Chapter 1

Introductory Chapter: Relevance of Soil pH to Agriculture

Suarau Odutola Oshunsanya

Additional information is available at the end of the chapter

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1. Why soil pH?

Soil pH is a master variable in soils because it controls many chemical and biochemical processes operating within the soil. It is a measure of the acidity or alkalinity of a soil. The study of soil pH is very important in agriculture due to the fact that soil pH regulates plant nutrient availability by controlling the chemical forms of the different nutrients and also influences their chemical reactions. As a result, soil and crop productivities are linked to soil pH value. Though soil pH generally ranges from 1 to 14, the optimum range for most agricultural crops is between 5.5 and 7.5. However, some crops have adapted to thrive at soil pH values outside this optimum range. The United States Department of Agricultural National Resources Conservation Service groups soil pH values as follows: ultra acidic (<3.5), extremely acidic (3.5–4.4), very strongly acid (4.5–5.0), strongly acidic (5.1–5.5), moderately acidic (5.6–6.0), slightly acidic (6.1–6.5), neutral (6.6–7.3), slightly alkaline (7.4–7.8), moderately alkaline (7.9–8.4), strongly alkaline (8.5–9.0) and very strongly alkaline (>9.0) [1].

Soil pH is affected by the mineral composition of the soil parent material and the weathering reactions undergone by that parent material. For instance, in humid environments, soil acidification occurs for a long time as the products of weathering leached by water moving laterally or downwards through the soil, while in the dry environments, soil weathering and leaching are less intense, and soil pH is often neutral or alkaline [2].

2. Soil acidification

Soil acidification is brought about by a number of processes such as high rainfall, crop growth, the use of fertilizers, acid rain and oxidative weathering.

2.1. High rainfall

Soils usually become acidic under heavy rainfall. This is because rainwater is slightly acidic (about 5.7) due to a reaction with CO_2 in the atmosphere that forms carbonic acid. As this rainwater passes through soil pores, it leaches basic cations from the soil as bicarbonates, which increases the percentage of AI^{3+} and H^+ relative to other cations in the soil. Root respiration and decomposition of organic matter by microorganisms also release CO_2 that increases the carbonic acid (H_2CO_3) concentration resulting to leaching.

2.2. Crop growth

Soil nutrients are taken up by crop roots in the form of ions (NO_3^-, NH_4^+, Ca^{2+} and $H_2PO_4^-$). Crop roots often take up more cations than anions. But crops must maintain a neutral charge in their roots for normal physiological processes to take place. H^+ ions are released by root crops to compensate for the extra positive charges resulting to acid soils.

2.3. Use of fertilizers

Some fertilizers such as ammonium (NH_4^+) fertilizers undergo nitrification process to form nitrate (NO_3^-), and during this process, H^+ ions are released leading to acid soils.

2.4. Acid rain

Oxides of sulfur and nitrogen are released into the atmosphere when burning fossil fuels. Released oxides react with rainwater in the atmosphere to form tetraoxosulphate (vi) acid and trioxonitrate (v) acid.

2.5. Oxidative weathering

Sulphides and other compounds containing Fe^{2+} produced acidity during oxidation process.

3. Soil alkalinity

Soil alkalinity increases with weathering of silicate, aluminosilicate and carbonate mineral compounds that contain Na^+, Ca^+, Mg^{2+} and K^+. The fore-listed minerals are usually added to the soil by the deposition of eroded sediments by water or wind. Soil alkalinity can also be increased by addition of water containing dissolved bicarbonates especially when irrigating with high-bicarbonate water. Insufficient water flowing to leach soluble salts can lead to accumulation of alkalinity in a soil. This is common in arid areas or poor internal soil water drainage situations, where the water that comes in is either transpired by crops or evaporates rather than flowing through the soil.

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Both acid and alkaline soils have influence on crop growth and development. For instance, agricultural crops grown in acid soils may experience some stresses such as AI, H and Mn toxicity as well as Ca and Mg nutrient deficiencies. Aluminum toxicity, which is the most widely spread problem of acid soils, occurs when aluminum is present in ionic Al^{3+} form. Aluminum ion Al^{3+} is the most soluble of all forms of aluminum at soil pH less than 5.0 (acidic condition). Aluminum is not a plant nutrient but an ionic form of Al^{3+} that enters crop roots passively through the process of osmosis. Aluminum inhibits root growth and development by interfering uptake and transport of essential nutrients, cell division, cell wall formation and enzyme activity. However, strong alkaline soils (sodic soils) are characterized with slow infiltration, reduced hydraulic conductivity and poor soil water retention capacity that make crops to experience water stress.

Generally, agricultural crops are varied in terms of suitability for soil pH range. Some crops can be intolerant of a particular soil pH due to a particular mechanism. For instance, soil pH 5.5 is not suitable for soybean plants when molybdenum is low in the soil, but the same pH 5.5 becomes optimum for soybean when molybdenum is sufficient in the soil. Most agricultural crops perform optimally around soil pH 7.0 (neutral). This shows that it is very important to bring both acidic and alkaline soils to neutral soil pH value for optimum performance of crops.

4. Amendment of soil acidity and alkalinity

The pH of acidic soil can be increased by using finely ground agricultural lime (limestone or chalk). The buffering capacity of the soil determines the amount of lime needed to increase pH of acidic soil. The buffering capacity of the soil largely depends on the amount of clay and organic matter present. Soils with high clay and organic matter will have high buffering capacity. Apart from limestone, other amendments such as wood ash, industrial calcium oxide (burnt lime), magnesium oxide, basic slag (calcium silicate) and oyster shells can be used to increase pH of acidic soils. On the other hand, the pH of alkaline soils can be decreased by using acidifying fertilizers or organic materials. Acidifying fertilizers include ammonium sulphate, ammonium nitrate and urea, while acidifying organic materials are peat or sphagnum peat moss. Elemental sulfur (90–99% S) has been successfully used at application rates of 300–500 kg ha^{-1} to reduce the pH of an alkaline soil. Therefore, farmers must be encouraged to regulate the soil pH value for optimal crop performance.

Author details

Suarau Odutola Oshunsanya[1,2]

Address all correspondence to: soshunsanya@yahoo.com

1 Department of Agronomy, University of Ibadan, Nigeria

2 Key Laboratory of Agro-Environment and Agro-Product Safety, Guangxi University, Nanning, China

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