



Understanding Soil pH and Its Influence on Plant Growth and Nutrient Availability

INTRODUCTION

Soil is a complex and dynamic system that supports plant life by providing physical structure, water, nutrients, and biological activity. Among the many properties that influence soil fertility, soil pH is one of the most significant. Soil pH affects chemical reactions in the soil environment, determines nutrient availability, influences microbial activity, and ultimately plays a central role in plant growth and productivity.

Although soils may contain sufficient quantities of essential nutrients, plants cannot always access them if the chemical conditions of the soil are unsuitable. Soil pH directly controls the solubility and mobility of many mineral nutrients, and even small shifts in pH can significantly alter nutrient availability. As a result, understanding and monitoring soil pH is a fundamental aspect of soil management in both agriculture and horticulture.

For gardeners, growers, and agricultural professionals, measuring and maintaining appropriate soil pH helps ensure that plants receive the nutrients they require for optimal growth. When soil pH falls outside the preferred range of a particular plant species, symptoms such as poor growth, chlorosis, or nutrient deficiencies may appear despite adequate fertilization.

WHAT IS SOIL pH?

Soil pH measures whether it is acidic or basic and expressed on a scale ranging from 0 to 14. The value represents the concentration of hydrogen ions (H^+) in the soil solution. A pH value of 7 is considered neutral, while values below 7 indicate acidic conditions and values above 7 indicate alkaline conditions.

The pH scale is logarithmic, meaning that each unit change represents a tenfold difference in acidity. For example, soil with a pH of 5 is ten times more acidic than soil with a pH of 6. Because of this logarithmic relationship, even relatively small changes in pH can have substantial effects on soil chemistry and plant nutrient availability.

Natural soils typically fall within a pH range of approximately 4.0 to 8.5, depending on factors such as climate, parent material, organic matter content, and land management practices. Highly weathered soils in regions with high rainfall often tend to be more acidic, while soils formed from calcareous (i.e. calcium carbonate) parent materials or located in arid climates are often more alkaline.

In practical terms, soil pH reflects the balance between acidic and basic components within the soil environment. These components originate from minerals, organic matter decomposition, biological activity, and external inputs such as fertilizers or amendments.

NUTRIENT AVAILABILITY AND SOIL CHEMISTRY

Soil pH strongly influences the chemical forms of nutrients present in soil. Essential plant nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and various micronutrients exist in different chemical states depending on the acidity or alkalinity of the soil.

Iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu), for instance, become less soluble as soil pH increases. In alkaline soils, these micronutrients often precipitate into insoluble compounds, reducing their availability to plants. As a result, plants growing in alkaline conditions may develop characteristic deficiency symptoms, as seen in figure 1, despite sufficient nutrient levels in the soil.

Phosphorus (P) availability is also strongly influenced by soil pH. In very acidic soils, phosphorus may react with iron and aluminum compounds to form insoluble minerals. In highly alkaline soils, phosphorus may instead bind with calcium. In both cases, the nutrient becomes less accessible to plants.

On the other hand, strongly acidic soils may increase the solubility of certain metals such as aluminum and manganese to levels that can become toxic to plant roots. Elevated aluminum concentrations in particular can inhibit root growth and reduce nutrient uptake.

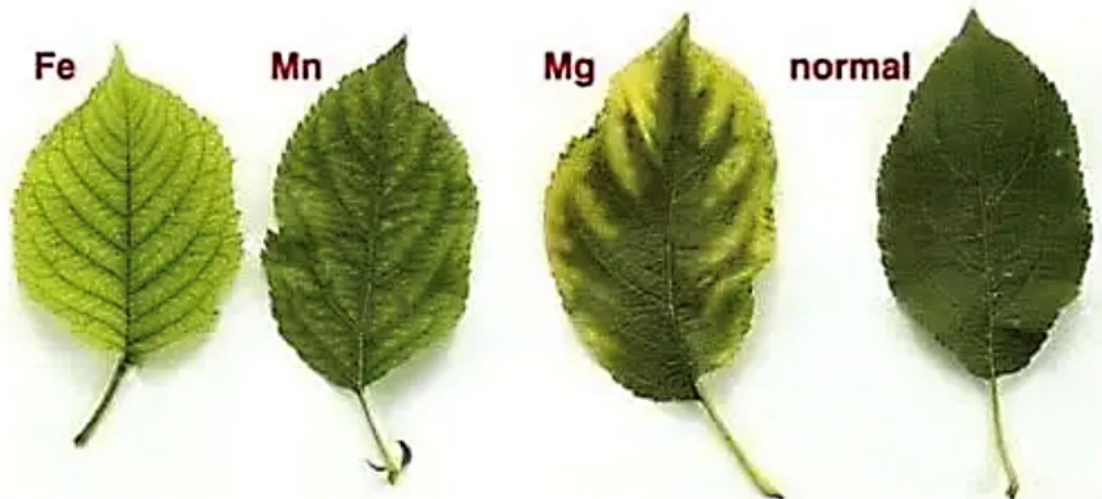


Figure 1. Comparison between iron, manganese and magnesium plant deficiencies.
<https://atami.com/blog/cultivation/iron-plant-deficiency-symptoms-causes-and-solutions>

These chemical interactions explain why soil pH is often described as a master variable in soil chemistry. By influencing multiple chemical processes simultaneously, soil pH indirectly affects nearly every aspect of plant nutrition.

PLANT ADAPTATION TO DIFFERENT SOIL pH RANGES

Different plant species have evolved to grow under specific soil conditions, including particular pH ranges. As a result, plants vary in their tolerance to acidic or alkaline environments.

Some plants are well adapted to strongly acidic soils, typically between pH 5.0 and 5.8. These species often originate from forest ecosystems where organic matter decomposition produces naturally acidic conditions. Examples include blueberries, cranberries, rhododendrons, azaleas, and certain ornamental shrubs.

Many common vegetables and garden plants prefer moderately acidic soils, generally within the range of pH 5.5 to 6.8. This group includes crops such as beans, carrots, garlic, peppers, tomatoes, and parsley. These plants tend to perform well in slightly acidic conditions where nutrient availability is relatively balanced.

A wide range of agricultural crops also grow successfully in slightly acidic soils, typically between pH 6.0 and 6.8. This category includes asparagus, onions, kale, broccoli, lettuce, and oats. The adaptability of these plants reflects the relatively stable nutrient availability within this pH range.

Finally, some plant species tolerate or even prefer neutral to slightly alkaline soils, generally between pH 7.0 and 8.0. Examples include cabbage, cauliflower, celery, cucumber, thyme, and certain Mediterranean herbs. These plants often originate from environments with calcareous soils or lower rainfall.

FACTORS THAT INFLUENCE SOIL pH

Soil pH is not fixed and may change over time due to both natural processes and human activities. Several factors influence the acidity or alkalinity of soil.

One important factor is climate, particularly rainfall. In regions with high precipitation, water percolating through the soil profile can leach basic cations such as calcium and magnesium. Over time, this process gradually increases soil acidity.

The mineral composition of the parent material from which the soil formed also plays a role. Soils derived from limestone or other calcium-rich rocks tend to be more alkaline, while soils formed from granite or sandstone often exhibit more acidic conditions.

Organic matter decomposition can also influence soil pH. As plant residues break down, organic acids may be released into the soil, contributing to increased acidity.

Human activities such as fertilizer application may also alter soil pH. Ammonium-based fertilizers, for example, can gradually lower soil pH as nitrogen undergoes microbial transformations in the soil.

ADJUSTING SOIL pH

When soil pH falls outside the preferred range for plant growth, it may be modified through the use of soil amendments.

To raise soil pH and reduce acidity, growers commonly apply materials containing calcium compounds. Agricultural lime (calcium carbonate) is one of the most widely used amendments for this purpose. Other materials such as wood ash or crushed eggshells may also contribute carbonate and help neutralize acidic soils over time.

Conversely, when soils are excessively alkaline, amendments may be applied to lower soil pH. Materials such as elemental sulfur, peat moss, or certain organic composts gradually increase soil acidity by releasing hydrogen ions during decomposition or microbial processes.

Because soil pH adjustments occur gradually and depend on soil texture, buffering capacity, and environmental conditions, amendments should be applied carefully and based on accurate soil measurements.

THE IMPORTANCE OF SOIL TESTING

Before attempting to modify soil conditions, it is essential to determine the existing soil pH through testing. Soil testing allows growers to assess the chemical environment of the soil and determine whether pH adjustments are necessary.

Regular soil testing provides several benefits. It helps identify whether soil is acidic or alkaline, guides the selection of appropriate soil amendments, and prevents the over-application of corrective materials. Overcorrecting soil pH can be as problematic as failing to adjust it, potentially creating new nutrient imbalances.

Soil pH may be measured using laboratory analysis or portable electronic pH meters. Modern digital pH meters allow growers to obtain quick and reliable measurements directly in the field or garden.

MEASURING SOIL pH

Accurate soil pH measurement typically involves collecting representative soil samples and preparing them for analysis. A common method involves mixing a measured quantity of soil with purified water (i.e. distilled water) to form a suspension. After allowing the mixture to stabilize, the pH of the solution can be measured using a calibrated pH electrode.

To measure soil pH in a garden plot the following procedure can be used:

- 1) Collect 5-6 random samples (~100g) of soil taken from a depth of 10-15 cm and mix together.
- 2) Mix 100g of soil sample from above and add 100 ml of purified water in a clean container.
- 3) Mix vigorously and let stand for 5-10 minutes.
- 4) Pour mixture, using a coffee filter, into a separate container
- 5) Using a calibrated pH meter, measure the pH of the filtered solution.



To measure soil pH in a garden container follow this procedure:

- 1) Water the plant until saturated 1 hour before testing.
- 2) After standing for at least 30-60 minutes, place a saucer under the plant.
- 3) Water the plant with purified water. Use enough water to collect 50 ml of the leachate from the saucer.
- 4) Using a calibrated pH meter the pH can be measured.



Electronic pH meters provide a convenient and precise method for monitoring soil conditions. By measuring soil pH regularly, growers can observe changes over time and make informed decisions about soil management practices.

Routine monitoring is particularly valuable in intensive gardening, greenhouse cultivation, and hydroponic systems, where nutrient availability and plant health depend strongly on maintaining stable chemical conditions.

CONCLUSION

Soil pH is a fundamental factor influencing plant growth, nutrient availability, and soil chemistry. Because it affects multiple chemical and biological processes simultaneously, soil pH plays a central role in determining the productivity and health of agricultural and horticultural systems.

Maintaining soil pH within the optimal range for a given crop species helps ensure that plants can access essential nutrients and develop healthy root systems. Regular soil testing allows growers to monitor soil conditions and make informed adjustments when necessary.

By understanding the relationship between soil pH, nutrient availability, and plant health, growers can create more stable and productive growing environments and improve the long-term sustainability of their soil management practices.