CONTINUING EDUCATION UNIT

# Problems Related to pH

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*This article is excerpted, with permission from the publisher, from the book* Abiotic Disorders of Landscape Plants: A Diagnostic Guide. *The book is published by University of California Agricultural and Natural Resources and is available from ISA.*

**LEARNING OBJECTIVES**

**The arborist will be able to**

- understand the concept of pH and how it affects plant growth and health.
- describe the symptoms associated with various elemental deficiencies and toxicities.
- explain some of the diagnosis and treatment difficulties associated with nutrient deficiencies and toxicities.

Soil reaction, expressed as pH, refers to the acidity or alkalinity of a soil, that is, the relative concentrations of hydrogen (acid) and hydroxide (alkaline) ions. A logarithmic-based scale from 0 to 14 is used to express pH. Equal concentrations of hydrogen and hydroxide ions produce a neutral reaction, a pH of 7.0. As a soil becomes more acidic, its pH decreases; as it becomes more alkaline, its pH increases. Soil pH

- affects the availability of plant nutrients in the soil
- influences the solubility of certain elements in the soil (for example, aluminum, manganese) that may become toxic
- affects the population and activity of soil microorganisms
- has a direct effect on the root cell function, which can influence water and nutrient uptake

Under most conditions, soil pH has a primarily nutritional effect on plants. An optimal pH for the availability of nutrients essential for plant growth, without becoming toxic, is from 5.5 to 7.0. At pH levels above or below this narrow range, the availability of one or more nutrient elements can be significantly reduced or increased. In strongly acid soils (below pH 5.5), the availability of calcium, magnesium, phosphorus, nitrogen, sulfur, molybdenum, and boron is reduced. At the same time, the availability of aluminum, iron, manganese, zinc, and copper is increased and could be toxic to plants and microorganisms. Except for molybdenum and chloride, micronutrients become less available as soil alkalinity increases. In strongly alkaline soils (above pH 7.5), iron, manganese, zinc, and copper become unavailable for plant use.

Microbial activity is also affected by pH. While fungi function over a wide pH range, bacteria and actinomycetes are favored by a slightly acid to alkaline pH. Nitrifying bacteria are inhibited when the pH is less than 5.5, and they are absent in very acid soils (Craul 1992).

The interaction between soil pH and aeration may affect micronutrient availability. Iron, manganese, and copper are generally more available in poorly drained or flooded acidic soils and may reach toxic levels (Brady and Weil 1996).

Calcareous, or high-lime, soils contain calcium carbonate ($CaCO_3$). Calcareous soils are typically light in color, silty in texture, and often poorly drained. The pH is alkaline, usually ranging from 7.5 to 8.5.

## Symptoms

Because soil pH affects the availability of nutrient elements, primary symptoms are seen as nutrient excesses or deficiencies in sensitive plants. Common symptoms are described in Table 1.

### Acid pH

Three micronutrients may become toxic at low pH: aluminum, manganese, and copper. Aluminum toxicity that occurs at pH less than 4.5 cannot be diagnosed from visual symptoms or the aluminum content of foliage (Chapman 1965). Roots typically are discolored, short, and stubby, but this may not be distinguishable on plants grown in some soils. Growth is reduced, but this in itself is not sufficient for diagnosis. Stunted roots have difficulty absorbing immobile nutrients such as phosphorus. Because of poor root growth and the reactions between aluminum and phosphorus, aluminum toxicity in plants resembles phosphorus deficiency (Singer and Munns 1987). Figure 1 illustrates the differences in plant growth in very acidic and slightly acidic soil.

**Table 1. pH ranges of soils and possible associated plant problems (adapted from Brady and Weil 1996).**

| pH scale | Soils where found | Description/problems | Common plant symptoms |
|---|---|---|---|
| 12 | | | |
| 11 | | | |
| 10, 9 | **Sodic soils** | White crust on soil; lack of drainage; water ponding on soil surface. Possible sodium toxicity. | Marginal leaf burn, chlorosis, death. |
| 8, 7 | **Calcareous soils** | Soil typically light-colored, fine-textured. Iron, zinc, and manganese deficiency. | Interveinal chlorosis and bleaching of new growth. |
| 6 | **Humid region arable soils** | Most plants tolerant. | None. |
| 5, 4 | **Forest soils** | At lower range, aluminum toxicity; calcium and magnesium deficiency may occur. | Reduced growth and chlorosis symptoms in sensitive plants at lower ranges. |
| 3, 2, 1 | **Acid sulfate soils** | Aluminum toxicity; calcium and magnesium deficiency. | Reduced growth and chlorosis symptoms; distorted new growth with necrotic areas. |

**Satisfactory for most plants** (pH 6–7)


**Figure 1. The pH on this cut slope ranged from 3.2, where few plants grew (left side) to 6.2, where growth was normal (right side).**

Manganese toxicity produces varied patterns of leaf distortion, yellowing, and necrosis, depending on the plant species. In citrus, leaves develop marginal yellowing and tiny necrotic spots (Labanauskas 1966).

Copper toxicity is expressed first as reduced growth. It may cause iron chlorosis symptoms by depressing the iron concentration in leaves. Like aluminum toxicity, it is associated with stunting, reduced branching, and thickening and discoloration of roots in many plants (Reuther and Labanauskas 1966).

## Alkaline pH

The primary symptoms associated with alkaline pH are deficiencies in iron, zinc, and manganese. These deficiencies are expressed as chlorosis of new growth (Figure 2). The patterns of chlorosis vary slightly. In broadleaf shrubs and trees, iron deficiency causes interveinal chlorosis with narrow bands of green along the veins. With manganese deficiency, the bands of green are typically wider. Zinc deficiency causes a more mottled chlorosis pattern and abnormally small leaves and short internodes. It is often difficult to distinguish among these elemental deficiencies because their symptoms are so similar. To further complicate diagnosis, more than one element may be deficient; a range in symptoms may result. Diagnosis is best made with tissue analysis.

Sensitive plants growing in calcareous soil are often deficient in iron, zinc, or manganese


**Figure 2. A common symptom of plants growing in alkaline soil is interveinal chlorosis on young foliage. This is due to unavailability of iron, zinc, or manganese at alkaline pH.**

because the ions are oxidized and unavailable for plants (Figure 3). New growth may be completely chlorotic, with necrotic areas.

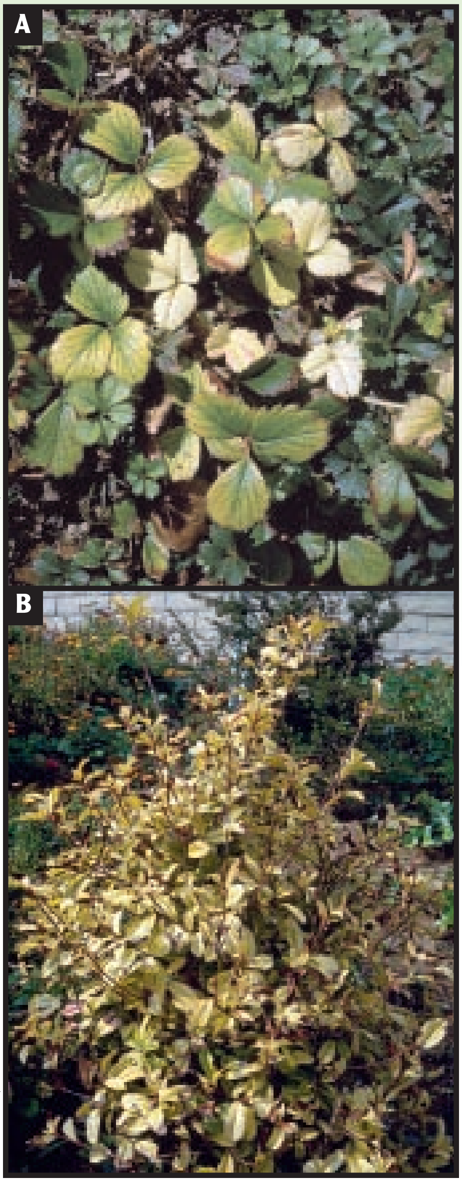


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**Figure 3. Common symptoms of sensitive plants growing in calcareous soil include (A) interveinal chlorosis as seen on this mock strawberry (*Duchesnea indica*) and (B) bleaching, as seen on photinia (*Photinia fraseri*). Another common symptom is poor growth.**

## Occurrence

Soil pH is determined by the parent material from which the soil is derived, amount of rainfall, vegetation, and soil drainage. Acidic soils tend to develop in high-rainfall and high-humidity areas, and also under coniferous forests. Alkaline soils tend to develop in low rainfall and poorly drained areas, and also under grasses.

Calcareous conditions are common in flood plains and valleys, and low pH soils are occasionally encountered. Acid subsoils may be exposed when soil cuts are made during site grading. Landscape soils are often highly manipulated and may differ from the native soil.

## Look-Alike Disorders

Calcium deficiency, copper toxicity, and herbicide toxicity (for example, caused by Surflan) may cause stunted root symptoms similar to low pH. Plants may appear deficient in phosphorus due to the inability of stunted roots to absorb phosphorus. Symptoms of iron, zinc, and manganese deficiencies can be caused by a number of factors.

## Diagnosis

Problems caused by soil pH can be diagnosed by collecting a soil sample from the root area and testing it for pH. Tests should include the related factors of calcium carbonate concentration (percentage of lime), as its presence affects possible treatments and sensitive plant species. Whether lime is present is more important to diagnosing problems than the quantity of lime in a soil. The amount of calcium carbonate indicates the buffering capacity of the soil against acidification should such treatment be considered. Tissue analyses can help diagnose suspected mineral toxicities that may occur at low pH (Table 2).

## Sensitive and Tolerant Species

Plants vary considerably in their tolerance to acid and alkaline conditions, although most plants grow satisfactorily in a pH range of 5.5 to 7.0 (Figure 4). In general, species are tolerant of the soils in which they have evolved; pH requirements can be estimated by evaluating the soils from the region in which the plants are native. Most pines are generally tolerant to highly acid soils. Spruce grow best on less acid soils. Hardwoods, on the other hand, generally tolerate alkaline soils.

Acid-loving plants, most of which are native to acidic soils, have difficulty absorbing iron and require a high degree of soluble iron in the soil. They perform best in acidic soils with pH of 5; at higher pH, they tend to show iron, zinc, or manganese deficiency symptoms (Figure 5). Plants that grow poorly in very acid soils (pH less than 5) are usually affected by aluminum toxicity.

Soils that are calcareous may limit growth and cause iron deficiency symptoms in species that are normally tolerant of low to moderate alkalinity.

**Table 2. Evaluating toxicity from soil and tissue analyses (Chapman 1965).**

| | | Soil analysis | | | Tissue analysis | |
|---|---|---|---|---|---|---|
| **Element** | **pH** | **Not harmful** | **Probably toxic** | **High** | **Normal** | **Toxic** |
| Aluminum | <4.5 | <0.5 ppm | 0.5–1.0 ppm | >1.0 ppm | — | — |
| Copper | <5.0 | — | — | >150 ppm | — | >20 ppm |
| Manganese | <5.5 | — | — | — | — | >1,000 ppm |

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**Figure 4. Plants vary in their tolerance to unusually low or high pH. This soil has a pH of 4.5. The gazania (*Gazania* spp.) on the left appears normal, while California poppy (*Eschscholzia californica*) on the right is chlorotic and stunted.**

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**Figure 5. Pin oak (*Quercus palustris*) requires acidic soils. When grown in alkaline soils (pH 7.8 in this photo), foliage shows symptoms of reduced growth, chlorosis, and necrosis (normal on left).**

## Remedies

Acid soils can be limed to increase the pH. The amount of lime required depends on the pH, the soil texture, and the cation exchange capacity of the soil.

Soil pH is usually reduced by incorporating acidifying materials such as sulfur, or gypsum, which contains sulfur. When sulfur is added to the soil, bacteria convert it to sulfuric acid. Warm temperatures, moist soil, and oxygen are required for bacterial activity. The reaction takes place slowly over 6 to 8 weeks under optimal conditions.

Calcium carbonate in the soil acts as a buffer against lowering the pH. If sulfur is applied to calcareous soils, the calcium carbonate reacts with sulfuric acid to produce water, carbon dioxide, and calcium sulfate. No increase in hydrogen ion concentration occurs, so there is no change in soil pH. The pH of calcareous soils and soils irrigated with water containing calcium carbonate cannot reasonably be lowered.

There is no remedy for high-pH calcareous soils; tolerant species should be planted in them. Symptoms of micronutrient deficiency can be treated with foliar applications of appropriate elements. Soil pH problems are summarized in Table 3.

### References


Brady, N.C., and R. Weil. 1996. *The Nature and Property of Soils* (11th edition). Prentice-Hall, Upper Saddle River, NJ.

Chapman, H.D. 1965. *Diagnostic Criteria for Plants and Soils*. University of California Division of Agricultural Sciences, Berkeley, CA.

Craul, P.J. 1992. *Urban Soil in Landscape Design*. Wiley, New York, NY.


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**Table 3. Summary of pH-related problems.**

| Soil pH | Symptoms | Diagnosis | Occurrence/ aggravating factors | Look-alike disorders | Treatment |
|---|---|---|---|---|---|
| | | | **ACID SOILS** | | |
| <5.0 | Typically expressed in micronutrient toxicities in sensitive plants. | Test foliage for microelement concentration. | | | Incorporate lime into soil to raise pH to desired level. |
| | Mottled chlorosis of leaves, followed by necrotic spots. | Manganese toxicity | Wet soils | Iron deficiency | Incorporate lime into soil to raise pH above 5.5. Improve drainage. |
| | Roots are short, thick, and stubby. | Aluminum toxicity | pH <4.5 | Surflan (pre-emergent herbicide) use and Ca deficiency cause similar effects on roots. Foliage may appear to be P deficient because of inability to take up P. | Incorporate lime into soil to raise pH above 5.5. Apply phosphorus. |
| | Interveinal chlorosis on foliage. Stunting, reduced branching; thickening and dark coloration of roots. | Copper toxicity | Heavy spraying of Bordeaux fungicides or copper sulfate fertilization | Iron deficiency | Incorporate lime into soil to raise pH above 5.5. |
| | | | **ALKALINE SOILS** | | |
| >7.5 | Typically expressed in micronutrient deficiencies in sensitive plants. | Test foliage for micronutrient concentration. | | | In noncalcerous soils, incorporate sulfur to lower pH over time. |
| | Interveinal chlorosis, most severe on new growth. | Iron deficiency | Cold soil temperatures | Similar symptoms can be caused by root disease or may be normal in early spring. | Refer to resources on nutrient disorders.* |
| | New leaves yellow, with wide, green bands along veins. | Manganese deficiency | | Similar symptoms can be caused by root disease or may be normal in early spring. | Refer to resources on nutrient disorders.* |
| | Leaves chlorotic, sometimes mottled with necrotic spots; small leaves; shortened internodes. | Zinc deficiency | | Similar symptoms can be caused by root disease or may be normal in early spring. | Refer to resources on nutrient disorders.* |

**Abiotic Disorders of Landscape Plants: A Diagnostic Guide*, from which this article and table are excerpted, has a section on diagnosing and treating nutrient deficiencies.

Labanauskas, C.K. 1966. Aluminum, pp. 264–285. In H.D. Chapman, ed., *Diagnostic Criteria for Plants and Soils*. University of California Division of Agricultural Sciences, Berkeley, CA.

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Singer, M.J., and D.N. Munns. 1987. *Soils: An Introduction*. Macmillan, New York, NY.

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## CEU TEST QUESTIONS

To receive continuing education unit (CEU) credit (1.0 CEU) for home study of this article, after you have read it, darken the appropriate circles on the answer form of the insert card in this issue of *Arborist News*. (A photocopy of the answer form is ***not*** acceptable.) A passing score for this test is 16 correct answers.

Next, complete the registration information, ***including your certification number***, on the answer form and send it to ISA, P.O. Box 3129, Champaign, IL 61826-3129. Answer forms for this test, **Problems Related to pH**, may be sent for the next 12 months.

***You will be notified only if you do not pass.*** If you do not pass, ISA gives you the option of re-taking the quiz until you do achieve a passing score.

1. In addition to affecting the availability of plant nutrients in the soil, soil pH also
   a. has a direct effect on root cell function
   b. affects the population and activity of soil microorganisms
   c. influences the solubility of certain elements
   d. all of the above
2. An optimal pH for the availability of nutrients essential to plant growth, without becoming toxic, is
   a. 4.5 to 6.0
   b. 5.0 to 6.5
   c. 5.5 to 7.0
   d. 6.0 to 7.5
3. In strongly acid soils, which of the following elements is reduced?
   a. calcium
   b. aluminum
   c. iron
   d. manganese
4. In strongly alkaline soils, which of the following can become unavailable?
   a. iron, manganese, zinc, and copper
   b. molybdenum and chloride
   c. magnesium, phosphorus, and nitrogen
   d. sulfur and boron
5. In soil pH less than 5.5, which of the following are inhibited or absent?
   a. aluminum and copper
   b. all fungi
   c. nitrifying bacteria
   d. actinomycetes
6. The pH of calcareous, or high-lime, soils is generally between
   a. 6.0 and 7.0
   b. 7.0 and 7.5
   c. 7.5 and 8.5
   d. 5.5 and 7.5
7. In acid soil resulting in poor root growth, aluminum toxicity in plants may resemble
   a. iron chlorosis
   b. phosphorus deficiency
   c. manganese deficiency
   d. nitrogen toxicity
8. Citrus leaves developing marginal yellowing and tiny necrotic spots may be a symptom of
   a. manganese deficiency
   b. manganese toxicity
   c. copper deficiency
   d. phosphorus toxicity
9. The primary symptoms of alkaline pH are associated with deficiencies of
   a. iron
   b. manganese
   c. zinc
   d. all of the above
10. In acid soils, interveinal chlorosis with narrow bands of green along the veins may be indicative of
    a. iron deficiency
    b. aluminum deficiency
    c. molybdenum deficiency
    d. all of the above
11. In acid soils, interveinal chlorosis with wider bands of green along the veins may be indicative of iron deficiency or a deficiency of
    a. magnesium
    b. manganese
    c. boron
    d. potassium
12. Because nutrient deficiency symptoms can be similar and because multiple elements may be deficient at once, diagnosis is best made with a
    a. pH meter
    b. tissue analysis
    c. hand lens
    d. phenolphthalein indicator
13. In alkaline soil, which element might be oxidized, making it unavailable for plant absorption?
    a. iron
    b. manganese
    c. zinc
    d. all of the above
14. In coniferous forests and areas of high rainfall or high humidity, soils tend to be
    a. acid
    b. alkaline
    c. neutral
    d. calcareous
15. Alkaline soils tend to develop in areas of
    a. low rainfall
    b. poor drainage
    c. grasses
    d. all of the above
16. Generally, the pH requirements of plants can be estimated by examination of the
    a. mature height and spread
    b. native region
    c. foliage color
    d. leaf tissue pH
17. When sulfur is added to the soil, bacteria convert it to
    a. iron chelates
    b. sulfuric acid
    c. manganese chelates
    d. soluble nitrates
18. Calcium carbonate in the soil acts as a buffer, resisting
    a. the lowering of pH by sulfur addition
    b. production of carbon dioxide
    c. an increase in pH due to higher hydrogen ion concentration
    d. all of the above
19. The best way to deal with high-pH calcareous soils is
    a. add sulfur
    b. add gypsum
    c. plant tolerant species
    d. add lime
20. If the concentrations of hydrogen and hydroxide ions in soil solution are equal, the pH
    a. will be less than 7.0
    b. will be equal to 7.0
    c. will be greater than 7.0
    d. cannot be determined from the information given