

Nature's pH Guardian: Understanding Soil Buffering Capacity and Why Soil Resists pH Change

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Introduction:

When you pour a large bucket of vinegar on your farm, you may not have realized it until now, but your crops may not even notice any difference at all! How can that be? The answer is the soil's buffering capacity—one of the most important concepts in soil science! The buffering capacity of soil is what allows the soil to buffer or "absorb" the effects of a sudden increase or decrease in either acidity or alkalinity, and keep the chemical equilibrium of the soil at the correct levels for the microorganisms, plants, and entire soil ecosystem. In general, the soil pH has a huge impact on crop production, microbial activity, and the availability of nutrients to crops. A pH unit change is equal to ten times change in the amount of acid in the soil. However, most soils have the ability to absorb both alkaline and acidic products in huge quantities, resulting in only minor to moderate pH changes. Learning about the buffering capacity of soil has very important, practical applications for everyone involved in agriculture, agronomy, or environmental

knowledge include predicting how soils will respond to pollution and/or excessive fertilizer use, as well as helping farmers determine how much lime to apply to acidic soils to improve their soils.

What Is Soil Buffering Capacity?

Soils have buffering capabilities so they are able to resist changes in pH (acidity) when strong acids and bases (alkalinity) come into contact with them. Soils can be complicated and consist of multiple components.

Cation Exchange Capacity (CEC) refers to the ability of clay particles and organic matter in a soil to adsorb and hold positively charged ions (cations) including: hydrogen, calcium, magnesium and potassium. The negatively charged surfaces of these two components provide exchange sites where hydrogen ions will be retained upon application of an acid to a soil so that the pH of the soil will not drop instantly.

Carbonate and Mineral Weathering Buffers refer to the process whereby acidity

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high amounts of calcium carbonate) results in the dissolution of limestone particles to produce calcium and bicarbonate ions that can neutralize the acidity.

Organic Matter as Buffer means that because soil organic matter contains many carboxyl and hydroxyl functional groups, it can donate or pick up protons depending upon the conditions of the particular soil. Thus, soils with a high percentage of humus will generally exhibit greater buffer capacity than similar soils having low amounts of humus, over a wider range of pH values.

Benefits in Agriculture:

Well-buffered soil naturally maintains the optimum pH range of 6.0 to 7.5, where most essential plant nutrients are most readily available. By keeping nutrients from being immobile in insoluble form, well-buffered soil allows them to be readily accessible to plants. In poorly buffered soils, a single large rainfall event or heavy fertilizer application can result in extremely high pH levels that can make nutrients temporarily or permanently unavailable to plants. In addition to preventing large swings in pH, well-buffered soils also protect against the gradual increase in acidity caused by fertilizers that contain ammonium, acid rain, and the breakdown of organic matter. These three factors are responsible for significant worldwide soil degradation. Soils with high organic matter and clay content

require much greater acid loads to achieve the same level of acidification than do sandy soils with little organic matter. After repeated applications of fertilizer to strongly buffered soils, very little pH movement will occur making these soils easier for farmers to manage with more stable soil characteristics without the need for continual pH correction.

The Effect on Crop Growth and Yield:

Long-term studies have proven that liming acidic soils and maintaining pH levels between 6.0 - 7.0 significantly increases wheat grain yields by 15%-30% on average, primarily due to increased phosphate availability. Soils with good buffering capacity also help keep the pH level above 5.8, which provides legumes (e.g., soybeans, peanuts, and chickpeas) with an increased nodulation and biological nitrogen fixation rate, thus reducing reliance on synthetic nitrogen applications. Additionally, soils' natural buffering capacity helps regulate typical pH fluctuations induced by flooding (e.g., rice production) through self-buffering. Therefore, managing buffering capacity is essential for horticultural crops with narrow pH ranges (e.g., brassicas) to ensure optimum production through pH management.

Environmental Benefits:

In addition to providing essential environmental benefits, soil buffering capacity has numerous ecological advantages. As the

pH level declines, heavy metals (e.g., zinc, lead, cadmium) may become more soluble, and therefore more mobile, because they bind less strongly to particles in the soil. Well-buffered soils can delay or prevent further acidification, so the heavy metals are bound in a less mobile form and have a lower chance of being transported into groundwater or food chains. With regard to carbon sequestration, a neutral pH level of well-buffered soils creates a conducive environment for a high degree of microbial activity and diversity, both of which favour the continuous building of organic matter (humus) in the soil. The residual effects of acid rain damage in Sweden and the Northeast U.S.A. is a clear example of how the buffering capacity of catchment soils within watersheds influences the amount of acid deposition the watershed can retain prior to acidification of the streams and/or lakes that are present in the watershed.

Limitations:

The amount of buffering produced cannot be continually produced. In addition, soils with a good buffer will eventually reach their maximum buffering capacity and that soil will become acidified due to excessive acid loading or depletion of organic matter. Measuring buffering capacity accurately can be challenging because useful tests for buffer pH have not yet been made widely available in developing countries. Also, pH of routine

water tests does not measure all aspects of the soil's ability to buffer. Decreases in the ability of the soil to buffer as a result of soil degradation also are going on. Examples include: soil erosion; loss of organic matter; and, waterlogging. Research indicates that, over the past 50 years of farming, the amount of SOM has been reduced by 40–60% in many heavily cultivated regions of South Asia, sub-Saharan Africa, and Latin America; this loss of SOM clearly has weakened the natural ability to buffer of many soils.

Conclusion:

Soil buffering capacity is one of nature's most amazing ways of reacting to instability in terms of chemistry; a built-in resilience system to protect the fragile but critical chemical make-up of the soil environment. This provides farmers with the information to make better decisions regarding rates for fertilizers and lime. This means accurately determining any issues with pH in their soil without unnecessarily over-using agronomic products. To environmentalists, it means that they should appreciate and recognize how soils can be utilized as a proactive defence against pollution and acidification. Due to the ever-increasing pressures of extreme weather conditions/climate changes and intensive farming practices on soils, preserving and re-establishing the soil's natural buffering

capacity must be a high priority. The value of soil buffering capacity as an indicator of the resilience of the soils upon which all sustainable agriculture relies (not only as a chemical characteristic) is the very foundation of soil buffering capacity.

