Fertilizing Fruit Crops
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Cooperative Extension Service
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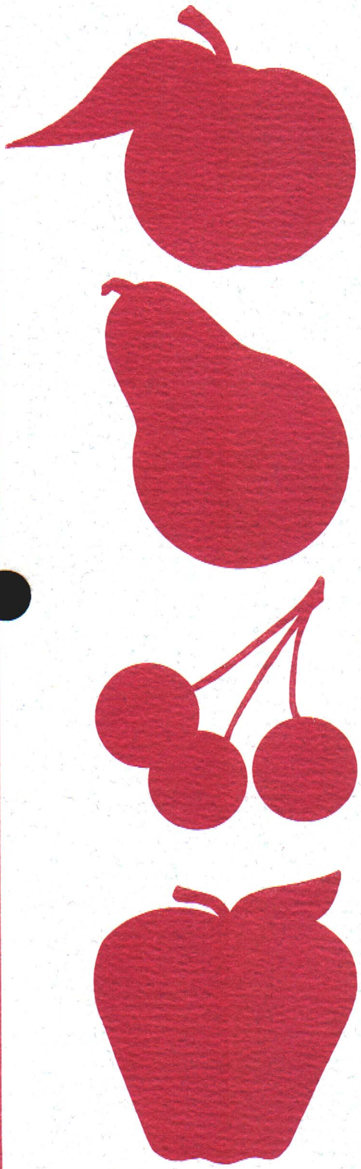
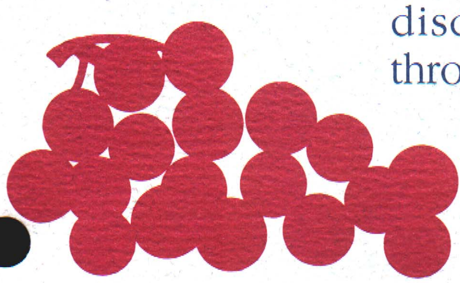


Fruit trees and vines require the following nutrient elements to grow and produce well: nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), sulfur (S), boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn). Fortunately, fruit growers need not be concerned about all of these nutrients because orchard soils contain adequate amounts of most. 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.

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



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FERTILIZING FRUIT CROPS

PART I

Diagnosing and Avoiding Nutrient Deficiencies

Fruit growers have three tools available in making decisions on fertilizer needs and diagnosing nutritional problems: visual symptoms, soil tests and tissue analysis.

Because each tool has advantages and limitations, growers are advised to utilize all three on a regular basis. 1

Visual Symptoms

Nutrient deficiencies or excesses usually cause symptoms that are fairly indicative of problems with specific nutrients. Growers can diagnose some nutrient disorders by closely inspecting plants if they are familiar with typical symptoms. 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. Occasionally, fruit crops are deficient in more than one element at the same time, further complicating visual diagnoses.

The greatest limitation of relying on the presence of symptoms to manage fruit nutrition is that symptoms indicate that 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 most common in Michigan fruit plantings are described below.

Nitrogen (N)

Nitrogen deficiencies are the most common nutrient deficiency in Michigan fruit crops. Most plantings require annual applications.

Deficiency. Trees produce short terminal shoots. As a rough guide, trees supplied with adequate N usually produce the following amounts of shoot growth: non-bearing apple, pear, cherry—12-24 inches; non-bearing peach—14-24 inches; bearing mature apple, pear, cherry—8-12 inches; bearing mature peach—12-15 inches.

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 earlier 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. 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)

Potassium deficiencies are common in Michigan cherry, peach and grape plantings and occur periodically in apples.

Deficiency. 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.

Excess. Although K does not cause toxicity, high soil K levels may inhibit Mg or Ca uptake and so induce deficiencies of these elements.

Magnesium (Mg)

Magnesium deficiencies occur periodically in Michigan fruit plantings and are most common in peaches and cherries.

Deficiency. Lack of 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 classified as *mobile* because symptoms tend to develop first on older leaves. Symptoms normally appear on foliage around midseason.

Boron (B)

Boron deficiencies are seen periodically on stone fruits but less frequently on apples and grapes.

Deficiency. Inadequate B results in a reduction in leaf size. No distinct patterns occur on individual leaves. New shoot growth is severely reduced, and tips of shoots 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.

Manganese (Mn)

Manganese deficiencies are rare in Michigan, although Mn toxicities have been a periodic problem on apples.

Deficiency. Manganese deficiencies are more likely on alkaline soils (pH greater than 7.0) and more prevalent during dry seasons. Although symptoms are similar to those of Mg deficiency, they first appear on young leaves. Youngest leaves yellow between the veins, with the main veins remaining green. In severe cases, symptoms may progress to older leaves on the shoot.

Toxicity. "Measles," a condition caused by toxic levels of Mn, is primarily 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. This is most often seen in young trees on replanted sites where lime has not been applied.

Zinc (Zn)

Zinc deficiencies have been seen periodically in Michigan cherry plantings but are rare in most other fruit crops. 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.

Soil Testing

Soil testing provides a means of monitoring soil pH and estimating nutrient supply. Research has shown, however, that 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.

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.) Separate samples from 0- to 8-inch depths and 8- to 16-inch depths are suggested, 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 6.5-6.8. 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.

Fruit sites that have been leveled or reshaped should be sampled more extensively prior to planting. Topsoil is usually removed, then replaced once the subsoil has been redistributed. Samples from the topsoil give little indication of variations in pH and nutrient levels in the subsoil. Sample both the topsoil (0-8 inches) and the subsoil (12-18 inches). Also consider sampling separately areas that were lowered by removal of subsoil and raised by addition of subsoil. These locations often vary considerably in nutrition and pH.

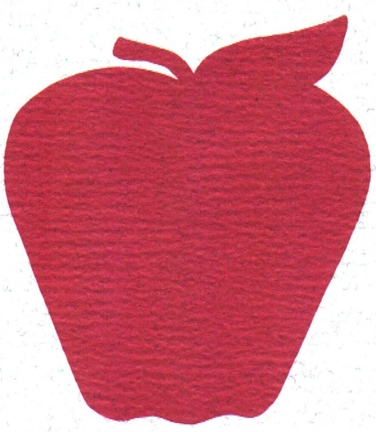


Table 1. Preplant P recommendations for apples, pears, stone fruits, grapes, strawberries and raspberries.

Soil Test Level (lb P/acre)	Recommendation (lb P_2O_5/acre)
20	90
40	70
60	40
80	20
100	0

Table 2. Preplant K recommendations for various fruit crops.

Soil Test (lb K/acre)	Recommendation (lb K_2O/acre)		
	Apples, Pears	Stone Fruits, Grapes, Raspberries	Strawberries
25	170	220	200
50	150	200	170
100	100	150	120
150	50	100	70
200	0	50	20
250	0	0	0

Sampling Soil from Established Orchards

Because most perennial fruit crops are deep-rooted, plants often obtain adequate amounts of most nutrients even though soil tests indicate that nutrient levels in the topsoil are low. Under these conditions, fertilizer applications are a waste of money because the plants will not respond to applications. In other situations, plants may not absorb adequate nutrients even though nutrient 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. Because soil pH has a strong influence on nutrient availability to plants, you may avoid many nutrient deficiencies by maintaining soil pH between 6.0 and 7.0. Nutrient deficiencies or excesses (toxicities) are more likely if the pH is below or above 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 fertilizer applications and sulfur sprays.

Sample soils from established fruit plantings periodically. Because changes in soil nutrient levels and pH are usually gradual, 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 that were limed or fertilized differently in the past. Single samples should not represent more than a 10-acre area. Each sample should be a composite of at least 20 probes.

Tissue Analysis

The most accurate indicator of the nutritional health of fruit crops is the concentration of nutrients in plant tissue. Plant tissue analysis can be used to correctly diagnose problems and monitor nutrient status to avoid problems. Presence of nutrient deficiency symptoms indicates an acute shortage in the plant and is usually accompanied by reduced yields or fruit quality. You can 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 would be advised if pH was too low, but magnesium sulfate would be preferred if soil Ca levels were 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.

Tissue analysis is most useful if you take samples on a regular 2- to 4-year cycle. Separate plantings may then be sampled in successive years and nutrient changes can be followed over time. Sample results from a single year can be difficult to interpret because weather or crop load may influence nutrient levels. Sampling over several years will provide more insight into changes and potential problems.

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

Nutrient	Crop					
	Apples, Pears	Cherries	Peaches, Plums, Apricots	Grapes (petioles)	Strawberries	Raspberries
N (%)	1.9-2.6 1.7-2.0[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)	30-50	25-40	30-50	25-50	30-90	25-50
Co (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 McIntosh apples.

Part II

Fertilizers

Fertilizers are materials containing plant nutrients. The nutrient content and the price of a fertilizer are the most important considerations in choosing materials. Other factors to consider are the reaction in soils (acidic or basic), ease of handling, 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.

Nitrogen Fertilizers

Because N is usually applied annually to fruit crops, you need to be familiar with the various sources. Nitrogen sources 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 lesss 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. For this reason, research comparing ammonium to nitrate sources of N have generally shown them to be equally effective. Sources that are 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.

Fertilizer	%N	Other nutrients present	Reaction[1]	Limestone equivalent[2] (lb $CaCO_3$/lb N)
Ammonium sulfate	20.5	S (24%)	acidic	5.3
Ammonium nitrate	32.3	none	acidic	1.8
Calcium nitrate	15.5	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	5.3
Potassium nitrate	13	K_2O (44%)	basic	2.0
Urea	46	none	acidic	1.8
Organic mulches, manures	variable	most	variable	variable

[1]acidic: reduces soil pH; basic: increases soil pH.
[2]Equals the amount of limestone 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 surface of the soil during warm weather. Urea may contain varying levels of the byproduct biurette, which can damage young trees in high concentrations.

Ammonium nitrate is also a 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 has the advantage of containing both nitrate N, which is immediately available, and ammonium N, which is retained in the soil and becomes available more slowly. If it's 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. Because nitrate leaches readily, this source should not be used in the fall or winter.

Ammonium sulfate is not commonly used on most 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—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.

Organic mulches and manures vary greatly in their nutrient content and effect on soil pH. Many are useful sources of N if they can be obtained and applied at reasonable cost. Common nitrogen concentrations in manures vary according to the source: dairy and horse, .7 percent; hog, 1 percent; poultry, 1.6 percent; rabbit and sheep, 2 percent.

Mulches may be as low as .2 - .6 percent N (wheat straw, bark mulch, sawdust) or as high as 1.0 - 1.5 percent N (bean or alfalfa hay). Most of these materials are expensive sources of N. Their beneficial effects on soil characteristics and moisture retention are more difficult to evaluate against cost.

Potassium Fertilizers

Although there are several fertilizer sources of potassium, choice of source should be based primarily on cost per unit of K_2O and whether the material contains other useful nutrients. Various sources appear equally effective in supplying K to fruit plants.

Muriate of potash (KCl) may be the most commonly used K source for Michigan fruit crops. It is high in analysis (60-62 percent K_2O) and inexpensive. Problems with chloride toxicity may be seen 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 is also extensively used. It is somewhat lower in analysis (50 percent K_2O) and usually more expensive than KCl. 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

Choice of P fertilizers should be based on 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 (18-20 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.

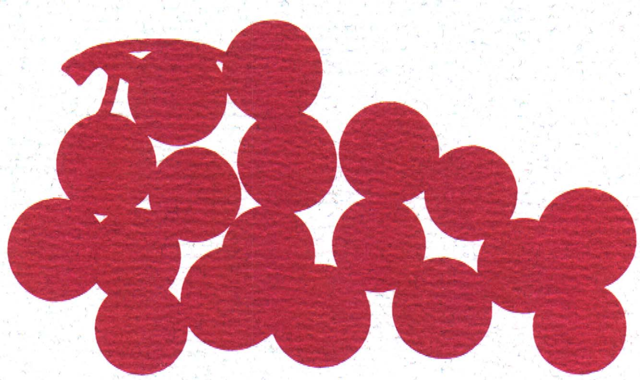
Monoammonium phosphate (MAP) has been used more frequently in recent years, both alone and in bulk blended fertilizers. MAP contains 48 percent P_2O_5, nearly all of which is readily available to plants, and 11 percent N. MAP has an acidifying effect on soils but is usually a competitively priced source 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 (3-8 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 lists some commonly used sources of secondary and micronutrients. Many can be used in ground or foliar applications, as discussed in Part III.



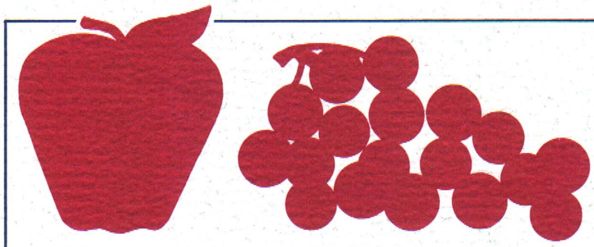


Table 5. Suggested sources of secondary and micronutrients for fruit crops.

Source	Analysis (%)							
	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)**								
elemental sulfur			50-99					
potassium magnesium sulfate (Sul-Po-Mag)		11	23					
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		
Ferbam fungicide						?		
***Manganese* (Mn)**								
manganese sulfate							32	
manganese chelates							variable	
***Zinc* (Zn)**								
zinc sulfate								22-36
zinc chelates								variable

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.

Fertilizer Placement and Timing

Place fertilizer where it is most accessible to the plant but distribute it to minimize the potential of burning roots. Most commercial fertilizers are salts that, if concentrated, can burn plant roots.

On young trees and vines, spread fertilizer in a circle 3 to 4 feet in diameter around each plant, making sure fertilizer is not in direct contact with the trunk. Apply fertilizer to mature orchards in a broad band about as wide as the tree canopy. On mature vineyards, spread fertilizer in the row in a band 5 to 6 feet wide.

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.

Tree Fruit Recommendations

Nitrogen

Although optimum N rates vary considerably from site to site, rates in the table below may be used 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.

Factors Affecting N Requirements

Heavy pruning stimulates vegetative growth and can reduce or replace N requirements. Heavily pruned trees should be fertilized lightly if at all.

Orchard floor management also affects N requirements. 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.

If hay, straw or manures are applied, nitrogen applications may be reduced or eliminated for a year until the tree response to these materials can be observed. It is difficult to predict how much N, if any, mulch materials will supply.

P, K, Ca, Mg Applications

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

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

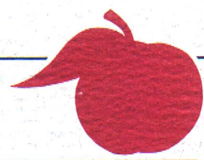


Table 6. Recommended N rates (oz N/tree) for tree fruit crops.

	Plant age (years in field)				
Crop	1	2-3	4-5	6-7	Mature[1] orchards
Apples, pears	2-3	4-6	7-9	10-12	12-16
Stone fruits	3-4	5-7	8-10	12-14	16-20

[1]For mature orchards, apply 50-75 lb N/acre (apples, pears) or 75-100 lb N/acre (stone fruits).

Potassium (K) applications of 150-300 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 2-4 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 2-3 lb/100 gal in June and July and 3-5 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 conditions or if no rain has fallen since the last spray. Apply 20-30 lb $CaCl_2$/acre during the season for best results.

If magnesium (Mg) is required, dolomitic limestone is the least costly source. Use 2-4 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):

Ground applications:

- 1.0-1.5 lb B/acre—apples, pears.
- 0.5-1.0 lb B/acre—cherries.
- 0.5 lb B/acre—peaches.

Foliar sprays:

- 0.5 lb B/100 gal (dilute) in first two cover sprays.

OR

- 1.0 lb B/100 gal (dilute) postharvest in September or October.

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 particularly sensitive to excessive B—apply B only if you know 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 have 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 (1-2 lb/100 gal) or 3-5 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.

Grape Recommendations

Nitrogen

Most mature vineyards require about 50 lb N/acre annually. Young plantings require about 10-15 lb N/acre for each year in the field. Vigorous vineyards on double curtain trellis systems may require 75-100 lb N/acre.

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 100-200 lb K_2O/acre. Vineyards on sandy soils are more prone to K deficiency and may require regular 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. Two post-bloom sprays of magnesium sulfate (Epsom salts) at 10 lb/100 gal are advised for 1 to 2 years until the limestone reacts in the soil.

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

Few micronutrient shortages have been seen 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 some 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.

The nutrient most commonly applied through trickle irrigation systems is nitrogen. 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.

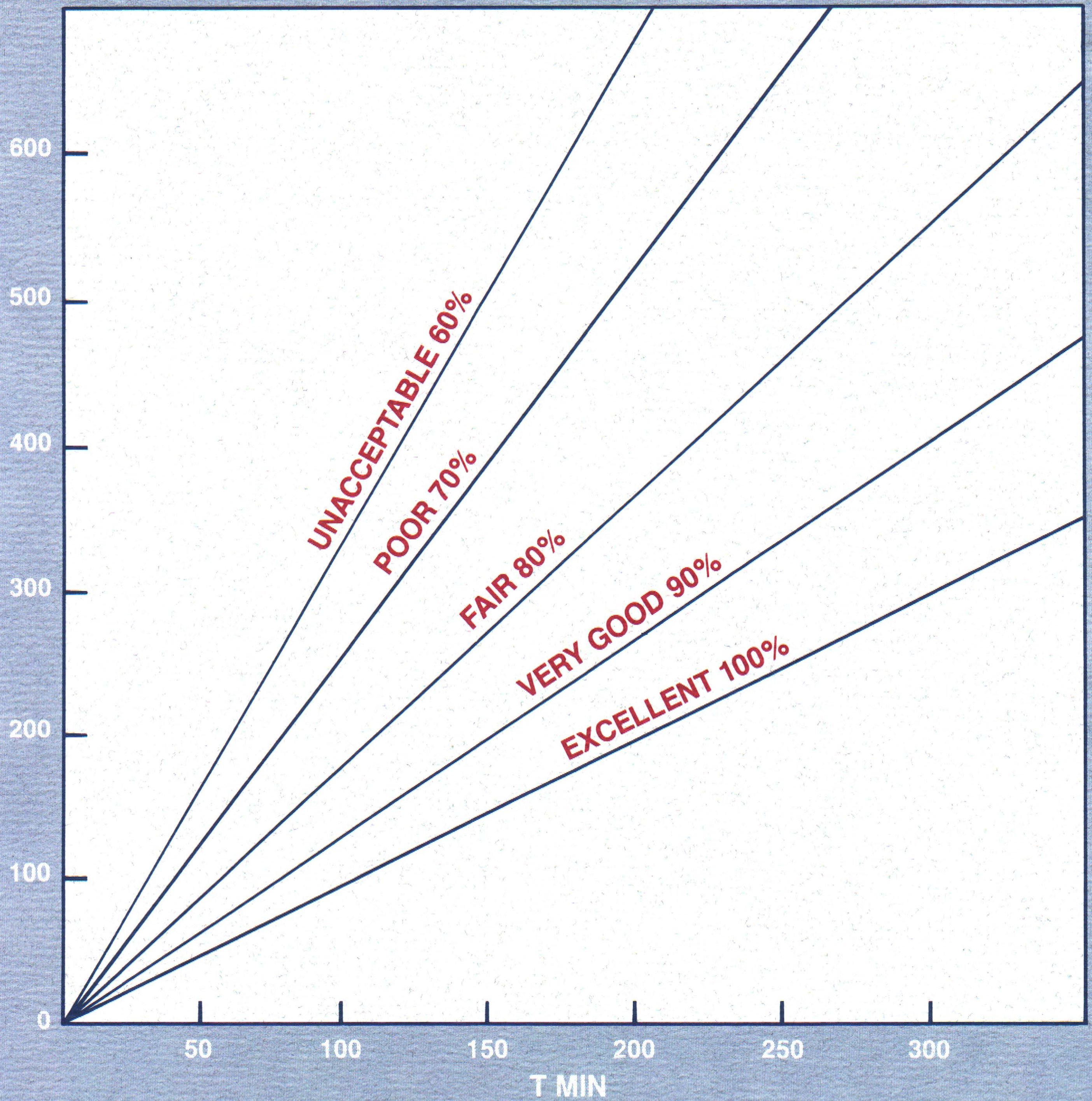
System Uniformity

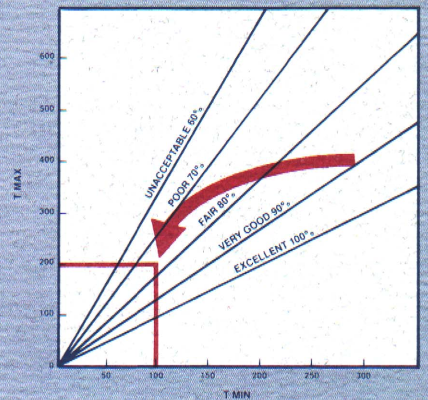
The most important requirement for effective fertilizer injection is system uniformity. Fertilizer cannot be applied uniformly to trees unless water delivery is uniform. A trickle system with 100 percent uniformity delivers exactly the same amount of water from each emitter per minute or hour. It is nearly impossible to obtain 100 percent uniformity, but a system uniformity of 80 percent or greater is needed before you can 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. Growers can conduct this test and will find it well worth the time spent.

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 could be 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

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 to 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.

emitter plugging by use of filters and proper system maintenance.

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.

Nitrogen Fertilizer Sources 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 7. 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.

Types of Injectors

Although several types of injectors are available, 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 mainline 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 final uniformity of fertilizer application as long as the injection time is long enough to disperse all of the fertilizer to the field.

Injecting 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 much more flexibility than ground applications because fertilizer is delivered to the roots of trees when they need it.

Research indicates that growers may reduce N rates by 50 to 65 percent by using injection systems. This means that 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 ⅓ to ½ lb through injection.

Trees are able to 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 one-half pound of ammonium nitrate is required annually per tree, split this into three or more equal applications, injecting at 2-week intervals beginning at about bloom time. For example, 0.16 lb per

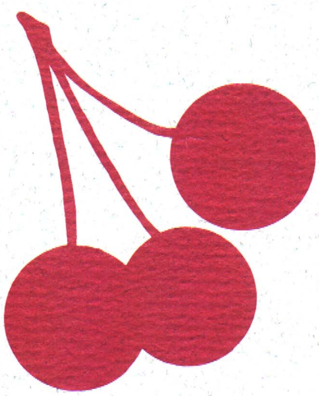


Table 7. Solubility of nitrogen fertilizers in water.

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

tree at bloom, and 0.16 and 0.18 lb per tree 2 and 4 weeks later.

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 × 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 groundwater.

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.

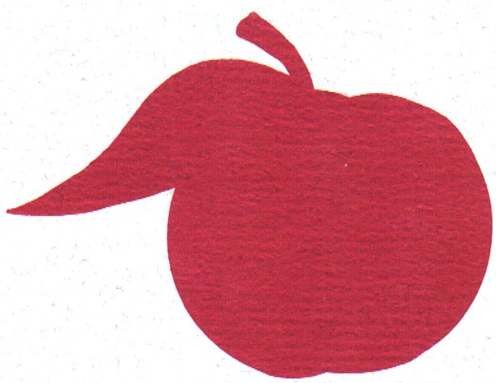
Injection Time

It is important to 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

E-471, "Lime for Michigan Soils."
E-449, "Plant Tissue Analysis for Determining Fertilizer Needs of Michigan Fruit Crops."
E-498, "Sampling Soils for Fertilizer and Lime Recommendations."
E-896, "N-P-K Fertilizers, Types, Uses and Characteristics."
E-2011, "Highbush Blueberry Nutrition."
Extension irrigation guide IFS/45-84, "Fertilizer Injection in Trickle Irrigation Systems."



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