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Impact of Soil pH on Plant Nutrient Availability and Biological Processes

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Abstract

Soil pH, a highly variable chemical property of the soil is considered major factor governing rest of the soil physical, chemical and biological properties and biological activities. So, this article considers the impact of soil pH on the nutrient availability for plants in the soil and biological processes occurring in the soil. Nutrients like aluminium, iron, manganese are available more at acidic pH and lesser at basic pH while, calcium, magnesium, molybdenum have higher availability at higher pH and lower at lower pH. Near neutral pH (6.5-7.5) has the maximum amount of nutrients available and favours most biological processes along with better root growth of plants. This article concludes that pH being variable and highly important factor, attains prime importance in soil management for production systems and slightly acidic soil pH is favoured for most production systems.

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Keywords

Biological activities, Neutral pH, Production systems, Soil management

Introduction

The relative acidity or alkalinity of the soil is described by the pH of the soil. Soil pH is defined as the negative logarithm of the hydrogen ion activity. The pH scale goes from 0 to 14 with pH 7 as the neutral point. Any result greater than 7 indicates that the concentration of H^+ ions in the solution is lower than at neutral pH, the solution is alkaline and there are more hydroxyl (OH^-) ions present than H^+ ions while value value lower than 7 indicates the higher H^+ ion concentration than at neutral pH, indicating acidic solution. Soils are acidic if they have a pH of less than 5, and very acidic if they have a pH of less than 4. Above the pH of 7.5, soils are termed alkaline, and above a pH of 8, they are called highly alkaline. Soil pH is measured using a suitable electrode connected to a pH metre. This type of soil analysis is included in most of the soil test procedures (Jensen, 2010).

Soil pH has a huge impact on plant nutrient availability and soil biogeochemical processes in the natural environment. As a result, soil pH is referred to as the "master soil variable" influencing a wide range of biological, chemical, and physical qualities and processes that affect plant development and biomass yield. In this article, we'll look at how soil pH influences processes that are tied to the biological, geological and chemical components of the soil environment.

Effect of pH on Plant Nutrient Availability

Soil pH has a big impact on the availability of several plant nutrients. The "optimal" soil pH is near to neutral, with neutral soils being anywhere between slightly acidic pH 6.5 to slightly alkaline pH 7.5. Most plant nutrients are maximally available to plants in the pH range of 6.5 to 7.5,

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and this pH range is also generally quite friendly with plant root growth. Nitrogen, potassium, and sulphur are three main plant nutrients that appear to be less directly affected by soil pH than many others, but are nevertheless affected to some amount. Phosphorus, on the other hand, is directly impacted. The HPO_4^{2-} phosphate ions tend to react fast with calcium (Ca) and magnesium (Mg) at alkaline pH values, such as pH 7.5, to create less soluble compounds. The $H_2PO_4^-$ phosphate ions react with aluminium (Al) and iron (Fe) to generate less soluble molecules at acidic pH levels. When soil pH exceeds 7.5, most micronutrients become less available, and are best available at a slightly acidic pH, such as 6.5 to 6.8. Molybdenum (Mo), on the other hand, appears to be less available at acidic pH and more available at mildly alkaline pH.

pH can affect nutrient availability by:

• Conversion of soluble forms to insoluble forms that plants cannot absorb,

• Development of low solubility complexes,

• Greater retention by soil clays and organic matter, and

• Can inhibit or stimulate microorganism activity.

Table 1: Soil pH and Interpretation

pH 5.0	pH 5.5	pH 6.0	pH 6.5	pH 7.0	pH 7.5	pH 8.0
Strongly acidic	Medium acidic	Slightly acidic	Neutral soil	Neutral soil	Mildly alkaline	Moderately alkaline
			Suitable for most crops			

(Source: McKenzie, 2003)

What Happens at Low Soil pH

Soil acidity affects plant growth in several ways:

• Concentration of Calcium may be deficient.

• More H^+ ions are available to exchange base cations, thereby removing them from exchange sites and releasing them to the soil solution.

• Lower pH increases the solubility of Al, Mn, and Fe, even to the toxic levels.

• Low pH reduces the availability of the macro- and secondary nutrients.

What Happens at High Soil pH

• When the soil pH is high more base cations will be on the particle exchange sites.

• Exchanged nutrients are either taken up by the plant or lost through leaching.

• Microbial activity may also be reduced or changed.

Effect of pH on Soil Biological Processes

1. Soil Microbial Activities

According to the literature, soil pH requirements for microbial activity range from 5.5 to 8.8. As a result, when soil pH reaches an optimal level, soil respiration increases. Fungal respiration is typically higher than bacterial respiration in low pH conditions, and vice versa; because fungi are better acclimated to acidic soil conditions than bacteria.

2. Soil Enzyme Activities

Soil pH is important for the normal functioning of enzyme activity in the soil, and it may also govern enzymes indirectly by affecting the bacteria that make them. This is evident in phosphorous enzymes, which have acid and alkaline operating windows in the pH ranges of 3.0-5.5 and 8.5-11.5, respectively. Organophosphorus hydrolase activity is highest at higher pH. Glycosidases, for example, have an optimal pH range of 4 to 6, but proteolytic and oxidative enzymes have an optimal pH range of 7 to 9. If various microbial species require lower nutrient concentrations to create biomass or have enzymes with varied nutrient affinities, changes in microbial community composition could potentially influence enzyme synthesis.

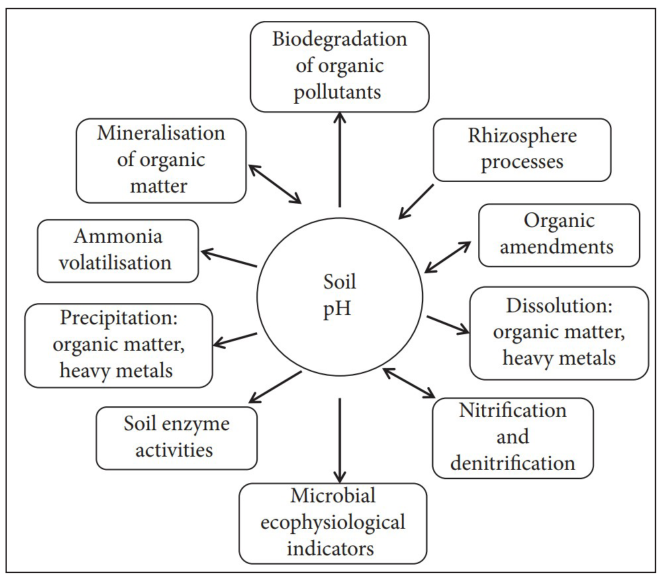

Figure 1: Effect of pH on bio-geochemical processes (Neina, 2019)

3. Organic Matter Mineralization

Microbial action often results in the mineralization of organic materials as carbon (C), nitrogen (N), phosphorus (P), and sulphur (S). Because of its direct effect on the microbial population and their activities, soil pH regulates mineralization in soils. This has implications for extracellular enzymes that aid in microbial metabolism of organic substrates. Furthermore, because the link between organic constituents and clays is broken with higher soil pH, the mineralizable fractions of C and N rise.

4. Nitrification

Nitrification, like many other bio-geochemical processes, is heavily influenced by soil pH. The microbial conversion of ammonium to nitrate is known as nitrification. It normally rises when the soil pH rises, but it eventually reaches an optimum pH of 8.5 (Pietri and Brookes, 2008).

5. Biodegradation

Like many soil biological processes, soil pH influences biodegradation through its effect on microbial activity, microbial community and diversity, enzymes that aid in the degradation processes as well as the properties of the substances to be degraded. Generally, alkaline or slightly acid soil pH enhances biodegradation, while acidic environments pose limitations to biodegradation. Usually, pH values between 6.5 and 8.0 are considered optimum for oil degradation.

Conclusion

The function of soil pH as a master soil variable with a bidirectional link with soil plant nutrient availability and biogeochemical processes is highlighted in this article. In some soil situations, the ideal soil pH could be used to improve the availability of specific nutrients. Between pH 6.5 and 8, mineralization and degradation processes such as C and N mineralization and pesticide breakdown take place. Slightly acidic soil pH can be concluded as the most suitable for most of the crops.

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