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Effect of Soil pH on Nutrient Availability and Crop Growth

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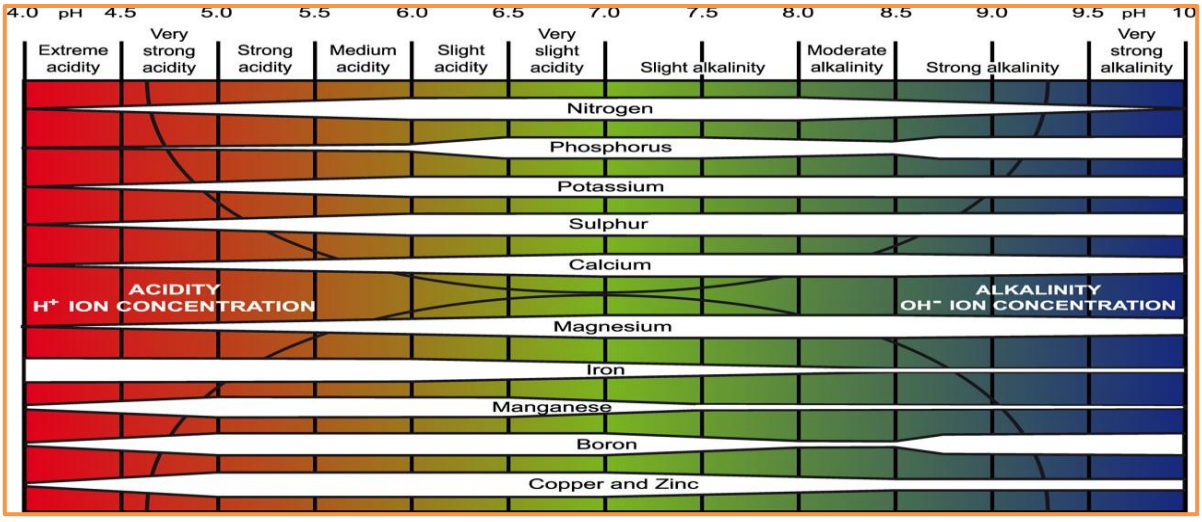
The pH of the soil provides a major impact on the availability of nutrients to plants, which in turn affects their health and productivity. The pH level of soil, indicating its acidity or alkalinity on a scale ranging from 0 to 14, has a direct impact on the chemical forms and solubility of different nutrients. The majority of nutrients are best accessible to plants when the pH level is slightly acidic to neutral, typically between 6.0 to 7.0. The presence of crucial nutrients like nitrogen (N), phosphorus (P), potassium (K) and micronutrients is significantly influenced by the pH level of the soil. Understanding the relationship between soil pH and nutrient behavior is essential for enhancing crop yield and promoting sustainable agriculture methods. Variations from this range may result in nutrient shortages or excesses, which can negatively affect plant development and crop production.

The solubility and accessibility of key nutrients, including nitrogen (N), phosphorus (P), potassium (K) and several micronutrients, are significantly influenced by the pH level of the soil. In soils with high acidity (pH < 5.5), the solubility of elements such as aluminium (Al) and manganese (Mn) increases. This can damage plant roots and hinder their ability to absorb nutrients. At the same time, important nutrients such as phosphorus become less accessible because of the formation of insoluble compounds. On the other hand, in alkaline soils (with a pH greater than 7.5), the availability of essential micronutrients like iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) minimize, resulting in deficiencies that may exhibit up as chlorosis and limited growth. Maintaining the optimal soil pH level is essential for enhancing nutrient availability and promoting healthy plant development. The pH level of the soil influences the activity of microorganisms and the biological processes that play a role in the cycling of nutrients within the soil. Understanding and effectively regulating soil pH is essential for approaching the difficulties faced in modern agriculture, such as soil deterioration, climate change and the need to enhance food production.

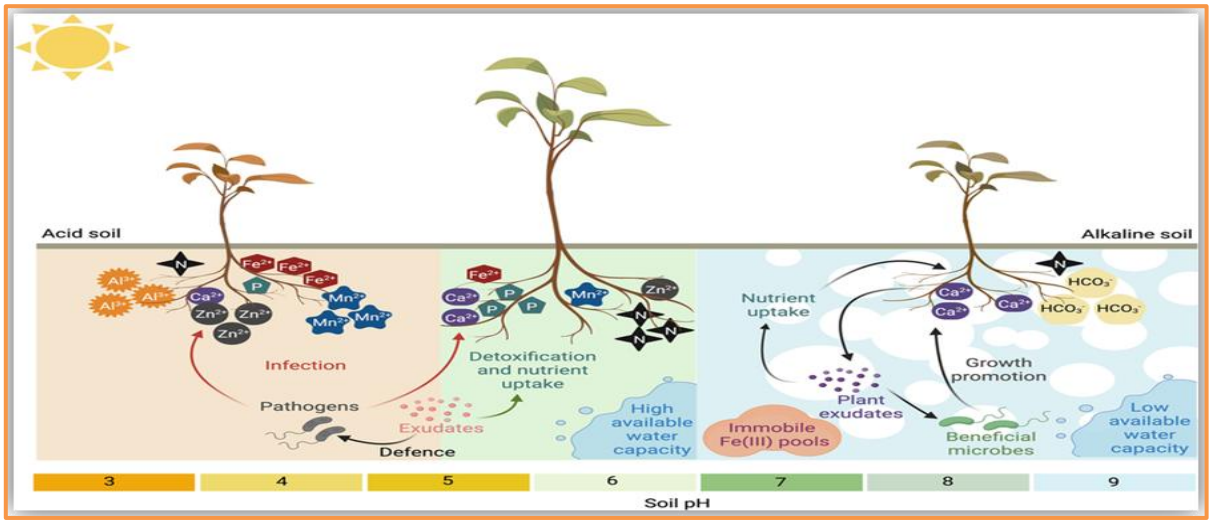
Influence of Soil pH on nutrient availability



The pH level of soil has an impact on the chemical forms and solubility of different nutrients, which subsequently affects how accessible these nutrients are to plants. In soils with a low pH of less than 5.5, the solubility of metals like aluminium (Al) and manganese (Mn) rises, which can negatively impact the health of plants. Aluminium toxicity, specifically, can hinder the growth and function of roots, thereby diminishing the plant's ability to absorb water and nutrients. Conversely, vital nutrients like phosphorus (P), calcium (Ca), and magnesium (Mg) become less available in very acidic soils because they either precipitate or adhere to soil particles. In alkaline soils, where the pH level is greater than 7.5, the presence of essential micronutrients like iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) decreases. This reduction occurs because these nutrients form insoluble compounds, specifically hydroxides and carbonates. This may result in a lack of these vital nutrients, which can appear as chlorosis and other deficiency in plants. The availability of phosphorus is diminished in alkaline conditions because it forms a precipitate known as calcium phosphate. The ideal pH range for the availability of nutrients is generally between 6 and 7. Within this range, the majority of vital nutrients are present in their most soluble states, allowing for easy absorption by the roots of plants. For example, nitrogen (N), when present as nitrate ($NO3^-$), is readily accessible within this pH range, promoting strong plant growth and development. The effect of soil pH on the availability of nutrients has direct implications for the health of plants. Plants that grow in soils with less than optimal pH levels frequently display signs of nutrient deficiencies or excesses, which can result in diminished growth and lower yields. Acidic soils may lead to limited root development and inadequate nutrient absorption because of aluminium toxicity and the decreased availability of vital nutrients such as phosphorus and calcium. On the other hand, alkaline soils may lead to shortages of micronutrients, resulting in signs such as interveinal chlorosis, which is the yellowing occurring between the veins of the leaves, as well as a decrease in photosynthetic efficiency. The study conducted by Bajoliya *et al.* (2024) emphasized that keeping soil pH within the ideal range can greatly improve nutrient absorption and the overall health of plants. Research has indicated that adding manure with recommended dose of fertilizers improve optimal soil pH. In turn, promotes root development and improves the absorption of nutrients.

Influence of soil pH on growth and development of crop

Managing soil pH is essential for maximizing the availability of nutrients and enhancing the health of plants. Different methods can be used to modify soil pH, based on whether the soil is extremely acidic or extremely alkaline.



Root growth: The pH level of soil impacts the growth and functioning of roots by affecting the solubility of harmful substances and the physical characteristics of the soil. In soils with high acidity, elevated levels of aluminum and manganese can hinder the growth and functioning of roots. On the other hand, in alkaline soils, the decreased availability of important nutrients can hinder the growth of roots. The ideal pH level of the soil encourages

strong root growth, enabling plants to effectively absorb water and nutrients. For example, research indicates that wheat (Triticum aestivum) grows optimally in soils with a pH level ranging from 6 to 7, whereas soybean (Glycine max) flourishes in soils that are slightly acidic to neutral, specifically with a pH between 5.5 and 7.0 (Muniya *et al*., 2023)

Microbial activity: Soil pH impacts the composition and functioning of microbial communities, which subsequently affects the availability of nutrients. Soils that are acidic generally exhibit reduced microbial activity and diversity, which impacts important processes like nitrogen fixation and the decomposition of organic matter. In comparison, soils that are neutral to slightly alkaline typically promote a more varied and dynamic microbial community. Improving soil health and fertility can be achieved by managing pH levels to enhance microbial activity, which in turn supports sustainable crop production.

Managing pH of soil for optimal crop growth

Managing soil pH is essential for enhancing the availability of nutrients and supporting the health of plants. Different methods can be used to modify soil pH, depending on whether the soil is excessively acidic or alkaline. The use of lime (Calcium carbonate) is a common method employed to increase the pH levels of acidic soils. Lime reduces the acidity of soil by interacting with hydrogen ions to produce water and carbon dioxide. This procedure not only raises the pH level of the soil but also provides calcium and magnesium, which are vital nutrients necessary for the growth of plants. The effectiveness of liming is influenced by several factors, including the quality of the lime, the type of soil, and the starting pH level of the soil. To reduce the pH levels in alkaline soils, one can utilize acidifying additives such as sulphur or fertilizers that produce acids. Including organic materials like compost or manure can aid in stabilizing soil pH and enhancing the overall health of the soil (Tekam *et al*., 2024)

Conclusion

The pH level of soil is essential in influencing the availability of nutrients and the overall health of plants, which makes it an important aspect of agricultural productivity and sustainability. This review has emphasized the ways in which soil pH affects the solubility and absorption of nutrients, which in turn impacts the overall growth and development of plants. It is evident that maintaining the soil pH within an ideal range is crucial for enhancing nutrient availability and promoting healthy growth in plants. The optimal pH range for the majority of crops is between 6 and 7, where essential nutrients are most readily available, and toxic elements are minimized. The effect of soil pH on the availability of nutrients highlights the significance of conducting regular soil tests and monitoring. By comprehending the existing pH levels and nutrient conditions of their soils, farmers are able to make well-informed choices regarding the required adjustments and management techniques to enhance soil quality. By keeping soil pH levels within the right range through specific adjustments and management techniques, farmers can enhance nutrient absorption, increase crop production, and promote sustainable farming practices. Ongoing research and innovation in managing soil pH will be crucial for addressing the changing challenges of modern agriculture and for securing food availability for future generations.

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