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Plant Nutrient Availability Mediated by Soil Reaction

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Abstract

By 2050, India would require around 333 million tonnes (MT) of food grain to feed its hungry population, compared to the estimated production of 297.5 MT in 2019-20. Chemical fertilizers are widely used in the agricultural crop production system. Since the beginning of the green revolution in Indian agriculture, this approach has become more prevalent. The green revolution included genetic advances (high-yielding cultivars), nutrient management (organic or inorganic), natural resource use (water), and agricultural chemical contributions (pesticides and fungicides). Now that the moment has come, scientists are focusing on the precise application of plant nutrient use efficiency in relation to crop yield. By mediating the soil rhizosphere, fertilizer is applied based on soil reaction. Crop productivity is influenced by the interrelated physical, chemical, and biological health of the soil, which is influenced by soil management practices in various ways.

Introduction

Soil pH is a measurement of the acidity and alkalinity of a soil solution, which influences nutrient solubility and availability in the soil. The concentration of hydrogen ions (H^+) in the soil determines its pH. In soil solution, acidic (low pH) soils have a high concentration of hydrogen ions (H^+), whereas alkaline or basic (high pH) soils have a low concentration of H^+. Cation and anion exchange capacities, or the amount of parking spots for nutrients on soil particles, are related to a soil's ability to keep and provide nutrients (Reddy, 2019). Soil pH has an impact on cation and anion exchange capabilities. pH is crucial in controlling the amount and strength of nutrient adsorption to soil surfaces because hydrogen ions change the charge on soil surfaces and the forms of nutrients in solution. Soil pH value ranged from 0 (highly acidic) to 14 (alkaline) (Figure 1).

Nutrient Dynamics

The pH is crucial in controlling the amount and strength of nutrient adsorption to soil surfaces because hydrogen ions change the charge on soil surfaces and the forms of nutrients in solution. Because hydrogen ions are involved in many precipitation and dissolution events, pH has an impact on the solubility of nutrients in soil. Slightly acidic to neutral soil pH (pH 6.0-7.5) are frequently the optimum for overall availability of nutrients (Figure 2).

The charge of the soil particles and SOM have a big role in the cation and anion exchange capacity of the soil. Cation exchange capacity (CEC) is a measure of how well a soil can bind cations like calcium and potassium. Clay and organic matter-rich soils have a higher CEC than silty or sandy soils. They have more buffering capacity as well. Because H^+ ions

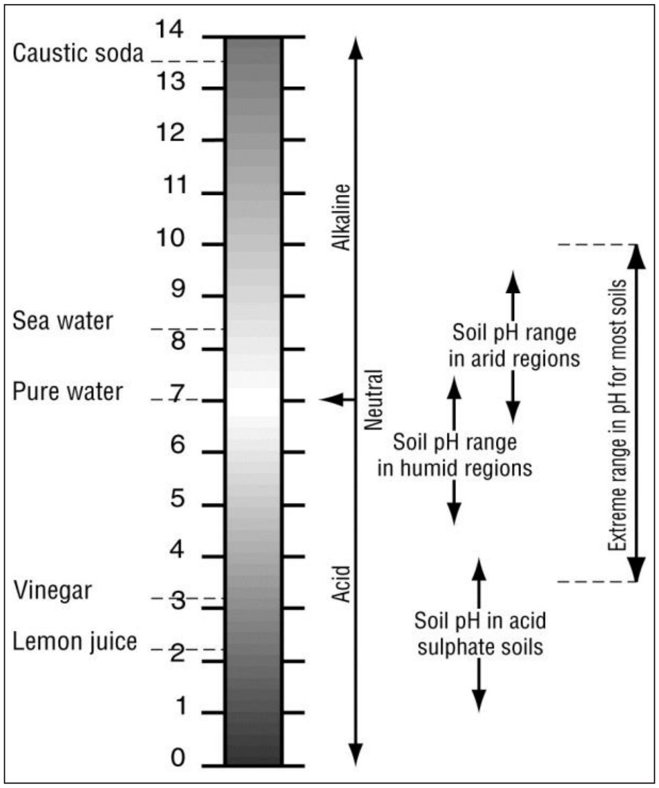

Figure 1: Soil pH value

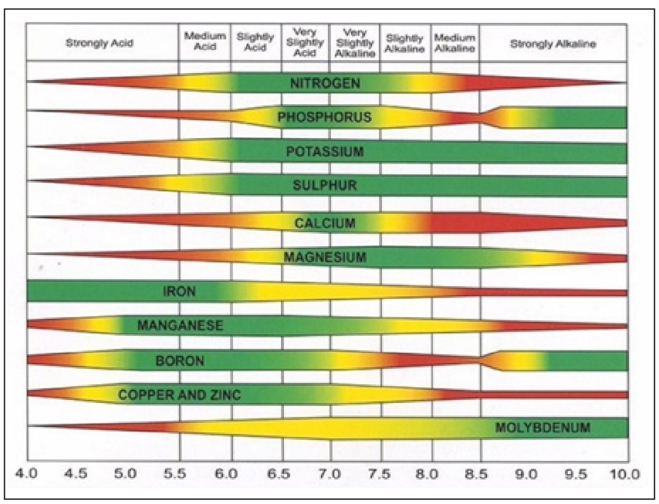

Figure 2: The impact of soil pH on crop nutrient availability. The larger the bar, greater availability (Anonymous, 2016)

take up space on the negative charges along the soil surface, displacing nutrients, soil pH influences nutrient availability. The size and charge of the nutrient molecules, as well as whether or not they can be lost *via* leaching, have an impact on nutrient availability.

The pH of acidic solutions is less than 7, while the pH of basic or alkaline solutions is larger than 7. Lower soil pH (acidic soil) leads in excessive aluminium and/or manganese concentrations in the soil solution, which can inhibit plant growth and microbiological activity. Fewer metal nutrients (*e.g.*, copper (Cu), iron, manganese (Mn), and zinc (Zn) may adhere to the soil surface at low pH (*i.e.*, acidic, high H^+ concentration), making them more available for plant uptake. The majority of agricultural soils in dry and semi-arid regions are near-neutral to basic, with pH values ranging from 6.5 to 8. The presence of base-forming cations coupled with carbonates and bicarbonates present naturally in soils and irrigation waters is the main reason for this (Ratan and Goswami, 2002). There is little leaching of base-forming cations due to low precipitation quantities, resulting in pH values greater than 7. The availability of nutrients for plant growth is influenced by the pH of the soil. Aluminum and manganese can become more available and hazardous to plants in very acidic soil, while calcium, phosphorus, and magnesium are less available. Phosphorus and most micronutrients become less accessible in excessively alkaline soil. Sulfur (S) and the base forming cations (Ca^{2+}, Mg^{2+}, K^+, and Na^+) are big molecules. These huge molecules do not adhere to soil particles as well as a large electrostatically charged balloon does to a wall (Figure 3). As a result, they quickly peel off of soil particles and enter

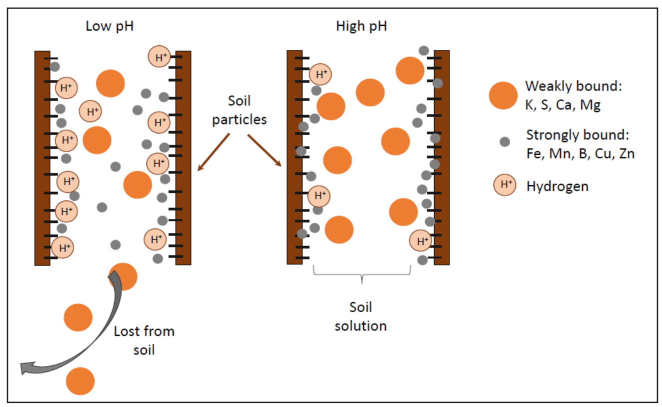

Figure 3: Mechanism of nutrient reaction in soil

soil solution, even at high pH (low H^+ concentration) (Reddy, 2019). They are displaced by H^+ at low pH and may not be plant accessible because they have been leached or uptake from the soil. Because nitrate (NO_3^-) does not attach well to soil, it is available at all pH levels.

In general, soil pH 6.5 to 8 makes nitrogen (N), potassium, calcium, magnesium, and sulphur more available, whereas soil pH 5 to 7 makes boron (B), copper, iron, manganese, nickel (Ni), and zinc more available. High quantities of H^+, aluminium, and manganese in soil solution can approach hazardous levels at pH less than 5.5, limiting crop productivity. Phosphorus is most readily available in soils with a pH of 5.5 to 7.5.

Crop Growth and Yield

Most of the agricultural crops are working within 6.5 to 7.5 ranges, whereas some of the crops are producing optimum yield under acidic and higher pH value (Dotaniya and Meena, 2013). Most of the crops are better performing under optimum pH of the soil, deviation in lower and higher side of the optimum pH, plant nutrient availability and crop yield potential adversely affected (Table 1). For example, for each bacterial species, the critical and optimal pH values governing *rhizobia* dispersion and symbiotic nitrogen fixation were identified (Dotaniya and Meena, 2017). The soil pH and rhizobia's nitrogen-fixing capacity were closely related. Tea soils must be acid; tea cannot be grown in alkaline soils. A desirable pH value is 5.8 to 5.4 or less. So, if the higher pH soils, it affects the water uptake pattern from soil to plant and drastically reduced the crop biomass.

Table 1: Optimum pH range requirement for crops

Crops	pH range	Crops	pH range
Maize	5.8-7.5	Potato	4.8-6.5
Wheat	6.3-7.0	Pumpkin	5.5-7.5
Paddy	5.5-7.5	Radish	6.0-7.0
Beans	6.0-7.5	Beet root	6.0-7.5
Soybeans	6.5-7.5	Broccoli	6.0-7.0
Groundnut	6.5-7.0	Brussels sprout	6.0-7.5
Sugarcane	5.0-8.5	Spinach	6.0-7.5
Cabbage	6.0-7.0	Squash	5.5-7.5
Carrot	5.5-7.0	Tomato	5.5-7.5
Cauliflower	5.5-7.5	Chilli	5.5-7.0
Celery/ Coriander	5.8-7.0	Pomegranate	5.5-8.5
Chives/ Onions	6.0-7.0	Grapes	6.0-8.0
Cucumber	5.5-7.0	Mango	5.5-7.5
Garlic	5.5-8.0	Cucumber	6.0- 7.0
Lettuce	6.0-7.0	Muskmelons	6.0- 7.5
Peas	6.0-7.5	Marigold	6.0 -7.5
Capsicum	5.5-7.0	Watermelon	6.0-7.5
Papaya	5.5 -7.5	Sunflower	6.0 -7.5
Forage crops	5.8-7.5	Tea	4.2-5.1
Guava	5.0-7.5	Moringa/ Drumstick	6.5-8.0

Conclusion

Soil pH, often known as soil response, is a measurement of the acidity or alkalinity of soil. The availability of nutrients for plant uptake is affected by the pH of the soil. Reduced solubility in very basic soils and increased susceptibility to leaching or erosion losses in acidic soils limit the availability of cation nutrients. The availability of anion nutrients is usually the polar opposite. For overall nutrient availability, crop tolerance, and soil microbial activity, soil pH levels near 7 are ideal. Chemical amendments can be used to change the pH of the soil, but these treatments are often not cost-effective and only work for a short period of time. The ideal pH range for plant growth varies depending on the crop. Most plants thrive in soil pH ranges of 6.0-7.5, as this is where the majority of nutrients are available.

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