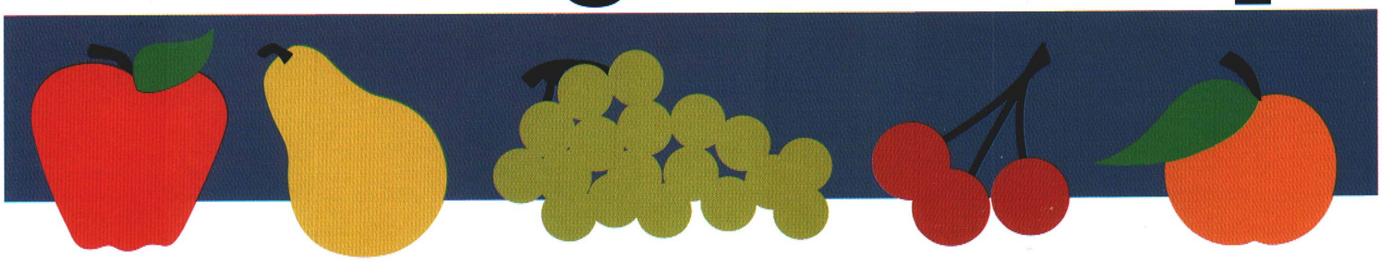
Fertilizing Fruit Crops



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Fruit trees and vines require the following mineral elements for satisfactory growth and production: nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn). Fortunately, soils used for fruit production in Michigan supply adequate amounts of most of these nutrients, and most growers need apply only a few nutrients. Apply nutrients only if you know the crop needs them. Applications above amounts needed by the crop are an unnecessary expense and may result in reduced fruit quality, toxicities or deficiencies of other elements.

Fertilizers can pollute lakes, streams and groundwater if used improperly. Fertilizers can contribute nitrate to groundwater and P to lakes and streams. Proper fertilizer rates and application practices minimize the adverse effects of nutrient movement out of fruit plantings and reduce fertilization costs. Information on environmentally sound nutrient and manure management practices is available in the two Michigan Department of Agriculture publications listed at the end of this bulletin.

This bulletin is divided into four parts. *Part I* describes methods for monitoring the nutrient status of fruit crops and diagnosing shortages and excesses. Fertilizer materials commonly used in fruit plantings are described in *Part II. Part III* outlines general fertilizer requirements of fruit crops and suggestions for correcting deficiencies. Fertilizer recommendations for blueberries are described separately in E-2011, "Highbush Blueberry Nutrition". Fertilizing fruit crops through trickle irrigation systems is discussed in *Part IV.*

PART I. Diagnosing and Avoiding Nutrient Deficiencies

Growers can determine fertilizer needs and diagnose nutritional problems by observing visual symptoms and using soil tests and tissue analysis. Because each method has advantages and limitations, utilize all three on a regular basis.

Visual Symptoms

Nutrient deficiencies or excesses usually cause symptoms that are fairly indicative of problems with specific nutrients. If you are familiar with typical symptoms, you can diagnose some nutrient dis-

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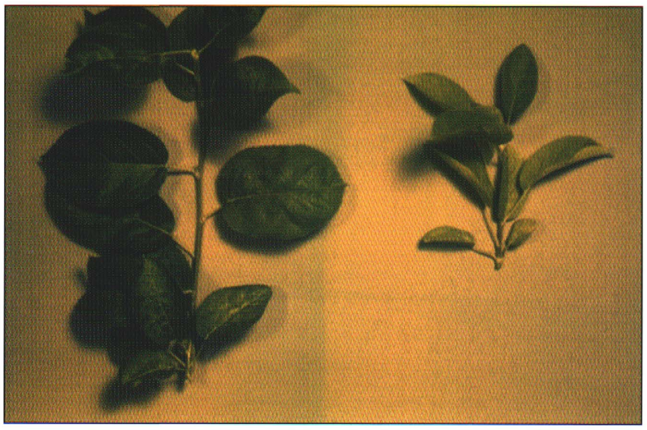
orders by closely inspecting plants. Unfortunately, correct diagnoses are often difficult because the "classic" symptoms for deficiencies or excesses of some elements are similar and symptoms may vary in the field. Diagnoses are further complicated when crops are deficient in more than one element at the same time.

The greatest limitation of relying on the presence of symptoms to manage fruit nutrition is that such symptoms indicate a problem already exists — reductions in growth, yield or fruit quality may have already occurred. The goal in fertilizing is to prevent nutritional problems and their symptoms from occurring. 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, trees supplied with adequate N usually produce the following amounts of terminal shoot growth: non-bearing apple, pear, cherry — 12 to 24 inches; non-bearing peach — 14 to 24 inches; bearing mature apple, pear, peach — 8 to 12 inches; bearing mature peach — 12 to 15 inches.



N-deficient apple shoot (right): small, pale green leaves, little extension growth.

N-deficient pear: pale green to bronze leaves, limited growth.

N-deficient peach: pale green-red chlorosis.

Deficient apple, peach and cherry leaves are pale green to yellow, and pear leaves may exhibit a bronze tint. 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. Twig growth is thin. Fruit set may be light, with a heavy June drop. Fruits will be smaller and often color and mature somewhat earlier than usual.

Excess nitrogen is a periodic problem in Michigan fruit crops and can severely reduce fruit quality and tree hardiness. Large, dark green leaves that remain on the plant late into the fall are indicative of too much N. Apples color poorly and lose firmness more readily in storage. Soluble solids are lower in grapes. Growth continues late into summer and fall and plants are more susceptible to winter injury. Shoot growth greatly exceeds optimum lengths listed above.

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 most severe as fruit approaches maturity during heavy crop years.

K-deficient apple showing necrosis (scorching) of leaf margins.

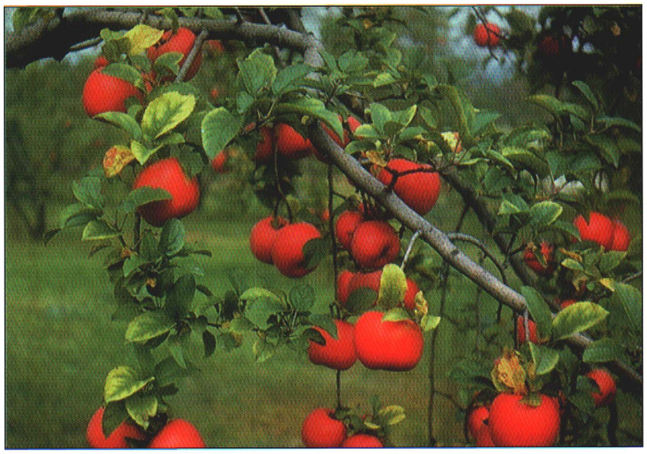
K-deficient peach shoot (left): marginal necrosis and leaf curling.

K-deficient sour cherry (right): marginal necrosis and leaf curling.

Although excessive K is not directly toxic, high soil K levels may inhibit Mg or Ca uptake and so induce deficiencies of these elements.

Magnesium (Mg)

Inadequate Mg is most common in Michigan cherries and peaches, where it 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 classified as *mobile* because symptoms tend to develop first on older leaves. Symptoms normally appear on foliage around midseason.

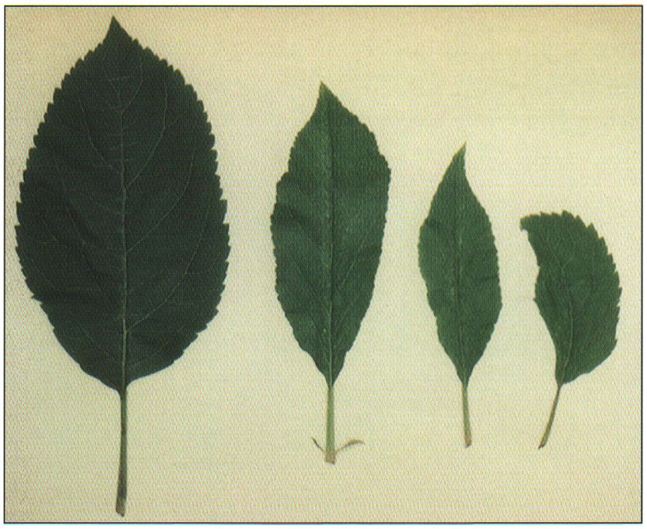


Mg-deficient apple: chlorosis between the main veins.

Mg-deficient sweet cherry showing discoloration near leaf margins.

B-deficient cherry showing dieback of shoot terminals.

Ca deficiency in apple fruit causes "bitter pit" necrotic lesions just under the skin.



B-deficient apple (right): leaves are thick and small, and shape is distorted.

Boron (B)

Inadequate B is most often seen in stone fruits and 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. Fruit set may be reduced on deficient trees. Young twigs of apple may develop a browning just beneath the bark, similar in appearance to the "measles" symptoms caused by excessive manganese.

B-deficient apple showing internal bark necrosis where cambial tissues die.

B-deficient pear fruit showing severe cracking.

Fe-deficient apple: interveinal chlorosis with leaves at shoot tips most affected.

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.

Mn-deficient apple: interveinal chlorisis.

Mn-deficient sweet cherry showing interveinal chlorosis.

Mn toxicity on apple: "measles" or necrosis of the bark cambium on younger stems.

"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 where lime has not been applied. Red Delicious is particularly susceptible to this problem.

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.

Zn-deficient apple showing "blind wood" where buds on the previous season's wood fail to break or exhibit weak growth.

Soil Testing

Soil testing provides a means of monitoring soil pH and estimating nutrient supply. However, a poor relationship exists between soil and plant nutrient levels in perennial crops. 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. Soil tests do give a reasonable estimate of the nutrient status of shallow-rooted crops such as strawberries and raspberries.

Zn-deficient apple: rosette of growth due to limited extension growth, and small leaves on the previous season's wood.

Preplant soil sampling

Collect soil samples from all orchard sites a year before planting. (Refer to Extension bulletin E-498, "Sampling Soils for Fertilizer and Lime Recommendations," for sampling instructions.) 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, it can be 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 in Tables 1 and 2. Preplant soil tests above 75 lb Mg/acre are generally adequate.

Sample fruit sites that have been leveled or reshaped more extensively before planting. Topsoil is usually removed, then replaced once the subsoil has been redistributed. Samples from the topsoil

Table 1. Preplant P recommendations for apples, pears, stone fruits, grapes, strawberries and raspberries.

Soil test level (ppm P)[1]	Recommendation (lb P_2O_5/acre)
10	90
20	70
30	40
40	20
50	0

[1]To convert to lb/acre, 6.7-inch depth, multiply by 2.

Table 2. Preplant K recommendations for various fruit crops.

	Recommendation (lb K_2O/acre)		
Soil test (ppm K)[1]	Apples, pears	Stone fruits, grapes, raspberries	Strawberries
15	170	220	200
25	150	200	170
50	100	150	120
75	50	100	70
100	0	50	20
125	0	0	0

[1]To convert to lb/acre, 6.7- inch depth, multiply by 2.

give little indication of variations in pH and nutrient levels in the subsoil. Sample both the topsoil (0 to 8 inches) and the subsoil (12 to 18 inches). Also consider sampling separately areas that were lowered by removing subsoil and/or raised by adding subsoil. These locations often vary considerably in nutrition and pH.

Sampling soil from established plantings

Most perennial fruit crops are deep-rooted and plants often obtain adequate amounts of most nutrients even though soil tests may indicate that nutrient levels in the topsoil are low. Under these conditions, plants will not respond to fertilizer and applications are an unnecessary expense. In other situations, plants may not absorb adequate nutrients even though levels in the topsoil appear adequate. Therefore, do not rely on soil testing alone to monitor crop nutrition.

Soil tests are most useful in monitoring soil pH in established orchards and vineyards. 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.

Although the pH in Michigan fruit plantings varies widely, soils too low in pH are more common than soils with an excessively high pH. Low pH may be due to the native soil acidity or repeated use of acidifying nitrogen fertilizers. The pH of many older plantings is low because of acidic fertilizer use.

Soil nutrient levels and pH usually change gradually, so sampling every 3 to 5 years is adequate to monitor established plantings. Take samples between the rows within the herbicide strip. Collect separate samples from areas with different soil types and areas that have been limed or fertilized differently. Single samples should not represent more than a 10-acre area. Each sample should be a composite of at least 20 probes.

Tissue Analysis

Nutrient concentrations in plant tissues are the most accurate indicator of the nutritional health of fruit crops. Plant tissue analysis can be used to diagnose problems and monitor nutrient status so that problems are avoided. The presence of nutrient deficiency symptoms indicates an acute shortage in the plant that may have reduced yields or fruit quality. Avoid these losses by using tissue analysis to identify nutrients approaching deficiency levels before yields decline or symptoms appear.

In some cases, soil tests are needed to determine the best method of correcting a deficiency identified through leaf analysis. For example, Mg deficiencies may result from low soil pH or excessively high soil Ca. Dolomitic lime applications are advised if pH is too low, but magnesium sulfate is preferred if soil Ca levels are excessively high.

MSU offers a tissue analysis service to fruit growers. (Refer to Extension bulletin E-449, "Plant Tissue Analysis for Determining Fertilizer Needs of Michigan Fruit Crops," for instructions on collecting and submitting tissue samples for analysis.) Computerized recommendations are provided for tree fruit, blueberry and grape samples based on optimum concentrations for the crop (Table 3). You may submit strawberry and raspberry leaf samples, but results and recommendations will be handwritten.

Table 3. Optimum nutrient concentrations in leaves and petioles (grapes) of Michigan fruit crops.

	Crop					
Nutrient	Apples, pears	Cherries	Peaches, plums, apricots	Grapes (petioles)	Strawberries	Raspberries
N (%)	1.9-2.6 1.7-2.2[1]	2.5-3.5	3.3-4.5	.80-1.2	2-.28	2-3
P (%)	.16-.30	.15-.30	.15-.25	.16-.30	.25-.40	.25-.40
K (%)	1.3-1.5	1.4-2.0	1.4-2.0	1.5-2.5	1.5-2.5	1.5-2.5
Ca (%)	1.1-1.6	1.2-2.0	1.5-2.5	.50-1.0	.70-1.7	.70-2.0
Mg (%)	.30-.50	.40-.80	.30-.50	.25-.40	.30-.50	.30-.60
B (ppm)	25-50	30-50	30-50	25-50	30-90	25-50
Cu (ppm)	10-20	15-30	10-20	10-50	10-30	10-30
Fe (ppm)	150-250	75-150	75-150	20-100	50-300	50-300
Mn (ppm)	50-80	35-60	50-100	30-60	50-150	50-150
Zn (ppm)	20-40	15-40	20-50	30-60	20-50	20-50

[1]Optimum range for Golden Delicious and Macintosh apples.

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.

PART II. Fertilizers

Fertilizers are materials containing plant nutrients. The nutrient content and the price per unit of nutrient are the most important considerations in choosing materials. Also consider the reaction in soils (acidic or basic), ease of handling, the rate at which nutrients become available to plants and secondary nutrients present in the fertilizer. The characteristics of fertilizers commonly used on fruit plantings are discussed below.

Fertilizers may corrode equipment and, if not properly handled and stored, present hazards to livestock, humans and the environment. Purchase fertilizer as needed and avoid storing large quantities on the farm. On-farm storage of bulk fertilizer is discussed in MSU Extension bulletin E-2335, "On-Farm Agrichemical Storage and Handling".

Nitrogen Fertilizers

N is usually applied annually to fruit crops, and various sources are available. These supply N as nitrate, ammonium or a combination 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. For this reason, ammonium sources of N are preferred over nitrate sources for fall or winter applications. Although most fruit crops preferentially absorb nitrate over ammonium, when soils warm and roots become active, ammonium is readily converted in the soil to nitrate. 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. The most common N sources used in Michigan fruit plantings are summarized in Table 4.

Table 4. Characteristics of N 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.

Urea is a high analysis source (46 percent N), easy to handle and generally inexpensive per unit of N. 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 varying levels of the byproduct biurette, which in high concentrations 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 N fertilizer for fruit crops. All nitrogen is supplied as nitrate, which is readily available and does not reduce pH. The greatest limitation of this source is the low analysis (15 percent N) and often 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 used for supplemental applications in May or June to avoid potential volatilization losses resulting from urea applications during the warm temperatures common at this time. Do not apply calcium nitrate in the fall or winter because nitrate leaches readily.

Ammonium sulfate is not commonly used on most Michigan fruit crops because it is very acidic, low in analysis (21 percent N) and relatively expensive. It is often applied to blueberries, which require a low pH, and can be useful in fruit plantings on alkaline soils, where a reduction in pH is desired. All N is in the ammonium form.

Diammonium phosphate (DAP) and *monoammonium phosphate (MAP)* have limited value for Michigan fruit crops. Both materials are relatively low in analysis (DAP is 17 percent N; MAP 11 percent N) and very acidic. They may be useful where P applications are needed because they contain about 50 percent P_2O_5.

Potassium nitrate is a very low analysis (13 percent N), expensive N source. It has little value in Michigan fruit plantings, except where K applications are needed. All N is in the readily available but leachable nitrate form.

Potassium Fertilizers

There are several fertilizer sources of potassium. Select a source primarily 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) may be the most commonly used K source for Michigan fruit crops. It is high in analysis (60 to 62 percent K_2O) and inexpensive. Chloride toxicity problems may occur if large applications (800 lb/acre) are made on established orchards or if muriate of potash 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. It is the preferred source for blueberries, which are more sensitive to chloride toxicity than other fruit crops.

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) has been used to some degree on fruit plantings but is an expensive source of potassium.

Phosphorus Fertilizers

Choose P fertilizers on the basis of the cost per unit of P_2O_5 as well as the availability (solubility) of P to the plant.

Superphosphate (normal) has been declining in popularity because of its relatively low analysis (18 to 20 percent P_2O_5). About 85 percent of the P_2O_5 in superphosphate is water soluble and readily available to the plant.

Concentrated superphosphate is a more common source because of its high analysis (46 percent P_2O_5). It is about 87 percent water soluble and is commonly used in bulk-blended materials.

Monoammonium phosphate (MAP) has been used more frequently in recent years, both alone and in bulk-blended fertilizers. MAP contains 48 percent P_2O_5, nearly all of which is readily available to plants, and 11 percent N. MAP has an acidifying effect on soils but is usually a competitively priced source of P_2O_5.

Diammonium phosphate (DAP) is slightly lower in P_2O_5 (46 percent) and higher in N (18 percent) than MAP. Nearly all of the P_2O_5 in DAP is readily available. This material is also acidic but is usually an economical source of P_2O_5.

Rock phosphate is a low analysis (3 to 8 percent P_2O_5), low solubility (< 1 percent) P source that has been generally replaced by the higher analysis sources described above.

Secondary and Micronutrient Fertilizers

Table 5 (see page 12) lists some commonly used sources of secondary and micronutrients. Many can be used in ground or foliar applications, as discussed in Part III.

Organic Nutrient Sources

Livestock manure, manure/bedding mixtures and plant residues (hay, straw) can be useful sources of nutrients for fruit crops. The nutrient content of manure needs to be known to calculate appropriate application rates. Nutrient concentrations commonly seen in manures are given in Table 6, but specific manures need to be analyzed to

Table 6. Nutrient content (lb/ton) for various manures.

Manure type	Total N	N available 1st year	P_2O_5	K_2O
Swine, fresh	10	8	9	8
Beef, without bedding	21	12	14	23
with bedding	21	11	18	26
Dairy, without bedding	9	6	4	10
with bedding	9	6	4	10
Sheep, with bedding	14	7	9	25
Poultry, without litter	33	28	48	34
with litter	56	42	45	34
Horse, with bedding	14	6	4	14

Table 5. Suggested sources of secondary and micronutrients for fruit crops.

	Analysis (%)							
Source	Ca	Mg	S	B	Cu	Fe	Mn	Zn
Calcium (Ca)								
limestone	31							
calcium sulfate (gypsum)	22		17					
calcium chloride	36							
Magnesium (Mg)								
dolomitic limestone	15-20	10-15						
magnesium sulfate (Epsom salts)		10	23					
potassium magnesium sulfate (Sul-Po-Mag)		11	23					
Sulfur (S)			50-99					
elemental sulfur		11	23					
potassium magnesium sulfate (Sul-Po-Mag)								
magnesium sulfate (Epsom salts)		10	13					
calcium sulfate (gypsum)	22		17					
Boron (B)								
Borax				11				
Borate-46				14				
Borate-65				20				
Solubor				20				
Copper (Cu)								
copper sulfate					25			
copper chelates					variable			
Iron (Fe)								
ferrous sulfate						20		
ferric sulfate						27		
iron chelates						variable		
Manganese (Mn)								
manganese sulfate							32	
manganese chelates							variable	
Zinc (Zn)								
zinc sulfate								22-36
zinc chelates								variable

determine accurate nutrient levels and application rates. Manure contains ammonium N and organic N. Generally, all of the ammonium N and 25 to 50 percent of the organic N is available to plants during the year of application. Manure analysis reports usually include total N, ammonium N, P_2O_5 and K_2O. Manure must be applied so that rates of available N do not exceed those recommended in Part III. Where soils contain greater than 75 ppm P (Bray P1 test), manure rates should not supply more P than is typically removed by the crop (about 50 lb P_2O_5 per acre). Manure applications should be avoided where soil P levels are very high (greater than 150 ppm P). Poultry manures vary considerably in their nutrient content, depending on their source and handling. Fresh materials are high in nutrients and can injure tree roots if applied at excessive rates.

Byproducts from fruit, vegetable and sugar beet processing can also serve as nutrient and organic matter sources for fruit crops. These materials are exempt from the permits required for land application of other solid wastes. However, application rates need to be determined so that they do not exceed recommended N and P rates. Because the composition of byproduct materials varies, representative samples need to be analyzed to determine their nutrient content. Generally, all of the ammonium N and 50 percent of the organic N in byproducts will be available to plants during the application year.

PART III. Fertilizer Recommendations for Michigan Fruit Crops

General N fertilizer programs recommended below are based on average conditions in Michigan fruit plantings. These may have to be adjusted to account for differences in soil types and management practices on specific sites. Recommendations for applications of other nutrients assume that there is evidence of a need.

Tree Fruit Recommendations

Nitrogen

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 much easier to apply additional N than to manage excessive vigor caused by too high rates. Excessive vigor is particularly damaging in new, high-density apple plantings.

Specific orchards may require more or less N than indicated in Table 7. Adjust these rates according to your conditions on the basis of leaf N concentrations and 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. Similarly, orchards heavily infested with weeds may require higher rates. 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. On young trees, spread fertilizer in a circle 3 to 4 feet in diameter around each plant, keeping fertilizer 8 to 10 inches away from the trunk. Fertilize newly planted vines and trees 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.

Table 7. Nitrogen rates (lb N/tree) for orchard crops.

Orchard age (years)	Apples and pears (trees per acre) 80	250	500	Stone fruit (130 trees per acre)
1	.05	.05	.04	.07
2	.10	.10	.08	.14
3	.15	.15	.08	.21
4	.20	.20	.08	.28
6	.30	.22	.08	.42
8	.40	.22	.08	.56
10	.50	.22	.08	.62
12	.60	.22	.08	.62
Maturity:				
(lb N/tree)	.75	.22	.08	.62
(lb N/acre)	60	55	50	80

Under Michigan conditions, spring and fall applications have been equally effective. Spring applications are advised on very sandy soils because fall applications may result in leaching losses. Many growers split their N applications, applying half in March or 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.

If manure or other organic N sources are used, know how much N the material contains before application, and adjust N fertilizer rates so that the total amount of N applied in the material and fertilizers does not exceed recommended N rates. It is difficult to predict how much N some mulch materials, such as straw bedding or hay, will supply. Fertilizer N rates may be reduced or applications stopped for a year until the tree response to these materials can be observed.

P, K, Ca, Mg Applications

Do not apply these materials unless you know a need exists.

Phosphorus (P). If phosphorus is needed, apply 200 to 400 lb of P_2O_5/acre. Because P moves very slowly in soil, these rates will sustain most fruit crops for many years.

Potassium (K). Applications of 150 to 300 lb K_2O/acre will correct most deficiencies. Stone fruit plantings on light, sandy soils may require these rates as a maintenance program every 3 to 5 years.

Calcium (Ca). Deficiencies are rare if pH is maintained above 6.0. Limestone applications of 2 to 4 tons/acre will correct shortages.

Inadequate Ca levels in apple fruit may result in disorders such as bitter pit or internal breakdown, or premature softening. Calcium sprays may reduce these problems but rarely 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 if weather is warm and humid 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 magnesium is required, dolomitic limestone is the least costly source. Use 2 to 4 tons/acre or rates recommended on a soil test report. 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.

Micronutrient Applications

Where shortages of B, Fe, Mn or Zn are known, the following applications are recommended.

Boron (B). Boron can be applied to the ground using 1.0 to 1.5 lb B/acre for apples and pears, 0.5 to 1.0 lb B/acre for cherries and 0.5 lb B/acre for peaches. Foliar sprays can also be used. Apply 0.5 lb B/100 gal (dilute) in the first two cover sprays, or 1 lb B/100 gal (dilute) in September or October when leaves are still active.

Do not concentrate more than two times. Because the difference between deficient and excessive B levels is small, apply B only if needed. Foliar sprays often give better control over the amount of B absorbed by the plant. Solubor is the most common B source. Peaches are very sensitive to excessive B — apply B only if leaf analyses indicate a need exists.

Iron (Fe). Iron deficiencies occur where soil pH is too high or drainage is poor. If symptoms indicate an Fe shortage and the pH is above 7.5, reduce pH with sulfur, aluminum sulfate or acidifying N fertilizers. Ground applications of iron on high pH soils have been inconsistent or ineffective. For temporary correction, use foliar sprays of the iron-containing fungicide Ferbam or commercial Fe chelates at recommended rates in early cover sprays.

Manganese (Mn). If 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). Response to ground applications of Zn has been inconsistent 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).

Grape Recommendations

Nitrogen

Most mature vineyards require about 50 lb N/acre annually. Young plantings require about 15 to 20 lb N/acre for each year in the field. Vigorous vineyards on double curtain trellis systems may require 75 to 100 lb N/acre. On young vines, spread fertilizer in a circle 3 to 4 feet in diameter around each vine. On mature vineyards, spread fertilizer in the row in a band 5 to 6 feet wide. Apply N between bud break and bloom.

Adjust N rates for each vineyard by observing vine growth, fruit soluble solid content and degree of winter injury. Overfertilized vines are often too vigorous, low in fruit soluble solids and more prone to winter injury because wood does not harden off in time for winter. Petiole analyses will aid in adjusting N rates.

Potassium

Potassium shortages are common in Michigan vineyards. If you know a shortage exists, apply 100 to 200 lb K_2O/acre. Vineyards on sandy soils are more prone to K deficiency and may require applications every 3 to 5 years.

Magnesium

Where Mg deficiency exists, check soil pH and apply dolomitic limestone at recommended rates if pH is below 5.5. Also apply two postbloom sprays of magnesium sulfate (Epsom salts) at 10 lb/100 gal for 1 to 2 years until the limestone reacts in the soil.

Micronutrients (B, Fe, Cu, Mn, Mo, Zn)

Micronutrient shortages seldom occur in Michigan grapes. Should symptoms or petiole analyses indicate a shortage, follow recommendations outlined for tree fruits.

PART IV. Fertilizing Through Trickle Irrigation Systems

Fertilizing through trickle irrigation systems requires careful thought and planning. Important factors to consider are: uniformity of water application (uniform fertilizer application is possible only if water application is uniform), method of injection, type of fertilizer, injection capacity and application scheduling.

Nitrogen is the nutrient most commonly applied through trickle irrigation systems. The benefits from injecting N fertilizers include a significant savings in material (at least a 50 percent reduction), less dependence on rainfall to move nitrogen to the root system, a more uniform and regular supply of N to the trees through the growing season, and reduced leaching losses of fertilizer N.

System Uniformity

The most important requirement for effective fertilizer injection is system uniformity. Fertilizer cannot be applied uniformly to trees unless water delivery is uniform. A trickle system with 100 percent uniformity delivers exactly the same amount of water from each emitter per minute or hour. It is nearly impossible to obtain 100 percent uniformity, but a system uniformity of 80 percent or greater is needed to consider fertilizer injection. If uniformity is less than 80 percent, correct the problem or *do not* attempt injection. A simple, rapid and accurate method for measuring system uniformity is described in Fig. 1. It is well worth the time spent conducting this test.

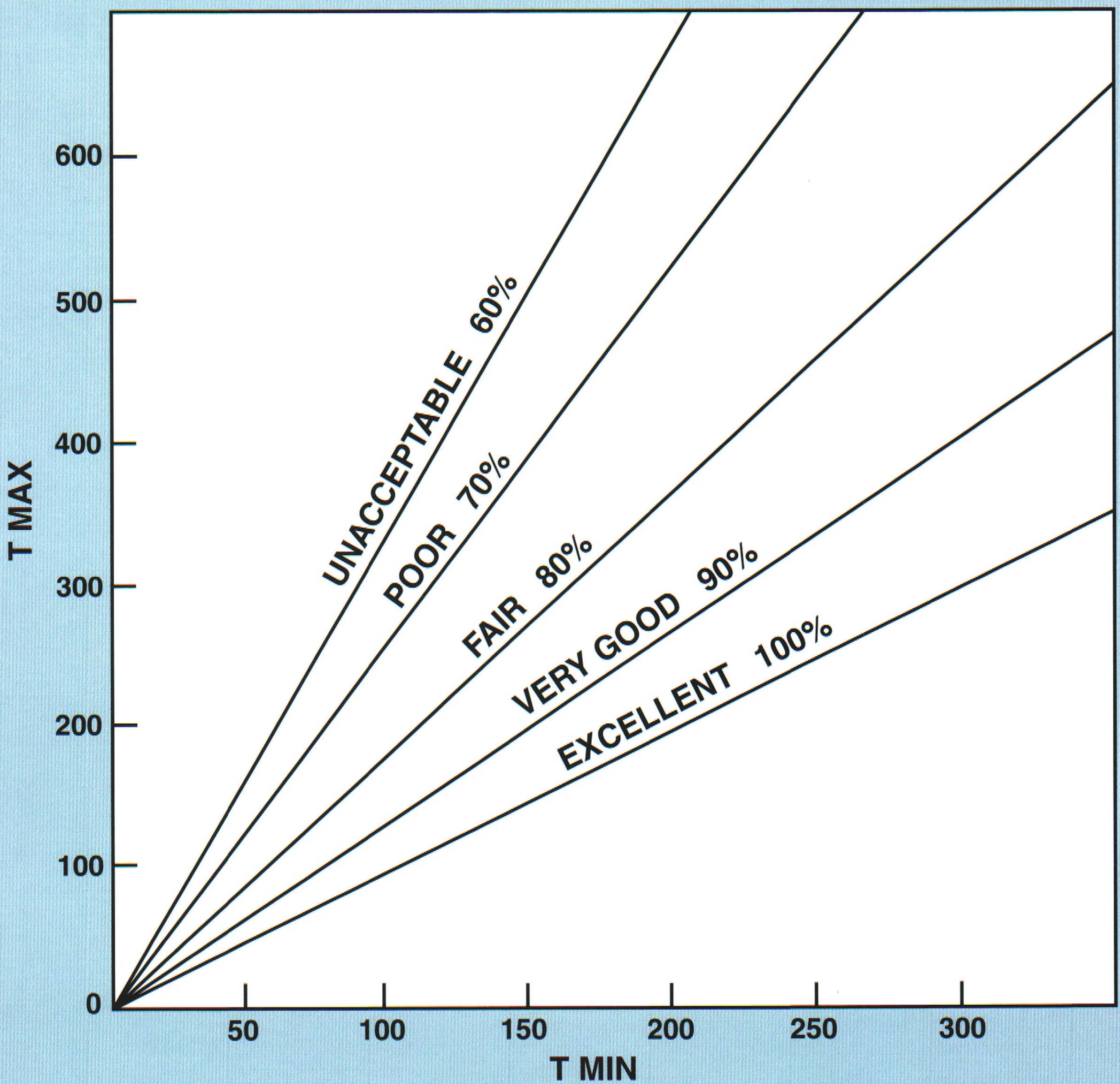
Use small containers (about 1 cup or 200 milliliters) to measure the flow from individual emitters. Mark these containers and record the time in seconds required to fill containers to the same mark at each of 18 emitters. Add the three highest times and find this point on the vertical axis marked T max. For the example in the figure, the sum of the three highest times equals 200 seconds.

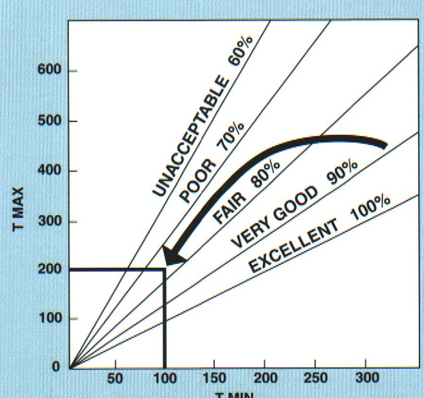
Next, add the three lowest times and find this on the horizontal axis marked T min. In the example shown, the sum of the three lowest times equals 100 seconds. Draw a vertical line up from your T min time and a horizontal line across from your T max time. The *emitter uniformity* is indicated where these lines intersect. In the example, emitter uniformity is only fair (77 percent) and fertilizer injection would *not* be recommended unless this were improved.

Non-uniformity of flow may result from improper system design, variation in emitter manufacture or emitter plugging. Rely on qualified individuals to design and install the system to avoid problems with design and manufacture. You can usually avoid emitter plugging by using filters and maintaining the system properly.

Pump output, system pressure and mainline flow usually fluctuate somewhat in each system. Improve uniformity by increasing the duration of the application and prolonging the fertilizer injection period as long as is practical.

Figure 1. Field method for calculating system uniformity.





How to collect the data

1. Choose a small container, 1 cup or 200 milliliters.
2. Choose 18 emitters at random from all parts of submain and measure the time it takes to fill the cup.
3. T max is the sum of the three highest times measured.
4. T min is the sum of the three lowest times measured.

How to use the chart

1. Find T max on the vertical axis and draw a horizontal line the right.
2. Find T min on the horizontal axis and draw a vertical line up.
3. The uniformity is shown by the intersection of the two lines.

Nitrogen Fertilizers for Injection

The most common N fertilizers for injection are 28 percent nitrogen solution, ammonium nitrate and urea. The 28 percent solution can be injected directly into the system, whereas ammonium nitrate and urea must be dissolved in water and then injected as solutions.

The solubility of several dry nitrogen fertilizers in water is given in Table 8. These are maximum rates of pure chemical (saturated solutions). Actual solubility of fertilizers is usually a little lower. Use these values as a guide and determine the actual solubility of the fertilizer in your irrigation water.

Table 8. Solubility of nitrogen fertilizers in water.

Fertilizer	lb/gal	grams/liter
Calcium nitrate	22.3	2670
Ammonium nitrate	5.8	700
Urea	9.9	1190
Potassium nitrate	1.1	135

Types of Injectors

Several types of injectors are available, but three are most common: *the Venturi* — liquid fertilizers or dissolved solid fertilizers are pulled into the system by a difference in pressure created by a constriction in the main line at the point of injection; *positive displacement pump* — the fertilizer is pumped into the system; *batch tank injector* — the stock fertilizer solution is held in a batch tank and a portion of the irrigation water is diverted to the tank by creation of a pressure gradient between the inlet and outlet of the tank.

Fertilizer concentrations in the irrigation system will vary with time depending on the injector used, but the type of injector does not affect the uniformity of fertilizer application as long as the injection time is long enough to disperse all of the fertilizer to the field.

Injection Fertilizer

How much fertilizer should be used and when should it be injected? Rate and timing will depend on tree age, variety, potential yield and root distribution, as well as soil type and experience and preference of the grower. Fertilizer injection provides growers greater flexibility than ground applications because fertilizer is delivered to the roots of trees when they need it.

Growers may reduce N rates by 50 to 65 percent by using injection systems. Thus a tree normally requiring 1 lb of ammonium nitrate applied annually to the soil surface will maintain the same vigor, yield and leaf N levels if fertilized with 1/3 to 1/2 lb through injection.

Trees recover injected nitrogen more efficiently because timing is improved and fertilizer is delivered directly to the root zone. A good rate to start with when injecting through a trickle system is half that normally applied to the soil surface. Adjust rates up or down depending on tree response.

Do not inject the entire annual rate at one time. If 1/2 pound of ammonium nitrate is required annually per tree, split this into three or more equal applications and inject at 2-week intervals beginning at about bloom time. For example, 0.16 lb per tree at bloom, and 0.16 and 0.18 lb per tree 2 and 4 weeks later, respectively.

Once you know the desired per tree rate for each application, multiply this by the number of trees in the irrigation zone to determine how much fertilizer you need for each batch. In the above example, 0.16 lb of ammonium nitrate is to be applied to each tree at bloom time. If there are 500 trees in the irrigation zone, apply 500 x 0.16 lb or 80 lb of ammonium nitrate to the block at bloom.

Efficiency and Leaching

When you coordinate fertilizer injections with irrigation schedules and expected rainfall, a high percentage of the fertilizer will remain in the root zone. Fertilizer may be leached out of the root zone and wasted if it is injected with an excessive amount of water or if it is injected immediately before or after another irrigation or heavy rain. Avoid irrigating just before or just after injecting fertilizer, and do not inject fertilizer when heavy rains are expected. Minimize leaching to improve efficiency and avoid nutrient movement into ground-water.

It is important to know the soil type in the orchard and estimate the extent of the tree root zone. As a general rule, sandy soils will hold about 1 inch of water per foot of soil, or about 0.6 gal water per cubic foot of soil. Loam soils will hold about 1.2 gal water per cubic foot, and clay soils about 1.6 gal.

One emitter per tree may not distribute water and nutrients to a sufficient percentage of the root volume. Two emitters per tree are usually adequate, but three or four emitters may be necessary in very sandy soils or on very large trees.

Injection Time

Operate trickle irrigation systems longer than the period of injection. Turn the system on and allow it to reach equilibrium or full operating level before injecting fertilizer. In most Michigan orchards, individual irrigation zones are 10 acres or less, and systems require 20 to 30 minutes to come to equilibrium.

Once the fertilizer injection is complete, run the system an additional 20 to 30 minutes to assure that all fertilizer has been purged from the lines. This will prevent fertilizer from settling out in the lines when the system is off and reduce the chances of emitter plugging.

Related MSU Publications

Lime for Michigan Soils. Michigan State University Extension bulletin E-471.

Plant Tissue Analysis for Determining Fertilizer Needs of Michigan Fruit Crops. Michigan State University Extension bulletin E-449.

Sampling Soils for Fertilizer and Lime Recommendations. Michigan State University Extension bulletin E-498.

N-P-K Fertilizers, Types, Uses and Characteristics. Michigan State University Extension bulletin E-896.

Highbush Blueberry Nutrition. Michigan State University Extension bulletin E-2011.

Fertilizer Injection in Trickle Irrigation Systems. Extension Irrigation Guide IFS/45-84, MSU Department of Agricultural Engineering.

Generally Accepted Agricultural and Management Practices for Nutrient Utilization. Michigan Department of Agriculture, Lansing.

Generally Accepted Agricultural and Management Practices for Manure Management and Utilization. Michigan Department of Agriculture, Lansing.

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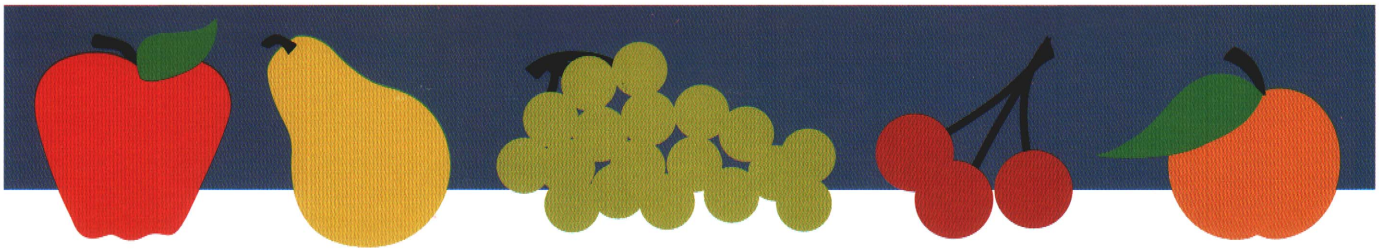

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