Apple Nutrition

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Diagnosing and Avoiding Nutrient Deficiencies

Visual Assessment

Nutrient deficiencies or excesses usually cause symptoms that are fairly indicative of problems with specific nutrients. Some nutrient disorders can be diagnosed by inspecting plants if you are familiar with symptoms. Unfortunately, incorrect diagnoses are common because the "classic" symptoms for deficiencies or excesses of some elements are similar and symptoms may vary in the field. Diagnoses are further complicated when crops are deficient in more than one element at the same time. A limitation of managing apple nutrition based on symptoms and plant tree appearance is that symptoms indicate a problem already exists -- reductions in growth, yield or fruit quality may have already occurred. The goal in fertilizing is to avoid nutritional problems. Symptoms of the nutrient disorders commonly seen in Michigan fruit plantings are described below. Generally, N and K shortages are common; P, Mg, B, Mn and Zn shortages occur occasionally; and Ca, S, Cl, Cu, Fe and Mo shortages are very rare.

Nitrogen (N). Deficient trees produce short terminal shoots. As a rough guide, apples should produce 8 to 12 inch shoots. Deficient apple leaves are pale green to yellow. Color develops uniformly on the leaf with no patterning or mottling, and leaf size is small. Nitrogen is *mobile* in trees. Symptoms first appear on *older leaves* because N moves out of older tissue into actively growing younger leaves. Leaves tend to drop early in the fall. Twigs are thin. Fruit set may be light with considerable June drop. Fruits are smaller and often color and mature early. Excess nitrogen can severely reduce apple quality and tree hardiness, and increase susceptibility to fireblight. Large, dark green leaves that remain on the plant late into the fall may indicate too much N. Apples color poorly and lose firmness more readily in storage. Shoot growth exceeds optimum lengths listed above.

Nitrogen deficiency: pale green leaves and reduced shoot growth.

Potassium (K). Deficiencies result initially in a yellowing of tissue along leaf margins. That tissue later turns a bronze color and may eventually die, producing a scorched zone along the edges of leaves as the deficiency progresses. Scorched areas do not extend between the veins of leaves. Because K is *mobile*, symptoms appear first on older leaves but may affect young leaves in severe cases. Fruits accumulate large amounts of K, so leaf symptoms are more likely and severe as fruit approaches maturity during heavy crop years. Although excessive K is not toxic, high soil K levels may inhibit Mg or Ca uptake and so induce deficiencies of these elements.

Potassium deficiency: burning of leaf margins (W. Styles).

Magnesium (Mg). Inadequate Mg causes a yellowing of tissue along leaf margins and between the main veins. Symptoms may initially develop along leaf margins, similar to K deficiency symptoms. As the deficiency progresses, the yellow regions turn brown and die, leaving a Christmas tree-shaped green area along the main veins in the middle of the leaf. Mg is fairly *mobile* so symptoms tend to develop first on older leaves, usually beginning around midseason.

Magnesium deficiency: chlorosis and necrosis (death) of tissue between the main leaf veins, in addition to early fruit drop (image: W. Styles)

Boron (B). Inadequate B results in a reduction in leaf size. No distinct patterns occur on individual leaves. New shoot growth is severely reduced, and shoot tips may die back in severe cases. Young twigs may develop a browning beneath the bark, similar in appearance to the "measles" symptoms caused by excessive manganese. Fruit set may be reduced. Fruit may become deformed and develop corky, dry lesions in the flesh.

Boron deficiency: misshapen fruit with internal corking.

Manganese (Mn). Manganese deficiencies are more likely on alkaline soils (pH greater than 7.0) and more prevalent during dry seasons. Symptoms are similar to those of Mg deficiency, but they appear first on young leaves. Youngest leaves yellow between the veins, while the main veins remain green. In severe cases, symptoms may progress to older leaves on the shoot. "Measles," a condition caused by toxic levels of Mn, is commonly seen on apple trees where soil pH is less than 5.5. The cambium tissue under the bark of young twigs dies, resulting in a cracked and broken bark surface. Measles is common in young trees on replanted sites that were not limed. Red Delicious is very susceptible to this problem.

Manganese deficient leaves on left (image: W. Stiles) and “measles” of bark cause by an excessive manganese in the cambium tissues.

Zinc (Zn). Zinc deficiencies occur periodically in northwestern Michigan orchards but are rare in other areas of Michigan. Leaves are much smaller than normal and narrow. The tissue between the main veins turns yellow and chlorotic. Shoot tips do not elongate fully, resulting in compressed internode lengths and a tuft or rosette of leaves at the terminal.

Zinc deficient shoots with small leaves and “blind wood” on two year-old shoots (image from F. Peryea).

Bitter pit associated with localized deficiency of calcium in apple fruit. Lesions typically concentrated towards the calix end of fruit.

Iron deficient leaves showing bleached appearance on youngest leaves, and necrotic margins (image on right from F. Dennis).

Tissue Analysis

Nutrient concentrations in apple leaves are excellent measure of tree nutritional health. Tissue analysis can help avoid deficiencies and associated losses by identifying problems before yields decline or symptoms appear.

Table 3. Optimum and deficient levels of nutrients in apple leaves.

Nutrient	Optimum range	Deficient level
N (%)	2.0-2.6 1.8-2.4[1]	2.0
P (%)	.16-.30	0.11
K (%)	1.3-1.5	1.0
Ca (%)	1.1-1.6	0.5
Mg (%)	.30-.50	0.2
B (ppm)	25-50	25
Cu (ppm)	10-20	4**
Fe (ppm)	150-250	25
Mn (ppm)	50-80	20**
Zn (ppm)	20-40	15**

[1]Optimum range for soft varieties, e.g. Golden Delicious and Macintosh.
**indicates deficient levels is not well defined

Leaf analysis results are interpreted by comparing concentrations to known optimum ranges. Tissue analysis is most useful if you take samples on a regular 2- to 5-year cycle. Sample young plantings more frequently -- their nutrient status can change rapidly. The nutrient status of mature plantings changes more gradually, so less frequent sampling is needed. Nutrient levels change annually because of weather and crop loads. Regular sampling over several years will provide the greatest insight into changes and potential problems.

The standard sampling procedure is to collect mature leaves from the middle of shoots in late July or early August. Other procedures, such as early season fruitlet sampling may be useful, but interpretation of results is difficult due to lack of data.

Soil Testing

The primary reason to test orchard soils is to monitor pH. Soil nutrient tests provide only a crude estimate of nutrient supply. Often fruit trees contain sufficient levels of a nutrient even though soil test values are low. Conversely, high soil nutrient levels do not assure an adequate supply to the tree.

Preplant P and K recommendations for apples.

Soil test level (ppm)	Recommendation (lb/acre)	
	P_2O_5	K_2O
10	90	180
20	70	160
30	40	140
40	20	120
50	0	100
60		80
70		60
80		40
90		20

Preplant soil sampling. Collect soil samples from all orchard sites a year before planting. Collect separate samples from 0- to 8-inch depths and 8- to 16-inch depths so that acidic or calcitic subsoil horizons can be identified. If lime is required, apply and incorporated into the soil before planting for a more rapid reaction. Lime soils before planting to pH 6.5 to 6.8. Fertilizers containing P or K can be incorporated at rates recommended. Preplant soil tests above 75 lb Mg/acre are generally adequate.

Sampling soil from established plantings. Apples are deep-rooted plants that often obtain adequate amounts of most nutrients even though soil tests may indicate that nutrient levels in the topsoil are low. Soil tests in established orchards are most useful in monitoring soil pH. Soil pH greatly influences nutrient availability to plants, and many nutrient deficiencies can be avoided by maintaining soil pH between 6.0 and 7.0. Nutrient deficiencies or excesses (toxicities) are more likely when the pH is outside of this range. Michigan orchards are very often too low in pH (too acidic). Low pH is usually due to repeated use of acidifying nitrogen fertilizers. If N fertilizers have been applied in a band under the tree row, soil pH may be much lower under the trees than in the row middles. This was clearly evident in orchards we survey in NW Michigan in 2000 (see figure).

Liming - pH Management
In choosing lime for orchards, consider: 1) calcium carbonate equivalent (neutralizing value); 2) particle size; 3) need for magnesium; and 4) cost and availability.

Calcium carbonate equivalent or neutralizing value (NV) describes how potent a material is relative to pure $CaCO_3$. The NV of agricultural lime usually ranges between 85 (less effective than $CaCO_3$) to 120 (more effective than $CaCO_3$). Lime recommendations given on soil test reports are for pure $CaCO_3$, so application rates may need to be adjusted up or down depending on the lime source.

The reaction rate of lime is very important because lime cannot be incorporated into orchard soils. Often surface-applied lime may require 1-3 years to alter soil pH in the tree root zone. Particle size dictates how fast lime reacts; finely ground materials react quickest because their surface area is greatest. Sieve or particle size information should be available for all lime sold in Michigan. Results are expressed as the percentage of the lime passing through screens of different size. A #8 mesh has 2.4 mm holes, and particles not passing this mesh are so big they should be considered 0% effective. Mesh #60 is much finer (0.25 mm holes). Particles passing through # 8 but not #60 are considered to be 50% effective, while particles passing through #60 mesh are considered 100% effective. Finer ground materials react more quickly in soils but may be more dusty and hard to spread. The best materials contain only a small percentage larger than #60 mesh size.

If orchard soils are also short of magnesium (Mg), a lime containing $MgCO_3$ should be chosen. Liming materials can contain different proportions of calcium carbonate ($CaCO_{3)}$ and magnesium carbonate ($MgCO_3$). Dolomitic lime or "high-Mag' lime contain significant amounts of Mg. Dolomitic lime may be best if soils contain 1) less than 35 ppm Mg, 2) if potassium (K) represents a greater Percent of Bases than Mg, or 3) if Mg represents less than 3% of the Total Bases.

Also consider the availability and cost in choosing lime. The lowest priced lime may not be the best buy when NV and sieve analyses are considered. Use the NV to calculate the cost per ton of calcium carbonate equivalents. Then use the sieve analysis information. Consider the proportion larger than mesh size #8 as ineffective filler, and that between mesh sizes 8 and 60 as only 50% effective.

Specialized Liming Materials. Pelletized lime is available that can be applied with fertilizer spreaders. The NV is typically similar to agricultural limes, and the original material is ground finely so it reacts quickly. Pelletized lime may cost four or five times as much as wet lime. Liquid lime or fluid lime are suspensions containing 50-75% lime and 25-50% water. Lime suspensions react quickly because the particles are small. Drawbacks include high costs and the lack of convenient application equipment for orchards. At least two manufacturing bi-products are sold as liming materials in Michigan. Dow-Lime is produced in the Ludington area and available through much of the state. This is a dolomitic (high Mg) lime that seems to react quickly in orchard soils. Monitor Sugar produces a finely ground, high-Ca lime material as a bi-product of sugar beet processing.

Spreading Lime on Orchards. One difficulty with liming orchards is that the application equipment must fit between the tree rows. An additional complication exists in orchards where fertilizer has been banded under the trees, creating gradients in pH between the herbicide strip and the row middles as discussed previously. Lime needs also to be banded under the trees in these situations. One approach is to apply pelletized lime with fertilizer spreaders. At least one company (Stoltzfus, Morgantown, PA) manufactures a wet lime spreader that is narrow enough (60 inches) to fit between orchard rows.

Fertilizing

Nitrogen (N) is applied annually to most Michigan apples. Fertilizers supply N as nitrate, ammonium or combinations of both. Nitrate is not bound tightly to soil particles and may be subject to leaching losses, whereas ammonium is retained on soil particles and is less prone to leaching. Although apples absorb nitrate more readily than ammonium, ammonium is readily converted to nitrate in warm soil. Research comparing ammonium to nitrate sources of N has generally shown them to be equally effective. Sources that are the least expensive per unit of N are usually preferred.

Urea is a high analysis, inexpensive source that supplies N as ammonium. It is acidic with a limestone equivalent of 1.8, meaning that 1.8 lb limestone will be required to neutralize the acidity from each pound of N applied as urea. Urea is best applied during cool spring weather because some N may be lost by volatilization if the material remains on the soil surface during warm weather. Urea may contain a byproduct (biurette) which can damage young trees, particularly on sandy soils.

Ammonium nitrate is another widely used, high analysis (32 percent N) source. It is as acidic as urea, requiring about 1.8 lb of limestone to neutralize the acidity from each pound of N applied. This material contains both nitrate N, which is immediately available, and ammonium N, which is retained in the soil and becomes available more slowly. If applied in the fall or winter, a large portion of the nitrate N may be lost by leaching before the soil warms and roots become active in the spring.

Calcium nitrate is a commonly used in orchards. All N is supplied as nitrate, which is readily available and does not reduce pH. The greatest limitation of this source is the high cost per unit of N. Many growers use a less costly, acidic N source such as urea or ammonium nitrate and lime periodically to maintain pH, rather than apply calcium nitrate annually. Calcium nitrate is often applied in May or June because it does not volatilized like urea during warm weather. Do not apply calcium nitrate in the fall or winter because nitrate leaches readily.

Ammonium sulfate, *diammonium phosphate (DAP)* and *monoammonium phosphate (MAP)* are not commonly used on Michigan apples because they are very acidic and relatively expensive. If orchard pH is too high, it can help to reduce pH to desired levels. MAP and DAP may be useful where P is needed because they contain about 50 percent P_20_5. *Potassium nitrate* is a very low analysis (13 percent N), expensive N source. It be a useful source when K is also needed. All N is in the readily available but leachable nitrate form.

Characteristics of some nitrogen fertilizers.

Fertilizers	% N	Other nutrients present	Reaction[1]	Limestone equivalent[2] (lb $CaCO_3$/lb N)
Ammonium sulfate	21	S(24%)	acidic	5.3
Ammonium nitrate	32	none	acidic	1.8

Calcium nitrate	16	Ca (19%)	basic	1.3
Diammonium phosphate (DAP)	17	P_2O_5 (50%)	acidic	4.1
Monoammonium phosphate (MAP)	11	P_2O_5 (48%)	acidic	3.5
Potassium nitrate	13	K_2O (44%)	basic	2.0
Urea	46	none	acidic	1.8

[1] acidic: reduces soil pH; basic: increases soil pH.
[2] Equals the amount of lime that is equivalent to the reaction of 1 lb N applied to the soil.

Nitrogen rates (lb N/tree) for apples.

Orchard age (years)	Trees per acre		
	80	250	500
1	.05	.05	.04
2	.10	.10	.08
3	.15	.15	.08
4	.20	.20	.08
6	.30	.22	.08
8	.40	.22	.08
10	.50	.22	.08
12	.60	.22	.08
Maturity:			
(lb N/tree)	.75	.22	.08
(lb N/acre)	60	55	50

Although optimum N rates vary considerably from site to site, use rates in Table 7 as an initial guide. Be conservative with N rates until you are familiar with the planting. It is easier to apply more N than to manage excessive vigor caused by too high rates. Adjust rates according to leaf N concentrations, orchard vigor, fruit quality, and productivity. Three factors that have the greatest effect on N requirements are soil type, orchard floor management and pruning. Orchards on fertile loam soils may require N at only half the recommended rates, whereas those on very sandy soils may require 50 percent more N. Sites previously used for alfalfa may contain high soil N levels and require much less fertilizer. Heavily sodded orchards may require 20 to 50 percent more N than clean cultivated plantings. Heavy pruning stimulates vegetative growth and can reduce or replace N requirements. Heavily pruned trees should be fertilized lightly if at all.

Place fertilizer where it is accessible to the plant, but distribute it to minimize the potential of burning roots. Most commercial fertilizers are salts; if concentrated, they can injure plant roots. Spread fertilizer in a circle 3 to 4 feet in diameter around young trees, keeping fertilizer 8 to 10 inches away from the trunk. Do this after enough rain has fallen to settle the soil.

Apply fertilizer to mature orchards in a broad band about as wide as the tree canopy. Apply N as growth begins in the spring. Split applications are advised on very sandy soils; apply half in April and half in June after fruit set is known. The second application can be reduced or skipped if a light crop is set to avoid excessive vigor that year.

Potassium (K). Orchards on sandy soils are most prone to K deficiency. Applications of 150 to 300 lb K_2O/acre will correct most deficiencies. These rates may be required every 2 to 4 years for orchards on sandy soils. Select K fertilizers based on cost per unit of K_2O and, content -- whether the material contains other useful nutrients. Various sources appear equally effective in supplying K to fruit plants.

Muriate of potash (KC1) is commonly used on Michigan apples. It is high in analysis (60 to 62 percent K_2O) and inexpensive. Chloride toxicity problems may occur if large amounts (800 lb/acre) are applied on established orchards or if the fertilizer is placed in direct contact with young trees. If high rates are required, fall applications are advised to allow the chloride time to leach out of the root zone before spring growth starts. *Potassium sulfate* also is used extensively. It is somewhat lower in analysis (50 percent K_2O) and usually more expensive than KC1. *Potassium magnesium sulfate* (Sul-Po-Mag) may be used if magnesium applications are also needed. This material is lower in potassium (22 percent K_2O) but also contains 11 percent Mg. Sul-Po-Mag is usually a more costly source of K than muriate of potash. *Potassium nitrate* (44 percent K_2O, 13 percent N) is sometimes used in orchards, but is expensive.

Phosphorus (P). Although Michigan apples seldom respond to P, applications may help maintain a healthy sod in row middles. Choose P fertilizers on the basis of the cost per unit of P_20_5 as well as the availability (solubility) of P. *Superphosphate* (normal) is a relatively low analysis (18 to 20 percent P_20_5) source where about 85 percent of the P_20_5 is water soluble and readily available. *Concentrated superphosphate* is a more popular because it has a higher analysis (46 percent P_20_5) and solubility (87%). *Monoammonium phosphate* (MAP) has been used more frequently in recent years. MAP contains 48 percent P_20_5 and 11 percent N. MAP has an acidifying effect on soils but is usually a competitively priced source of P_20_5. *Diammonium phosphate* (DAP) is slightly lower in P_20_5 (46 percent) and higher in N (18 percent) than MAP. Nearly all of the P_20_5 in MAP and DAP is readily available.

Calcium (Ca). Apple trees nearly always obtain enough Ca from soils if pH is maintained above 6.0 with appropriate liming. Apple fruit, however, often obtain inadequate Ca even when the trees are adequately supplied. This results from the limited mobility of Ca in trees and causes bitter pit, internal breakdown, or premature softening. Calcium sprays usually reduce these problems but seldom eliminate them. A program of 8 to 10 sprays at 2-week intervals from late June until harvest is best. Calcium chloride at 2 to 3 lb/100 gal in June and July and 3 to 5 lb/100 gal in August and September is as effective as other Ca sources supplying the same amount of Ca. Apply sprays on a dilute basis or concentrated no more than two times. Reduce rates during warm, humid weather, or if no rain has fallen since the previous spray. Apply 20 to 30 lb $CaC1_2$/acre during the season for best results.

Magnesium (Mg). If leaf analysis results or development of symptoms indicate a need for Mg in Michigan orchards, soil pH is nearly always too low, and dolomitic lime is the best treatment. Use 2 to 4 tons/acre or rates recommended on a soil test report. Since lime takes a year or more to begin working, you may use magnesium sulfate (Epsom salts) at 10 lb/100 gallons in the first two cover sprays for two or three years until the lime reacts in the soil.

Boron (B). Only apply B if leaf analysis results indicate a need. The difference between deficient and excessive B levels is small, and B toxicity is very damaging. If a need exists, B can be applied to the ground using 1.0 lb B/acre, or as foliar sprays of 0.5 lb B/acre in one of the first two cover sprays, or 0.5 to 1 lb B/acre in September or October when leaves are still active. Solubor is a common B source.

Manganese (Mn). If leaf analysis results indicate a deficiency exists, apply manganese sulfate at 5 lb/100 gal dilute basis or Mn chelate products at recommended rates in the first two cover sprays. Do not concentrate sprays more than two times. If excess Mn exists, check soil pH and apply lime as needed.

Zinc (Zn). Orchards do not respond consistently to ground applications of Zn on high pH soils. Foliar sprays of Zn chelates at recommended rates and timing are the preferred Zn sources. Zinc sulfate may also be used with equal amounts of hydrated lime in the first two cover sprays (1 to 2 lb/100 gal) or 3 to 5 lb in a postharvest (September) spray. The fungicides Dithane M-45 and Zineb are also effective sources of Zn if applied to registered crops at labeled rates (observe label restrictions on time of application).