Lawn and Garden Soil Test Interpretations and Fertilizer Recommendation Guide

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Introduction

This publication describes the methods used to provide soil test interpretations and fertilizer recommendations for residential lawns and gardens. These guidelines have been developed from research conducted in Missouri or adapted from work done in adjacent Midwest states.

Soil samples collected from lawns and gardens should be submitted with the Horticulture Soil Sample Information forms (MP555). Information recorded on these forms, along with soil test data, provides the basis for recommendations. On the last page of this publication is a copy of the Horticulture Soil Sample Information form used. The forms can be obtained from county University Outreach and Extension Offices and from Soil Testing Laboratories in Columbia and Portageville. The forms can also be downloaded from the Soil Testing Lab's Web site http://www.soiltest.psu.missouri.edu/. The information supplied in this form will result in a better fertilizer recommendation and interpretation of the soil test results.

Because residential landscape plantings and lawns are of relatively small size, specific directed management is possible for a specific area, such as a front yard or an area around a tree or bush. Proper nutrient management considers a soil's ability to supply plants with essential nutrients. Fertilizer and amendment recommendations are then based on soil tests. By eliminating the guesswork of providing nutrients, plant growth and appearance can be optimized, and excessive and potentially environmentally harmful fertilizer applications can be avoided.

Soil sampling

Proper collection of a soil sample is a very important part of soil testing. The soil sample must be representative of the area sampled. Otherwise, interpretations and recommendations based on the results could be misleading, inaccurate and potentially counterproductive. A common error is that too small or too large an area is sampled from a garden or lawn. Proper depth and number of subsamples are also important.

Individual samples should be taken from any area that may require different nutrient needs for a plant or areas that may differ in soil properties that could affect plant growth. The specific area from which a sample is to be taken can vary. From the perspective of soil properties, factors to consider in selecting an area to sample include topography, slope, texture, soil color and drainage.

Because soils are inherently variable in their distribution of plant nutrients, an individual soil sample should be a composite of several subsamples. Thus, the composite sample becomes an "average" of the soil in the area to be represented. Each composite sample should consist of 6 to 12 subsamples. The subsamples should be mixed, and cores or chunks of soil should be broken apart. From this mixed soil, a pint of soil should be sent to the Soil Testing Laboratory, preferably in a soil sample bag or box. Soil sample boxes are available at the county University Outreach and Extension centers or from the University of Missouri Soil Testing Laboratories in Columbia and Portageville.

Soil samples may be taken any time of the year. However, fall sampling is preferred, as there is more time to plan fertilizer and lime management. A soil tube, soil auger or a garden trowel or spade are all appropriate tools for collecting samples. Scrape off surface vegetation or litter and take the sample to the desired depth. For gardens and lawn establishment, sample to a depth of 6 inches. For established lawns, sample to a depth of 3 to 4 inches. For established trees, shrubs and other perennials, sample to a depth of 6 inches. At the time of establishment of perennials, it is preferable to take another sample at 6 to 12 inches in order to adjust subsoil pH if required.

Soil testing

In soil testing, laboratory procedures measure plant-available nutrients in the soil. Soil tests are only an **index** of the total amount of nutrients available to plants. Variables like weather and plant growth affect the soil's ability to supply nutrients. Soil test values are rated according to the probability of a plant's response to supplemental fertilizer. Table 1 shows an example of the ratings that might be used to describe the probability of a response to fertilizer.

Table 1. General relationship between soil test rating and the probability of response to fertilizer.

Soil test rating	Probability of response to fertilizer	Fertilizer recommendation
Very low	greater than 90%	Large applications for soil building purposes.
Low	60 – 90%	Annual applications to maximize plant growth and increase soil fertility.
Medium	30 – 60%	Annual applications to maximize plant growth.
High	less than 10%	Small annual applications to maintain soil level. Amounts may be doubled and applied in alternate years.
Very high	unlikely	None until level drops back into the high range.

A listing of the soil test procedures used by the Soil Testing Laboratories is provided below. The first eight listed are provided with a regular soil test analysis.

1. Soil pH_s (1:1 soil:solution). Solution is 0.01M $CaCl_2$
2. Lime requirement (neutralizable acidity) Modified Woodruff Buffer Method
3. Organic matter (%) loss on ignition
4. Extractable phosphorus (Bray-1 P)
5. Exchangeable potassium (ammonium acetate (NH_4OAc) extraction)
6. Exchangeable calcium (NH_4OAc extraction)
7. Exchangeable magnesium (NH_4OAc extraction)
8. Cation exchange capacity (estimated from exchangeable K, Ca, Mg, and neutralizable acidity)
9. Extractable zinc (DPTA extraction)
10. Extractable sulfur (calcium phosphate in acetic acid extraction)
11. Extractable iron, manganese and copper (DPTA extraction)
12. Exchangeable sodium (NH_4OAc extraction)
13. Hot water extractable boron (0.1% $CaCl_2H_2O$)
14. Nitrate-nitrogen and ammonium-nitrogen (2 M KCl extraction)
15. Soluble salts (electrical conductivity in a 1:1 soil:water ratio)
16. Particle size analysis (hydrometer method)

Fertilizers

All commercially sold fertilizers report the percentage of primary nutrients (nitrogen, phosphorus and potassium) that are contained within the fertilizer. These three nutrient percentages are referred to as the fertilizer grade. It is shown on the fertilizer label and is guaranteed by the manufacturer. Nitrogen is expressed on an elemental basis (N), while phosphorus and potassium are reported on an oxide basis, P_2O_5 and K_2O. Thus, a 10 lb bag of fertilizer with a grade of 5-10-10 would contain 0.5 lb of nitrogen, 1 lb of phosphorus as P_2O_5, and 1 lb of potassium as K_20.

Many different fertilizer grades are marketed. For lawn and garden fertilizers, blends of different sources are common. Despite the availability of many different grades, the N-P-K ratio in a fertilizer seldom matches the recommended N-P-K ratios suggested by soil tests. Consequently, some compromise is required when applying fertilizer nutrient recommendations, and one or more nutrients will need to be over- or underapplied. Single-nutrient fertilizers are also available, and a separate application of such a fertilizer could be used to supplement an application of a fertilizer blend that would under- or oversupply a nutrient. Urea (46-0-0), concentrated super-phosphate (0-46-0), and potassium chloride (0-0-60) are examples of single-nutrient fertilizers for nitrogen, phosphorus and potassium, respectively.

Choosing a fertilizer grade

Suppose a soil test results in an N-P-K recommendation of 2 lb nitrogen, 4 lb phosphorus and 1 lb potassium per 1000 square feet. The N-P-K ratio of the recommendation then is 2-4-1, and a fertilizer with a grade close to this ratio should be chosen. If at the local store, the following grades are available; 5-15-5, 12-12-12, 10-20-10, and 15-30-5, then what would be the appropriate grade to choose? A compromise for one or more nutrients will be necessary. With these grades the N-P-K ratios are 1-3-1, 1-1-1, 1-2-1 and 3-6-1, respectively. One should first try to match the ratio between the nitrogen and phosphorus, as these are the nutrients recommended in the two largest amounts. Second, the ratio between phosphorus and potassium should be considered. When trying to match N-P ratios, 10-20-10 and 15-30-5 could be picked. If we chose 10-20-10 we will be slightly overapplying K, and if we pick 15-30-5 we will be underapplying K, when matching the N and P recommendations. Proper application of nitrogen and phosphorus is preferred in most situations, as both over- and underfertilization of these nutrients can lead to undesirable growth and production. It will be acceptable to apply slightly more K than what is required. So the best choice is to pick 10-20-10.

Calculating the fertilizer amount to apply based on soil test recommendations

Once the fertilizer grade is chosen, two more steps need to be followed to determine the amount of fertilizer material applied. Using the example above and assuming that the fertilizer is for a garden, then the 10-20-10 grade is chosen. The fertilizer will be applied to match the nitrogen and phosphorus requirements, because we need to base our calculations on providing the nutrient that is required the most. In this example the goal is to provide 4 lb of phosphorus per 1000 square feet.

Step 1: Determine the amount of fertilizer material (10-20-10) to apply per 1000 square feet.

Divide 4 lb (of phosphorus) by the percent (on a decimal basis) of phosphorus in the fertilizer.

$$\frac{lb\ nutrient/1000\ sq\ ft}{\%\ nutrient\ in\ fertilizer/100} = lb\ fertilizer/1000\ sq\ ft \qquad \frac{4\ lb/1000\ sq\ ft}{20/100} = 20\ lb/1000\ sq\ ft$$

Step 2: Calculate the total amount of fertilizer to apply.

Multiply the garden or lawn area to be fertilized (in sq ft) by the fertilizer rate (in lb per 1000 sq ft). In this example, assume a 4000 sq ft area (40 ft × 100 ft).

$$garden\ area\ (sq\ \ ft) \times \frac{lb\ \ fertilizer}{1000\ sq\ \ ft} = \frac{lb\ \ fertilizer}{garden} \qquad \frac{4000\ sq\ \ ft}{garden} \times \frac{20\ lb\ \ fertilizer}{1000\ sq\ ft} = \frac{80\ lb\ \ fertilizer}{garden}$$

A useful rule of thumb when applying fertilizer is that 2 cups of fertilizer approximates one pound.

Soil pH

Soil pH is a measurement of a soil's reaction, i.e., its acidity or alkalinity. Most Missouri soils have a pH less than 7.0 and thus have varying degrees of acidity. Alkaline soils (those with a pH greater than 7.0) are not common to Missouri. A soil's acidity level affects nutrient availability, the activity of soil microbes and the growth of plants.

The University of Missouri Soil Testing Lab makes two measurements of soil acidity – salt pH (pH_s) and neutralizable acidity (NA). The pH_s is a measurement of active acidity. This is the acidity that plant roots are exposed to. Reserve acidity, is the source of active acidity. It is measured by a different laboratory procedure and is reported as neutralizable acidity. Lime recommendations are based on soil pH_s and neutralizable acidity. Another pH measurement commonly used by commercial labs is water pH (pH_w), which tends to be 0.5 units higher than pH_s. However, the actual difference depends on natural salt levels in the soil.

On soil test reports, pH_s is rated according to the ranges in Table 2. Soils with a pH_s rating of very low to low have a definite need for limestone, as growth is likely reduced. At low pH_s iron, aluminum and manganese become very soluble and can reach toxic levels. In general most plants prefer a pH_s range of 6.0 to 7.0. In the medium range, limestone may be needed in coming seasons, as the soil acidifies naturally or through the application of manure or ammonium-based fertilizers. A very high rating indicates that the pH_s is greater than desired, and nutrient availability may be reduced. A very high pH_s may also be an indicator of other soil problems, which could limit plant growth. An excess pH_s indicates severely alkaline conditions, which would strongly restrict plant growth. At high pH_s, micronutrient availability is reduced, which can result in deficiency. Where the pH_s is greater or less than the desired range, some corrective measure is recommended.

Despite the soil pH_s ratings listed in Table 2, plants vary in preferable soil pH_s. Most prefer a slightly acid pH_s between 6.0 and 7.2. Vegetables, annual flowers and turf grasses are included in this group. Perennial horticultural plants prefer soil pH_s ranging from strong acid loving to alkaline loving (Table 3).

Table 2. Soil pH_s ratings for lawns and gardens.

Rating	pH_s
Very low	< 5.0
Low	5.0 - 5.8
Medium	5.8 - 6.5
High	6.5 - 7.5
Very high	7.5 - 9.0
Excess	> 9.0

Limestone recommendations

Limestone recommendations vary according to the pH_s preference of the plant (Table 3). If a plant is not identified in Table 4, then it is assumed to prefer a slightly acid soil (pH_s 5.5 - 6.5). Limestone applications of more than 100 lb/1000 sq ft are not recommended at any one time. When recommendations suggest more, a second application is recommended six months to one year later.

Although limestone is the most commonly used liming material, wood ashes can also be effective toward increasing soil pH. However, wood ashes are only 40 percent as effective as limestone and are high in potassium. When used repeatedly, wood ashes could potentially build soil potassium to excessive levels. A lime recommendation of 100 lb/1000 sq ft would require 250 lb/1000 sq ft of wood ashes.

Guidelines for lowering pH_s

The growth and appearance of some perennial plants is optimized by a low soil pH_s. When the soil pH_s is greater than desired, finely ground elemental sulfur is recommended to lower the soil pH_s. Sulfur is recommendation varies depending on the pH_s preferences of plants. A recommendation for sulfur depends on a target pH_s (Table 5) and the cation exchange capacity (CEC) of the soil.

Table 3. Limestone recommendations for crops with different pH_s preferences.

Category	Apply lime when	Limestone recommendation
Alkaline loving	$pH_s < 6.5$	Lime (lb/1000 sq ft) = neutralizable acidity × 25
Slightly acid loving	$pH_s < 6.0$	Lime (lb/1000 sq ft) = neutralizable acidity × 25
Medium acid loving	$pH_s < 5.0$	Lime (lb/1000 sq ft) = 50
Strong acid loving	$pH_s < 4.0$	Lime (lb/1000 sq ft) = 50

Equations for calculating a sulfur recommendation at differing cation exchange capacities are given below:

At a CEC ≤ 10: Sulfur (lb/1000 sq ft) = (pH_sTest - pH_sTarget) × 5 + 0.5

At a CEC 10 - 18: Sulfur (lb/1000 sq ft) = (pH_sTest - pH_sTarget) × 10 + 0.5

At a CEC > 18: Sulfur (lb/1000 sq ft) = (pH_sTest - pH_sTarget) × 18 + 0.5

Sulfur reacts slowly with the soil and takes about three to six months to reduce the soil pH. Sulfur should be incorporated into the soil. On established lawns, pH adjustment is usually unrealistic because sufficient amounts cannot be applied to effectively lower pH without adverse effects (leaf burn). Iron sulfate also lowers soil pH_s (as do other sulfur containing fertilizers). It reacts much faster than elemental sulfur (within three to four weeks).

Table 4. pHs preferences of various plants

Strong acid loving	Medium acid loving	Slightly acid loving		Alkaline loving
$pH_s < 5.0$	$5.0 < pH_s < 5.5$	$5.5 < pH_s < 6.5$		$pH_s > 6.5$
Azalea	African violet	Anemone	Ivy, English	Asparagus
Blueberry	Am. bittersweet	Apple	Larkspur	Arborvitae
Camellia japonica	Begonia	Ash	Lilac	Barberry
Ferns	Black gum	Aster	Maple*, Norway*	Black walnut
Gardenia	Bleeding heart	Birch	Maple, *Silver*	Calendula
Heather	Boxwood	Box elder	Maple, *Sugar*	Celery
Huckleberry	Chokecherry	Buckeye	Marigold	Clematis
Hydrangea *(blue)*	Cyclamen	Candytuft	Mock orange	Deutzia
Lily, *Calla*	Cypress	Cannis	Narcissus	Forget-me-not
Magnolia	Delphinium	Carnation	Pansy	Geranium
Pine, *White*	Easter lily	Cedar	Oak, *Black*	Hydrangea *(pink)*
Potato	Holly	Centaurea	Oak, *Bur*	Junipers
Rhododendron	Iris, *Japanese*	Chrysanthemum	Oak, *White*	Lupine
Rhubarb	Lily	Columbine	Pear	Morning glory
Sweet potato	Maple, *Red*	Cosmos	Peony	Nasturium
Watermelon	Oak, *Pin*	Crabapple	Petunia	Redbud
	Oak, *Red*	Crocus	Plum	Spinach
	Pecan	Daffodil	Poinsettia	Sweetpeas
	Phlox	Dahlia	Poplar	
	Pine	Dogwood	Poppy	
	Sweetgum	Elderberry	Primrose	
	Viburnum	Elm	Raspberry	
	Vinca	Forsynthia	Rose	
	Weigela	Ginko	Russian olive	
		Gladiolus	Smokebush	
		Grape	Snapdragon	
		Hackberry	Spruce	
		Hawthorne	Trumpet creeper	
		Hickory	Tulip	
		Hollyhock	Violet	
		Honeysuckle	Virginia creeper	
		Hyacinth	Yew	
		Iris, *Bearded*	Yucca	

Table 5. Sulfur recommendations for crops with different pH_s preferences.

Category	Apply sulfur when	Target pH_s
Alkaline loving	None	-
Slightly acid loving	$pH_s > 7.5$	6.5
Medium acid loving	$pH_s > 6.5$	5.5
Strong acid loving	$pH_s > 5.5$	5.0

Nitrogen recommendations

Nitrogen is the nutrient that is most often limiting for plant growth. Soils generally contain large amounts of nitrogen, but it is mostly present in soil organic matter in forms unavailable to plants. Nitrogen is released from organic matter relatively slowly and the amount is generally insufficient to meet the needs of growing plants. Several soil and weather variables affect the release of soil nitrogen and what happens to it in the soil following release. Consequently, a reliable soil test for determining nitrogen availability has not been developed. Rather current soil tests estimate nitrogen released from organic matter. Soil organic matter content and CEC are the two variables measured in a soil test that are used for calculating available nitrogen. Nitrogen recommendations are based on plant nitrogen need, soil organic matter and management.

Vegetables, annual flowers, perennials and establishment of lawns

When soil organic matter levels are less than desired, then fertilizer nitrogen is recommended. The desired organic matter (OM) level depends on CEC as shown in Table 6 and in the following equations.

For CEC ≤ 10: $$OM\ desired = \{2 + [(CEC - 6) \times 0.2]\}$$

For CEC ≥ 11: $$OM\ desired = \{3 + [(CEC - 11) \times 0.1]\}$$

Table 6. Desired organic matter levels for lawn establishment and other horticultural plants.

Cation exchange capacity	Desired organic matter
meq/100 g soil	(%)
6 or less	2.0
8	2.4
10	2.8
12	3.1
14	3.3
16	3.5
18	3.7
20	3.9
22	4.1
24	4.3
26	4.5
28	4.7
30 or greater	4.9

Using the above equation of desired organic matter level, calculate recommended by the following equation:

$$Nitrogen\ (lb/1000\ sq\ ft) = \frac{OM\ desired - \%\ Organic\ Matter}{43.56} \times 25$$

For the two different CEC categories, the above equation then expands to the following two equations:

When the CEC is 10 or less:

$$Nitrogen\ (lb/1000\ sq\ ft) = \frac{\langle \{2 + [(CEC - 6) \times 0.2]\} - \%OM \rangle \times 25}{43.56}$$

When the CEC is greater than or equal to 11:

$$Nitrogen\ (lb/1000\ sq\ ft) = \frac{\langle \{3 + [(CEC - 11) \times 0.1]\} - \%OM \rangle \times 25}{43.56}$$

In the calculation of these equations, numbers greater than 0.75 are rounded to the nearest half pound. Numbers greater than zero but less than or equal to 0.25 are rounded to 0.5. Table 7 shows the values calculated using the above equations.

Table 7. Nitrogen fertilizer requirements for vegetables, annual flowers, perennials and establishment of lawns.

Organic matter	Cation exchange capacity (meq/100 g)									
	6	8	10	12	14	16	18	20	22	24
(%)	lb N/1000 sq ft									
0.2	1.0	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.5
0.4	1.0	1.0	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0
0.6	1.0	1.0	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.0
0.8	0.5	1.0	1.0	1.5	1.5	1.5	1.5	2.0	2.0	2.0
1.0	0.5	1.0	1.0	1.0	1.5	1.5	1.5	1.5	2.0	2.0
1.2	0.5	0.5	1.0	1.0	1.0	1.5	1.5	1.5	1.5	2.0
1.4	0.5	0.5	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5
1.6	0.5	0.5	0.5	1.0	1.0	1.0	1.0	1.5	1.5	1.5
1.8	0.5	0.5	0.5	0.5	1.0	1.0	1.0	1.0	1.5	1.5
2.0	0	0.5	0.5	0.5	0.5	1.0	1.0	1.0	1.0	1.5
2.2		0.5	0.5	0.5	0.5	0.5	1.0	1.0	1.0	1.0
2.4		0	0.5	0.5	0.5	0.5	0.5	1.0	1.0	1.0
2.6			0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.0
2.8			0	0.5	0.5	0.5	0.5	0.5	0.5	1.0
3.0				0.5	0.5	0.5	0.5	0.5	0.5	0.5
3.2				0	0.5	0.5	0.5	0.5	0.5	0.5
3.4					0	0.5	0.5	0.5	0.5	0.5
3.6						0	0.5	0.5	0.5	0.5
3.8							0	0.5	0.5	0.5
4.0								0	0.5	0.5
4.2									0	0.5
4.4										0

Lawn maintenance

Nitrogen nutrition of turf goes beyond the simple supply of nitrogen for adequate growth. Health and appearance are highly valued attributes. Consequently, nitrogen recommendations are based on turf nitrogen requirements, regardless of the nitrogen supply from the soil.

Table 8. Nitrogen recommendations for lawns based on species and management level.

	Management level			
	Average maintenance		High maintenance	
Grass species	OM < 3%	OM ≥ 3%	OM < 3%	OM ≥ 3%
	lb nitrogen/1000 sq ft			
Cool-season grasses (fescue, bluegrass, rye)	2	2	4	3
Warm-season grasses (bermudagrass, zoysiagrass, buffalograss)	2	1	3	2

Plant-available nitrogen primarily exists in two forms, ammonium and nitrate. Whether derived from manufactured fertilizer, organic fertilizer, soil organic matter or manure, nitrogen is eventually converted by soil microbes into ammonium and nitrate. Organic sources of nitrogen could be considered slow-release forms, since nitrogen from them must be "mineralized" to the ammonium and nitrate forms. Commercial nitrogen fertilizers that are slow-release are usually sold as a product called ureaform or a derivative of urea such as methylol urea or methylene urea. Most often commercially sold fertilizer for lawns and gardens contains a blend of quick-release and slow-release nitrogen sources.

Suggested application times are intended to optimize nitrogen availability during the growing season to produce the best aesthetic appearance and health of lawns. Improperly timed applications can stimulate growth that can eventually be harmful to the health of a lawn. Conversely, properly timed applications, such as early fall applications for cool-season lawns, stimulate tillering and enhance root growth, which will thicken a lawn and encourage recovery from summer stresses.

Phosphorus recommendations

Phosphorus exists in acidic soil as rather insoluble forms of iron and aluminum phosphates and in alkaline soil as insoluble calcium phosphates. Plants take up phosphorus as the orthophosphate anion ($H_2PO_4^-$), which is present in the soil in relatively small amounts (supplied by relatively insoluble phosphorus). The Bray-1 P soil test estimates plant-available phosphorus.

Soil phosphorus compounds are rather insoluble, which limits phosphorus movement in the soil. Phosphorus fertilizer usually moves less than an inch from the point of contact with the soil. Consequently, phosphorus fertilizer should be mixed into the soil or band applied for gardens or when planting landscape plants.

The following equations are used to provide phosphorus recommendations for vegetables, annual flowers and perennials, for lawn establishment and for lawn maintenance (Table 9). Phosphorus recommended for lawn establishment is twice that required for maintenance. PST is the phosphorus soil test value.

Vegetables, annuals, and perennial landscape plants

$$Phosphorus \ \ (lb\ P_2O_5\ /1000\ sq\ ft) = \frac{110\left(\sqrt{80} - \sqrt{PST}\right)}{4 \times 43.56}$$

Lawn establishment

$$Phosphorus \ \ (lb\ P_2O_5\ /1000\ sq\ ft) = \frac{110\left(\sqrt{60} - \sqrt{PST}\right)}{4 \times 43.56}$$

Lawn maintenance

$$Phosphorus \ \ (lb\ P_2O_5\ /1000\ sq\ ft) = \frac{110\left(\sqrt{60} - \sqrt{PST}\right)}{8 \times 43.56}$$

Table 9. Phosphorus fertilizer recommendations and ratings.

Soil test phosphorus	Soil test rating	Vegetables, annuals, perennials	Lawn establishment	Lawn maintenance
lb/acre		--------------------- lb/1000 sq ft --------------------		
5	Very low	4.0	3.5	1.5
10	Very low	3.5	3.0	1.5
15	Very low	3.0	2.5	1.0
20	Very low	3.0	2.0	1.0
25	Low	2.5	1.5	1.0
30	Low	2.0	1.5	0.5
35	Low	2.0	1.0	0.5
40	Low	1.5	1.0	0.5
45	Medium	1.5	0.5	0.5
50	Medium	1.0	0.5	0.5
55	Medium	1.0	0	0
60	Medium	1.0	0	0
65	High	0.5	0	0
70	High	0.5	0	0
75	High	0	0	0
80-120	High	0	0	0
> 120	Very high	0	0	0

Potassium recommendations

Available potassium exists in the soil as the K^+ ion. Because potassium attaches to clay minerals in the soil, movement and supply of potassium in the soil depends on soil texture and consequently CEC. On nonsandy soils, potassium movement is greatly restricted. So potassium fertilizer should be mixed into the soil in gardens or prior to planting landscape plants. On sandy soils the absence of much clay allows potassium to move more freely, such that it can actually leach from the root zone.

Fertilizer recommendations are dependent on soil test potassium and CEC. The equations below are used to calculate potassium recommendations. Potassium recommendations for lawn establishment are 25 percent more than for maintenance. Soil test ratings and fertilizer recommendations for potassium are given in Tables 10 and 11.

Vegetables, annuals, perennial landscape plants and lawn maintenance

$$Potassium\ (lb\,K_2O/1000\ sq\ ft) = 75.5 \times \frac{\sqrt{160 + (5 \times CEC)} - \sqrt{KST}}{4 \times 43.56}$$

Lawn establishment

$$Potassium\ (lb\,K_2O/1000\ sq\ ft) = 75.5 \times \frac{\sqrt{160 + (5 \times CEC)} - \sqrt{KST}}{4 \times 43.56} \times 1.25$$

Recommendations are made to the nearest half pound. KST is the potassium soil test value.

Table 10. Potassium fertilizer recommendations and ratings for vegetables, annuals, perennials and lawn establishment.

Soil test potassium	Soil test rating	CEC (meq/100 g soil) 6	8	10	12	14	16	18	20	22	24
lb/acre		lb/1000 sq ft									
40	very low	3.0	3.5	3.5	3.5	4.0	4.0	4.0	4.0	4.5	4.5
60	very low	2.5	3.0	3.0	3.0	3.0	3.5	3.5	3.5	4.0	4.0
80	very low	2.0	2.5	2.5	2.5	2.5	3.0	3.0	3.0	3.0	3.5
100	very low	1.5	2.0	2.0	2.0	2.0	2.5	2.5	2.5	3.0	3.0
120	low	1.0	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.5	2.5
140	low	1.0	1.0	1.0	1.5	1.5	1.5	1.5	2.0	2.0	2.0
160	low	0.5	0.5	1.0	1.0	1.0	1.0	1.5	1.5	1.5	2.0
180	low	0	0.5	0.5	0.5	1.0	1.0	1.0	1.0	1.5	1.5
200	medium	0	0	0	0.5	0.5	0.5	0.5	0.5	1.0	1.0
220	medium	0	0	0	0	0	0.5	0.5	0.5	0.5	1.0
240	medium	0	0	0	0	0	0	0	0.5	0.5	0.5
260	high	0	0	0	0	0	0	0	0	0	0
280	high	0	0	0	0	0	0	0	0	0	0
≥ 300	very high	0	0	0	0	0	0	0	0	0	0

Table 11. Potassium fertilizer recommendations and ratings for lawn maintenance.

Soil test potassium	Soil test rating	CEC (meq/100 g soil)									
		6	8	10	12	14	16	18	20	22	24
lb/acre		lb/1000 sq ft									
40	very low	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.5
60	very low	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0
80	very low	1.0	1.0	1.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5
100	very low	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5
120	low	0.5	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
140	low	0.5	0.5	0.5	0.5	0.5	1.0	1.0	1.0	1.0	1.0
160	low	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.0
180	low	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
200	medium	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5
220	medium	0	0	0	0	0	0.5	0.5	0.5	0.5	0.5
240	medium	0	0	0	0	0	0	0	0.5	0.5	0.5
260	high	0	0	0	0	0	0	0	0	0	0
280	high	0	0	0	0	0	0	0	0	0	0
≥ 300	very high	0	0	0	0	0	0	0	0	0	0

Calcium recommendations

Available calcium exists in the soil as the Ca^{2+} ion. It adsorbs to clay in the soil, so the amount and supply of calcium depend on soil texture and CEC. The calcium rating assigned to a soil is dependent on CEC and soil test calcium (Table 12). With less clay to hold calcium on low CEC or sandy soils, less soil test calcium is necessary to obtain a high calcium rating.

Table 12. Calcium rating by soil test calcium and the soil CEC.

Rating	Soil CEC		
	≤ 10	10 - 20	> 20
Low	Ca ≤ 1000	Ca ≤ 3000	Ca ≤ 5000
Medium	1000 < Ca ≤ 1600	3000 < Ca ≤ 5000	5000 < Ca ≤ 8000
High	Ca > 1600	Ca > 5000	Ca > 8000

Calcium deficiency in soils for plant growth is relatively rare, but it can occur on acid sandy soils. Because calcium is a major component of limestone, adequate calcium levels are often linked to adequate soil pH. When the pH is less than preferred, calcium is supplied by the application of limestone. Calcium contributes to soil aggregate formation, and thereby improves soil tilth. When pH is adequate yet the soil calcium level is less than desired, then gypsum (calcium sulfate) can be applied to supply calcium without greatly affecting pH. Table 13 shows the pH_s ranges of different groups of plant for which gypsum is recommended. Gypsum is not recommended when soil has a high calcium rating. Gypsum is also not recommended when the lime recommendation is greater than 100 pounds per 1000 square feet.

Table 13. Soil pH_s ranges for which gypsum is recommended.

Plant	pH_s range to recommend gypsum
Strong acid loving plants (e.g., blueberries, potatoes, azaleas)	4.3 - 5.0
Medium acid loving plants (e.g., asparagus, beets, cabbage, begonia, holly)	5.0 - 5.5
Slightly acid loving plants (most fruits, vegetables, landscape plants, turf)	5.5 - 6.5
Alkaline loving plants (e.g., arborvitae, geranium, sweetpeas)	6.5 - 7.5

The recommended amount of gypsum to apply is calculated by the following equation and is summarized in Table 14.

$$Gypsum\ (lb/1000\ sq\ ft) = \frac{[(CEC \times 300) - CaST] \times 30}{400}$$

CaST is the calcium soil test value.

Table 14. Gypsum recommendations as varied by calcium soil test and CEC.

Soil test calcium	CEC (meq/100 g soil)											
	6	8	10	12	14	16	18	20	22	24	26	28
lb/acre	lb/1000 sq ft											
600	90	135	215	254	296	338	380	422	450	495	540	585
1000	60	105	150	195	240	285	330	375	420	465	510	555
1400	30	75	120	165	210	255	300	345	390	435	480	525
1800	0	0	0	135	180	225	270	315	360	405	450	495
2200	0	0	0	105	150	195	240	285	330	375	420	465
2600	0	0	0	75	120	165	210	255	300	345	390	435
3000	0	0	0	45	90	135	180	225	270	315	360	405
3400	0	0	0	15	60	105	150	195	240	285	330	375
3800	0	0	0	0	30	75	120	165	210	255	300	345
4200	0	0	0	0	0	45	90	135	180	225	270	315
4600	0	0	0	0	0	15	60	105	150	195	240	285
5000	0	0	0	0	0	0	30	75	120	165	210	255
5400	0	0	0	0	0	0	0	0	90	135	180	225
5800	0	0	0	0	0	0	0	0	60	105	150	195
6200	0	0	0	0	0	0	0	0	30	75	120	165
6600	0	0	0	0	0	0	0	0	0	45	90	135
7000	0	0	0	0	0	0	0	0	0	15	60	105
7400	0	0	0	0	0	0	0	0	0	0	30	75
7800	0	0	0	0	0	0	0	0	0	0	0	45
8200	0	0	0	0	0	0	0	0	0	0	0	0

Magnesium recommendations

Magnesium is available to plants as the Mg^{2+} ion. Like calcium, it is primarily held in the soil by clay particles. Its deficiency typically occurs on acid, low-CEC or sandy soils. On soils with marginal magnesium levels, magnesium deficiency to plants can be induced by a heavy application of potassium or a heavy application of calcitic limestone.

Soil magnesium ratings are based on the percent magnesium saturation, which is calculated using soil test magnesium and CEC (see equation below). Magnesium ratings are given in Table 15.

$$\%\ Magnesium\ \ saturation = \left(\frac{MgST/240}{CEC} \right) \times 100$$

Table 15. Magnesium rating by soil test magnesium and the soil CEC.

Rating	% Magnesium saturation
Very low	≤ 2
Low	2 – 5
Medium	5 – 10
High	10 – 30
Very high	30 – 55
Excess	> 55

No magnesium fertilizer is recommended with a rating of medium or greater. Magnesium recommendations are calculated using the equation below and are shown in Table 16. MgST is the magnesium test value. If CEC is less than 6, assume 6; if greater than 24 assume 24.

$$Mg\ \ (lb/1000\ sq\ ft) = \frac{CEC \times (240 - MgST)}{20 \times 43.56}$$

Magnesium can be supplied from dolomitic limestone, which can also correct low soil pH that may be coincident with low soil magnesium levels. Other sources of magnesium include potassium magnesium sulfate (trade names of K-Mag or Sul-Po-Mag; 11% magnesium), magnesium sulfate (Epsom salts, 10% magnesium) and magnesium oxides.

Table 16. Magnesium recommendations as varied by magnesium soil test and CEC.

Soil test magnesium	CEC (meq/100 g soil)									
	6	8	10	12	14	16	18	20	22	24
lb/acre	lb/1000 sq ft									
20	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
40	1.5	2.0	2.5	3.0	3.0	4.0	4.0	4.5	5.0	5.5
60	1.0	1.5	2.0	2.5	3.0	3.5	3.5	4.0	4.5	5.0
80	0	1.5	2.0	2.0	2.5	3.0	3.5	3.5	4.0	4.5
100	0	0	1.5	2.0	2.0	2.5	3.0	3.0	3.5	4.0
120	0	0	0	1.5	2.0	2.0	2.5	2.5	3.0	3.5
140	0	0	0	1.5	1.5	2.0	2.0	2.5	2.5	3.0
160	0	0	0	0	1.5	1.5	1.5	2.0	2.0	2.0
180	0	0	0	0	0	1.0	1.0	1.5	1.5	1.5
200	0	0	0	0	0	0	1.0	1.0	1.0	1.0
220	0	0	0	0	0	0	0	0.5	0.5	0.5
240	0	0	0	0	0	0	0	0	0	0

Micronutrients

Micronutrients are used by plants in only small amounts. Yet when micronutrients are deficient, reductions in yield or plant growth can be as severe as those caused by deficiencies of the primary nutrients. Micronutrients are analyzed by the University of Missouri Soil Testing Laboratory; however, recommendations are not at present provided on the Soil Test Reports. This section on micronutrients provides the ratings and recommendations that are appropriate for lawns and gardens. The micronutrients that are measured and discussed here include boron, copper, iron, manganese and zinc.

Because micronutrients are required in small amounts, they are often included in the blends of commercially available lawn and garden fertilizers. Consequently, normal fertilization for nutrients such as nitrogen or phosphorus often results in application of micronutrients. Fertilizers consisting of specific micronutrients are also available.

Boron recommendations

Boron is available to plants as H_3BO_3. It is mobile in the soil and is subject to leaching, especially on sandy soils. It also does not accumulate in the soil, so boron-responsive crops may need annual applications. Boron availability may be reduced on neutral to alkaline soils. A deficiency should be identified by soil test or plant analysis before a boron fertilizer application is made, because excessive boron is very toxic to plants. Soil test ratings for boron are given in Table 17.

Table 17. Boron rating by soil test value.

Boron rating	Boron soil test value (ppm)
Low	≤ 0.4
Medium	0.4 – 0.9
High	> 0.9

Even when boron is deficient, fertilizer boron recommendations are as little as a 0.5 to 1.5 ounces per 1000 square feet. Fertilizer sources of boron include Borax (11% B), Boric acid (17% B) and Solubor (28% B).

Copper recommendations

The copper ion Cu^{+2} readily binds with organic matter in the soil. Copper may be available to plants as the Cu^{+2} ion or as a chelated ion with organic matter. Deficiencies are most likely to occur on organic soils, rather than the mineral soils of Missouri. No fertilizer recommendations are given for copper, but a soil test rating is given in Table 18.

Table 18. Copper rating by soil test value.

Copper rating	Copper soil test value (ppm)
Low	≤ 0.2
High	> 0.2

Manganese recommendations

Manganese exists in the soil as various oxides and hydroxides, but is available to plants in the Mn^{+2} form. This form represents only a small fraction of the total amount of manganese in the soil. Soil pH, organic matter level and aeration all can affect manganese availability. Neutral to alkaline soil pH and a high organic matter level can decrease manganese availability. Very acid soils can result in manganese toxicity.

Soil test ratings for manganese are given in Table 19. If a manganese deficiency occurs, apply 0.3 to 0.6 ounce of manganese per 1000 square feet. Fertilizer sources of manganese include manganese sulfate (27% Mn) and manganese chelate (12% Mn).

Table 19. Manganese rating by soil test value.

Manganese rating	Manganese soil test value (ppm)
Low	≤ 1.0
High	> 1.0

Iron recommendations

Iron is an abundant element in the soil; however, it exists in relatively small amounts in a plant-available form, Fe^{+2}. Iron deficiency symptoms (an interveinal chlorosis) of plants occur frequently on high pH_s soils (pH_s > 7.5) in which soil iron is unavailable to plant roots. Soil application of inorganic iron fertilizer is ineffective, as iron reacts with the soil to form insoluble compounds. Soil application of iron chelates can be effective for some vegetable plants. Deficiencies are best treated by a foliar application of an iron fertilizer solution. A long-term correction can be achieved by the application of farmyard manure, which keeps available iron in a chelated form. Ratings of soil iron are given in Table 20.

Table 20. Iron rating by soil test value.

Iron rating	Iron soil test value (ppm)
Low	≤ 2.1
Medium	2.1 – 4.5
High	> 4.5

Zinc recommendations

Zinc is available to plants as the ion Zn^{+2}. Zinc deficiencies in Missouri have been noted on sandy or low organic matter soils and on eroded or graded soils that have had the subsoil exposed or alkaline soils. Zinc soil test ratings and recommended fertilizer application are given in Table 21.

Soil application of zinc sulfate can be used to correct a zinc deficiency. If a zinc chelate is used, the fertilizer rate can be reduced to 20 percent of the inorganic rate. Zinc is relatively nonmobile in the soil, so incorporation into the root zone is recommended. A single zinc application may be effective for three to five years. Correction of deficiencies during the growing season can be achieved by very dilute foliar applications of chelated zinc.

Table 21. Zinc rating by soil test value.

Zinc rating	Zinc soil test value (ppm)	Zinc to apply (lb/acre)
Low	≤ 0.5	10
Medium	0.5 – 1.0	5
High	> 1.0	0

Soluble salts

Soluble salts include electrolyte compounds that dissolve in the soil water. Soluble salt level is also referred to as the salinity level. At high levels soluble salts can reduce water uptake in the plant, restrict root growth, cause root tip burn and in general reduce plant growth and fruit or vegetable yield. The salts essentially compete with plants for soil water. Seed germination and seedling growth are the most sensitive growth stages to high salinity levels. Plant species and cultivars vary in their sensitivity to soil salts. The sensitivity of plants to soluble salt levels is shown in Table 22. The soil test to measure soluble salts is electrical conductivity. Soluble salt content is reported in units of mmhos/cm.

Most Missouri soils are sufficiently leached by precipitation such that very low salinity levels exist. Human activities are usually the cause of high salinity levels. Excessive use of deicing salts (primarily in the form of sodium chloride) on streets and sidewalks can result in high salt levels in immediately adjacent areas. Over-fertilization, fertilizer spills or placing fertilizer too close to roots can create soluble salt problems for plants. Pet urine or feces can also cause localized areas with salt problems.

Table 22. Soluble salt levels and relative plant sensitivity.

Electrical conductivity	Salinity level	Effect on plant growth
mmhos/cm		
0 to 2	non-saline	none
2.1 to 4	very slightly saline	sensitive plants are inhibited
4.1 to 8	moderately saline	many plants are inhibited
8.1 to 16	strongly saline	most cultivated plants inhibited
> 16	very strongly saline	few plants are tolerant

Appendix

Several statements regarding nitrogen management may be included with recommendations. Statements regarding nitrogen management are based on an organic matter ratio (OM ratio).

$$OM\ ratio = \frac{\%\ Organic\ Matter}{Desired\ \ \%\ Organic\ Matter}$$

The conditions for which statements are provided are given below.

When the OM ratio (%Organic Matter/Desired %Organic Matter) is less than 0.8 and when establishing cool- or warm-season grasses, the statement given is:

The soil needs additional organic matter. See MU Extension publication G6955 "Improving Lawn and Landscape Soils" for suggestions.*

For establishment of cool-season grasses, the statement given is:

For lawn maintenance, apply one pound of nitrogen per 1000 square feet in early September and again in early November in addition to the phosphate and potash recommended above.

If the OM ratio is less than 0.9 and the crop code is for vegetables, annual flowers and all perennial plants (including all acidity preferences), the statement given is:

The soil needs additional organic matter. See MU Extension publication G6950 "Steps in Fertilizing Garden Soil" and G6956, "Making and Using Compost" for suggestions.*

For average maintenance of cool-season grasses, the statement given is:

Apply one pound of nitrogen per 1000 square feet in early September and again in early November or April-May. If available, use a fertilizer containing about one half of the nitrogen in a slow release form. See MU Extension publication G6705 "Cool-Season Grasses: Lawn Maintenance Calendar."*

For high maintenance of cool-season grasses, the statement given is:

For lawn maintenance, apply three fourths to one pound of nitrogen per 1000 square feet at each of the following times - May, September, October and November. If available, use a fertilizer containing about one half of the N in a slow release form. Continue applying recommended amounts of phosphate and potash annually. See MU Extension publication G6705 "Cool-Season Grasses: Lawn Maintenance Calendar."*

For average maintenance of warm-season grasses, the statement given is:

> *Apply one half to one pound of nitrogen per 1000 square feet in late May and again in mid-July. See MU Extension publication* G6706 "Establishment and Care of Zoysiagrass Lawns."*

For high maintenance of warm-season grasses, the statement given is:

> *Apply one to one and a half pounds of nitrogen per 1000 square feet in late May or early June and again in July and August. See MU Extension publication* G6706 "Establishment and Care of Zoysia Lawns."*

*MU Extension publications can be found on the Web at http://muextension.missouri.edu/explore/.

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Email: drstl@missouri.edu

http://www.soiltest.psu.missouri.edu

Soil Sample Information for Lawns and Gardens

Serial No. H 00001 H

Name ____________________ Date ____/____/20____

Address ____________________

City __________ State ____ Zip __________

Phone __________ Fax __________

Email ____________________

County to be billed ____________________

Account No. Firm __________ (if applicable) Outlet __________ (if applicable)

Firm ____________________

Address ____________________

City __________ State ____ Zip __________

Phone __________ Fax __________

Email ____________________

Plant Code for Lawn and Gardening Options (for instructions see back of form)

Plant Code — Plants

Gardens
1 Vegetables
2 Annual flower garden

Lawns
3 Fescue, bluegrass, ryegrass (establishment)
4 Fescue, bluegrass, ryegrass (avg. maintenance)
5 Fescue, bluegrass, ryegrass (high maintenance)
6 Bermudagrass, buffalo-grass, zoysia (establishment)
7 Bermudagrass, buffalograss, zoysia (avg. maintenance)
8 Bermudagrass, buffalograss, zoysia (high maintenance)

Shrubs/Trees/Fruits/Ornamentals
9 Perennial bedding plants (specify)
12 Shrubs (specify) (e.g. azalea, hydrangea, rhododendron, Am. Bittersweet, boxwood, forsythia, honey-suckle, lilac, arborvitae, barberry)
16 Trees (specify) (e.g. magnolia, white pine, pin oak, hooly, sweetgum, ash, birch, spruce, junipers, redbud)
18 Fruit tress (specify)
19 Nut trees (specify)
20 Blueberries
21 Strawberries, blackberries, gooseberries, raspberries
22 Grapes
23 Vines, ground covers (specify)
24 Bulbs (specify)
25 Roses
27 Other or not specified

Lab No. (lab use only)	Sample	Sample identification (No more than 12 letters or numbers)	Sampling depth	Last Limed (<1; 2-5; >5)	Lawn and Garden Options 1: Plant Code	1: Specific plant	2: Plant Code	2: Specific plant	3: Plant Code	3: Specific plant	Check (✔) Test(s) Desired: Regular	Zinc	Sulfur	Fe,Mn,Cu	Salts	Sodium	pHw	Nitrate-N	Boron	Soil texture
	1																			
	2																			
	3																			
	4																			

Regular fertility test includes pH, N.A., P, K, Ca, Mg, CEC and OM

Comments: ____________________

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