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Authors
Perry, Ed
Hickman, Gary W

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Fertilizing Landscape Trees

ED PERRY, Horticulture Farm Advisor, University of California Cooperative Extension, Stanislaus County; **GARY W. HICKMAN,** Horticulture Farm Advisor, University of California Cooperative Extension, Mariposa County

UNIVERSITY OF CALIFORNIA
Agriculture
and Natural Resources
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INTRODUCTION

Sixteen fertilizer elements are required for plant growth. Three of the elements—carbon (C), hydrogen (H) and oxygen (O)—are provided by air (through CO_2) and water (H_2O). In the soil, plant roots absorb the remaining 13 elements: nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), sulfur (S), magnesium (Mg), manganese (Mn), zinc (Zn), boron (B), copper (Cu), iron (Fe), molybdenum (Mo), and chlorine (Cl). The first six are termed *macronutrients* because the plant uses them in large amounts. The last seven are called *micronutrients* because they are used in much smaller quantities. The 16 elements are considered essential because

- in the absence of any one of these elements, the plant will fail to complete its life cycle
- each element is specific and cannot be replaced or substituted for by another element
- each element has a direct effect on the plant (rather than an indirect effect, such as repelling insects that might prevent the plant from completing its life cycle)

Nutrient deficiencies, especially deficiencies in nitrogen, phosphorus, and potassium, are not common in most woody landscape plants, except in palm trees, which often develop nitrogen, potassium, manganese, and magnesium deficiencies. Woody plants growing in soil-less media in containers can often develop nutrient deficiencies. When nutrient deficiencies do occur, they cause reduced shoot growth and leaf size, leaf chlorosis, and necrosis and dieback of plant parts.

At times, landscape trees exhibit symptoms that resemble certain fertilizer deficiencies. However, these symptoms are usually the result of other plant problems such as poorly drained soils, over- or under-watering, pH extremes, root diseases, plant pests, or other factors. In these cases, adding fertilizer does not correct the real problem and may contribute to other problems. Improper or excessive fertilization can damage plants, cause increased pest problems, and may pollute surface or underground water.

DIAGNOSING NUTRIENT DEFICIENCIES

Methods for diagnosing nutrient deficiencies include visual symptoms, soil analysis, and leaf analysis.

Visual Symptoms

Visual symptoms of nutrient deficiencies are uncommon in most woody landscape plants, except for iron deficiency in some species and situations. Detailed descriptions of deficiencies are available to aid in making such a diagnosis. However, the visual method is highly unreliable. Most leaf symptoms shown by trees are usually caused by such problems as root diseases, insects, root pruning, soil compaction, adverse soil temperatures, low oxygen, or poor drainage, all of which may reduce nutrient uptake. Symptoms resembling nutrient deficiencies are rarely caused by actual nutrient shortages. For example, research trials have shown no correlation between visual symptoms of nitrogen deficiency and leaf nitrogen content as determined by laboratory leaf analysis.

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Soil Analysis

A soil analysis can be used to determine the amount of elements present in the soil. However, testing for all of the required elements has limited value, as the nutrient levels in the soil rarely correlate with the nutrient levels in the plant. The availability of nitrogen, for example, depends on soil conditions and root distribution, making a soil analysis report difficult to interpret. Additionally, there are no research-based guidelines available to compare soil nutrient levels with landscape tree growth and needs. Soil tests are more useful for determining pH, texture, total salts, and toxic levels of boron, chloride, and sodium.

A good soil analysis is based on careful soil sampling. To test for pH or for saline or sodic conditions, take separate samples to represent a range of plant conditions from poor growth to good growth. Take samples from the surface to 12 inches (30 cm) deep for shrubs, and from the surface to 24 inches (60 cm) deep for trees. If needed, sample in 12-inch increments down to the lower depths. Using a soil tube, auger, or shovel, take several small subsamples from around the tree or shrub, then mix the samples to produce a single composite sample. Approximately 1 quart (1 l) of soil is adequate for laboratory analysis. The results of soil tests must be interpreted by a person experienced in evaluating laboratory data in relation to the soil and plants involved.

Leaf Analysis

Leaf analysis is a quantitative method for diagnosing nutrient deficiencies in woody plants. This method is considered reliable, as there is a strong correlation between the analysis and the actual nutrient status of the plant. Leaf analysis is widely used in orchard crops, where the minimum levels of elements needed for growth and crop production have been precisely determined. Such levels have not been determined for most landscape trees. Most of the information on leaf analysis for landscape plants is based on trees growing in containers, nurseries, or other controlled areas such as arboretums. This information may not be closely correlated with tree responses in the landscape.

Recent studies in California have established a range of values for leaf nitrogen in 25 landscape trees (table 1). To develop the table, leaf samples for each species were taken from 20 mature, healthy trees in the landscape and analyzed for total nitrogen. Although this does not establish the absolute minimum leaf nitrogen concentrations, comparing these values to those of a suspected nutrient-deficient tree can be helpful. If the leaf nitrogen from the suspected tree is within the range for that species shown in table 1, then factors other than fertilizer deficiency are likely causing the problem.

For a leaf nutrient analysis, select recently matured leaves near the shoot tip. Collect leaves at random from around the tree. For a toxicity analysis, collect leaves showing symptoms. Take leaf samples from trees suspected to be nutrient-deficient and from healthy trees of the same species growing nearby. Compare the results of the two analyses. Compare the results of a leaf analysis with the ranges of leaf nitrogen in table 1.

Table 1. Range of total nitrogen (percent total N on dry weight basis) in leaves of selected landscape tree species

Common name	Scientific name	Range*
Bradford pear	*Pyrus calleryana* 'Bradford'	1.1–1.9
camphor tree	*Cinnamomum camphora*	1.2–2.0
Chinese hackberry	*Celtis sinensis*	1.4–2.8
Chinese pistache	*Pistachia chinensis*	1.6–3.0
Chinese tallow tree	*Sapium sebiferum*	1.7–2.7
cork oak	*Quercus suber*	1.5–2.2
crape myrtle	*Lagerstroemia indica*	1.1–3.5
deodar cedar	*Cedrus deodara*	1.0–1.4
eucalyptus	*Eucalyptus* spp.	1.8–2.1
goldenrain tree	*Koelreuteria paniculata*	1.9–3.5
holly oak	*Quercus ilex*	1.3–2.8
honey locust	*Gleditsia triacanthos*	2.3–3.1
London plane tree	*Platanus acerifolia*	1.4–2.6
maidenhair tree	*Ginkgo biloba*	1.4–2.4
Modesto ash	*Fraxinus velutina* 'Modesto'	1.8–2.7
olive	*Olea europa*	1.3–1.9
Raywood ash	*Fraxinus oxycarpa* 'Raywood'	2.1–2.9
silver maple	*Acer saccharinum*	2.0–3.4
southern magnolia	*Magnolia grandiflora*	1.0–3.5
tulip tree	*Liriodendron tulipifera*	1.2–2.8
Valley oak	*Quercus lobata*	*2.1–2.9*
white alder	*Alnus rhombifolia*	1.9–2.6
white birch	*Betula pendula*	2.2–3.4
white mulberry	*Morus alba*	2.0–3.6
zelkova	*Zelkova serrata*	1.8–2.8

Source: Adapted from E. Perry and G. W. Hickman, A survey to determine the leaf nitrogen concentrations of twenty-five landscape tree species, J. Arboriculture 27(3) (2001): 152–158.

Note: *Range of 20 trees sampled. Samples taken from trees growing in landscapes.

DIAGNOSING AND CORRECTING SPECIFIC NUTRIENT DEFICIENCIES

Nitrogen Deficiency

Symptoms. In all plants, nitrogen deficiency causes an overall decrease in plant vigor. Shoots are short and small in diameter, and leaves are small. In nitrogen-deficient broadleaf plants, older leaves become generally chlorotic (uniformly yellowish-green), while young leaves may retain their typical green color. In fall, reddish leaf color is more pronounced, and leaf drop may occur earlier than normal. Species with compound leaves may have fewer leaflets. Flowering plants usually bloom normally, but bloom may be delayed.

In nitrogen-deficient conifers, needles are yellowish, short, and close together. In older conifers, the lower crown may be yellow, while the upper part remains green. Young nitrogen-deficient conifers may not develop side branches.

Nitrogen-deficient palm trees have decreased vigor and small, light green to yellow leaves. There is a gradation in color from old to young leaves, with the oldest leaves being most chlorotic. In severe cases, leaves are almost completely yellow or whitish, and growth ceases.

Symptoms caused by anything that restricts root growth and reduces nutrient uptake, including soil diseases, insects, root pruning, soil compaction, adverse soil temperatures, lack of oxygen, and poor drainage, are often confused with symptoms of nitrogen deficiency.

Occurrence. Nitrogen deficiency is uncommon in established landscape plants. Exceptions include newly planted trees growing in very sandy or highly leached soils, plants growing in containers, and palm trees. The nitrate form of nitrogen, one of the forms absorbed by plant roots, is soluble and may be leached below the root zone in certain rapidly drained soils. Incorporating large amounts of nondecomposed organic amendments into soil may also result in temporary nitrogen deficiencies in shallow-rooted plants. In palms, nitrogen deficiency occurs commonly in container-grown plants and in sandy, rapidly drained soils.

Correcting Nitrogen Deficiency. When a careful diagnosis (including a leaf tissue analysis) indicates the need for added nitrogen, several nitrogen-containing materials are available. These include ammonium sulfate (21-0-0), calcium nitrate (15-0-0) and urea (45-0-0). The general recommendation for nitrogen application to landscape trees is 2 to 4 pounds of elemental nitrogen per 1,000 square feet (1 to 2 kg per 100 sq m) of surface area. The method of application—broadcast, placed in holes, or injected into the soil—has been shown to be an unimportant factor in availability of the applied nutrient. The simplest method is to broadcast the fertilizer around the rooting area of the tree and water it in. Reapply only when another diagnosis indicates a deficiency.

Phosphorus Deficiency

Symptoms. Visual symptoms of phosphorus deficiency are variable. In broadleaf plants, leaves may be dark green, especially when young. Leaf veins may be purple, especially on the underside of the leaves. Leaves may be sparse, slightly smaller than normal, and distorted, and they may drop earlier in fall. Older leaves may turn purple-bronze, with dead tips. Shoots are normal in length but smaller in diameter. Phosphorus-deficient flowering plants produce fewer flowers.

In phosphorus-deficient conifers, the needles on older trees are dull blue-green or gray-green. As the deficiency becomes more severe, needles die, starting low in the tree and progressing upward. Few or no secondary needles may grow. In seedlings, needles turn purple, starting at the tips of lower needles and progressing inward and upward.

Symptoms caused by preemergent herbicide damage may be confused with phosphorus deficiency. Herbicide damage can cause leaf distortion and a red to purple color change in leaves, followed by marginal necrosis. Symptoms of preemergent herbicide damage usually occur in older leaves first, as with phosphorus deficiency.

Occurrence. Phosphorus deficiency is rare in landscape plants, as few soils lack adequate amounts of phosphorus. Young or shallow-rooted plants may become phosphorus deficient where topsoil has been removed, as by grading for new construction.

Correcting Phosphorus Deficiency. When a careful diagnosis indicates the need for added phosphorus, use 2 to 4 pounds of elemental phosphorus per 1,000 square feet (1 to 2 kg per 100 sq m), incorporated into the soil. Available materials include superphosphate (0-20-0) and ammonium phosphate (16-20-0).

Potassium Deficiency

Symptoms. The leaves of potassium-deficient broadleaf plants develop marginal and interveinal chlorosis, followed by necrosis. The necrosis progresses inward until the entire leaf blade is scorched. The most recently matured leaves are affected first. With time, the symptoms become more pronounced on the older leaves. Leaves may crinkle and roll upward. The tips of the current season's shoots die back late in the season. Fewer flower buds form.

In potassium-deficient conifers, the oldest foliage becomes dark blue-green, progressing to yellow and red-brown. The needles are often stunted, and the tips of needles become necrotic.

Symptoms of potassium deficiency in palms vary among species, but they always appear first on the oldest leaves. The most common symptom in palms is yellow stippling on leaves, which progresses to the younger leaves as the deficiency worsens. The yellow spots appear translucent when viewed from below. In some species, the symptoms are marginal or tip necrosis of the older leaves, with few or no yellow spots. The most severely affected leaves or leaflets will be completely necrotic and withered. Leaf midribs may be orange rather than green. In date palms (*Phoenix* spp.), the tips of older leaves develop a dull orange-brown discoloration. Most palms are susceptible to potassium deficiency, but it is most severe in royal (*Roystonea* spp.), queen (*Syagrus romanzoffianum*), coconut (*Cocos nucifera*), date, and areca (*Areca* spp.) palms.

For all plant species, potassium deficiency is diagnosed primarily from visual symptoms. Leaf analysis may be unreliable, as potassium is mobile in plants and may be leached from leaves by rain or sprinkler irrigation.

The early symptoms of potassium deficiency are often confused with the yellow and brown spots resulting from sucking insects or from leaf spot diseases. Preemergent herbicide damage can also cause marginal and interveinal chlorosis followed by necrosis. Also, symptoms of preemergent herbicide damage usually occur in older leaves first, as with potassium deficiency.

Occurrence. Potassium deficiency is rare in broadleaf and coniferous landscape plants, but it is relatively common in palm trees. In palms, the deficiency develops readily in sandy, rapidly drained soils, especially where frequent irrigation is being applied, or in palms growing in container media. It is relatively uncommon in palms growing in clay soils.

Correcting Potassium Deficiency. When a careful diagnosis indicates the need for added potassium, use 5 to 15 pounds of elemental potassium per 1,000 square feet (2.4 to 7.3 kg per 100 sq m), incorporated into the soil. Available materials include potassium nitrate (13-0-44) and potassium sulfate (0-0-50). Complete fertilizers containing potassium are also available.

Iron Deficiency

Symptoms. Symptoms of iron deficiency (iron chlorosis) are expressed as the yellowing of leaves due to a lack of chlorophyll. In iron-deficient broadleaf plants, the areas between the veins (interveinal areas) of young leaves are chlorotic, with distinct narrow green veins. Because iron is immobile in plants, the older basal leaves remain green as young leaves become chlorotic. With extreme iron deficiency, young leaves are small, almost white, and may have necrotic margins and tips. Shoots are normal in length but small in diameter. Twigs defoliate and die as the deficiency increases in severity.

In iron-deficient conifers the older needles and the lower crown remain green, while new needles are stunted and chlorotic.

The new leaves of iron-deficient palm trees are uniformly chlorotic, especially in poorly aerated soil or when the tree has been planted too deeply.

Iron deficiency symptoms closely resemble those caused by manganese deficiency and may also be confused with symptoms of damage caused by preemergent herbicides. Iron deficiency occurs on new leaves, however, and preemergent herbicide injury occurs primarily on older leaves. Soil compaction, root injury caused by construction, or poor drainage can aggravate iron deficiency symptoms or cause symptoms similar to iron chlorosis. Leaf analysis is not a reliable method for diagnosing iron deficiency.

Occurrence. The concentration of iron in soil is usually adequate for plant growth. Various soil conditions are usually responsible for making the element unavailable to plants. For example, the availability of soil iron to plants decreases as soil pH rises above 7.0, and it decreases in cold, wet, or poorly drained soils. Iron deficiency symptoms are variable within trees, between adjacent trees, and between species. Iron deficiency in palm trees is uncommon; when it does occur in palms, it usually appears in trees growing in poorly aerated soils or in trees that have been planted too deeply. Trees adapted to acidic soils (acid-loving) such as pin oak *(Quercus palustris)*, red oak *(Quercus rubra)*, and sweet gum (*Liquidambar styraciflua)* are often iron-deficient in alkaline soils (soils above pH 7.0). In many areas with high-pH soils, iron chlorosis is the most common nutrient deficiency seen in landscape plants.

Correcting Iron Deficiency. Confirmed iron deficiency may be corrected with soil applications of iron-containing fertilizers. For a more rapid correction, iron chelates may be applied to the soil or foliage. The effect of iron chelates is relatively short-lived, however, lasting only 1 to 3 years. Trunk injections of iron also give temporary correction of iron chlorosis but injure the trunk. When caused by adverse soil conditions, long-term to permanent correction of iron chlorosis is achieved by adding soil amendments to lower pH (soil acidification) or by adopting improved cultural practices such as avoiding overwatering, improving soil aeration, and using plants tolerant of alkaline soils. If necessary, suggested corrective amounts are ½ to 1 pound of chelated iron applied to the soil surface, or 12 pounds of iron sulfate incorporated into the soil, per 1,000 square feet (0.2 to 0.5 kg chelated iron or 5.9 kg iron sulfate per 100 sq m).

Manganese Deficiency

Symptoms. In manganese-deficient broadleaf plants, new leaves become yellow, with wide green bands along the veins. As the element concentration decreases, interveinal necrotic spots develop. In some plants, leaf margins may be wavy, crinkled, or curled. Shoot growth may be reduced.

In conifers, new growth is stunted and chlorotic, and older needles and the lower crown remain green.

The new leaves of manganese-deficient palm trees are uniformly chlorotic with interveinal necrotic streaks and are small in size. As the deficiency worsens, newly emerging leaves are necrotic, distorted, and withered. Older leaves may be completely withered and distorted ("frizzletop"), scorched, and greatly reduced in size. Affected queen *(Syagrus romanzoffianum)* and pygmy date *(Phoenix roebelenii)* palms develop a flat-headed appearance caused by leaf stunting. In severely deficient palms, growth ceases, and emerging leaves consist only of necrotic and stunted petioles.

Manganese deficiency symptoms closely resemble those caused by iron deficiency or preemergent herbicides (manganese deficiency occurs on new leaves, and preemergent herbicide injury occurs primarily on old leaves first).

Occurrence. The total amount of manganese in soil is usually adequate for plant growth, yet soil factors often make the element unavailable to plants. Although it is deficient in landscape plants less often than iron, manganese is usually deficient under similar conditions and in a variety of landscape plants. The availability of manganese to plants decreases as soil pH rises above 6.5, and it decreases in poorly drained soils that are high in organic matter. Trees adapted to acidic soils may be manganese deficient in alkaline soils (soils above pH 7.0). In palms, manganese deficiency is most common in queen palm, pygmy date palm, and sago palm (*Cycas revoluta*), while *Washingtonia* spp. palms appear resistant. The deficiency often occurs when soils are alternately well-drained and waterlogged. Symptoms are also more likely to occur in plants suffering from drought. Manganese deficiency in palm trees is very common in alkaline soils, but it can also occur in poorly drained soils or where soil temperatures are cool.

Correcting Manganese Deficiency. Confirmed manganese deficiency may be corrected with soil or foliar applications of manganese-containing fertilizers. The symptoms are usually alleviated by adding soil amendments to lower pH (soil acidification) or by adopting improved cultural practices such as avoiding overwatering, improving soil drainage, and using plants tolerant of alkaline soils. If necessary, correction amounts are 5 to 20 pounds of manganese sulfate per 1,000 square feet (2.4 to 9.8 kg per 100 sq m), incorporated into the soil. Manganese chelates may also be applied to the soil or foliage. The effects of foliar sprays are short-lived, however, often lasting no longer than 1 year.

Zinc Deficiency

Symptoms. In zinc-deficient broadleaf plants, leaves are uniformly yellow and sometimes mottled with necrotic spots. Leaves are small ("little-leaf"), very narrow, and pointed. The deficiency causes extremely shortened internodes, resulting in tufts of leaves (rosettes, or "witches' broom") at the tips of small-diameter shoots. Older leaves eventually drop.

In zinc-deficient conifers, needles are stunted and chlorotic. Branches may also be stunted and may die back. Trees may lose all but first- or second-year needles.

Zinc deficiency symptoms may be confused with symptoms caused by glyphosate (systemic herbicide) injury.

Occurrence. The amount of zinc in soil is usually adequate for plant growth, yet soil conditions often make the element unavailable to plants. The availability of zinc to plants decreases as soil pH rises above 6.5 (becomes more alkaline). The symptoms are variable within the tree and between adjacent trees. Since the level of zinc is highest in surface soils, practices that reduce rooting in surface soil, such as grading or shallow cultivation, may increase zinc deficiency. Zinc deficiency is also aggravated in soils high in phosphorus. It is rare in palm trees.

Correcting Zinc Deficiency. Confirmed zinc deficiency may be corrected with applications of zinc-containing fertilizers. For a more rapid correction, zinc chelates may be applied to the soil or foliage. The effect of zinc chelates is relatively short-lived, especially foliar applications. Symptoms may be alleviated by adding soil amendments to lower pH (soil acidification). For soils with a pH of lower than 6.0, apply 2.5 pounds of zinc chelate per 1,000 square feet (1.2 kg per 100 sq m) to the soil surface; if the soil pH is above 6.0, apply 4 pounds (2 kg per 100 sq m).

Magnesium Deficiency

Symptoms. Magnesium deficiency is very rare in broadleaf and coniferous landscape plants. In palms, the ends of leaves become bright yellow. Individual fronds have a band of yellow around the outer perimeter, while the midrib and portions of leaves near the midrib remain green. Lower fronds may senesce prematurely.

Occurrence. Magnesium deficiency is common on palm trees growing in the southwestern United States. Date palms (*Phoenix* spp.) are most susceptible.

Correcting Magnesium Deficiency. Magnesium deficiency in palms may be corrected with soil applications of magnesium sulfate. Symptomatic leaves do not recover and must be replaced by new growth. Do not remove symptomatic leaves until the leaves have turned brown; magnesium is mobile in plants and can move from old leaves to new leaves. If necessary, suggested correction amounts of magnesium sulfate are 25 to 50 pounds per 1,000 square feet (12.2 to 24.2 kg per 100 sq m), incorporated into the soil.

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University of California
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Communication Services
6701 San Pablo Avenue, 2nd Floor
Oakland, CA 94608-1239

Telephone: (800) 994-8849 or (510) 642-2431

FAX: (510) 643-5470

E-mail inquiries: danrcs@ucdavis.edu

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