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Orchard Nutrition Management

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Orchard Nutrition Management

Success in the fruit business depends upon both the level of production per acre attained and the percentage of total yield that meets the quality standards of the market being served. Neither high yields of poor quality fruit nor low yields of premium quality fruit are likely to provide sufficient income to make orcharding a profitable venture, regardless of how the fruit is marketed.

It is therefore important to analyze all components of the orchard system and the management practices within that system to determine where adjustments might result in desirable improvements in the type of fruit being produced. Orchard nutrition must be considered within this context because of the direct effects of nutritional factors on yield and quality of fruit, and because of the many interrelationships of nutrition with other components of the total system.

The primary objective of any nutrition management program is to provide conditions that favor the development of healthy trees capable of producing high yields of top quality fruit. Attention must be given to the prevention of extreme conditions, such as deficiencies or toxic excesses of elements, that could seriously impair tree performance in any one season or throughout the life of the orchard. To achieve this it is necessary to: 1) evaluate the current nutritional status of the orchard, 2) consider how other orchard conditions and practices may influence nutrient requirements, and then 3) interpret this information into an effective fertilization program.

DIAGNOSING ORCHARD NUTRITIONAL STATUS

Soil Testing

Many studies show poor relationships between soil test results and leaf analyses in orchards. This is partly because fruit trees are deep-rooted in good orchard soils, and often only the surface soils (6–8 inches) are sampled. It is also related to the fact that tree roots are active during much of the year, accumulating nutrients that are stored in various parts of the tree and later mobilized. Additional limitations in using soil testing to evaluate nutrient status of orchards are associated with problems in obtaining samples representative of conditions throughout the root zone and throughout the orchard.

Recognizing such problems, care must be taken in how soil samples are obtained, and in how the results of soil testing are interpreted. Before new orchards are planted, soil testing provides the best means of determining the type and amount of lime required, and the relative levels of calcium, magnesium, potassium, and phosphorus in the soil. In existing orchards, soil testing provides additional information necessary for interpreting results of leaf analysis and in formulating fertilization programs.

Sampling Orchard Soils

Several factors must be considered in sampling orchard soils:

- Restrict the area sampled to a uniform soil type or condition within the orchard. If several distinctly different soil types, soil textures, drainage conditions, or depths to impervious layers, or if different fertilizer, lime, or crop histories exist in the orchard, they should be sampled separately. The area included in any one sample collection generally should not exceed 10 acres.
- Sample topsoil and subsoil separately. Most surface-applied fertilizer and lime materials move slowly into the soil or may be bound to soil particles near the surface. As a result, surface soil samples often more nearly reflect the accumulation of elements from recent fertilizer applications, while subsoil samples may indicate either inherent soil fertility or the effects of long-term fertilization and liming programs. Separate samples of surface and subsurface soil provide a means of evaluating both of these factors.
- Scrape away the surface 1-inch of soil, then collect samples from the 1–8 inch depth, and separate samples from the 8–16 inch depth. Although samples may be collected with a spade, a soil auger is usually a more convenient tool. To avoid micronutrient contamination of samples, do not use chrome-plated or galvanized tools or containers. Sample thoroughly throughout the area being tested. A single sample taken from one or two spots is not adequate. In a 10-acre orchard, a minimum of 10 to 20 subsamples is suggested.
- Thoroughly mix the 1–8 inch subsamples together to provide a sample for the soil test. Treat the 8–16 inch subsamples similarly.

Soil Test Interpretation

Soil pH. Orchard soils should be maintained in the range of pH 6.0 to 6.5 throughout the soil profile to optimize nutrient availability. Problems associated with low pH (below about pH 5.0) include: measles of Delicious apples, associated with excessive uptake of manganese; calcium and magnesium deficiencies; restricted root growth or regeneration, particularly of new lateral roots affected by aluminum toxicity; reduced availability of phosphorus; reduced efficiency of nitrogen and potassium use and poor response to applied nitrogen and potassium fertilizers.

Higher soil pH (6.3 or above) may reduce availability of micronutrients such as manganese, copper, zinc, and boron. High soil pH may be associated with soil parent materials, in some cases with excessive lime applications, or reflect carbonate accumulation due to poor internal drainage.

Lime requirement. Quantities of lime required to adjust the pH of a soil are determined by the buffering capacity of the soil (cation exchange capacity) and the amount of pH change desired. The buffering capacity of the soil is closely related to soil texture and organic matter content, being greater in finer-textured silty or clayey soils or soils with high organic matter levels, and less in coarser-textured sands or gravelly soils that often have lower organic matter levels.

The amounts and types of lime to be applied should be determined on the basis of pH adjustment and on the amounts of calcium and magnesium in both the topsoil and subsoil (largely determined by organic matter content and soil texture).

Soil classification. New York soils are classified according to texture and parent materials into five soil management groups, ranging from medium- to fine-textured soils developed from lake sediments (Group I) to coarse-textured soils formed from gravelly or sandy glacial outwash or glacial lake beach ridges or deltas (Group V). (See *Cornell Field Crops and Soils Handbook* for more information about characteristics of soils within management groups.) The content of colloidal materials (clay and organic matter) is greatest in the finest-textured soils and least in the coarsest-textured soils. The cation exchange capacity or buffering capacity (ability of a soil to adsorb and release elements such as calcium, magnesium and potassium) is directly related to the content of colloidal materials.

Organic matter content is particularly important for its contribution to the cation exchange capacity of coarse-textured (Group V) soils. The cation exchange capacity is important in estimating the appropriate quantities of calcium and magnesium required in managing the soil in question.

The approximate cation exchange capacities of soils within these groups are estimated as follows:

Management group	*Topsoil*	*Subsoil*
Group I soils	25[1]	17[2]
Group II soils	20	13
Group III soils	18	12
Group IV soils	16	11
Group V soils	12	8

[1]milliequivalents per 100 gms of soil.
[2]Subsoil estimated as approximately two-thirds of topsoil values.

Calcium (Ca). Many of the low-calcium-related problems in tree fruits are directly attributable to inadequate amounts of soil calcium. Low levels of soil calcium are usually associated with low soil pH and low cation exchange capacity, particularly in subsurface soils. In some finer-textured soils, however, calcium availability and uptake may be more directly related to exchangeable acidity than to either pH or total amount of calcium in the soil. If properly limed, most soils contain abundant quantities of calcium. Imbalances involving calcium, potassium, and magnesium are often cited as problems in orchards soils. In most cases, inadequate amounts of one or more of these elements are of greater importance than are imbalances in tree nutrition. Such shortages are particularly significant in subsurface soils.

Magnesium (Mg). Most tree fruits have a high requirement for magnesium. Except for those derived from parent materials high in magnesium content, i.e., the high-lime soils of New York's Central Plains, most orchard soils in the Northeast are low in magnesium. Raising soil pH by applying calcitic limestone increases availability of the magnesium present in the soil but does not correct the long-term problem of low magnesium supply. Applying lime high in magnesium (dolomitic limestone) to low-pH soils is the usual method for correcting a low magnesium supply.

Preplant soil preparation. Thorough incorporation of adequate amounts of lime prior to planting a new orchard is essential. At this time, the topsoil (0–8 inch depth) should be adjusted to pH 7.0 and subsoil (8–16 inch depth) to pH 6.5.

Calcium and/or magnesium requirements for preplant soil preparation are estimated to represent approximately 67 and 13 percent, respectively, of the total cation exchange capacity in the topsoil; and 58 and 12 percent, respectively, in the subsoil. This represents a calcium-magnesium ratio of 5:1 on an equivalent basis, or 8.23:1 on a weight basis. These ratios are used in computations to estimate calcium and magnesium requirements and should not be interpreted as precise requirements. Acceptable ratios may vary within broad ranges, depending upon soil, crop, and environmental conditions. On this basis, approximate calcium and magnesium requirements for soils of the different management groups are as follows:

Soil management group		*Pounds of element/acre 8-inch depth* *Calcium*	*Magnesium*
I	topsoil	8,900	1,100
	subsoil	*5,900*	*700*
II	topsoil	7,100	850
	subsoil	*4,700*	*600*
III	topsoil	6,400	780
	subsoil	*4,300*	*500*
IV	topsoil	5,700	700
	subsoil	*3,800*	*450*
V	topsoil	4,300	500
	subsoil	*2,800*	*350*

Established orchards. Since it is not feasible to incorporate lime deeply into the soil in established orchards, surface applications of lime are used for applying calcium and magnesium, and for maintaining pH at desired levels. The objectives in liming established orchards are to maintain a pH of 6.5 in the topsoil and at least 6.0 in the subsoil. The calcium and magnesium requirements for established orchards represent approximately 58 and 12 percent, respectively, of total cation exchange capacity in the topsoil; 52 and 10 percent in the subsoil. Again, these are not precise ratios, but are used for computational purposes. For soils of the different management groups, the values for calcium and magnesium are approximately as follows:

Soil management group		*Pounds of element/acre 8-inch depth* *Calcium*	*Magnesium*
I	topsoil	7,800	950
	subsoil	*4,600*	*550*
II	topsoil	6,200	750
	subsoil	*3,700*	*450*
III	topsoil	5,600	700
	subsoil	*3,300*	*400*
IV	topsoil	5,000	600
	subsoil	*2,900*	*350*
V	topsoil	3,700	450
	subsoil	*2,200*	*250*

The wide range of soil types within each management group makes it advisable to consider them on an individual basis, as provided by a soil test analysis. This is particularly important with soils in management group V, which includes the sandy loams, sands, and gravelly soils, some of which may have only 50 percent or less of the cation exchange capacity listed for the average of this group. Although the desired ratio of calcium to magnesium should be the same as for other members of this group, the actual amounts of these elements applied to such soils must be reduced because of the lower cation exchange or buffer capacity.

It is recommended that both topsoil and subsoil samples be submitted for analysis to obtain the best recommendations for the specific soils found on an orchard site.

Potassium (K). The amount of fertilizer potassium required varies according to the potassium-supplying power of the soil, a characteristic that depends largely upon the type and amount of clay component (included in the classification of soils according to the soil management groups). Relative levels of potassium suggested for soils of the different management groups are indicated in Table 1.

Table 1. Suggested potassium levels by soil management group.

Soil management group	*Potassium (lb/8-inch depth)* *Topsoil*[1]	*Subsoil*[2]
I	520	300
II	450	260
III	430	250
IV	400	240
V	330	200

[1]Increases from 2 to 2.6 percent of C.E.C., I to V.
[2]Increases from 1.5 to 2.1 percent of C.E.C., I to V.

Phosphorus (P). Two factors, low soil-test phosphorus and low pH, should be considered in judging the status of this element. Because fruit trees are deep-rooted and actively absorb phosphorus over a long season, soil-test phosphorus is a poor indicator of phosphorus status. As soil pH increases, phosphorus availability also increases. Thus, even with a low level of soil phosphorus, trees are usually able to absorb adequate amounts of this element. Sometimes, soil phosphorus may be so low that fertilizer phosphorus is needed, especially for establishing a new orchard. Recommendations for high rates of phosphorus in orchards in some areas are based on their need in establishing and maintaining legume ground covers. Phosphorus requirements of grass sods are lower than those of legumes and more nearly approximate those of fruit trees.

Application of too much phosphorus can increase problems of zinc and copper deficiency. It is not clear whether these problems occur only in the soil, or both in the soil and within the tree.

Soil phosphorus should receive the most attention during soil preparation before the orchard is planted. Movement of phosphorus into the soil from surface applications is extremely slow in most situations, and thus primary emphasis in established orchards should be on maintaining an "adequate" level of phosphorus as determined by leaf analysis rather than soil testing.

General rates of fertilizer phosphorus application recommended per acre 8-inch depth for preplanting soil preparation and for established orchards are indicated in Table 2.

Table 2. Soil test phosphorus values and rates of phosphate (P_2O_5) application for orchards.

Soil test value (lb P per acre)	*Pounds P_2O_5 to apply per acre*	
	Pre-planting	*Established orchards*[1]
<1	120	60
1–3	100	60
4–8	60	30
9+	40	0

[1]Do not apply phosphate to established orchards unless leaf analysis also indicates a need for additional phosphorus.

Closer approximations of phosphate fertilizer needs based on soil tests may be estimated using the following formulas:

Preplant soil preparation: (9-soil test P) x 10 + 40 = pounds P_2O_5 per acre. Both topsoil and subsoil samples should be used in determining total phosphate needs.

Established orchards: (9-soil test P) x 5 + 20 = pounds P_2O_5 per acre.

Boron (B). Prior to planting a new orchard, a soil test provides the best guide to the need for boron. After the orchard has been planted, however, both leaf and soil analyses are suggested, particularly when determining the need for boron applications in stone fruit orchards.

Relative soil test levels of boron for soils of different textures are indicated in Table 3.

Table 3. Boron soil test levels for soils of different textures.

	Soil texture		
Relative level	*Loam, silt loam*	*Sandy loam*	*Loamy sand*
	lb B/a	*lb B/a*	*lb B/a*
Very high	>2.4	>1.8	>1.2
High	1.6–2.4	1.2–1.8	0.7–1.2
Medium	0.8–1.6	0.6–1.2	0.4–0.7
Low	<0.8	<0.6	<0.4

Other elements. Standards for interpreting soil analyses for elements such as copper, manganese, and zinc are not established, but analyses of soils from potential orchard sites and from established orchards indicate that these elements are frequently inadequate for optimal tree growth and cropping. Since the availability of all three of these elements is reduced at higher pH levels (>pH 6.3), greater attention to their management is required when soils are limed to recommended levels.

Leaf Analysis

In contrast to soil analysis, which indicates total amounts of certain elements in the soil, leaf analysis indicates the amounts of the various elements that have been taken up by the tree and translocated to the foliage. To this extent, leaf analysis provides a more complete picture of the current nutritional status of the trees. Many factors that influence leaf composition must be considered when interpreting leaf analysis results.

Leaf Sampling

Newly formed leaves, older leaves, flower buds, or fruit collected at various times may best reflect the status of individual elements. Specifying particular types of samples for each of 10 elements, however, is not practical. Standard sampling procedures attempt to overcome some of these problems and simplify somewhat the comparison of sample results with standard values.

Times of leaf sample collection. The levels of most elements vary with leaf age, either during the season or along the shoot. To compare leaf samples to standards, the leaves sampled must be comparable in physiological age to those used in developing the standards. Leaf samples should be collected between 60 and 70 days after petal fall, when the concentrations of most elements are relatively stable. Leaf samples collected much earlier tend to contain higher concentrations of elements such as nitrogen and potassium, and lower levels of calcium. Conversely, samples collected appreciably later tend to have lower nitrogen and potassium and higher levels of calcium.

Method of sample collection. Leaf analysis standards are based on samples of mid-shoot leaves collected from current-season terminal shoots on the periphery of the tree. Foliage developed on shaded interior shoots or on spurs may differ significantly in their content of several elements. Mixing leaves from such different locations is not advised.

- Samples should consist of 100 leaves collected from several trees in the area being sampled. Trees may be selected at random, or by following a predetermined pattern. No more than 2 leaves should be taken from an individual terminal shoot. On larger trees, shoots sampled should be approximately 4–7 feet above ground level. With young trees and those in high-density plantings, height of shoots sampled should be representative of the majority of the foliage.

  Leaves of different varieties may differ greatly in material composition. Sample the major variety in the orchard. Do not mix leaves from two varieties because the sample will not be representative of either. If more detailed information is desired on varietal differences, they should be sampled separately.

- Sample trees that are uniformly representative of the general condition of the orchard in terms of vigor, crop load, pruning, etc. Avoid areas with distinctly different soil conditions or tree vigor. If more specific information about such areas is desired sample these areas separately.
- Do not mix leaves from young and old trees. Distinctly different levels of some elements are associated with the differences in vigor of shoot growth and relative crop load on young trees and those that have produced several crops of fruit.
- At the time that leaf samples are collected, record observations of such factors as length and thickness of terminal shoot growth, relative size and appearance of leaves, incidence of disease or insect damage, visual symptoms of deficiencies, crop load, severity of pruning, and effectiveness of weed control. These may be useful in interpreting the results from the leaf analysis. An information sheet to be completed at the time of leaf sample collection may be similar to that on page 7.

Sample preparation. In most cases, the content of elements such as nitrogen, phosphorus, potassium, calcium, magnesium, or boron is not affected appreciably by washing samples prior to drying. Surface contamination by dust, soil, pesticide sprays, or foliar nutritional sprays, however, may result in significantly higher levels of iron, manganese, zinc, and copper in samples that are not washed prior to drying. Washing samples in a mild detergent solution (most dish-washing liquids are suitable) and then rinsing three times in distilled water[1] is helpful in reducing contamination. If samples are washed, the leaves should be lightly scrubbed together in the detergent solution and in the three separate rinse waters. Washing should be completed quickly to avoid soaking the leaves. After the final rinse, samples should be drained (spread out on paper toweling) before being placed in paper bags for drying.

[1]Caution: Some domestic water supplies contain various amounts of iron, manganese, copper, or zinc. Using distilled water for washing leaf samples helps to avoid this source of contamination.

Table 4. Leaf analysis standards for tree fruits (dry weight basis).

Element	*Crop*	*Desired level*
Nitrogen	Young nonbearing apples and pears	2.4–2.6%
	Young bearing apples and pears	2.2–2.4%
	Mature soft apples and pears	1.8–2.2%
	Mature hard apples and processing	2.2–2.4%
	Cherries, plums, prunes	2.4–3.4%
	Peaches	3.0–4.0%
Phosphorus	All crops	0.13–0.33%
Potassium	All crops	1.35–1.85%
Calcium	All crops	1.3–2.0%
Magnesium	Apples and pears	0.35–0.50%
	Stone fruits	0.40–0.60%
Boron	Apples and pears	35–50 ppm
	Stone fruits	30–50 ppm
Zinc	All crops	35–50 ppm
Copper	All crops	7–12 ppm
Manganese	All crops	50–150 ppm
Iron	All crops	50+ ppm

Interpretation of Leaf Analysis Results

The first step in evaluating the nutritional status of orchards is to compare results of the leaf analysis with a set of standard values. Standards presently in use in the Leaf Analysis Service Program in New York State are summarized in Table 4.

Nitrogen (N) levels must be considered according to the type of fruit, tree age and variety, crop load, tree vigor, and the purpose for which the fruit is intended. The most desirable nitrogen management program provides a relatively high nitrogen status early in the season to encourage rapid leaf development, fruit set, and flower bud formation, and then allows nitrogen to decline gradually as the season progresses to favor fruit color development and tree hardening. Optimum growth of young trees is associated with leaf nitrogen values of approximately 2.4 to 2.6 percent (pome fruits) and higher (stone fruits). As trees mature, less vegetative growth is desired and the "satisfactory" level of nitrogen is generally reduced to improve color development and fruit firmness.

Points to consider in judging nitrogen status from leaf analysis include:

- *Rapid growth of young trees* is desirable to develop the fruiting system and encourage early cropping. During the developmental period, rate of tree growth is directly correlated with nitrogen status, but excessive late-season growth must be avoided to allow the trees to develop cold hardiness.
- *Fruit color* development in bearing-age trees (red and yellow varieties) is delayed when nitrogen levels are too high. If other factors are equal, the percentage of red color is reduced by about 5 percent for each 0.1 percent increase in leaf nitrogen. This relationship is particularly significant with the less-highly colored fruit varieties or strains. Yellowing of Golden Delicious fruit shows a similar reduction as leaf nitrogen increases.
- *Fruit size and flesh firmness* are usually inversely related, and both are influenced by nitrogen status of the tree. Size generally increases with higher nitrogen levels if the crop load is not excessive and other factors are not limiting. Since flesh firmness decreases as fruit size increases, the optimal nitrogen level would be that providing the best combination of size and firmness determined by the requirements of the market.
- *Varietal differences* in fruit coloring and/or flesh firmness must guide evaluation of leaf nitrogen status. To accommodate such differences, various apple varieties are grouped into two general categories for interpreting leaf nitrogen status in mature orchards:

Cornell University College of Agriculture & Life Sciences Cooperative Extension Service Leaf Analysis Program for Tree Fruits
Department of Pomology * Analytical Laboratory * 135A Plant Science * Ithaca, NY 14853
(607) 255-1785

NAME ______________________ LEAF SAMPLE #: __________

STREET ______________________ FIELD #/NAME: __________

CITY/STATE ______________ZIP ________ DATE SAMPLED: __________

COUNTY ____________ TELEPHONE: (   ) ______–______ COLLECTED BY: __________

EXTENSION AGENT ______________________

If a soil sample was submitted for this area: Topsoil sample ID # ________ Subsoil sample ID # ________

FRUIT DESCRIPTION

[ ] Apple [ ] Nectarine
[ ] Pear [ ] Sweet Cherry
[ ] Plum [ ] Tart Cherry
[ ] Prune [ ] Other: ________
[ ] Peach (specify)

________ Variety
________ Strain
________ Rootstock

AGE

[ ] Young non-bearing
[ ] Young bearing
[ ] Mature
[ ] Old

MARKET

[ ] Fresh
[ ] Processing
[ ] Juice

CROP LOAD

This Year:	Last Year:
[ ] Excessive	[ ] Excessive
[ ] Heavy	[ ] Heavy
[ ] Good	[ ] Good
[ ] Light	[ ] Light
[ ] Very Light	[ ] Very Light
[ ] None	[ ] None

FRUIT SIZE

This Year:	Last Year:
[ ] Very Large	[ ] Very Large
[ ] Large	[ ] Large
[ ] Good	[ ] Good
[ ] Small	[ ] Small
[ ] Very Small	[ ] Very Small

SHOOT LENGTH

[ ] Under 4"
[ ] 4" to 8"
[ ] 8" to 12"
[ ] 12" to 18"
[ ] Over 18"

SHOOT DIAMETER

[ ] Less than a pencil
[ ] Equal to a pencil
[ ] Thicker than a pencil

PRUNING SEVERITY

Dormant THIS year:	Summer THIS year:	Dormant LAST year:	Summer LAST year:
[ ] Severe	[ ] Severe	[ ] Severe	[ ] Severe
[ ] Moderate	[ ]Moderate	[ ] Moderate	[ ]Moderate
[ ] Light	[ ] Light	[ ] Light	[ ] Light
[ ] None	[ ] None	[ ] None	[ ] None

CONDITION OF TRUNKS

[ ] No Damage [ ] Mechanical Damage
[ ] Mouse Damage [ ] Burr Knots
[ ] Winter Injury [ ] Herbicide Injury

EXTENT OF DAMAGE

[ ] Light
[ ] Moderate
[ ] Severe

SOIL TYPE: ______________
(NAME)

TEXTURE: ______________

DRAINAGE: ______________

DEPTH TO PAN OR BEDROCK: ___ (inches)

SOIL MANAGEMENT

Between Rows:
[ ] Sod
[ ] Clean cultivated
[ ] Trashy cultivated

In Rows:
[ ] Sod
[ ] Cultivated
[ ] Herbicide strip
[ ] Herbicide squares
[ ] Mulch
[ ] Other (specify) ______

LIME APPLICATIONS
(Tons per acre)

[ ] This year ______
[ ] Last year ______
[ ] 2 years ago ______

FERTILIZER APPLICATION (Indicate rates per acre or per tree)

NITROGEN:

____
This year-Spring

____
Last year-Fall

____
Last year-Spring

OTHER THAN NITROGEN:

____
This year-Spring

____
Last year-Fall

____
Last year-Spring

NUTRIENT SPRAYS

Applied THIS year:
[ ] copper [ ] magnesium
[ ] boron [ ] manganese
[ ] zinc [ ] nitrogen
[ ] other ________

MISCELLANEOUS MATERIALS

Applied THIS year:
[ ] COCS [ ] Bordeaux Mixture
[ ] Kocide [ ] Tribasic Copper Sulfate
[ ] Dikar [ ] Dithane F-45, M-22
[ ] Ferbam [ ] Phybam-S
[ ] Zineb [ ] Niacide M
[ ] Polyram [ ] Manzate 200

ANY ADDITIONAL COMMENTS: ______________________________

____

Soft varieties (leaf nitrogen of 1.8–2.2 percent for mature trees) intended for fresh market: Cortland, Empress, Gala, Golden Delicious, Jerseymac, Jonagold, Jonamac, Jonathan, Macoun, McIntosh, Mutsu, Paulared, Spartan, Tydeman Red, other early ripening varieties.

Hard varieties (leaf nitrogen of 2.2–2.4 percent for mature trees): Delicious, Empire, Idared, Liberty, Melrose, R.I. Greening, Rome, Stayman, York Imperial, other varieties, including those in the soft category, if the fruit is intended for the processing market.

- *Biennial bearing* tendencies of mature apple trees become more pronounced as leaf nitrogen falls below approximately 2.2 percent. Careful attention must be given to fruit thinning to minimize the biennial tendency in Golden Delicious and varieties such as McIntosh when leaf nitrogen is reduced to levels of 1.8–2.0 percent to favor color development.
- *Vigor of shoot growth* offers an additional guide to adequacy of nitrogen if all other nutrients are adequate. A minimum of 8 to 12 inches of terminal shoot growth on nonspur apple varieties, and from 6 to 8 inches on spur types usually indicates sufficient vigor. Excessive watersprout growth frequently results from excessive pruning, particularly heading cuts, and is not a reliable indicator of vigor of the fruit bearing shoots. Interpretation of leaf nitrogen levels in trees that are producing very limited amounts of new growth requires caution. In such trees, nitrogen accumulates to adequate or higher-than-desired levels because of the limited growth. This condition is often associated with deficiencies of metals such as copper and zinc.
- *General nitrogen relationships* that should be considered in judging leaf nitrogen status include:
  (a) Leaf nitrogen tends to be higher in samples from trees that are carrying heavy crops. Off-year trees are generally lower in leaf nitrogen content. This condition reflects the inverse relationship between shoot growth and fruiting; trees bearing a lighter crop produce more shoots. Under such conditions, the concentration of nitrogen per unit of leaf dry weight is lower, although the total amount of nitrogen in leaves may be similar to that in a tree carrying a full crop.
  (b) Leaf nitrogen is reduced by drought or sod/weed competition. Availability of soil nitrogen is dependent upon soil water availability. Sod or weed competition, by removing nitrogen from the rooting zone and reducing soil water supply, significantly limits nitrogen availability to the trees and results in lower leaf nitrogen.

Phosphorus (P) levels in leaf samples vary somewhat, according to fruit type and variety. Leaf phosphorus levels above 0.13 percent usually indicate an adequate supply within the tree. Leaf samples from stone fruits are generally higher in phosphorus content than those from apples or pears. Likewise, McIntosh leaf samples generally contain lower concentrations of phosphorus than those of Delicious. Since the availability of phosphorus is strongly influenced by soil pH, low leaf-phosphorus values frequently indicate a low soil pH condition that is limiting uptake of phosphorus. At the other extreme, high values frequently result from the accumulation of phosphorus when growth and leaf expansion are limited by deficiencies of other elements such as zinc.

Potassium (K) values in the range of 1.3 to 1.8 percent are generally considered to be adequate for tree fruit crops. Visual symptoms of potassium deficiency are usually evident with leaf potassium values of 0.75 percent or less. These symptoms may include a purple stippling on the outer edge of the lower leaf surface, or a marginal necrosis of the leaf with a narrow purple band or line between the necrotic (dead) tissue and the normally green tissue of the remainder of the leaf. Fruit set on potassium-deficient trees may be normal, but the fruit is smaller than normal, has poor, dull color, and an insipid flavor due to lack of acidity. Trees that are low or deficient in potassium are more susceptible to winter cold injury and spring frost damage to buds and flowers.

Leaf potassium shows an inverse relationship with crop load. Thus, a value of 1.3 percent potassium may be adequate in a sample from a heavily cropping orchard, but might indicate a marginal supply in a lightly cropping or nonbearing orchard. Leaf potassium levels of 2 percent or greater are not uncommon with young nonbearing trees; such levels decline as trees mature and the level of cropping increases.

Recent research with Empire and McIntosh apples has shown that fruit size and color is correlated positively with leaf potassium, and that levels in the range of 1.5 to 1.8 percent must be sustained to achieve optimum production and fruit size and color with these varieties.

The nitrogen-potassium ratio often provides additional information in judging potassium status, both in terms of fruit quality and tolerance of trees to winter cold and spring frosts. In general, the requirement for potassium increases as the level of nitrogen increases. A ratio of 1.00–1.25:1 (N:K) represents a favorable balance for varieties such as McIntosh, while a ratio of 1.25–1.50:1 is more appropriate for varieties such as Delicious. On this basis, a McIntosh leaf sample containing 1.8 percent nitrogen should contain approximately 1.44–1.80 percent potassium, while a Delicious sample containing 2.4 percent nitrogen should contain 1.6–2.0 percent potassium. High N–K ratios usually indicate that potassium supply is inadequate, while low ratios might indicate either that the nitrogen supply is too low or that the potassium supply is too high.

In addition to tree age and level of cropping, soil moisture supply and soil management practices affect leaf potassium status. If the soil potassium supply is adequate, moisture stress may limit availability of potassium and result in low leaf potassium levels. Soil management practices such as the use of clean-cultivated or herbicide strips along the tree row, or mulching that reduces moisture stress, generally result in higher leaf sample potassium. Mulching with hay, straw, or other organic materials reduces moisture stress; in addition, lower soil temperature under such mulches also favors uptake of potassium. It should also be recognized that some mulching materials, particularly hay, contain potassium, the amount varying with the type and quality of the material.

Calcium (Ca) content of leaf samples considered to be adequate range from 1.3 to 2.0 percent. Values in the upper half of this range, i.e., 1.6–2.0, are generally required to minimize low-calcium-related fruit problems. Low leaf calcium is often, but not always, associated with low soil calcium supply and low pH, particularly in the subsoil. This usually reflects inadequate lime application prior to planting the orchard and/or failure to maintain an adequate liming program throughout the life of the orchard. When adequate soil calcium is available, low leaf calcium may be the result of boron deficiency and/or zinc deficiency. Normal applications of potassium or magnesium have little effect on calcium unless soil calcium supply is low.

Calcium in leaves is positively correlated with leaf nitrogen under normal growth conditions. This relationship exists because a large part of the calcium and nitrogen are taken into the tree and moved to the leaves as the result of water movement due to transpiration. Increasing nitrogen, by increasing growth and leaf surface, raises total transpiration. Excessively high nitrogen supplies, however, frequently promote development of a high leaf-to-fruit ratio that accentuates the problems associated with low calcium in the fruit. This is particularly important when soil moisture is inadequate because calcium is removed from the fruit as water is moved from fruit to leaves under moisture stress conditions.

Disorders associated with low calcium supply include bitter pit, cork spot, and premature senescent breakdown of the fruit in apples. Shortages of calcium may also result in limited growth of roots and shoots. These problems are often associated with excessive tree vigor, light crops, and any other factor that induces large fruit size. They are frequently observed to be more severe on young trees.

Magnesium (Mg) concentrations within the range in the guidelines are usually satisfactory, but should be considered in relation to potassium. The requirement for magnesium increases as the potassium status of the tree increases. For practical purposes, a ratio of the percentages of K to Mg in the leaf sample of 4:1 or greater usually indicates that the magnesium supply is not adequate. Thus, a leaf magnesium content of 0.35 percent may be adequate with leaf potassium at 1.4 percent or less, while a magnesium content of at least 0.45 percent would be necessary if the potassium content were 1.8 percent.

When the magnesium supply is marginal, deficiency symptoms may appear as a yellowing (chlorosis) of leaves on fruit-bearing spurs or in the mid- to older portions of vigorous shoots, particularly on young trees. As the deficiency advances, the leaves on fruit-bearing spurs may show increasingly severe chlorosis and death (necrosis) of tissues between main veins and/or along the leaf margins.

Premature fruit ripening and accentuated preharvest fruit drop are often associated with magnesium deficiency. Blind wood, a lack of bud development, and weak, brittle spurs are also frequently associated with magnesium deficiency.

Boron (B) shortages frequently occur in orchards, particularly on coarse-textured soils and during dry seasons. Leaf concentrations of 30 to 50 ppm boron are required for normal tree performance. When boron is inadequate various types of corking disorders may develop in or on the fruit. Shortages of boron are associated with impaired growth or dieback of roots and shoots, premature ripening of fruit, and accentuated preharvest fruit drop. Fruit set may be reduced on trees low in boron because of abnormal flower development, poor pollen germination, and/or reduced growth of pollen tubes. Low boron levels are often associated with calcium deficiency problems.

Boron toxicity can be induced by overapplication of boron, either to the soil or in foliar sprays. Visual symptoms of boron toxicity on the foliage may include a loss of green color in a V-shaped area along the midrib of the leaf, malformation of the shoot tip and newly formed leaves, and shoot dieback. Abnormal ripening and softening of the fruit may also occur, leading to flesh breakdown during storage.

Interpretation of leaf boron values must recognize past boron application practices. If no foliar sprays of boron were used prior to leaf sample collection, a leaf level of 30 to 50 ppm usually indicates an adequate boron supply. However, if post-petal-fall boron sprays were used, leaf levels in the 30 to 50 ppm range indicate a need to continue boron applications, preferably as combination soil and foliar treatments. Fruit analysis is considered to be the most sensitive means of diagnosing boron status, but is not used extensively in making fertilizer recommendations.

Zinc (Zn) is involved in the regulation of growth and fruiting. It is an essential element in the production of growth-regulating hormones within the tree and has been shown to have a role in pollen tube growth. Zinc also influences calcium metabolism. Shortages of zinc are prevalent in the Northeast and deficiencies may be evident in various ways; weak shoot growth, poor fruit set, reduced size and color of fruit, and advanced maturity of fruit are some of the symptoms. Zinc has also been shown to influence the degree of cold hardiness of trees and frost hardiness of flowers.

Interpretation of leaf zinc levels is complicated by zinc-containing materials in foliar applications and by interactions with phosphorus. If no foliar sprays containing zinc have been applied, 35–50 ppm indicate adequate zinc; 20–35 ppm indicate a low zinc status; less than 20 ppm indicate a zinc deficiency. Relying strictly on these levels to judge zinc status may be misleading for two reasons: 1) growth is reduced as zinc becomes limiting. This limited growth results in accumulation of zinc to higher concentrations than would occur with normal growth, and 2) high levels of phosphorus tend to reduce the availability of zinc within the tree as the result of the formation of inactive zinc phosphate precipitates. When zinc is limited, the reduced growth also tends to result in higher concentrations of phosphorus within the leaf tissue, further accentuating the problem.

An evaluation of the ratio of phosphorus to zinc in the leaf tissue provides a second means of determining relative zinc status. This ratio is calculated by dividing the ppm of phosphorus by the ppm of zinc. (To convert percent to ppm, move the decimal point four places to the right; 0.20 percent P is equal to 2,000 ppm P.) When used in conjunction with the leaf Zn values indicated, either 20 ppm zinc or a P–Zn ratio of 150 or greater indicates that zinc is deficient, while 35 ppm or higher zinc levels with P–Zn ratios of 100 or less usually indicate an adequate supply of zinc.

These interpretations cannot be applied directly to samples that have been sprayed with a zinc-containing material because of the presence of inactive zinc contaminants. With knowledge of the foliar application program, however, these approaches may be helpful in arriving at a more satisfactory diagnosis of zinc status. Examining the foliage for visual symptoms of zinc deficiency provides a third means of verifying the adequacy of the zinc supply.

Manganese (Mn) deficiency is found more frequently on high-pH soils and on coarse-textured soils. The primary effect of manganese deficiency is through reduced photosynthesis. Manganese availability is strongly influenced by soil pH. Manganese toxicity, i.e., measles in Delicious apple trees, occurs at low pH, usually near 5.0 or below, in soils not adequately limed. Manganese is usually more readily available in poorly drained soils where aeration is limited. For example, manganese availability may be excessive in a poorly drained soil at pH 5.5, but normal in a well-drained soil at the same pH. Necrosis of the phloem as a result of manganese toxicity is frequently confused with other problems such as oil spray damage, or deficiencies of copper or boron.

Concentrations of 50 to 150 ppm of manganese indicate adequate amounts of this element in leaf samples from trees that have not been sprayed with manganese-containing materials. Concentrations below 35 ppm are usually accompanied by manganese deficiency symptoms which include interveinal yellowing (chlorosis). Such leaves tend to be thinner than those from trees with an adequate level of manganese.

Leaf samples from trees that have been sprayed with manganese-containing fungicides may show high levels of manganese. Much of this manganese is not physiologically active within the tree and can be ignored. Reducing or eliminating such sprays during the next season usually results in lower levels of manganese in leaf samples, indicating little or no carryover of manganese from foliar applications during the previous season. When excessively high manganese levels are found in leaf samples, however, it is advisable to verify that this is not related to a low pH problem.

Iron (Fe) contents of leaf samples fluctuate over a considerable range, often in response to variations in soil and weather conditions and with contamination of samples by dust. Iron status of orchards in New York State is generally not a problem.

Copper (Cu) shortages can be a problem on coarser-textured soils and on soils with a pH 6.3 or higher. Levels of 7–12 ppm in leaf samples generally indicate a satisfactory copper level. Symptoms of copper deficiency are associated with leaf contents of 3.5 ppm or less, and may appear as a roughening and enlargement of lenticels on shoots, followed by necrosis, shoot dieback during the season of growth, and limited fruit set in spite of heavy bloom. Leaf size is often severely reduced. Both fruit size and red color development are reduced by copper deficiency.

Multiple deficiencies involving two or more elements are not uncommon. Potassium-magnesium, calcium-magnesium, boron-zinc, zinc-manganese, zinc-copper and other combinations have been encountered. In many such cases, tree growth is restricted and the levels of all elements in the leaf samples may be within the ranges considered to be satisfactory for normal tree performance. Visual examination of the trees, past performance, soil tests, and trial applications of the suspected problem elements may be necessary before the cause or causes of such problems can be determined. When the supplies of two or more elements are marginal, correction of one deficiency usually accentuates the appearance of symptoms associated with deficiencies of the other element(s) marginal in supply.

Other factors, such as the condition of the roots and conducting tissues, abnormal soil conditions, and damage to the roots from nematodes or diseases, may affect the results of leaf sample analysis and should be considered in the interpretation of results. Physical damage to limbs, trunks, or roots, whether by mechanical means or injury by rodents, or insect or disease problems may also affect nutrient uptake or translocation within the tree. Likewise, injuries to buds or foliage as a result of low temperature during winter, spring frosts, herbicides, or various pesticides can influence the growth and nutrient content of leaf samples.

Visual Symptoms of Nutritional Problems

Alterations in the physical appearance of leaves, shoots, bark, flowers, fruit, or roots resulting from abnormal nutrient supplies form the basis for describing symptoms associated with particular conditions. Plant function has already been impaired by the time visual symptoms have developed. It should also be recognized that numerous external and internal factors other than nutrient supplies may be involved in the development of visually apparent symptoms in various parts of the tree. Deficiency symptoms of some elements are often induced by excessively high supplies of other elements. Multiple nutrient deficiencies modify or mask the symptoms of the individual nutrient deficiencies. Visual symptoms, therefore, should be used in conjunction with leaf analysis and soil testing in diagnosing nutritional status.

Definition of terms:

Chlorosis – loss of green color or yellowing.
Necrosis – death of tissue.
Pigmentation – development of colors other than green.
Wilting – drooping from lack of water.
Curling – rolling or twisting of leaves.
Dieback – death of shoots or branches from the outer extremities toward older wood.

Symptoms of Nutrient Deficiencies and Excesses

Nitrogen (N) deficiency

Leaves – Older leaves are affected first. Leaves are small, uniformly light green or yellowish. Necrotic spots in peach leaves drop out leaving a "shot-holed" appearance. Petioles may be reddish and form sharp angles with shoots. Tips and margins may show necrosis. Leaves develop bright colors and drop early in fall.

Shoots/spurs – Short, thin and spindly. Bark is yellowish-orange in color.

Flowers – Size may be reduced, pollination period shortened. Tendency toward alternate-year flowering and fruiting is increased.

Fruit – Fruit set may be reduced. Increased sensitivity to thinning agents. Increased June-drop. Fruit is small and highly colored.

Roots – Color is normal yellowish-white. Amount of root growth is abundant in relation to shoot growth.

General comments – Growth and fruiting of young trees is delayed. Trees are more susceptible to winter injury. Deficiency is aggravated by dry weather and/or weed competition. Symptoms may indicate physical damage to trunks, limbs, or roots, or impaired root activity as the result of disease, insect, nematode, or herbicide injury.

Nitrogen excess

Large, succulent, dark green leaves and excessive shoot growth. Large, poorly colored fruit with poor storage quality. Increased susceptibility to several diseases, such as fire blight of pear and apple. Prolonged growth in fall increases susceptibility to early cold and winter injury.

Phosphorus (P) deficiency

Leaves – New leaves are small, bluish-green, with purple pigmentation of leaf margins or main veins on undersides. Brown spotting or bronzing of leaves may accompany purpling in some species. Older leaves drop early.

Shoots – Shoots are thin, short, and upright. Lateral shoot development is reduced, buds fail to grow or start late.

Flowers – Flowering is reduced. Flowering is delayed in spring.

Fruit – Fruit quality is poor. Stone fruits may show greenish ground color, flesh may be soft, puffy, acidic, and of poor flavor.

Roots – Growth may be reduced.

General comments – Symptoms are more likely to appear early in the season and disappear later in summer. Deficiency is not generally seen in tree fruits, more frequently a problem with nonwoody plants and cover crops. May be a problem with nursery trees grown in fumigated soil and transplanted into fumigated soil.

Phosphorus excess

Symptoms are those of zinc and copper deficiencies.

Potassium (K) deficiency

Leaves – Symptoms appear in older leaves first. Leaves are small. Initial stages may consist of darkening or browning (etching) of undersides of leaf margins or yellowing of leaf margins. In some species the first symptom may be a recurving of petioles along with upward rolling of leaf blades. More advanced stages include necrosis advancing from margins toward the mid-rib. Necrotic tissue varies in color: pears, black; apples, brown; peaches and cherries, gray. Necrotic speckling and scorching of leaves is common.

Shoots – Reduced growth; slender shoots and weak spurs. Shoots may exhibit dieback in severe cases.

Flowers – Flowering is abundant with mild deficiency, decreasing or eliminated as the severity of the deficiency increases.

Fruit – Small, poorly colored, low acidity (lacks flavor). May hang on tree after leaf fall.

Roots – Color is normal but development is limited.

General comments – Potassium deficiency is more prevalent with heavy crops of fruit, high nitrogen levels, or inadequate water supplies. Susceptibility of trees to winter injury and blossoms to frost injury is increased by potassium deficiency.

Potassium excess

Symptoms of excessive potassium are those associated with deficiencies of magnesium and calcium.

Calcium (Ca) deficiency

Leaves – Identification of calcium deficiency symptoms is not usually possible because of simultaneous occurrence of other problems. In controlled studies, new leaves are affected first, developing thin chlorotic bands on margins. Chlorotic spotting and scorching in centers of spur leaves (may also develop in lateral shoot leaves) followed by defoliation beginning at shoot tips.

Shoots – Growth is stunted. Shoot tips may exhibit dieback.

Roots – Growth is severely restricted. Roots are stubby, short, and weak. Root tips die.

Fruit – Symptoms associated with calcium deficiency include bitter pit and cork spot of apples. Bitter pit is characterized by small, soft necrotic spots in the fruit flesh that collapse, leaving hollow areas, either prior to or after harvest. Cork spot is characterized by development of isolated hard corky areas in the flesh. Both disorders are more severe in large fruit or in light crop years, being intensified by high leaf-to-fruit ratios. Excess nitrogen or excessive pruning accentuate these problems.

General comments – Calcium deficiency symptoms are more severe in fruit from young trees and are accentuated by high potassium and nitrogen supplies. Wide fluctuations in moisture supply during the growing season increase the severity of problems associated with low calcium.

Calcium excess

No distinctive symptoms.

Magnesium (Mg) deficiency

Leaves – Mid-shoot and older shoot leaves and those on spurs bearing fruit are affected first, progressing toward younger leaves. Leaf size is not generally affected except in severe deficiencies. Marginal and/or interveinal chlorosis followed by necrosis and leaf drop. Color of affected areas may vary: yellow, reddish, brown, or black. Patterns of chlorosis/necrosis vary with species and status of other nutrient elements, particularly nitrogen. In some cases, loss of green color from leaf margins may leave a triangular area of green tissue along the midrib. In others, the chlorosis or necrosis may appear as isolated areas between the main veins of the leaf. Leaves on fruiting spurs show symptoms before those on nonfruiting spurs. Affected leaves drop early.

Shoots – Vigor is reduced. Shoots and spurs are thin, weak, and brittle.

Flowers – Not generally affected but flowering may be reduced if excessive leaf drop occurs early in the preceding summer.

Fruit – Matures and drops early. Preharvest fruit drop is accentuated.

Roots – Small in diameter and growth is restricted.

General comments – Deficiency is more severe on rapidly growing young trees or on trees with heavy crop loads. Aggravated by dry weather and increases in severity as potassium level increases. Early leaf drop leads to blind wood as result of poor lateral bud development on current season extension growth.

Magnesium excess

May compete with calcium uptake when soil supply of calcium is inadequate.

Boron (B) deficiency

Leaves – Young leaves may be small, twisted, thick, leathery, otherwise misshapen. Main veins may be large, lacking chlorophyll, cracked, or corky. Chlorosis and cupping are common. Leaves may form rosettes at nodes.

Shoots – Death of growing points with growth from lateral buds forming "witches brooms." Exudation of gum from necrotic areas on twigs. Shoots repeatedly die back from tips. Conducting tissues are poorly developed, resulting in wilting of leaves and shoots.

Flowers – Flowering is reduced. Abnormal development of flowers. Pollen development and germination are reduced. Blossom blast occurs in pears. Fruit set may be severely reduced.

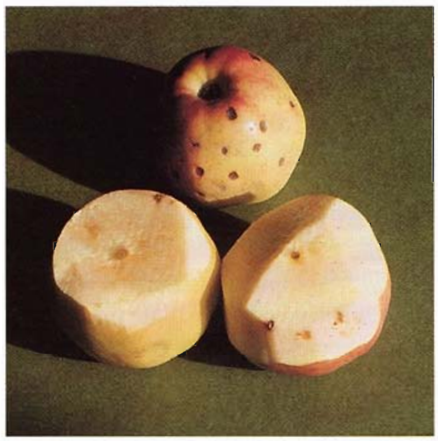
Fruit – Various types of external and internal corking disorders including drought spot, weather checking, and cracking of fruit. Fruit matures early and drops prematurely. Fruit surface may develop a pebbly appearance in some cases, gum-

Nitrogen deficiency–peach

Potassium deficiency–apple

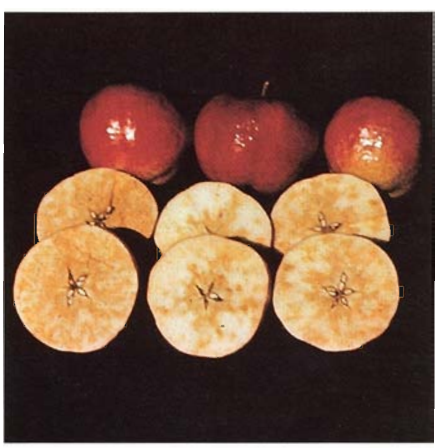
Magnesium deficiency–apple

Magnesium deficiency–sweet cherry



Calcium deficiency,
bitter pit symptom–apple

Calcium deficiency, senescent
breakdown symptom–apple



Boron deficiency–apple

Boron toxicity–apple

Zinc deficiency–peach

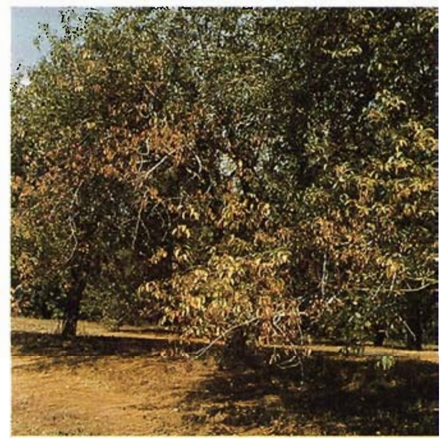
Zinc deficiency–tart cherry

Zinc deficiency (rosetting)–
tart cherry

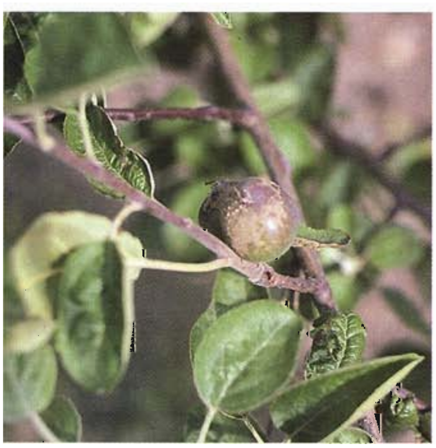
Copper deficiency–apple

Manganese deficiency–apple

Manganese toxicity (measles)–apple



Drought injury–sweet cherry



Cold injury–apple

Herbicide (diuron+terbacil) injury–apple

Herbicide (glysophate) injury–tart cherry ming may occur in other cases. Fruit has poor quality and a mealy texture.

Roots – Growth is restricted. Root tips become necrotic and die back.

General comments – Deficiency is aggravated by dry weather and heavy crop load. It is usually worse on coarse-textured soils and on heavily limed soils. Low boron supply may accentuate deficiencies of other nutrient elements because of impaired root function. Susceptibility of trees to winter injury is increased.

Boron excess

Symptoms include chlorosis of tissues along the midrib of the leaf. Defoliation occurs from shoot tip toward the base. Fruit maturity is advanced, with uneven ripening of areas of flesh within the fruit. Skin and flesh of stone fruits may exhibit cracking. Many symptoms of toxicity are similar to those of deficiency.

Zinc (Zn) deficiency

Leaves – Leaves at shoot tips are stunted, narrow, and misshapen. Terminal shoot leaves develop a mottled chlorosis of tissues between the veins. Leaf margins may be irregular or wavy. Rosettes of new leaves at the tips of shoots with poor growth of lateral shoot buds may be common.

Shoots – Growth is stunted, consisting of thin, weak wood. Shoots may die back early in the growing season.

Flowers – Flowering and fruit set are reduced.

Fruit – Fruit is small, pointed, poorly colored. Fruit ripens early and lacks flavor.

Roots – Growth appears normal.

General comments – Zinc deficiency is accentuated by high soil pH, excess phosphorus, high soil organic matter content, and low soil temperature. Trees and flowers are more susceptible to injury by low winter temperatures and frosts.

Zinc excess

Excessively high zinc levels may induce copper deficiency.

Copper (Cu) deficiency

Leaves – Newly developing leaves are stunted or misshapen, narrow with irregular margins. Young leaves may exhibit a whitish mottled chlorosis of tissues between the veins. Bronzing and necrosis of leaves may also be evident.

Shoots – Growth is stunted. Shoots are willowy. Shoot tips wilt and shoots die back. A proliferation of growth may occur from buds below the dead shoot tips. Dead leaves are brown and do not drop from the shoot. Lenticels on young shoots become enlarged and corky.

Flowers – Flowering may be reduced. Fruit set is reduced or eliminated.

Fruit – Fruit is small with poor color and quality.

Roots – Symptoms not adequately defined.

General comments – Copper deficiency is aggravated by high soil pH and high concentrations of phosphorus in soils and within the tree.

Copper excess

The first symptom of excess copper in the soil is death of roots. Subsequent leaf symptoms are those of deficiencies of other elements such as zinc.

Manganese (Mn) deficiency

Leaves – Mid-shoot and older leaves are affected first. Leaves may be thin and exhibit a "herringbone" chlorosis pattern between main veins. Chlorotic areas are light green to yellow. Affected leaves drop early.

Shoots – Growth is reduced and consists of weak, thin wood. Shoot dieback may occur when deficiency is severe.

Flowers – Flowering and fruit set are reduced due to limitation of photosynthesis in the leaves.

Fruit – Size and color may be reduced.

Roots – Symptoms not described.

General comments – Manganese deficiency is accentuated by high soil pH.

Manganese excess

Primary symptom is necrosis of the bark or "measles."

Iron (Fe) deficiency

Leaves – Yellow chlorosis of tip leaves while even small veins remain green. In severe cases the veins also lose green color. Necrosis of the tips and margins of leaves develops as the deficiency progresses.

Shoots – Growth is stunted and shoots may die back.

Flowers – Flowering and fruiting may be reduced.

Roots – Growth is stunted in severe deficiencies.

General comments – Iron deficiency is more frequent on soils with high pH or poor drainage.

Sulfur (S) deficiency

Leaves – Leaves at shoot tips develop a uniform yellow chlorosis. Orange and red pigmentation of tissue between veins may be followed by necrotic spotting.

Shoots – Growth is stunted. Shoots are thin, woody, and erect.

General comments – Information about sulfur needs and symptoms in tree fruits under northeastern conditions is too incomplete to provide more definitive descriptions.

DEVELOPING FERTILIZATION PROGRAMS

Fertilization programs must be developed on the basis of need as determined by the requirements of the crop and the characteristics of the soil on which it is being grown. Effects of soil management practices on nutrient availability, and of cultural practices such as pruning on tree vigor and nutrient requirements, are significant factors that must be accounted for in adapting the program to individual orchards. Above all other factors, however, the effect that the program has on yield and quality of the fruit crop must be the primary concern.

Physical soil conditions throughout the root zone affect not only the depth of rooting, but also the distribution and type of root system that develops. Slowly drained or imperfectly drained soils are subject to low-oxygen conditions that may result in damage to tree roots, impairment of root function, and alterations in the availability of various nutrient elements. Likewise, coarse-textured soils are more subject to moisture stress and may require special attention in dealing with elements such as nitrogen, boron, and magnesium. Many nutritional problems of orchards are often more directly attributable to poor soil physical conditions than to the fertilization program. Such problems must be identified and avoided or corrected before new orchards are established.

Fertilizer Nutrient Requirements and Sources

Lime

An adequate liming program based on soil tests should be the first consideration in developing orchard fertilization plans. Lime is the most economical source of calcium and magnesium. Regulation of soil pH through liming is also necessary to achieve optimal response to other nutrient elements.

Type and fineness of lime. Solubility of lime, and therefore the rate at which it is effective in neutralizing soil acidity, is influenced by the fineness to which it is ground as well as its chemical composition. Effectiveness is expressed as the Effective Neutralizing Value (ENV) and is an estimate of the percentage of the total weight that will react within the first year after application. Soil test recommendations for lime must be increased to account for the ENV of the lime to be applied. Additional information about the equivalent neutralizing values, and calcium and magnesium contents of limestones available for use in New York State is available from the Department of Soil, Crop and Atmospheric Sciences at Cornell University.

In general, hydrated (slaked) lime and burnt lime (oxides) are more reactive than ground limestone. Extra-finely ground limestone in a water-clay suspension (sometimes called liquid lime) is relatively quickly available, but low rates of application and high cost usually limit its long-term effectiveness. Of these forms, ground limestone is usually suggested for most orchard situations.

Placement of lime. Time required for lime to act is influenced by method of placement (i.e., soil contact) and by fineness of the material. In preparing soil before planting a new orchard, maximum benefit is obtained by thoroughly harrowing or rototilling the lime into the surface soil, and then plowing to work it as deeply as possible into the soil. If large quantities of lime are required it should be applied in split applications. Working one-half to two-thirds of the total amount of lime into the soil as indicated above, plus thoroughly harrowing the remainder into the topsoil after plowing, is often suggested as an appropriate method for liming during preplant soil preparation. With some fine-textured soils that require large quantities of lime, application of about two-thirds of the total lime required in such a manner, followed by biennial surface applications of additional lime may be necessary to achieve the desired goal.

Surface applications of lime in established orchards move slowly into the soil and must be considered as long term corrective or maintenance programs. Regularly scheduled applications of lime on a 2-, 3-, or 4-year interval basis, as predicted by soil tests, represent the best available means of maintaining pH and calcium and magnesium supplies in the soil.

The type of lime (i.e., calcitic or dolomitic) should be determined by the need for magnesium. In most cases, even if soil magnesium is fairly high, dolomitic lime is suggested for orchards. Dolomitic lime generally has a greater neutralizing value than calcitic lime.

Nitrogen

The direct relationship between nitrogen status and tree vigor is well substantiated. Likewise, the undesirable effects of excess nitrogen on fruit color, firmness, and storage quality are generally recognized. Managing nitrogen to obtain optimal results requires that the influence of a variety of factors on nitrogen requirements be considered.

Total annual utilization of nitrogen by mature apple trees on seedling rootstocks has been estimated at about 100 pounds per acre per year; 200 pounds per acre per year for peaches. Of this total, 30–40 pounds is permanently removed in a crop of apples, and 60–70 pounds in a crop of peaches. The remainder is used in developing leaves and wood and eventually may be recycled. Studies with apple trees on size-controlling rootstocks indicate that for practical purposes, the nitrogen requirements of mature trees can be considered to be proportional to the amount of structural wood contained in trunks, scaffold limbs, and large roots. Thus, trees on size-controlling rootstocks such as M.9 have a much lower total nitrogen requirement than those on less-dwarfing or seedling rootstocks.

Differences in the capacity of soils to supply nitrogen through normal biological processes probably have the greatest impact on the amount of fertilizer nitrogen required in orchards. New York State soils in management groups I, II, and III have the capacity to supply from 60 to 80 pounds of nitrogen per acre per year without additional fertilizer nitrogen application. Soils in groups IV and V are more variable but are capable of supplying from 35 to 80 pounds of nitrogen per acre per year. The efficiency of nitrogen fertilizer use with these soils varies from 55 to 80 percent.

Different methods of soil management, particularly within the tree row, alter the fertilizer nitrogen requirement through their effects on soil moisture and competition of the ground cover for nitrogen. Eliminating grass and weed competition with weed-free strips along the tree-row effectively reduces the need for nitrogen fertilizers by 60 percent or more. Under such conditions, fertilizer nitrogen requirements may vary from less than 15 to more than 75 pounds of nitrogen per acre per year. Failure to compensate for soil and sod management differences of these magnitudes often result in excessive nitrogen uptake and the associated problems of excessive tree vigor, poor fruit color, and loss of storage quality. Complete sod cover within the row reduces nitrogen and decreases the efficiency of fertilizer nitrogen use by the trees; therefore, with sod covers higher rates of nitrogen fertilization are required.

Leaf nitrogen values, plus grower observations and experience, offer the best means for adjusting the rate of nitrogen fertilizer use. In general, a 10 percent increase or reduction in nitrogen application is usually reflected as a 0.1 percent change in leaf nitrogen content. Differences in vigor or coloring potential of varieties or strains, water availability, and pruning practices must also be considered. In some cases, nitrogen may have to be eliminated from fertilization programs for one or more seasons to achieve the desired goal.

The method of placement of nitrogen fertilizer materials also influences the application rate. Root development is limited by sod competition, and elimination of this competition, as by using herbicides, results in more profuse root development throughout the soil under the treated area. Maximum efficiency of fertilizer use would result from applications limited to the weed-free area. Spreading the fertilizer under the trees in rings or bands or over the weed-free strips along the tree rows is more efficient, requiring one-third to one-half the amount of material needed in broadcasting over the entire orchard floor.

During preplant soil preparation, an application of nitrogen at 40 pounds per acre is suggested for cover crop establishment. An additional 40 pounds per acre is suggested when the cover crop is plowed down or when seeding the permanent grass sod. Animal manures, if used, should be applied before establishing the cover crop, prior to plowing in the cover crop, or thoroughly disked into the soil after plowing down the cover crop.

Immediately after new trees are planted in early spring, an application of 3–5 gallons per tree of a water-soluble fertilizer solution, such as 6 pounds of 20-20-20 mixed in 100 gallons of water, is suggested. This helps to settle the soil around the roots and provides a small amount of readily available nutrients. During the first season care must be exercised to avoid damage to the trees by dry fertilizers. In most cases, an application of 0.6–1.0 ounce of actual nitrogen per tree applied after leafing out provides adequate nitrogen for the first season. This rate is equivalent to 4–6 ounces of calcium nitrate or 2–3 ounces of ammonium nitrate per tree.

A second application at these rates, applied one month later, may be needed on coarse-textured soils that are low in organic matter, did not have manure applied, or did not have a green manure crop plowed down.

In the second season, an early spring application of actual nitrogen at the rate of 0.1–0.2 pound per tree, depending upon soil texture, should provide enough nitrogen to supplement the soil supply. If this application is made by means of a spreader that places the fertilizer in a 3–4 foot wide band centered on the tree row, 40–60 pounds of actual nitrogen per acre are usually sufficient. Foliar applications may then be used as necessary to supply additional nitrogen.

Beginning in the first or second season, leaf samples taken during the first two weeks of August should be used to determine the need for adjusting subsequent nitrogen applications.

Sources of nitrogen. Ammonium nitrate and urea are the most frequently used sources of nitrogen. Characteristics of these and some other commonly available nitrogen sources are summarized in Table 5.

The acidity/basicity values indicate the residual effects of fertilizer materials on soils in terms of pounds of pure limestone ($CaCO_3$) required to neutralize those with acidic residues, or the amounts of limestone equivalent to those with basic residues. The acidic residue of ammonium nitrate applied at 100 pounds per acre (33.5 pounds actual N) would neutralize approximately 62 pounds of pure $CaCO_3$. Conversely, the basic residual of calcium nitrate applied at a rate of 216 pounds per acre (33.5 pounds actual N) would be equivalent to the addition of approximately 43 pounds of limestone. Because the cost of lime is much lower than the cost of nitrogen, the choice of the form or source of nitrogen for soil applications is most frequently made on the basis of cost per unit of nitrogen. One should be aware, however, that nitrogen applications do increase soil acidity and lime requirements.

Animal manures vary in composition according to the animal source, method of handling, and amount of bedding, litter, or other materials mixed with them. When accurate nitrogen rates are to be applied, a manure analysis is required to determine manure rates to be used.

Numerous orchard trials indicate that the source of nitrogen used in soil applications is less important than the amount of actual nitrogen applied. An exception to this is that calcium nitrate may be preferred for application to newly set trees after they have leafed out, since it is less likely to burn tender trunk tissues.

Research with field crops indicates that as much as 30 percent of the nitrogen content of urea may be lost by volatilization from soil surface applications that are not incorporated. This has rarely been a significant factor in orchard fertilizer trials to date, probably because of the lower rates of application involved, low quantities of nitrogen required by the trees, and the large pool of soil nitrogen available.

Table 5. Characteristics of commonly available sources of nitrogen.

			Acidity or Basicity (lb $CaCO_3$/lb of N)	
Source	*Percent nitrogen*	*Pounds per 1 lb N*	*Acidity*	*Basicity*
Ammonia, anhydrous	82	1.22	1.8	–
Ammonia, aqua	20	5.00	1.8	–
Ammonium nitrate	33.5	2.98	1.8	–
Ammonium polyphosphate	12	8.33	4.1	–
Ammonium sulfate	20.5	4.88	5.4	–
Calcium nitrate	15.5	6.45	–	1.3
Diammonium phosphate	16–18	5.56	4.1	–
Monoammonium phosphate	11	9.09	5.3	–
Nitrate of soda-potash	15.5	6.45	–	1.3
Potassium nitrate	13	7.69	–	2.0
Sodium nitrate	16	6.25	–	1.8
Urea	45	2.22	1.6	–
Nitrogen solutions	variable[1]	–	–	–

[1]Nitrogen solutions may consist of mixtures of urea plus ammonium nitrate, aqua ammonia, or anhydrous ammonia plus urea or ammonium nitrate or both of these materials. Consult supplier for analysis.

Phosphorus

Phosphate fertilization of orchards is often overemphasized. Requirements of mature fruit trees for phosphorus are relatively low. Estimated annual removal by the fruit is approximately 10–20 pounds per acre of elemental phosphorus (20–45 pounds of P_2O_5).

Ordinary superphosphate (0–20–0) and triple superphosphate (0–45–0) are the sources most frequently used in orchards. Monoammonium phosphate (11–48–0), diammonium phosphate (20–54–0), various other phosphate compounds, and animal manures are additional sources of phosphorus used in preplant soil preparation or in established orchards.

Greatest attention should be placed on preplant incorporation of phosphate throughout the rooting zone, at least in the upper 16-inch depth of the soil. Applications of phosphates to the soil surface in established orchards are inefficient in meeting crop needs and have not resulted in economic responses in trials conducted in New York. High rates of phosphate application can increase zinc and copper deficiencies. Surface applications of excessive amounts of phosphate fertilizer are also likely to contribute to water pollution through surface runoff of rain or irrigation water. Incorporation of appropriate rates of phosphate during preplant soil preparation should provide ample phosphorus for the life of the orchard, provided that soil pH is maintained in a range of 6.0–6.5 throughout the root zone. Liming increases the availability of phosphorus without additional phosphate application.

Potassium

Potassium deficiencies are common in orchards of the Northeast. Potassium requirements of tree fruits are frequently greater than for nitrogen. Total use in tree crops approximates 120–200 pounds of potassium (150–240 pounds of K_2O) per acre, about half of which is permanently removed in the fruit crop.

The form of potassium applied should be determined on the basis of both the amount of potassium required and the available soil magnesium. Muriate of potash (0–0–60) is a suitable material if the magnesium supply is high. When both potassium and magnesium supplies are low both elements should be applied using a material containing both elements, such as sulfate of potash-magnesia (0–0–22–11). When the magnesium supply is adequate, and only small amounts of potassium and nitrogen are needed, nitrate of soda-potash (15–0–14) may be a suitable material. Because stone fruits are sensitive to chloride, an alternative to muriate of potash (potassium chloride) should be considered whenever large amounts of potassium are needed for established trees. An application of muriate of potash in the fall after harvest is less likely to present a problem with the stone fruits than if applied in early spring.

The amount of fertilizer potassium required is influenced by the potassium-supplying ability of the soil as discussed under soil test interpretation. Coarser-textured soils with lower potassium-supplying ability generally require greater attention to both rate and frequency of application of potassium fertilizers than do the finer-textured soils. However, root development in clay loam and clay soils may be limited to the extent that potassium fertilizer requirements are as great as loams and silt loams. For practical purposes, unless the soil potassium supply exceeds the values indicated under soil test interpretation, minimum rates of application under New York conditions should be about 80–100 pounds of fertilizer potash (K_2O) per acre per year.

As with nitrogen, placement influences efficiency of potassium fertilizer use. Spreading the material evenly over the weed-free band in herbicide-strip management systems, or under the tree canopy, is more efficient and requires less material than broadcasting over the entire orchard floor. Applying potassium fertilizers in narrow, 6–8 inch bands on both sides of the row approximately one-half the distance from the trunk to the outer spread of the branches also has been effective.

Timing of potassium fertilizer applications is not as critical as with nitrogen. Applications after harvest but before the soil freezes have resulted in a more rapid plant response than similar applications the following spring. Fall is preferred when appreciable amounts of potassium must be applied.

Calcium

Limestone is the primary and most economical source of calcium. A consistent soil testing and liming program is a basic requirement in managing soil calcium supply. The calcium requirement, as determined by soil test results, should be used to determine the amount of lime required.

Gypsum (24 percent calcium) has been used as a source of calcium, but has not been shown to be more effective than lime in supplying calcium under orchard conditions.

Other materials commonly used as soil-applied fertilizers containing calcium include ordinary superphosphate (20 percent) and triple superphosphate (14 percent). Calcium nitrate (24 percent) has also been considered as an additional source for orchards; however, the actual amount of calcium applied is minimal at normal rates for nitrogen. For example, the application of 216 pounds of calcium nitrate per acre (33.5 pounds of actual N) would contribute approximately 45 pounds of calcium per acre.

Magnesium

As a general rule, the magnesium required in orchard soils is very similar to that for soybeans and birdsfoot trefoil—double the amounts suggested for most crops. Dolomitic limestone is the most-used source, but the magnesium content of dolomitic-type limestones from different sources varies considerably. Whenever possible, dolomitic-type lime should be selected for its magnesium content and the amount of magnesium required. Since the magnesium in dolomitic limestone is not immediately available to the trees, it may be necessary to initially supplement the lime applications with a more soluble form of magnesium in some situations.

Other sources of magnesium for soil application include kieserite (17.3 percent), magnesium oxide (49–56 percent), sulfate of potash-magnesia (11 percent), and Epsom salts (10 percent magnesium). Soluble forms such as sulfate of potash-magnesia or kieserite are preferred to magnesium oxide for surface applications, but if thoroughly incorporated into the soil, as in preplant preparation, magnesium oxide can be used effectively.

Boron

Soil applications of boron are essential in managing the supply of this element. Inadequate soil boron frequently results in poor root growth and inefficient uptake of other nutrients such as calcium and potassium. Boron is readily mobile within the soil and can be effectively supplied through soil surface applications in established orchards. When a new site is being prepared for planting, it is recommended that appropriate amounts of boron be thoroughly mixed into the topsoil.

Annual application of boron, either mixed with other fertilizer materials or as a separate application, is suggested for meeting the basic need for this element. Rates of boron to be applied are determined on the basis of the soil texture, boron already present as indicated by soil test (see soil test boron table), and the crop. For apples and pears, rates of elemental (actual) boron suggested for application include: none if the soil test level is already very high, 1 pound per acre if the soil test is high, 2 pounds per acre if the soil test is medium, and 3 pounds per acre if low. When a soil test is not available, a rate of 2 pounds per acre is suggested for apples and pears when the boron level in leaf samples is less than 35 ppm.

Stone fruits such as peach are extremely sensitive to both deficiencies and excesses of boron and should be treated only if the leaf analysis and soil tests indicate a need for boron application. **Rates of boron for soil application in stone-fruit orchards should not exceed one-half of the rates indicated for apples and pears unless both soil and leaf analysis results indicate that greater amounts are required.**

Granular fertilizer-grade borate (14.3 percent boron) applied at 7 pounds per acre of orchard provides 1 pound of actual boron. For convenience, this material can be blended with other fertilizer materials. Solubor® (20 percent boron) applied with an herbicide sprayer has also been effective.

A complete boron program frequently includes both a soil application to meet the basic need of the crop, plus one or more foliar applications to supply additional boron at critical stages of crop development.

Zinc

Surface applications of zinc fertilizers in established orchards have not been sufficiently effective to be recommended. Availability of zinc is reduced by high soil pH, high levels of soil phosphorus and soil organic matter, and by low soil temperature.

Current studies involving thorough incorporation of zinc sulfate to provide 120 pounds of zinc per acre during preplant soil preparation suggest that this approach may be beneficial, but require further evaluation.

Manganese

Supplemental manganese applications may be required in orchards on high pH, well-drained, coarse-textured soils and on some finer-textured soils. Applications of manganese sulfate to the soil or in foliar sprays have been effective. Soil applications have been more effective on sandier soils than on those of finer textures. Effectiveness of soil applications of manganese is primarily determined by soil pH, being severely reduced at pH 6.5 or higher. Since manganese availability is reduced as soil pH increases, foliar applications are frequently more cost-effective.

Standards for interpreting soil test results for manganese are not well developed. If a manganese deficiency is suspected, thorough incorporation of manganese sulfate at rates to provide 120 pounds of manganese per acre during preplant soil preparation is suggested as a means of supplying this element.

Copper

As with zinc, copper applications to the soil surface are generally ineffective for orchards. Thorough incorporation of copper sulfate to provide 90–120 pounds of elemental copper per acre during preplant soil preparation has been beneficial in terms of tree growth and leaf copper.

General Comments on Preplant Soil Preparation

Thorough incorporation of fertilizer and lime throughout the rooting zone, at least the top 16–20 inches of the soil, increases their long-term effectiveness. Because of the expense of applying relatively large quantities of materials such as zinc, copper, and manganese sulfates, it is suggested that these materials be worked into bands of 5- to 6-foot widths centered on the intended tree rows. These applications should be completed during the season prior to anticipated planting to minimize the potential for injury to plants from high salt concentrations.

When large quantities of materials are applied, two-thirds of the total should be lightly disked into the topsoil and then plowed to a depth of 12–14 inches; then apply the remaining one-third and thoroughly disk it into the upper 8–10 inches.

Foliar Application of Nutrients

Foliar application of nutrients provides an opportunity for supplying essential elements directly to the foliage, flowers, or fruit at times when rapid response may be required. Cold weather during bloom or cold soils in the spring often limit the availability of nutrients while increasing the plant requirements during this critical period. Likewise, the amounts of certain elements required for the rapid development of foliage and shoot growth during the grand period of growth often exceeds the rate at which they can be supplied by normal root absorption and transport processes. In still other cases, foliar application may offer the best means of supplying a particular element, either because it cannot be effectively supplied through the soil, or to precisely control the time and rate that the element is available to the plant. Foliar application of nutrients should, however, be considered as a method for supplementing soil-applied fertilization programs, not as a substitute for them.

Foliar application of nutrients involves the possibility of either damage to the crop or ineffectiveness from inappropriate rates, methods, or timing. The two major points governing this are: 1) the proper rate to apply in the individual orchard situation, and (2) the manner and time appropriate for the specific situation.

Differences in tree sizes and densities of planting make the tree-row-volume technique of determining the amount of material to be applied most suitable for adjusting rates to various orchard situations. Cornell recommendations are based on the application of 0.7 gallon of dilute spray equivalent per 1,000 cubic feet of tree-row-volume of well-pruned trees. Determining the dilute spray requirement in this manner provides the basis for calculating the appropriate rate of material per acre.

After the appropriate rates of materials have been determined, how the sprayer is set up to apply them must be considered. The volume of water used to apply different materials to the intended target should be determined by the type of material and/or the purpose for which it is being applied. Nutritional sprays should be applied in sufficient volumes of water to ensure adequate uptake by the foliage during the initial wetting period. Thus, relatively high volumes of water are required for optimal results. Most studies have shown that concentrating tank mixes of nutritional sprays by a factor of 6 or 8X increases both the difficulty of obtaining thorough distribution and the risk of injury to the crop. It is therefore recommended that nutritional sprays be applied as dilute or near dilute—not over 3X concentrate—sprays (mixing at 3 times the dilute rate per 100 gallons of spray and applying this mixture at one-third of the gallonage required for a dilute spray).

Weather conditions at the time nutritional sprays are applied should be closely monitored. Slow drying conditions or high temperatures, i.e., relative humidity approaching 80 percent and/or temperature approaching 80°F, favor increased absorption of the applied materials, but also increase the potential for injuring the foliage or fruit.

Nitrogen

Reasons for using foliar applications of nitrogen might include adjustment of the nitrogen status of flower buds to encourage improved fruit set and to supplement or replace a part of the nitrogen applied to the soil. A low nitrogen status of flower buds leads to a more rapid degeneration of the ovules, so reducing the effective pollination period. This is of particular importance during long, cool bloom periods when pollen tube growth is retarded. In such situations, nitrogen sprays either in the fall (between harvest and leaf drop) or prior to bloom in the spring are often beneficial. Fruit set on trees low in nitrogen, i.e., with previous-year leaf sample levels below about 2.2 percent, may be improved by using nitrogen sprays. Nitrogen sprays should also be considered in the year following a heavy crop. Such sprays are not likely to be beneficial if the previous-season leaf samples contained 2.4 percent or more nitrogen.

Other situations in which nitrogen sprays may be useful include those where maximum vegetative growth is desired or where soil applications might result in excessive nitrogen being taken up by the trees at times detrimental to fruit color or quality or to maturation of the woody tissues.

Inclusion of nitrogen in sprays containing some of the other nutrients often increases their uptake by the foliage. Urea is the most frequently used form of nitrogen for foliar application to apples and pears. Foliar sprays of urea are not recommended on stone fruits because they do not absorb and utilize urea efficiently. Because of danger of injury to foliage, only those formulations of urea that contain less than 0.25 percent biuret should be used in foliar sprays. The usual rates of application suggested are 3 pounds of urea (1.35 pound N) per 100 gallons (dilute rate equivalent) in prebloom sprays, and 5 pounds of urea (2.25 pounds N) per 100 gallons in petal fall or later sprays. Tank-mix concentrations of urea at rates greater than 10 pounds per 100 gallons may injure young foliage.

Foliar applications of nitrogen applied later than 10–14 days after petal fall may delay fruit coloring and increase the risk of early winter cold injury to the trees. Applications later than this should be avoided unless there are visual symptoms of nitrogen deficiency.

Calcium nitrate has been used in foliar applications on apples and pears, but is not recommended on certain apple varieties such as Delicious because it may induce the development a cork spot-like disorder in the fruit.

Potassium

Foliar application of potassium to fruit trees has been beneficial in orchards on soils with inadequate supplies, but not in those containing adequate potassium. The source of potassium for use in foliar sprays must be chosen carefully. Potassium nitrate (46.5 percent K_2O equivalent) and potassium sulfate (27 percent K_2O equivalent) are most frequently used for foliar application. Rates of 6–10 pounds of either material per 100 gallons of water, applied as a dilute spray, have been suggested when foliar symptoms of potassium deficiency are present. Trials with various complete (N-P-K) materials formulated for foliar application indicate that these usually contain too much nitrogen and phosphorus and not enough potassium to meet crop needs. These trials indicate that the amount of potassium required to obtain a significant improvement in fruit size and/or color with apples is similar to that recommended for soil application; i.e., 60 pounds or more of K_2O per acre.

Magnesium

Foliar sprays of Epsom salts ($MgSO_4$-$7H_2O$) are an effective temporary means of supplying magnesium to many fruit crops. These sprays supply enough magnesium to prevent deficiency symptoms if used at the appropriate rate and time, but they should be considered as a supplement to, rather than a substitute for, adequate soil applications of magnesium.

In mature orchards, three sprays applied at 10- to 14-day intervals beginning at petal fall may be adequate. The suggested rate of Epsom salts for these sprays is 15 pounds per 100 gallons of dilute spray equivalent (1.5 pounds Mg). Such sprays have been effective at tank-mix concentrations up to 15X. Avoid the application of Epsom salts under slow-drying or high-temperature conditions when severe damage to the foliage may occur.

Magnesium chelates have a low magnesium content and have not been sufficiently effective as foliar sprays.

Calcium

Foliar applications of calcium are frequently used in established apple orchards to prevent fruit disorders such as bitter pit, cork spot, and senescent breakdown during storage. Both calcium chloride and calcium nitrate have been suggested for controlling bitter-pit and cork spot, and for delaying senescent breakdown in certain varieties of apples. This approach should be considered as a special treatment when low-calcium-related problems are likely to be exaggerated and not as a substitute for an adequate liming program. Such conditions include orchards where soil calcium is inadequate, where trees are extremely vigorous as a result of excessive pruning or over-application of nitrogen, or where fruit set is below normal.

Calcium chloride (78 percent $CaCl_2$) applied at a rate of 1–2 pounds per 100 gallons, dilute equivalent basis, in 3 or 4 sprays at 14-day intervals beginning 7–10 days after petal fall, followed by 2 sprays at 3–4 pounds per 100 gallons, 4 and 2 weeks before harvest, provides partial control of these disorders. These rates provide 27–48 pounds of $CaCl_2$ (7.5–13.4 pounds Ca) per acre for orchards that require 300 gallons of dilute spray per acre for thorough coverage. Rates should be reduced according to tree-row-volume for smaller trees to minimize injury to foliage and fruit. In some areas, calcium chloride is added to each of the summer pesticide applications. These sprays may cause foliage and/or fruit injury if applied when low temperatures and wet weather delay drying of the spray, and under high temperature (over 80°F) and/or high humidity conditions.

Calcium nitrate applied at 2–4 pounds per 100 gallons, dilute equivalent basis, may be used in place of calcium chloride to control bitter pit, but is not suggested for Delicious and York Imperial. These and possibly other varieties develop a cork spot-like disorder when sprayed with calcium nitrate.

Chelated forms of calcium have not been effective as foliar sprays because of the low amounts of calcium that they provide.

Alternative proprietary calcium compounds are available for use as foliar sprays and/or dips. Effectiveness of these are comparable to that of calcium chloride when used at rates providing equivalent rates of calcium. Likewise, the relative crop safety is similar to that of calcium chloride when applied at equivalent rates.

The best control of bitter pit that develops after harvest and senescent breakdown during storage has been obtained with postharvest dipping or flooding of fruit with a solution containing 20 pounds of calcium chloride (7.2 pounds Ca) per 100 gallons of water.

Boron

Foliar applications containing boron have been effective for preventing drought spot, checking and cracking of the fruit surface, and internal corking of the fruit, as well as shoot dieback from boron deficiency. Additionally, postharvest and prebloom foliar boron sprays have been shown to increase fruit set. Foliar applications of boron are not effective in supplying adequate amounts of this element to the roots of fruit trees.

Rates and timing of boron sprays may vary according to their purpose. Prebloom to bloom sprays are usually applied from the time that blossoms are exposed in the bud until and including full bloom, using rates of 0.5–1 pound of Solubor® (the most common boron source for foliar application) per 100 gallons of dilute spray equivalent. These rates provide 0.3–0.6 pound of B per acre in orchards that require 300 gallons of dilute spray equivalent for thorough coverage. A prebloom application is suggested when the previous-season leaf sample boron level is less than 35 ppm. This application provides boron to the flower during the critical period of development of the ovules and anthers, improves pollen germination and pollen tube growth, and improves early season leaf and shoot growth. A prebloom spray of boron is also beneficial in overcoming the effects of winter injury to buds. Prebloom foliar applications of boron have little effect on boron content of leaf samples collected in mid-summer, but do increase calcium uptake in some cases.

Postbloom sprays containing 1 pound of Solubor® (0.2 pound B) per 100 gallons of dilute spray equivalent are frequently recommended at petal fall or in one or more cover sprays within the first month after petal fall. These sprays have a greater effect than prebloom applications in preventing cork formation or premature fruit ripening due to boron deficiency, and in increasing the leaf content of boron, but usually have little effect on calcium uptake. Boron sprays generally should not be used late in the season because of the possibility of stimulating abnormal ripening and breakdown of the fruit. Applications 7–10 days after petal fall and at approximately 30 days after petal fall may be required with crops such as apples and pears.

Postharvest boron sprays have been beneficial in improving fruit set of pears, prunes, and cherries in some cases. This response is independent of any increase in leaf boron content during the following season and is based on improved development of the reproductive organs within the flowers. Rates of 1–2 pounds of Solubor® per 100 gallons of dilute spray equivalent are suggested for postharvest applications while the foliage is still active.

Although boron sprays have been applied successfully using low-volume spraying equipment, this method increases risk of injury from overapplication, particularly near the sprayer manifold. Further, since boron applied as a foliar spray is not readily mobile within the tree it is essential to obtain thorough and uniform coverage. Therefore, tank-mix concentrations of 1X to 3X should be used when possible, and should not exceed 6X–8X.

Foliar applications of boron should be used to supplement soil applications but should not be applied unless the boron status of the trees is known. Because of the extreme sensitivity of apricots and peaches to excessive boron, foliar and soil applications to these crops must be made with utmost caution.

Zinc

Foliar application is effective for supplying zinc to established fruit trees. One of the most critical periods that a zinc shortage may seriously impair tree performance is between budbreak and fruit set. A zinc shortage at this time often results in poor growth of the leaves and new shoots as well as abnormal development of pollen tubes, ultimately resulting in poor seed set. Later in the season, the effects of limited zinc are small fruit and/or poor color development. Zinc is not readily mobile within the tree and applications must be thorough and timely for optimal response.

Various methods of applying zinc are available, the most common being late-dormant sprays of zinc sulfate, summer applications of zinc chelates or other materials, and postharvest applications of zinc-containing products. Zinc-containing fungicides have been partially effective in established orchards, but have not met total requirements or completely corrected a zinc deficiency.

Application of zinc-sulfate (20 or 36 percent zinc) at the late-dormant period for stone fruits, or dormant to silver-tip stage for apples and pears is effective in supplying part of the total zinc requirement. These materials are applied at approximately 3.5–5 pounds of actual zinc per 100 gallons as dilute sprays, alone or with fresh hydrated lime as a safener. These sprays should be dilute (not over a 2X tank-mix concentration) to obtain adequate coverage of the buds and shoot surfaces. Oil sprays following zinc sulfate dormant sprays increase penetration of the zinc sulfate into buds and spur tissues and have resulted in extensive damage. Likewise, freezing weather (frosts) occurring within 2–4 days before or after the dormant spray has increased the uptake of zinc sulfate and resulted in killing of spur systems on apple trees.

Sprays of EDTA-zinc chelates provide a greater degree of safety and can be applied during later stages of tree growth. Two or more sprays of the EDTA-zinc chelates applied at 10- to 14-day intervals beginning 1–2 weeks after petal fall are frequently required in a zinc maintenance program. Several formulations of chelated zinc are available and should be used at rates recommended by the manufacturers. A prebloom application may also be needed to stimulate early bud, leaf, and shoot development if the zinc status of the orchard is marginal to deficient. In any case, foliar applications of zinc are necessary on an annual basis and not as a one-time curative treatment.

CAUTION: Several forms of chelated zinc are available, many of which have not been thoroughly evaluated for use on fruit crops. For example, NTA-zinc chelate is used safely in fertilizers applied to the soil for some crops and through trickle irrigation systems for tree fruits, but this material has caused severe defoliation when used as a foliar spray. Consult local fruit specialists if there are questions about a particular material.

Zinc oxide has been suggested for foliar application, but has not improved tree performance. Leaf samples from trees sprayed with zinc oxide or similar materials may show high levels of zinc, but a high percentage of this zinc is apparently present as physiologically inactive contamination.

Postharvest tree sprays of zinc materials have shown variable results. In some cases, 3–6 pounds of 36 percent zinc sulfate in combination with 5 pounds of urea per 100 gallons as a dilute spray has been effective in mature apple orchards following harvest. In other cases, this and other materials applied in this manner have not justified recommendation.

Manganese

Manganese can be effectively supplied to fruit trees by soil application, but in many cases foliar application of either manganese sulfate or manganese-containing fungicides is more economical. One spray of manganese sulfate at a rate of 2 to 4 pounds (0.5–1.0 pound Mn) per 100 gallons, dilute equivalent, applied 7–10 days after petal fall is often adequate to prevent deficiency symptoms over the remainder of the season.

Manganese-containing fungicides have provided enough of this element to prevent the appearance of deficiency symptoms when used in several postbloom sprays at rates normally applied for disease control.

Alternative manganese sources for foliar application, including chelated forms, should be used according to product label instructions. Some product labels caution that they should be used with a zinc material, i.e., the EDTA chelates, to minimize the potential of injury. It is advisable to test these materials on a limited scale before assuming that they are safe and effective for use in a particular situation.

Copper

Foliar applications of Bordeaux mixtures or fixed-copper fungicides are usually effective in supplying copper to fruit trees. Use extreme caution with these materials as sprays because they can cause severe injury to young leaves and russeting of the fruit. It is suggested that these materials be applied only when deficiency symptoms occur or foliar analyses indicate a need. For apples and pears, a spray of a fixed-copper fungicide such as tribasic copper sulfate at labeled rates is suggested for application between the green-tip and one-fourth inch green stage of development if the previous year's leaf samples contain less than 7 ppm copper. Applications of most copper compounds after flower buds have emerged have generally been unsatisfactory because of fruit and leaf injury.

In severe cases of copper shortage, a postharvest spray of a copper-containing fungicide in addition to the green-tip spray has been more effective than either spray alone.

In general, when leaf samples indicate a need for copper in any of the tree fruit crops, it is suggested that copper-containing fungicides be used at times and rates recommended for disease control on that crop. Examples of such uses include the control of fire blight in apples and pears, black knot in plums and prunes, leaf spot in cherries, and leaf curl in peaches.

Research on applying low rates of some copper materials during the later part of the growing season is encouraging, but there is insufficient evidence to recommend this practice.

Special Considerations in Foliar Application of Nutrients

To minimize the number of sprays applied in the orchard it is frequently desirable to combine various nutrient materials, or to add them in tank mixes with pesticides. Several precautions must be observed, however.

Fixed-copper fungicides used as a source of copper at the late-dormant to one-fourth inch green stage of development, according to crop, are compatible with superior spray oils that might be applied at that time.

Generally, urea, Solubor®, EDTA-zinc chelates, and Epsom salts are compatible. Urea, Solubor®, and EDTA-zinc chelate have been used together safely in prebloom sprays on apples and pears. A tank-mix combination of urea plus Epsom salts has sometimes injured young apple foliage; if both are required we suggest they be applied as separate sprays.

Solubor® and presumably other forms of boron should not be tank-mixed with any pesticide contained in water-soluble plastic packages because it inhibits the dissolution of the plastic. Solubor® should not be tank-mixed with oil.

Epsom salts may increase the pH of the tank mix, and if used with pH sensitive pesticides such as organophosphates, or miticides, or some fungicides, pH of the tank mix should be tested and adjusted by adding a suitable buffering agent.

Although Epsom salts, Solubor® and EDTA-zinc chelate are compatible for use in postbloom sprays, many orchardists prefer not to add all three to one tank mix. A petal fall spray may then contain Epsom salts alone or with Solubor®; the first cover spray (7–10 days after petal fall) a combination of Epsom salts plus Solubor®; the second cover spray (10–14 days later) a combination of Epsom salts plus EDTA-zinc chelate; and the third cover spray (14 days later) a combination of Solubor® plus EDTA-zinc chelate.

Calcium chloride generally contains lime as a contaminant and adding it to a tank mix will raise the pH of the solution. As indicated for Epsom salts, pH of the tank-mix solution should be tested and adjusted if pH-sensitive pesticides are included. Combining calcium chloride with Epsom salts may present a problem under some conditions when they react to form a calcium sulfate precipitate.

Unless the compatibility of a particular nutrient source with a pesticide is known it is more judicious to apply them separately. Physical compatibility of materials can be easily determined by mixing the appropriate rates of them in a jar of water. This test does not provide information about possible chemical incompatibilities, however. Check product labels and with industry representatives before mixing to be sure that various tank mixes are appropriate.

Fertigation

Application of fertilizers through irrigation systems is referred to as fertigation. Although fairly common in arid areas, experience with fertigation under humid conditions is limited. The most feasible use of this technique in orchards of the Northeast is for adding various soluble fertilizer materials through trickle or drip irrigation systems. The efficiency of fertilizer uptake and use with this method is enhanced because applied materials move rapidly to the root system with the water. As suggested here, the use of this approach presumes that additions of lime, phosphate, and other nutrients have been completed as specified in preplant soil preparation.

Trials conducted in New York during the past five years indicate that nitrogen, potassium, magnesium, boron, and zinc can be effectively supplied through fertigation. In these trials, the total amounts of fertilizer materials to be supplied were applied in 10 weekly applications.

The fertilizer materials should first be dissolved in water before injecting them into the irrigation lines. The system should be run long enough to fill the lines with water before injecting the fertilizer solution, and completely flushed after the injection has been completed to avoid plugging by undissolved salts or other contaminants.

Ammonium nitrate is a suitable source of nitrogen for trickle irrigation systems.

Monoammonium phosphate or other forms of phosphates should not be used with magnesium sulfate (Epsom salts) because the reaction between these materials will form insoluble magnesium phosphate that will plug the emitters.

Rates of 0.5–0.75 ounce of ammonium nitrate per tree in each of 10 weekly applications have been used to provide 0.1–0.15 pound of actual nitrogen per tree over the season. These rates may be satisfactory for young nonbearing trees, but must be closely followed through leaf analysis and adjusted as necessary to achieve the desired nitrogen levels in leaves.

Application of potassium through trickle irrigation systems also offers an efficient means of meeting crop requirements. Trials to date indicate that muriate of potash (0–0–60) is a suitable source. Rates of muriate of potash in the range of 100–120 pounds (60–72 pounds K_2O) per acre of orchard per season, using 10–12 pounds per acre per application, appear to be appropriate but should be adjusted as indicated by leaf analysis.

Epsom salts or magnesium sulfate solutions can be used to provide magnesium in fertigation. Weekly applications of 35–40 pounds or more of Epsom salts (3.5–4.0 pounds Mg) per acre of orchard may be required. As indicated under nitrogen sources, no phosphate materials should be applied at the same time that magnesium sulfate is being injected into the irrigation system.

Solubor® is a suitable source of boron for fertigation, but rates of application must be closely monitored. A rate of 0.5–1.0 pound of Solubor® per acre of orchard (0.1–0.2 pound of actual B per acre) per application has been used successfully with young apple trees growing on a silt-loam soil. This rate may provide more boron than is required for coarse-textured soils because of the increased efficiency of uptake with this method. We suggest that these rates be reduced by one-half, or that the boron be added only in alternate applications with such soils. As with nitrogen and potassium, leaf analysis is critical to monitor boron levels in the trees and to make appropriate rate or timing adjustments.

Application of a liquid chelated zinc through trickle irrigation systems will effectively supply this element. Research trials suggest that 8–10 weekly applications of EDTA-zinc (6 percent Zn) at rates sufficient to provide 10 to 15 pounds or more of zinc per acre per season may be necessary.

Application of a suitable copper material such as EDTA-copper chelate through trickle irrigation systems probably offers another alternative for supplying copper, but information on rates is insufficient to provide a recommendation at this time. Rates of application using this method should be carefully monitored by leaf analysis to avoid a copper toxicity problem.

GENERAL CONSIDERATIONS

Planning an orchard fertilization program should begin long before the orchard is planted. Much can be accomplished by incorporating lime and fertilizers into the soil during the seasons or years prior to planting. The amounts of materials applied should be based on the totals needed to provide adequate supplies of calcium, magnesium, potassium, and phosphorus throughout at least the top 16–20 inches of the soil. The amounts of these elements required can be best judged from soil tests calibrated for the differences in nutrient-supplying capacity of different soil types. After the orchard has been established it is much more difficult to make rapid and large changes in soil supplies of nutrient elements such as calcium, potassium, magnesium, and phosphorus by applying them to the surface.

Surface applications of fertilizers such as potassium, calcium, magnesium, phosphorus, zinc, or copper may require several seasons, if ever, to penetrate to the lower depths of the root system of mature fruit trees. Nevertheless, this may be the most feasible method for adding large quantities of calcium, magnesium, potassium, and phosphorus.

Various micronutrients differ in their relative mobility in the soil and therefore differ in the most appropriate method of application. A combination of soil and foliar applications is considered to be the best approach for boron, while foliar sprays are usually more cost-effective with zinc, copper, and manganese in established orchards. With the continuing trend toward intensified production systems using higher densities of smaller trees, fertigation offers an effective means of more closely regulating the supply of nutrients, providing improved nutrient availability, and/or enhancing efficiency of fertilizer use.

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