# SOIL REACTION FOR OPTIMUM CROP PRODUCTION IN TEA PLANTATIONS

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Going through the reports sent out to the tea plantations by the Soil Analytical Division of the Tea Research Institute on the pH of soil samples, it is evident that the majority of the tea fields are recording a pH of much less than 4.5-5.0 and in many instances the values are even as low as 3.7 to 4.0. It is very important, at this stage, to make the plantations aware of the dangers of such low pH soils with respect to their nutrient retentive capacities and effects on tea nutrition.

The availability of soil nutrients is influenced to a very great extent by the reaction of the soil and by the soil management practices followed by the plantations. The acidity of the soil governs the intake of both major and minor nutrients from the soil solution. The increased growth of crops, that is seen as a result of the adoption of good soil management practices, is, in most cases, due to an increase of available soil nutrients resulting from these practices. In other words, the problems of soil management are largely those which centre around the problems of nutrient availability.

**What is soil reaction and how can it be expressed**

Soils may be spoken of as being acid, neutral or basic in reaction. Soils containing an excess of acid materials are said to be acid in reaction, while soils containing an excess of base materials are said to be basic or alkaline in reaction. If the quantities of acidic and basic materials are equal, the soil is said to be neutral.

The method commonly used in measuring and expressing degrees of acidity or alkalinity in soils is in terms of pH values. The scale for measuring soil reaction is made up of 14 divisions or values. These values represent the logarithm of the reciprocals of the hydrogen ion concentrations of the acid solution at different soil reactions. The pH value may be expressed mathematically as:

$$pH = \log \frac{1}{(H^+)}$$

Freshly distilled water contains the same number of $H^+$ and $OH^-$ ions, and is therefore neutral.

$$H_2O \rightleftharpoons H^+ + OH^-$$

When the soil solution contains the same number of $H^+$ and $OH^-$ ions, it is also neutral.

At neutrality, the hydrogen-ion concentration has been determined to be 0.000, 0001 or $1 \times 10^{-7}$ grams of hydrogen per litre of solution (moles).

Substituting this concentration into the formula

$$pH = \log \frac{1}{10^{-7}}$$

$$= \log 10^7$$

$$= 7.0$$

Thus at neutrality the pH of the medium is 7. It is important to remember that the pH scale is logarithmic and a change of one unit on the scale represents a ten-fold change in hydrogen-ion concentration (acidity) in the soil solution. Thus a soil with a pH of 6 is ten times more acid than a soil with a pH of 7; one with a pH of 6 is only one tenth as acid as a soil with a pH of 5.

Consideration of soil acidity is important because these conditions exert strong influences on root development as well as activity of soil bacteria and fungi, and availability of wide range of nutrients including phosphorus, zinc, boron, manganese, and copper to name a few.

**Soil reaction as influenced by soil management practices**

When virgin soils are put under cultivation, they lose rapidly much of their organic matter through oxidation and much of their nitrogen and bases (specially K, Ca and Mg) through leaching and crop removal. Many of our tea soils have passed and are now passing through this process.

As the basic elements are removed from soil complexes through leaching and crop removal, they are replaced by hydrogen so that a great increase in the acidity of the soil usually results. In our tea soils, this trend of soil reaction toward high soil acidity has been further hastened through the use of acid-forming fertilizers such as ammonium sulphate since the commencement of inorganic fertilizer use for tea in Sri Lanka. In this connection, the process of nitrification and its effects on soil pH are important.

Nitrification is a bacterial process, and it results in the conversion of ammonium nitrogen (from applied fertilizers specially as sulphate of ammonia) to nitrate nitrogen

$$2NH_4^+ + 3O_2 \longrightarrow 2NO_2 + 2H_2O + 4H^+$$

Nitrification contributes to soil acidification through the production of hydrogen-ions. All forms of ammonium nitrogen increase soil acidity because of this process. Further the accompanying sulphate ion ($SO_4^{2-}$) in ammonium sulphate also increases acidity by removing away the metal ions such as Mg and Ca in the soil. When the acidity of the soil is greatly increased by such practices, many beneficial soil processes are interfered with, as discussed elsewhere in this paper.

**Soil reaction and its influence on nutrient availability**

Many changes take place in the soil when the soil becomes acid or when the acidity of the soil is increased through the use of acid fertilizers. Some of these changes are of importance to us because it is often the lack of plant nutrients and not an acid reaction that makes an acid soil unproductive.

The pH value around 5.0 marks an important transition point in soils from the stand point of the availability or solubility of soil compounds. Nutrients such as iron, manganese, boron and aluminium increase in solubility below this pH but are much less soluble at pH levels above this value.

Most of the tea soils in Sri Lanka contain an abundance of iron, manganese and aluminium compounds in insoluble forms. Plants require iron and manganese but only in very small quantities. In fact, if they are present in the soil solution in more than very low concentrations, they exert a toxic effect on plant growth. Apparently soils with the reactions between 4.5 to 5.5 supply plants with adequate quantities of both iron and manganese in the soluble ferrous and manganous forms. Neither iron nor manganese deficiency is likely to be found in plants growing on acid soils. On the other hand, excess quantities of iron and manganese may become available at pH values below 4.5 and toxic influences on plant growth may result. This is also true of the element aluminium. Though tea is reported to be an aluminium accumulator one does not know for certain the actual mechanism it plays in the physiology of the tea bush, and the level at which it could cause toxic effects on the plant. The percentages of both manganese and aluminium in tea have been found to increase as the soil pH decreases.

The high solubility of aluminium and iron at low pHs also brings about another problem on the utilization of phosphates by tea plants. As already pointed out soluble iron and aluminium compounds from the insoluble iron and aluminium compounds begin to appear in the soil solution at about a pH value of 5.0 and great quantities may become soluble if the pH value of the soil is allowed to drop to 4.0. Because of this, available phosphorus is probably combined in the soil with iron and aluminium to some extent at a pH of 5.0 and as the pH of the soil is reduced, the solubility of the iron and aluminium phosphates is reduced until a minimum solubility is reached at about 3.5 to 4.0. Since soluble phosphates will unite readily with soluble iron and aluminium compounds, especially aluminium, and become precipitated as insoluble phosphate compounds, tea growing on very acid soils will show phosphorus starvation. In addition there is good evidence to indicate that soluble aluminium itself is toxic to many plants.

**Influence of soil reaction on the availability of magnesium**

Acidity in the soil is correlated with a lack of bases such as Ca and Mg in the colloidal complex. For this reason acid soils can yield but little available magnesium and calcium. Also high acidity even in the presence of adequate soluble magnesium interferes with the ability of plants to take up and retain soluble magnesium. Thus, magnesium deficiencies are possible in tea fields recording very low pH values (less than 4.5), especially acid sandy soils in which the colloidal content, and therefore the exchange capacity is low.

**Adjusting soil reaction through the use of agricultural lime**

The regular use of dolomite for the purpose of supplying Mg and reducing the acidity of tea soil has been recommended by the TRI. It is to be noted that in the past the practice of liming has not been rigidly adhered to as to cause a significant retardation in the drift of cultivated tea soils towards greater acidity, although today there is a greater awareness of the benefits of this practice.

Agricultural lime recommended by the TRI is composed of compounds of calcium and magnesium as dolomitic limestone containing not less than 18-20% MgO and with a particle size not less than 50% through 100 mesh and the balance through 30 mesh.

The major purposes of applying dolomitic limestone to acid tea soils are to neutralize acids, to precipitate soluble compounds excessively present in tea soils (such as manganese and aluminium) which are toxic to plant growth, and to introduce calcium and magnesium — two elements essential for growth of tea. The introduction of calcium into the soil colloid is also important as its salts are strong flocculents and tend to maintain soils in a good physical condition.

Considering all the above facts one will note that when effects of soil pH are overlooked crop growth can be severely affected. Soil pH must therefore be monitored regularly to be certain that yield-limiting conditions do not develop, which is very likely below a pH of 4.5. Soil analysis is the best tool to monitor and to predict this effect.

A word about how the addition of dolomitic limestone improves the pH and nutrient status of the tea soil will also be of some interest to the reader. The following illustration demonstrates the reaction between dolomitic limestone (Ca Mg $(CO_3)_2$ and soil acidity.

$$Ca\,Mg\,(CO_3)_2 + 2H_2O \longrightarrow Ca^{2+} + Mg^{2+} + 2H\,CO^-_3 + 2\,OH^-$$

$$2H^+ + 2OH^- \longrightarrow 2H_2O$$

(soil acidity)

Dolomitic limestone dissolves in water forming a calcium ion, ($Ca^{2+}$), magnesium ion, ($Mg^{2+}$), bicarbonate ions ($HCO_3$) and hydroxyl ions (OH). The calcium and magnesium ions are adsorbed by the colloids, replacing hydrogen ions ($H^+$) from the reserve acidity on the colloid. The replaced hydrogen ions react with hydroxyl ions ($OH^-$) producing water. Subsequently, the amount of reserve acidity which is in equilibrium with the soil pH is reduced and the soil pH increases (becomes less acid).