0						
3	Fall	2.0 to 2.6	0.4 to 0.6	0.6 to 0.8									1[3/] to 2

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Recommended gallonage:
Air: 10-20 gallons per acre
Concentrate: 50-100 gallons per acre.
Dilute Sprays: 100-300 + gallons per acre
[3/]For prevention of yellow-spot the following summer.

Foliar Spray Program: ***Lemons and Limes***

Spray No.	Growth Stage	N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Recommended Nutrients											
		Suggested Application Rate (Pounds per Acre)[1/2/]											oz.
1	New spring growth flush before flowering	7 to 10	1.0 to 1.5	1.5 to 2.0				0.50 to 0.75	0.25 to 0.50				
2	August - September	2.0 to 2.6	0.4 to 0.6	0.5 to 0.8									

Corn (including sweet corn) - The vegetative growth stage applications (optional) are made to stimulate and continue rapid vegetative growth. Applications made at this time are especially useful in enhancing recovery following cold, wet weather and/or herbicide stress (18). The second series of applications during ear fill promotes larger kernels on heavier, more developed ears (reproductive growth stages).

Foliar Spray Program: ***Corn***

Spray No.	Growth Stage	N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Recommended Nutrients											
		Suggested Application Rate (Pounds per Acre)[1/]											oz.
1 or	Cold, wet conditions 3 - 4 leaf stage	0.62 to 0.75	1.25 to 2.25	0.62 to 0.75	0.30 to 0.40	0.05 to 0.125	0.12 to 0.25	0.25 to 0.5	0.08 to 0.5	0.25 to 0.5	0.09 to 0.17	0.25 to 0.1	
1	Normal conditions 6-8 leaf stage	0.62 to 0.75	1.25 to 2.25	0.62 to 0.75	0.30 to 0.40	0.05 to 0.125	0.12 to 0.25	0.25 to 0.5	0.08 to 0.5	0.25 to 0.5	0.09 to 0.17	0.25 to 0.1	
2	7 - 10 days after Spray No. 1	0.62 to 0.75	1.25 to 2.25	0.62 to 0.75	0.30 to 0.40	0.05 to 0.125	0.12 to 0.25	0.25 to 0.5	0.08 to 0.5	0.25 to 0.5	0.09 to 0.17	0.25 to 0.1	
3	Early silk	4.0 to 5.0	2.0 to 2.5	2.0 to 2.5	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0	0.17 to 0.35	0.25 to 0.5	0.5 to 1.0	0.17 to 0.35	0.1 to 0.2	
4 thru 5	7 - 10 days apart	4.0 to 5.0	2.0 to 2.5	2.0 to 2.5	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0	0.17 to 0.35	0.25 to 0.5	0.5 to 1.0	0.17 to 0.35	0.1 to 0.2	

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 100-300 gallons of water per acre.

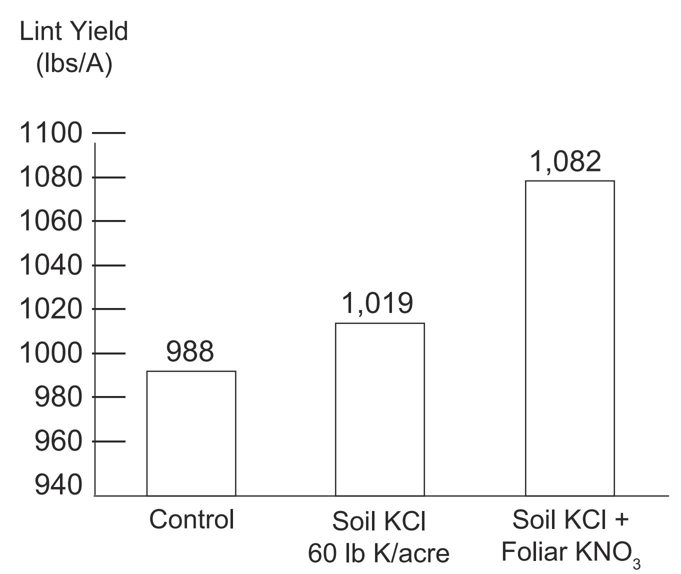
Cotton - Cotton has shown to be most sensitive to low potassium availability than most other field crops.[1/] Cotton sensitivity to low potassium availability is exacerbated by widespread potassium deficiencies in more recent years across the Cotton Belt, primarily associated with the use of higher-yielding and faster fruiting cotton varieties and increased use of nitrogen.

Cotton potassium deficiencies have only partially been corrected via preplant or mid-season sidedress applications of potassium. Foliar potassim applications have been successfully integrated with soil applications to attain a much better potassium response in cotton, primarily because the foliar application can be timed to apply potassium later in the growing season when it is most critical for fiber growth, strength and micronaire.

Figure A-1 shows University of Arkansas work evaluating soil-applied potassium and foliar-applied potassium.[1/]

figure A-1.

Foliar-Applied K Versus Soil-Applied K*



*University of Arkansas study. Lint yields are averages for seven sites between 1989 and 1992

The Arkansas study has shown that foliar-applied potassium (potassium nitrate gave the biggest yield increase, followed closely by potassium thiosulfate and potassium sulfate) increased the distribution of potassium in the fiber, seed, and capsule wall of the developing boll. The development of the boll load occurs late in the season, which coincides with a decrease in root activity and potassium supply to the boll, explaining the need for a timely, supplemental foliar application of potassium on cotton.

The optimum timing of foliar-potassium application is during the boll development period starting soon after flowering and continuing at two-week intervals for six to eight weeks until boll maturity. The optimum foliar-potassium rate has been shown to be about 5 pounds potassium per acre per application.[1/] Petiole analysis prior to and during boll development can adjust foliar-potassium rates as needed.

[1/]Oosterhuis, D., Foliar fertilization with potassium nitrate in cotton. *Solutions*, May/June 1993.

Foliar feeding programs for cotton have shown that supplemental feeding can enhance production and quality. Products and programs can also be used to compensate for known nutrient deficiencies.

As in any other treatment, the timing of application is of great importance, as are the type of formulation and ingredients. Initial application should be made at the first sign of bloom to help improve the set. A properly selected program will aid in holding the earlier developing bolls on the plant. A second application of nutrients will aid the later developing bolls, and should be made approximately three weeks after the first.

Foliar feeding should be used to supplement a soil fertilization program, by providing nutrients at critical stages of growth. The usual result is a yield increase and an improvement in fiber quality, as well as more uniform maturity.

Foliar nutrients can be applied in conjunction with most insecticides to eliminate the cost of separate applications.

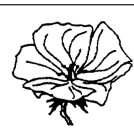
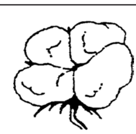
APPLICATION RATES PER ACRE AND TIMING

First sign of bloom
Three weeks later

Foliar Spray Program: *Cotton*

Spray No.	Growth Stage		Recommended Nutrients											
			N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
			Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1	First open flowers stage		6 to 13										0.15 to 0.25	
2	14 - 20 days after Spray No. 1		6 to 13										0.15 to 0.25	

For Prevention/Correction of Potassium Deficiency

Spray No.	Growth Stage		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
1	First open flowers		6 to 13		4 to 5								0.15 to 0.25	
2	Green bolls		6 to 13		4 to 5									
3 thru 4	First bolls split		6 to 13		4 to 5									

1/Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
2/Applied in 10-20 gallons of water per acre.

Cranberries - Test conducted on cranberries by a university experiment station over a 12-year period, have shown economic benefits from the use of foliar nutrient programs. The most significant response is a reduction of storage rot. After eight months in storage, rot was as high as 38% in untreated cranberries, vs. a low of 3-5% in treated cranberries. Increased storage life is a result of firmer berries.

Cranberries have shown other benefits including improved color, more uniform maturity and increased yield. Vines have responded with increased growth and vigor, too.

APPLICATION RATES PER ACRE AND TIMING

Hook stage
Just after fruit set

Foliar Spray Program: ***Cranberries***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1	Hook stage	2.5 to 3.5	0.6 to 0.75	0.8 to 1.00				0.10 to 0.25				0.1 to 0.2	
2	Just after fruit set	2.5 to 3.5	0.6 to 0.75	0.8 to 1.00				0.10 to 0.25				0.1 to 0.2	

Cucumbers, Melons, and Other Cucurbits - Cucurbits respond readily to foliar nutrient programs. Properly timed applications help to increase fruit set and yield, plus other benefits including improved fruit shape and size and blossom drop reduction. Earlier maturity can also result from foliar applications, with more yield ready for harvest at the first picking.

Greater yields per picking, increased total yield per acre, more number ones and substantially extended picking intervals have been recorded on treated acreages.

For an incrase in fruit set, an early foliar application should be made at the first sign of bloom in the field. A second application three weeks later encourages more bloom, promotes vine development and aids the previous set.

APPLICATION RATES PER ACRE AND TIMING

First sign of bloom
Two to three weeks later
Optional: Above application rates may be continued at two-week intervals. (Selected combinations.)

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

Foliar Spray Program: *Cucumbers, Melons and Other Curcurbits*

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo oz.
		Suggested Application Rate (Pounds per Acre)[1/ 2/]											
1	Just after bloom	6.0 to 7.0	1.5 to 2.0	2.0 to 2.5									
2	2 - 3 weeks after Spray No. 1	6.0 to 7.0	1.5 to 2.0	2.0 to 2.5									

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

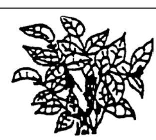
Edible Beans (Green, Lima, Snapbeans, Seed) - Foliar feeding programs are highly effective on beans. They're specifically designed to provide supplemental and deficient nutrients at critical stages of plant growth. Regardless of variety, process, dry and seed beans have shown reliable increases in yield and quality from the application of foliar programs.

Properly applied at the onset of bloom, the nutrients supplied not only reduce blossom drop, but aid pod development. This can result in increased number of pods, more beans per pod and an overall greater yield. A series of tests on snapbeans, for example, showed yield increases from 230 to 700 pounds per acre. On dry beans increases have varied from 250 to 800 pounds per acre. On a range of edible bean varieities, 2.5 to 5 sacks (cwt) were reported with average yield increases between 15% and 18%. There are other benefits, too. Seed beans, in replicated trials, have shown reduced internal cracking, with improved germination.

Optimum application of foliar nutrients coincides with the onset of plant growth cycles. The first application should be made at the first sign of bloom. This increases the number of blooms set and resulting pods. It also helps reduce blossom drop which frequently occurs during hot, dry weather. A second application two to three weeks later assists additional bloom and pod set, and increases the number and size of beans in the pod.

Foliar nutrients can also be used to maintain and stimulate bean plants and their root systems when they are stagnated by cold or wet weather.

Foliar Spray Program: ***Edible Beans (Green, Lima, Snapbeans, Seed)***

Spray No.	Growth Stage		Recommended Nutrients											
			N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
			Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1	Just after bloom		4.0 to 6.5	1.0 to 1.5	1.5 to 2.0		1.0 to 2.0						0.25 to 0.5	
2	2 - 3 weeks after Spray No. 1		2.0 to 2.5	0.5 to 1.0	0.8 to 1.2		1.0 to 2.0						0.25 to 0.5	
3	Pod set		2.0 to 2.5	0.5 to 1.0	0.8 to 1.2									

1/Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
2/Applied in 10-20 gallons of water per acre.

Grain Sorghum - The vegetative growth stage applications are optional and are used primarily to stimulate growth and recovery through periods of environmental and/or nutrient stress (notably sulfur, zinc and iron). The reproductive growth stage applications promote head and grain fill.

Foliar Spray Program: *Grain Sorghum*

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1 or	Cold, wet conditions: growth stage 1-2[3/] (3-5 leaf stage)	0.75 to 0.75	1.50 to 2.25	0.75 to 1.25			0.20 to 0.40	0.18 to 0.35		1.0 to 2.0			
1	Normal conditions: growth stage 2-3[3/] (5-leaf growing point differentiation)	0.75 to 0.75	1.50 to 2.25	0.75 to 1.25			0.20 to 0.40	0.18 to 0.35		1.0 to 2.0			
2	7- 10 days after Spray No. 1	0.75 to 0.75	1.50 to 2.25	0.75 to 1.25			0.20 to 0.40	0.18 to 0.35		1.0 to 2.0			
3	Reproductive growth stage: just after soft dough (stage 7)[3/]	4.0 to 5.0	2.0 to 2.5	2.0 to 2.5	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0	0.12 to 0.25	0.25 to 0.5	0.5 to 1.0	0.17 to 0.35	0.1 to 0.2	
4 thru 5	Repeat 7-10 days apart	4.0 to 5.0	2.0 to 2.5	2.0 to 2.5	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0	0.12 to 0.25	0.25 to 0.5	0.5 to 1.0	0.17 to 0.35	0.1 to 0.2	

Iron Chlorosis Symptoms

1 thru 3	3 applications at onset of chlorosis 7 - 10 days apart	3 to 5					0.5 to 1.0			2 to 3			

1/ Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
2/ Applied in 10-20 gallons of water per acre.
3/ From: "How a Sorghum Plant Develops," R. L. Vanderlip. Contribution No. 1203, Agronomy Department, Kansas Agricultural Experiment Station, Manhattan, KS 86502

Grapes (Table and Wine) - Over a number of years, grapes have shown good response to nutritional spray programs. Foliar feeding reduces nutrient stresses that can adversely affect yields and quality.

Grape vines are under continual nutrient stress during the growing season. Condtions such as cool weather or cold soil can increase vine nutrient stress. Critical stress periods for grapes occur at fourth to sixth leaf as clusters and shoots are forming, just prior to bloom, and shortly after bloom. Timely applications before or during these periods can aid in reducing nutrient stress and give vines the boost they need to set and produce a larger crop with improved quality. Regular use of programs helps grow healtheir vines.

Table grapes have responded with earlier maturity, larger berry size, more uniform maturity and yield increases. Improved color development has been demonstrated on colored varieties.

Wine grapes have shown yield increases of more than one ton per acre. Increases in sugar development and maturity ratio have also been noted, as well as beneficial effects on cluster weight, number of berries per cluster and number of clusters per vine. In replicated test plots on Concord grapes over a two-year period, average yield increases of up to two tons have been achieved through use of foliar programs.

APPLICATION RATES PER ACRE AND TIMING

Fourth to sixth leaf (4" to 12" new shoot growth)
One week prior to bloom to two weeks after bloom

On table grapes, an additional application can be combined with the second gibberellic acid spray to promote sugar development and earlier maturing.

Black leaf caused by low potassium levels can be corrected by applications of foliar potassium.

Foliar Spray Program: *Grapes*

Spray No.	Growth Stage		Recommended Nutrients											
			N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
			Suggested Application Rate (Pounds per Acre)[1/] [2/]											oz.
1	4-6 leaves (4-12" new shoot growth)		1.5 to 2.5	0.3 to 0.5	0.4 to 0.8				0.10 to 0.25				0.1 to 0.2	
2	7-14 days before bloom		1.5 to 2.5	0.3 to 0.5	0.4 to 0.8									
3	Flower buds separated		1.5 to 2.5	0.3 to 0.5	0.4 to 0.8									

Foliar Spray Program: *Kiwi Fruit*

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/] [2/]											oz.
1 or	Extension shoot growth	2.5 to 3.5	0.5 to 1.0	1.00 to 1.25		0.5 to 1.0			0.5 to 1.0			0.12 to 0.25	
1	Flower buds visible	2.5 to 3.5	0.5 to 1.0	1.00 to 1.25		0.5 to 1.0			0.5 to 1.0			0.12 to 0.25	
	Flowering												
2	Petal fall, developing fruit	2.5 to 3.5	0.5 to 1.0	1.00 to 1.25									
3	Up to harvest	2.5 to 3.5	0.5 to 1.0	1.00 to 1.25									

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

Lettuce and Spinach - Foliar nutrient programs for head and leaf lettuce and spinach offer important benefits that result in an overall better return to the grower. Foliar applications are designed to supplement soil fertility programs by supplying critically needed nutrients when roots can't keep up with plant demands.

The following benefits have been observed from foliar nutrient programs on lettuce.

ï Increased production with more cartons on first cutting and increased carton weight.
ï Reduced top burn.
ï More uniform maturity, more even head size.
ï Better keeping quality.
ï Greater resistance to disease.
ï Better color.
ï Improved vigor with more erect leaves.
ï Faster recovery from hail damage.

Foliar sprays provide nutrients in wettable powder formulations for exended feeding and in soluble liquid formulations for rapid absorption by the plant. Liquid programs are used on lettuce until the last insecticide spray before harvest.

The post thinning application gives lettuce a shorter recovery time with increased plant vigor. In head lettuce, application just before the head starts to form aids development of a larger, more solid head.

APPLICATION RATES PER ACRE AND TIMING

Head Lettuce*
After thinning
Rosette stage
Ten days later

Romaine Or Leaf Lettuce*
After thinning
Ten-day intervals (after thinning)

*Add two to three pounds LoBI Urea to each of the above head or leaf lettuce applications as desired.

Foliar Spray Program: *Head Lettuce/Romaine or Leaf Lettuce*

Spray No.	Growth Stage		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
			Recommended Nutrients											
			Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
Head Lettuce														
1	After thinning		2.5 to 3.5	0.60 to 0.75	0.80 to 1.00		0.25 to 0.50		0.10 to 0.25				0.1 to 0.25	
2	At rosette stage		2.5 to 3.5	0.60 to 0.75	0.80 to 1.00		0.25 to 0.50		0.10 to 0.25				0.1 to 0.25	
3	10 - 14 days later		2.5 to 3.5	0.60 to 0.75	0.80 to 1.00									
Romaine or Leaf Lettuce														
1	After thinning		2.5 to 3.5	0.60 to 0.75	0.80 to 1.00		0.25 to 0.50		0.10 to 0.25				0.10 to 0.25	
2	At rosette stage		2.5 to 3.5	0.60 to 0.75	0.80 to 1.00		0.25 to 0.50		0.10 to 0.25				0.10 to 0.25	
3	At head formation		2.5 to 3.5	0.60 to 0.75	0.80 to 1.00									
4	10-14 days later		2.5 to 3.5	0.60 to 0.75	0.80 to 1.00									
5	10-14 days later		2.5 to 3.5	0.60 to 0.75	0.80 to 1.00									

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

Onions - A foliar nutrient program provides several benefits on dry, green and seed onions. Applied as soon as there is sufficient leaf area to accept the nutrients, onion plants respond with increased growth and vigor. A second application 10 to 14 days after enhances this effect and results in an increased yield of firmer, more uniform bulbs at harvest.

With greatest firmness, onions store and ship better. And the larger, more uniform bulk size enables growers to command a better price at market.

On seed onions, foliar feeding programs are used for increased yields and better seed germination qualities. Green onions respond with improved color and size.

APPLICATION RATES PER ACRE AND TIMING

Green Onions
4" high
Repeat at ten-day intervals
(Selected combinations 2-3 lbs. LoBi Urea may be added to later applications.)

Dry Onions
6" to 10" high
(Add spreader sticker)
Repeat at two to three weeks later*
(Selected combinations)

Seed Onions
(Sufficient foliage to hold spray)
(Add spreader sticker)
Bolting to start of head formation
(Add spreader sticker)

*On dry onions, a third application may be made three weeks before harvest (Omit LoBi Urea in third application).

Foliar Spray Program: ***Seed Onions***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1	Bolting to early head formation	2.5 to 3.5	0.5 to 0.75	0.8 to 1.0	0.75 to 1.0								
2	Repeat at 10-14 day intervals	2.5 to 3.5	0.5 to 0.75	0.8 to 1.0	0.75 to 1.0								

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

Foliar Spray Program: ***Dry Onions***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1	Early head formation	2.5 to 3.5	0.50 to 0.75	0.80 to 1.0	0.75 to 1.0								
2	Repeat at 10-14 day intervals	2.5 to 3.5	0.50 to 0.75	0.8 to 1.0	0.75 to 1.0								

Foliar Spray Program: ***Green Onions***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1	4" high	0.75 to 1.3	0.1 to 0.3	0.2 to 0.4									
2	Repeat at 10-day intervals**	0.75 to 1.3	0.1 to 0.3	0.2 to 0.4									

**Later applications may receive 2-3 lbs/A LoBi Urea or low burn nitrogen.

Peaches, Plums, Nectarines, Apricots - Higher yield and grade in stone fruit, plus increased fruit size can be achieved with carefully planned and timed foliar nutrient programs. Depending on variety and program choice, earlier and more uniform maturity can also be achieved.

Nutritional spray programs can also be designed to produce firmer fruit with better handling characteristics. In terms of tree response, year-to-year use of nutritional sprays will improve tree vigor and give more consistent production.

APPLICATION RATES PER ACRE AND TIMING

Pre-bloom to early bloom
Three to five weeks later

If poor fruit set has been a problem, a program of two applications should correct the problem in the subsequent season for most varieties. A pre-bloom application will aid in increasing and holding set for the current season. Application made at petal-fall or later will principally influence fruit size and quality. Where thinning is necessary, one application should be made after thinning.

In areas east of the Mississippi, lower rates in the recommended ranges should be used.

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

Foliar Spray Program: *Peaches, Plums, Nectarines, Apricots*

Spray No.	Growth Stage		Recommended Nutrients											
			N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
			Suggested Application Rate (Pounds per Acre)[1/] [2/]											oz.
1	Shuck split to open flowers		5.0 to 6.5	1.0 to 1.5	1.5 to 2.0							1.0 to 2.0		
2	Petal fall		5.0 to 6.5	1.0 to 1.5	1.5 to 2.0							1.0 to 2.0		
3 thru 4	Developing fruit to harvest		5.0 to 6.5	1.0 to 1.5	1.5 to 2.0	0.75 to 1.0								

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Recommended gallonage:
- Air: 10-20 gallons per acre
- Concentrate: 50-100 gallons per acre.
- Dilute Sprays: 100-300 + gallons per acre

Foliar Spray Program: *Peanuts*

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/2/]											oz.
1	Early bloom and repeat 10-14 days later	2.0 to 2.6	0.4 to 0.6	0.6 to 0.8								0.04 to 0.06	
2	Early pod development and repeat 14-21 days later and until pods are filled	5.5 to 6.5	1.0 to 1.5	1.5 to 2.0								0.10 to 0.15	

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 100-300 gallons of water per acre.

Pears - A foliar feeding program can increase the set and yield of pear trees. Fruit firmness and keeping quality have also been significantly improved, along with enhanced pollenizing of bloom on trees receiving foliar nutrients.

In one series of tests, blocks were sprayed with varying combinations of products. Yield increases of nearly a box per tree were noted in the foliar-fed trees. In addition, pressure tests on the treated pears indicated an increase of as much as two pounds over the check.

APPLICATION RATES PER ACRE AND TIMING

First white to open cluster

A tank mix should be applied early in the reproductive cycle for improved fruit set and increased tree vigor.

Petal-fall to first cover

A second spray should be applied at petal-fall or with the first cover spray to aid in producing firmer, higher quality fruit.

Three to four pounds of zinc may be applied with dormant superior oil up to green bud stage to increase zinc levels.

Foliar Spray Program: ***Pears***

Spray No.	Growth Stage		Recommended Nutrients											
			N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
			Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1 or	Dormant to bud break								2.5 to 3.0					
1 or	Bud scales separated to buds exposed								2.5 to 3.0					
1	Tight cluster to first white		5.5 to 6.5	1.0 to 1.5	1.5 to 2.0				1.0 to 1.5				0.10 to 0.25	
2	Petal fall		5.5 to 6.5	1.0 to 1.5	1.5 to 2.0	1.0 to 1.5								
3	Fruit set		5.5 to 6.5	1.0 to 1.5	1.5 to 2.0	1.0 to 1.5								

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Recommended gallonage:
Air: 10-20 gallons per acre
Concentrate: 50-100 gallons per acre.
Dilute Sprays: 100-300 + gallons per acre

Peas, Lentils - Green, seed and dry pea varieties and lentils respond well to nutritional spray programs. Various field trials show foliar-fed fields produce more peas per pod, more pods per plant and higher overall yields per acre.

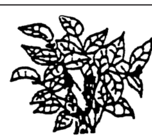
A foliar program helps provide critically needed nutrients during periods of stress, such as bloom, when roots can't keep up. On peas, this results in reduced blossom drop, greater pod set and fuller pods. Yield improvements of 20% have been noted. Exceptional comparative results have been obtained when plants are under servere heat stress at bloom time.

On seed peas, quality is improved. Dry pea yields have shown increases of three to five sacks, with up to 1,600 pound increases reported.

Benefits of a foliar nutritionl program also include earlier maturity. On green peas, the period between bloom and harvest can often be reduced up to three weeks.

Foliar nutrients also help boost pea growth when cold or wet weather conditions interfere with either the application or uptake of soil nutrients.

Foliar Spray Program: ***Peas, Lentils***

Spray No.	Growth Stage		Recommended Nutrients											
			N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
			Suggested Application Rate (Pounds per Acre)[1/ 2/]											oz.
1	Just after bloom		4.0 to 6.5	1.0 to 1.5	1.5 to 2.0		1.0 to 2.0						0.25 to 0.5	
2	2 - 3 weeks after Spray No. 1		2.0 to 2.5	0.5 to 1.0	0.8 to 1.2		1.0 to 2.0						0.25 to 0.5	
3	Pod set		2.0 to 2.5	0.5 to 1.0	0.8 to 1.2									

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

Pecans (including Walnuts, Pistachios, Filberts and Hazelnuts) - The application of nutritional spray products to nut trees has resulted in substantial benefits to growers. Tested and used on pecans since the early 1970's, foliar programs increase the production of nuts and shelled nutmeats per acre. Yield increases of shelled nutmeats have averaged over 15% in specific grower trials.

Foliar programs for pecans take the total nutritional requirements of the trees into consideration. And while they are not intended to replace regular soil fertility schedules, these programs have shown economic results when applied as a supplementary practice.

APPLICATION RATES PER ACRE AND TIMING

At Pre-pollination
10 lbs. Urea; or 2 lbs. per 100 gallons

At first or second cover
10 lbs. Urea; or 2 lbs. per 100 gallons

Foliar Spray Program: ***Pecans (including Walnuts, Pistachios, Filberts and Hazelnuts***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/2/]											oz.
1	Pre-pollination	2.0 to 2.5	0.3 to 0.5	0.6 to 0.8								0.1 to 0.2	
2	First or second cover	2.0 to 2.5	0.3 to 0.5	0.6 to 0.8								0.1 to 0.2	

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Recommended gallonage:
Air: 10-20 gallons per acre
Concentrate: 50-100 gallons per acre.
Dilute Sprays: 100-300 + gallons per acre

Peppers, Eggplant, Okra - Nutritional spray programs on these crops have resulted in:

ï Increased yields from heavier set
ï Larger, firmer fruit
ï Greater plant longevity for prolonged production
ï Control of blossom end drop
ï Earlier, more uniform maturity

An application at bud stage helps establish healtheir plants and sets more fruit per plant. A second application two weeks later promotes the development of the early set fruit and prolongs plant vigor for longer production. For extra production, a third application two weeks later is recommended.

1. Dilute sprays containing N-P-K Ca-S-Zn-Mn have given good results.

2. A spray solution of P-Ca-Zn should be used where blossom end drop is a problem.

Foliar Spray Program: ***Peppers, Eggplant, Okra***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/2/]											oz.
1	At bud stage	2.0 to 2.5	0.3 to 0.5	0.6 to 0.8	0.5* to 1.0*		0.25 to 0.5	0.25 to 0.5	0.1 to 0.3				
2	10-14 days after Spray No. 1	2.0 to 2.5	0.3 to 0.5	0.6 to 0.8	0.5* to 1.0*		0.25 to 0.5	0.25 to 0.5	0.1 to 0.3				
3	10-14 days after Spray No. 2	2.0 to 2.5	0.3 to 0.5	0.6 to 0.8	0.5* to 1.0*		0.25 to 0.5	0.25 to 0.5	0.1 to 0.3				

*Ca beneficial where blossom end drop is a problem.

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

Potatoes - Potatoes respond exceptionally well to nutritional spray programs. Higher yields and more No. 1's are reported from the big potato growing areas of the Northeast, East, Midwest, Northwest and in California and Arizona. Years of experience have shown that foliar spray programs can influence the early growth and development of potato tubers and help increase quality and tonnage at harvest.

Foliar nutrient programs should be used to supplement regular soil fertilizer schedules.

Foliar programs with combinations of carefully selected plant nutrients applied beginning at tuber initiation, help maintain adequate levels of these nutrients for development of the tubers. Later season programs with potassium, phosphate and zinc, help prevent early die by keeping vines healthy.

Common results of a foliar nutrient program include a 20-25% increase in yield. Special nutrient programs have resulted in higher specific gravity, with improved storage and chipping quality. Foliar programs have also been useful in reducing potatoe defects, including hollow heart and internal brown spots.

APPLICATION RATES PER ACRE AND TIMING

When plants are 6" to 10" high
10-14 days later, repeat twice

Foliar Spray Program: ***Potatoes***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/2/]											oz.
1	When plants are 6" to 10" high (tuber initiation)	2.5 to 3.5	0.50 to 0.75	0.80 to 1.00	1.0 to 1.0		0.75 to 1.0	0.25 to 0.5				0.10 to 0.25	
2	10-14 days after Spray No. 1	2.5 to 3.5	0.50 to 0.75	0.80 to 1.00	1.0 to 1.0		0.75 to 1.0	0.25 to 0.5				0.10 to 0.25	
3	10-14 days after Spray No. 2	2.5 to 3.5	0.50 to 0.75	0.80 to 1.00	1.0 to 1.0		0.75 to 1.0	0.25 to 0.5				0.10 to 0.25	

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

Small Grain (barley, oats and wheat) - Treatment during early growth stages (at or before tillering) or with 2,4-D applications has been shown to increase the number of heads set (8, 16). Later applications during early boot stage aid in filling out developing heads(16). Excessive amounts of nitrogen during early boot may cause excessive vegetative growth leading to lodging losses and/or leaf burn with extremely high rates of urea ammonium nitrate or liquid urea solutions. Leaf burn during boot stage has been shown to decrease leaf area or expression of the flag leaf, causing decreases in yields (7). A maximum rate of nitrogen application during pre-boot/boot stages should be no more than 25 pounds per acre. For best results, two applications should be made, totaling no more than 10-15 pounds per acre of nitrogen, applied two weeks prior to flag leaf stage. If only one application is made, an early application at or before tillering in combination with 2,4-D is recommended, avoiding the special application at boot stage.

Although the foliage burn effects of urea ammonium nitrate solution and chloride (Cl) have been mentioned earlier, fertilizer solutions of a 20-0-3 or 20-0-3-3 sulfur aplied at 80-100 pounds per acre plus 0-125-0.25 lbs A. I. per acre of 2,4-D at or just prior to tillering have proven beneficial to yield (stimulates more tillering) and inhibit the the fungus causing take-all root (5,16). Slight to moderate foliage burn with these formulations may result, but when applied at or just prior to tillering, recovery more than compensates for the effects of the application. These formulations can be applied with conventional spray equipment (i.e., normal nozzles, spacings, pressures, ground speed) used in soil-applied fertilizer solutions. Following are fertilizer formulations for 20-0-3 or 20-0-3-4S:

POUNDS OF INGREDIENT
PER TON OF FORMULATION

FERTILIZER GRADE (N-P-K-S)

Ingredients	20-0-3	20-0-3-4S[1/]	20-0-3-4S
Water	474	410	154
UAN 28%	1429	1011	1270
12-0-0-26[2/]	--	308	308
KCl[3/]	97	97	97
Urea	--	174	--

[1/]This formulation has better solubility at lower temperature than the alternative solution using only UAN 28% and 12-0-0-26 as N sources.
[2/]12-0-0-26 as ammonium thiosulfate.
[3/]KCl as 0-0-62.

Foliar Spray Program: *Small Grains*

Spray No.	Growth Stage	N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo oz.
		Recommended Nutrients — Suggested Application Rate (Pounds per Acre)[1/ 2/]											
1	Application in combination with 2,4-D* at or just before tillering	3.0 to 4.0	0.5 to 1.0	1.0 to 1.5	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0	0.35 to 0.7	0.35 to 0.7	0.5 to 1.0	0.25 to 0.75	0.1 to 0.2	
2	At or before tillering	3.0 to 4.0	0.5 to 1.0	1.0 to 1.5	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0	0.35 to 0.7	0.35 to 0.7	0.5 to 1.0	0.25 to 0.75	0.1 to 0.2	
3	Post tillering	3.0 to 4.0	0.5 to 1.0	1.0 to 1.5	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0	0.35 to 0.7	0.35 to 0.7	0.5 to 1.0	0.25 to 0.75	0.1 to 0.2	
4 or	Boot stage	3.0 to 4.0	0.5 to 1.0	1.0 to 1.5	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0	0.35 to 0.7	0.35 to 0.7	0.5 to 1.0	0.25 to 0.75	0.1 to 0.2	
2	At or before tillering	3.0 to 4.0	0.5 to 1.0	1.0 to 1.5	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0	0.2 to 0.35	0.25 to 0.5	0.25 to 0.5	0.07 to 0.2	0.05 to 0.2	
3	10-15 days after Spray No. 2	3.0 to 4.0	0.5 to 1.0	1.0 to 1.5	0.5 to 1.0	0.5 to 1.0	0.5 to 1.0	0.2 to 0.35	0.25 to 0.5	0.25 to 0.5	0.07 to 0.2	0.05 to 0.2	
4	Boot stage	1.5 to 2.0	0.5 to 1.0	0.5 to 1.0	0.25 to 0.5	0.25 to 0.5	0.35 to 0.75	0.2 to 0.35	0.25 to 0.5	0.25 to 0.5	0.07 to 0.2	0.05 to 0.2	

*2.4-D rate: 0.125-0.25 lbs A.I. per acre.

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

Soybeans - Foliar fertilization of soybeans has shown a highly variable degree of response, as summarized in Table A-4 (21). A major contributing factor to soybean variable response to foliar applications (aside from application rate, timing and sufficiency of the soil-applied fertility program) may be due to soybean cultivar differences in how much seed nitrogen comes from redistribution and how much of that redistributed nitrogen comes from the soybean leaf (21). Data from Tables A-5 and A-6 support that those soybean varieties that depend on >55 percent of the redistribution of nitrogen to seed coming from the leaves are most likely to respond to later season (R3 and later) foliar applications. Corsoy varieties exhibit high percentages of leaf contribution to seed nitrogen and exhibited the highest degree of response to foliar treatments while Williams showed significantly less leaf contribution to redistributed nitrogen to the seed, and also showed significantly less yield response to foliar applications. Sorting these kinds of characteristics among the multitudes of currently available soybean varieties may prove to be next to impossible, but certain guidelines follow which will lend more consistency to foliar applications on soybeans.

Table A-4.

Results of Published Trials of Foliar Fertilization of Soybeans (21)

	Stage of 1st Application	Times of Application	Total Dose of N-P-K-S lbs/A	Source	Yield Effects %
Wiedenfeld, et al., 1981	R-5	3	36-5-10-2	1	0
Lessman & McCutchen, 1979	R-3	2	24-3.6-6.6-1	1	0
	R-3	2	1-0.4-0.4-0	2	0
	R-2	2	12-1.8-3.3-0.5	3	0
Vasilas, et al., 1980	R-5	4	77-8-26-5	4	+33
Parker & Boswell, 1980	R-5	3	77-8-27-5	4	-11
Garcia & Hanway, 1976	R-5	4	74-7-22-7	4	+35
Robertson, et al., 1977	R-4	4	129-13-39-6	4	0
Poole, 1981	R-5	4	88-9-26-4	4	0
Sesay & Shibles, 1980	R-5	4	74-7-22-4	5	

1. FOLIANÆ, Allied Chemical, NB
2. BAYFOLANÆ, Helena Chemical, TN
3. RIGHT-ONÆ, Right Way Chemical, TX
4. TVA, Muscle Shoals; components from other sources added.
5. Source not identified

Table A-5.

N Redistribution in Soybeans (21)

Cultivar	Seed N from Redistribution - % -	Leaf Contribution to Redistribution - % -
Corsoy	55	64
Williams	83	45
Lincoln	100	50
Elf	78	58
Kent	61	62
Essex	82	46
York	100	46
LSD (0.05)	29	NS

Zeiher, et al., 1982

Table A-6.

Effect on Soybeans of Foliar Fertilization in Relation to Variety (9)

Variety	Number of Comparisons	Yield, kg/ha Untreated	Yield, kg/ha Treated	Change in Yield, %
Amsoy	16	2845	2818	-0.9
Bragg	21	2535	2447	-3.5
Corsoy	24	2211	2171	-1.8
Forrest	8	3587	3384	-5.7
Wells	11	2400	2144	-10.7
Williams	16	2724	2535	-6.9

Foliar applications have shown the best responses when made twice during the seed filling period (stages R3-R5)[1/] (12). Yield increases resulted not from bigger seeds, but more seeds due to seeds developing that otherwise may have aborted due to lack of nutrition. A base solution of N-P_2O_5-K_2O-S in a 10-2.4-4.0-0.65 has been shown to give the most favorable responses at a rate of 250 pounds per acre at each of three applications. Mixing formulation and application timing guidelins for this foliar fertilizer grade are given below under: Timing: Nutritionally sound prior to growth stage R3.

Recent work in Missouri culminating in 1993 has shown 3.3 to 6.3 bushels per acre yield responses when the soybean foliar program also has both magnesium and boron included. Total applied magnesium was 1 pound per acre, and for boron 0.5 pounds per acre, beginning at growth stage R3. The best results were obtained when the magnesium and the boron rates were split equally between two applications (0.5 pounds per acre magnesium X 2; 0.25 pounds per acre boron X 2).

Earlier applications (stages V3-V4)[1/] are essential for correcting chlorosis or poor nodulation using combinations of nitrogen, iron and manganese.

Foliar Spray Program: ***Soybeans***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[2/3/]											oz.
1	For correction of chlorosis (Stages V3-V4) when first signs of chlorosis appear	3.5 to 5.0							1.0 to 1.5	1.5 to 2.0			
2	7-10 days after Spray No. 1	3.5 to 5.0							1.0 to 1.5	1.5 to 2.0			
3 thru 4	Growth stage R3-R5 two applications 7-10 days apart	15 to 20	4 to 6	8 to 10	0.5 to 1.0	0.5 to 0.5	1.5 to 1.5	0.17 to 0.35			0.25 to 0.75	0.2 to 0.25	
Nutritionally Sound Prior to Growth State R3													
1 thru 3	Starting at growth stage R3 three applications 7-10 days apart	10 to 12	2 to 3	3.5 to 4.5	0.5 to 1.0	0.25 to 0.33	1.5 to 1.5	0.17 to 0.35	0.35 to 0.75	0.5 to 1.0	0.25 to 0.75	0.10 to 0.16	

[1/]From: "How a Soybean Plant Develops," Steve W. Richie, John J. Hanway, and Harvey E. Thompson, Iowa State University of Science and Technology Cooperative Extension Service, Ames, IA 50010

[2/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.

[3/]Applied in 10-20 gallons of water per acre

MIXING FOLIAR FERTILIZER FOR SOYBEANS (9)

The following procedure is suggested for preparing a solution for foliar application to soybeans that fits the nutrient ratio suggested by Dr. John Hanway. The grade will be 10-2.4-4.0-0.6S and will require an application rate of 250 pounds per acre at each of three applications.

Formulation	Pounds per ton	Pounds per 100 pounds	Grams per kilogram
Urea (46-0-0)	435	21.75	217.5
Potassium polyphosphate (0-26-25)	185	9.25	92.5
Potassium sulfate (0-0-50-17S)	70	3.50	35.0
Water	1310	65.50	655.0
	2000	100.0	1000.0

Procedure

1. Dissolve the potassium sulfate in the total quantity of water.
2. Add the urea and dissolve completely.
3. Add the potassium polyphosphate solution.
4. Add 0.1% surfactant.

There will very likely be a small amount of fine residue to settle out of the mixture from impurities in the potassium sulfate. If the solution is decanted, this should cause no problem in spraying.

The above is intended only as a method of mixing and does not constitute a recommendation for use for any particular purpose.

Strawberries - Strawberries have responded to foliar nutrients with increased yields, earlier production and improved berry color, flavor and sugar development. Foliar programs can also be used to reduce blossom drop. Yield increases of more than a ton per acre have been observed. Treated berries are firmer, hold up better and show increased resistance to fungus attacks in the field and after picking.

The initial application at the first sign of bloom is made to promote vine growth, early season fruiting and improved set. A second application two weeks later helps to prolong vine vigor and fruiting. As a further aid to increasing total yield and quality, additional applications at 14 to 20-day intervals are recommended.

An application in the period September 1-15 aids in the developmen of fruiting buds for the following spring.

Urea-N and formulated "complete" nutrient sprays are commonly applied to large acreages of strawberries in southwestern Michigan during the fruiting period to maintain fruit size. Here again, spraying is done in connection with the application of insecticides and fungicides. Similar sprays are occasioally used on raspberries, grapes, tomatoes, sweet corn, cucumbers, and melons during the late spring and early summer The materials are added to the spray tank and applied along with insecticides and fungicides.

APPLICATIONS RATES PER ACRE AND TIMING

First sign of bloom
Two weeks later
Follow at two-week intervals

For perennial beds, the following additional applications are recommended
Early spring at 6" to 8" new growth
Fall applicaion September 1-15

Foliar Spray Program: ***Strawberries***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/2/]											oz.
1 thru 3	First sign of bloom Repeat 14 days later Follow at 14-21 day intervals	2.5 to 3.5	0.5 to 1.0	0.8 to 1.25	1.0 to 1.5	0.5 to 1.0			0.5 to 1.0			0.25 to 0.25	

Ca: Petal fall up to harvest
Mg and B: Shoot extension to flower buds visible

For Perennial Beds

1 thru 2	Early spring at 6"-8" new growth and Again in fall (September)	1.5 to 2.5	0.3 to 0.5	0.4 to 0.8									

Sugar Beets - Field trials with foliar feeding programs show that it is possible to increase the total yield of sugar beets, increase total sugar per acre, and reduce beet nitrogen content.

In these trials, beet yields increased an average 1.6 tons per acre, with a 1.2% improvement in sugar. There was an average gross sugar increase of nearly 1,100 pounds per acre, and a 1% reduction in nitrogen content. In other tests, sugar increases have ranged up to 2.2%, with an average increase of .9%. Net weight beet yield increases have ranged up to 2.5 tons, with an average increase of 1.9 tons per acre.

Recent results have also demonstrated the ability of foliar nutrient programs to reduce frost injury on transplanted or newly emerged beets.

APPLICATION RATES PER ACRE AND TIMING

Crown area 8" to 10" across
Three to four weeks later

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

Foliar Spray Program: ***Sugar Beets***

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[1/2/]											oz.
1 thru 2	When crown is 8" to 10" across Repeat 3 to 4 weeks later	6.0 to 6.5	1.25 to 1.5	1.75 to 2.0				0.50 to 0.75	0.25 to 0.50			0.20 to 0.25	

Tomatoes - Foliar sprays have shown a number of important benefits on tomatoes. Properly selected and timed applications result in increased yields. In process tomatoes, up to 1% net increase in solids has been reported, along with increased production. Fruit matures more evenly to aid machine harvesting, too. Yield improvements ranging from 20% to 30% over untreated plants have been observed with both fresh market and process tomatoes.

Other benefits include earlier maturity, firmer fruit with improved handling and storageability, increased resistance to heat and improved flavor and color. Foliar feeding also helps hold ripe fruit on the vine with less breakdown.

A foliar nutrient program offers flexibiliy to help control specific problems such as blossom-end rot, or can be designed to supply any combination of nutrients needed to compensate for local deficiencies.

APPLICATION RATES PER ACRE AND TIMING

Foliar application at very early bloom helps to set more fruit. The program for process tomatoes is designed to hold on the early-ripening fruit and even up maturity, so there are more firm, ripe tomatoes on the vines at harvest. Programs for fresh market fruit can prolong vine vigor for longer production, more pickings and more fruit per picking.

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

Foliar Spray Program: *Tomatoes (Fresh Market)*

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[2/3/]											oz.
1	First sign of bloom	2.0 to 2.5	0.5 to 0.7	2.0 to 2.5		0.4 to 0.5	0.4 to 0.8	0.6 to 1.2	1.0 to 1.5			0.10 to 0.25	
2 thru 4	14-21 days after Spray No. 1; Sprays 3 and 4 follow at 10-14 day intervals	2.0 to 2.5	0.5 to 0.7	2.0 to 2.5			0.4 to 0.8					0.10 to 0.10	
For Correction of Blossom-End Rot													
1 and 2	First sign of bloom; repeat 21 days later 7-10 days apart	2.0 to 2.5			1.0 to 1.5							0.10 to 0.25	

Foliar Spray Program: *Tomatoes (Process and Canning)*

Spray No.	Growth Stage	Recommended Nutrients											
		N	P_2O_5	K_2O	Ca	Mg	S	Zn	Mn	Fe	Cu	B	Mo
		Suggested Application Rate (Pounds per Acre)[2/3/]											oz.
1	First sign of bloom	3.0 to 4.0	0.5 to 0.7	3.0 to 4.0		0.4 to 0.5	0.4 to 0.8	0.6 to 1.2	1.0 to 1.5			0.10 to 0.25	
2	21 days after Spray No. 1	3.0 to 4.0	0.5 to 0.7	3.0 to 4.0		0.4 to 0.5	0.4 to 0.8					0.10 to 0.25	
Correction of Blossom-end Rot													
1 and 2	First sign of bloom and repeat 21 days later	3.0 to 4.0			1.0 to 1.5							0.10 to 0.25	

[1/]Rates are given as guidelines only; a tissue test is highly recommended as a basis for correct nutrient need and rates of application.
[2/]Applied in 10-20 gallons of water per acre.

TISSUE ANALYSIS: AVERAGE VALUES AND CRITICAL LEVELS

	Percent						Parts per Million						
	N	S	P	K	Mg	Ca	Fe	Al	Mn	B	Cu	Zn	Mo
ALFALFA (10-20% Bloom)													
Average	4.6	.30	.40	2.7	.42	1.8	95	85	60	44	13	36	2.2
Critical	2.5	.10	.15	1.4	.18	.85	25		25	20	5	13	.6
CORN (Ear Leaf)													
Average	3.05	.26	.33	2.4	.30	.48	95	105	60	13	10	33	1.1
Critical	1.40	.12	.20	1.2	.09	.20	25		30	4	4	13	.3
GRAIN SORGHUM (Boot Stage, Leaf Blades)													
Average	2.7	.24	.38	2.1	.19	.42	85	80	50	12	9	30	1.1
Critical	1.4	.11	.21	1.2	.09	.17	30		18	4	3	10	.3
SMALL GRAINS BARLEY (Boot Stage, Leaf Blades)													
Average	2.2	.24	.33	1.7	.14	.36	55	23	31	10	7	30	.3
Critical	.6	.05	.08	.75	.06	.19	20		18	4	4	14	.3
OATS (Boot Stage, Leaf Blades)													
Average	2.2	.21	.33	2.6	.22	.38	80	80	48	9	9	23	.9
Critical	1.0	.11	.13	1.0	.11	.16	20		20	4	5	12	.4
WHEAT (Boot Stage, Leaf Blades)													
Average	2.8	.28	.36	2.6	.18	.45	60	50	42	10	9	32	.8
Critical	1.25	0.12	0.11	1.0	0.10	0.10	10		10	5	3	11	
SOYBEANS (Leaves)													
Average	5.2	.36	.38	2.2	.50	1.2	95	60	58	41	13	39	2.2
Critical	3.0	.20	.16	1.2	.12	.3	25		20	15	6	15	.6

CALIBRATION OF FIELD SPRAYERS

There are several ways to check equipment for rate of application per acre. Keep in mind that there are four (4) factors which will determine the application rate. These factors are: (1) spray nozzle orifice size, (2) nozzle spacing, (3) application speed, and (4) operating pressure.

The following is one suggested method to be used in calibration for maximum accuracy:

STEP 1 - After inserting selected spray nozzles in the boom at the proper spacing, fill sprayer tank with water to a known level.

STEP 2 - Spray 4 rods (660 feet or 1/8 mile) at the desired operating speed under field conditions similar to those which will be encountered under actual application (calibration on a road, for example, will give different results than on soft cultivated ground). Mark throttle or note tachometer reading so that the same speed can be maintained later.

STEP 3 - Refill tank to previous level, measuring amount of water added.

STEP 4 - Calculate rate of application per acre as follows:

$$\frac{\text{No. of Gal. Water Used} \times 66 \times 0.91 \text{ (Factor*)}}{\text{Boom Width in Feet}} = \text{Gal. Applied Per Acre}$$

*Factor is used to convert from density of water to 10 lbs./gal. material.

Example: If 5 gallons of water are used on 660 feet and boom width is 30 feet, spray rate is 10 gallons per acre of liquid weighing 10 pounds per gallon.

$$\frac{5 \times 66 \times 0.91}{30} = \frac{300.3}{30} = 10 \text{ gallons per acre}$$

STEP 5 - If the spray rate is below that desired, increase the pressure. If the rate is too high, lower pressure or increase operating speed and repeat Steps 2 through 4.

ALTERNATE METHOD . . . . . .

CALIBRATION OF FIELD SPRAYERS

$$\frac{\text{SWATH WIDTH IN INCHES}}{100} = \text{Acres / Mile}$$

Example: 40' Swath Width

$$\frac{480''}{100} = 4.8 \text{ Acres / Mile}$$

CALIBRATION CHECK LIST - GROUND EQUIPMENT

ï Inspect sprayer tank. Make sure it is free of rust, scale, dirt, sediment from previously sprayed material, or other foreign matter.

ï Rinse tank and half fill with clean, filtered (100 mesh) water.

ï Remove and clean all nozzles and screens by soaking and brushing with stiff bristle brush. Do not use hard objects which could scratch or deform nozzles, especially if nylon or plastic nozzles are used.

ï Replace suction filter screen. Flush hoses, controls, and booms (end caps removed) with clean water from tank.

ï Inspect nozzles for wear or damage. Verify that they are all the same size and type.

ï Use wide angle, hollow cone nozzles.

ï Align each nozzle at 90Ω angle straight down from spray boom (28).

ï Inspect pressure regulator, valves, controls, pressure gauges, and other parts for proper operation.

ï Check hoses and connections for leaks.

ï Calibrate sprayer over same soil conditions as field being sprayed using clamp-on type calibrator jar or other methods with proven accuracy.

PARTICLE SIZE INFORMATION

Particle Size Range (Microns)[1] Median Volume	Comparative Subject in Particle Size	Time For Particle To Fall 10 Feet (Seconds)	Drift in 3 M.P.H. Wind 10 Ft. Fall (Feet)	No. of Particles Per Sq. In. Rate of 1 Gal./Acre
5000 to 2000	Heavy Rain	0.85 0.9	3.5 4	1 1/3 per sq. ft. 21 per sq. ft.
2000 to 1000	Intense Rain	0.9 1.1	4 5	21 per sq. ft. 1
1000 to 500	Moderate Rain	1.1 1.6	5 7	1 9
500 to 100	Light Rain	1.6 11	7 48	9 1,152
100 to 50	Misty Rain	11 40	48 175	1,152 9,200
50 to 10	Wet Fog	40 1,020	175 4,500	9,200 1,152,500
10 to 2.0	Dry Fog	1,020 25,400	4,500 11,200	1,151,500 1,144,060,000
1.0 to 0.1	Fumes	Suspended In Air 2/	--	--
0.1 to .001	Smoke	Suspended In Air 2/	--	--
Below .001	Molecular Dimensions	--	--	-

[1] One Micron = 1/25400 of an inch
25.4 Microns = .001" (one thousandth of an inch)
1000 Microns = 1 millimeter
[2] Below 0.1 Microns, particles are suspended in air due to molecular shock (Brownian Motion)

DO'S AND DON'TS OF FOLIAR APPLICATION

ï **Do** obtain an accurate plant tissue analysis before foliar spraying.

ï **Don't** foliar spray plants under drought conditions, or when plants are under other forms of stress, such as disease or insect damage.

ï **Don't** foliar spray during hot, dry mid-day temperatures. The best time is late evening; however, early morning or overcast days are acceptable.

ï **Don't** foliar spray under windy conditions if drift into adjacent fields is a factor.

ï **Do** use narrow tires and foliage deflectors on ground applicators and adjust wheels to accommodate row widths to avoid damage to plant foliage.

ï **Do** clean application equipment thoroughly before spraying.

ï **Do** use wide angle hollow cone spray nozzles in ground applicators.

ï **Do** select the proper nozzle spray tip that will operate within the desired pressure range of your pump capacity.

ï **Do** calibrate each spray nozzle for proper volume using pressure setting and ground speed desired.

ï **Do** adjust nozzles on boom to spray at a 90Ω angle straight down from spray boom.

ï **Do** adjust boom height above plant canopy for uniform spray pattern.

ï **Do** make sure all hoses, pumps or pipelines are thoroughly drained of any other plant food products and flushed with water before use.

ï **Do** flush residual amounts of fertilizer solution from aluminum equipment with water after use to avoid possible pitting of equipment from prolonged exposure.

REFERENCES CITED

1. Albion Laboratories, Profitable Farming is a Science. Albion Laboratories, Clearfield, Utah.
2. Barel, D. and C. A. Black, 1979. Foliar Application of Phosphorus. I. Screening of various inorganic and organic phosphorus compounds. Agron. 4.71:21-24.
3. Barel, D. and C. A. Black, 1979. Foliar Application of Phosphorus. II. Yield responses of corn and soybeans sprayed with various condensed phosphates and phosphate-nitrogen compounds in greenhouse and field experiments.
4. Birch, P. D. 1972. Horticultural Science. Vol. 47, No. 1.
5. Christensen, N. W., T. J. Jackson, and R. L. Powelson. 1982. Suppression of take-all root rot and stripe rust diseases of wheat with chloride fertilizers. Oregon Agric. Exp. Stn. Technical Paper No. 6379. Dep. of Soil Science and Dep. of Botany and Plant Pathology, Oregon State University, Corvallis, OR 97331.
6. Coffman, Robert. Foliar feed your soybeans. In: Farm Journal. 1976.
7. Follet, R. H., L. S. Murphy, and R. L. Donahue. Nitrogen fertilizers. pp. 23-82. In: Fertilizers and soil amendments. Prentice-Hall Inc. 1981.
8. Gerwig, James. 1985. Still time to top dress small grain with nitrogen. In: Crops and Soils Management, South Dakota State University, Brookings, SD.
9. Gray, Robert C. 1977. Foliar fertilization with primary nutrients during the reproductive stage of plant growth. In: The Fertilizer Society. Proc. No. 164.
10. Halliday, D. J. 1961. Foliar application of major nutrients to fruit and plantation crops. In: Outlook on Agriculture 3:111-115.
11. Hergert, G. W. 1976. Sprinkler application of fertilizer nutrients. Solutions, 1976.
12. Herman, J. C. Foliar fertilization boosts soybean yields in Iowa State University tests. Solutions, Mar./April, 1976, pp. 14-18.
13. Jyung, W. H. and S. H. Wittwer, 1963 a. Foliar absorption - a metabolic process. American Journal Bot.
14. Kavazanjian, Nancy. Fertilizers as post additives. Agrichemical Age. May, 1986.
15. Larsen, Tom. In: Fertilizers as post additives. Agrichemical Age. May, 1986.
16. Leffingwell. 1985. In: Foliar feeding: A guide to extra profit. Leffingwell: A business of Uniroyal Chemical, Brea, California.
17. McAllister, R. S. Rain fastness of acifluorfen and bentazon combinations with adjuvants for weed control in soybeans. 1985 North Central Weed Control Conference.
18. McNall, L. R. Foliar applications of micronutrients. Solutions, November/December, 1967. pp. 8-13.
19. __________ Foliar feeding. Solutions. November/December, 1972. pp. 62-65.
20. Owen, M.D.K. Liquid nitrogen - herbicide mixes after corn emergence. Insect, weed, and plant disease newsletter. p. 55, 1C-452(6). May 2, 1986. Cooperative extension service, Iowa State University, Ames, Iowa.
21. Pace, Gary M. Foliar fertilization: some physiological perspectives. In: paper presented to American Chemical Society, September 13, 1982.
22. Rohm and Haas Company. 1986. Blazer/Basagran/10-34-0 research update. Technical bulletin Issue 20.
23. Stoller Chemical Company. Product manual and nutrient deficiency guide. Fourth Ed.
24. VanBuren, Ned. Foliar fertilization: Fitting together the pieces of the puzzle. Solutions, March/April, 1981. pp. 22-44.
25. Wallace, A. 1962. A decade of synthetic chelating agents in inorganic plant nutrition. University of California, Los Angeles.
26. Wittwer, S. H. 1964. Foliar absorption of plant nutrients. In: Advancing frontiers of plant sciences. Insitute for the Advancement of Science and Culture, New Delhi, India, Vol. 8.
27. __________ M. J. Bukavac and H. B. Tuckey, 1963. Advances in foliar feeding of plant nutrients. In: Fertilizer Technology and Usage. pp. 429-455. Soil Science Soc. of America, Madison, Wisconsin.
28. __________ 1967. Foliar applicaton of nutrients. In Plant Food Review. Nov. , 1967. pp. 11-14.
29. Personal communication with Don Johnson, Arcadian Corporation, 1984.
30. Personal communication with Ed Krysl, Texas Sulphur Products, Borger, Texas, 1984.
31. Personal communication with Wendell Saunders, Delavan Corporation, West Des Moines, Iowa. 1986.

INDEX