23.

Genesis, Characteristics, and Reclamation of acid soils

Learning objectives

To study the genesis, characteristics and reclamation of acid soils

Soil acidity refers to presence of higher concentration of H^+ concentration in soil solution and at exchange sites. Soil acidity is a major problem in relation to plant growth and therefore acid soils are called a problem soil. Acid soils are characterized by low soil pH, which varies form strongly acidic (4.5-5.5) to extremely acidic (<4.5) and with low base saturation.

Soil acidity is of three kinds *viz.,* active acidity, exchangeable acidity and residual acidity. The hydrogen ions in the soil solution contribute to active acidity. It may be defined as the acidity developed due to concentration of H^+ and Al^{3+} ions in the soil solution. The concentration of hydrogen ion in soil solution due to active acidity is very small, implying that only a meager amount of lime would be required to neutralize active acidity. Inspite of smaller concentration, active acidity is important since the plant root and the microbes around the rhizosphere are influenced by it.

The concentration of exchangeable Al and H ions contribute to exchangeable acidity. It may be defined as the acidity developed due to adsorbed H and Al ions on soil colloids.

Aluminium hydroxyl ions and H and Al ions present in non – exchangeable form with organic matter and clay account for the residual acidity.

Total acidity = Active acidity + Exchangeable acidity + Residual acidity

Sources of soil acidity

Leaching due to heavy rainfall

Acid soils are common in all regions where rainfall or precipitation is high enough to leach appreciable amounts of exchangeable bases from the surface soils and relatively insoluble compounds of Al and Fe remains in soil. The nature of these compounds is acidic and its oxides and hydroxides react with water and release hydrogen ions in soil solution and become acidic. Besides, when the soluble bases are lost, the H^+ ions of the carbonic acid and other acids developed in the soil replace the basic cations of the colloidal complex. As the soil gets gradually depletes of its exchangeable bases through constant leaching, it gets desaturated and becomes increasingly acid.

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

$$H_2CO_3 + CaCO_3 \rightleftharpoons Ca(HCO_3)_2 \downarrow$$

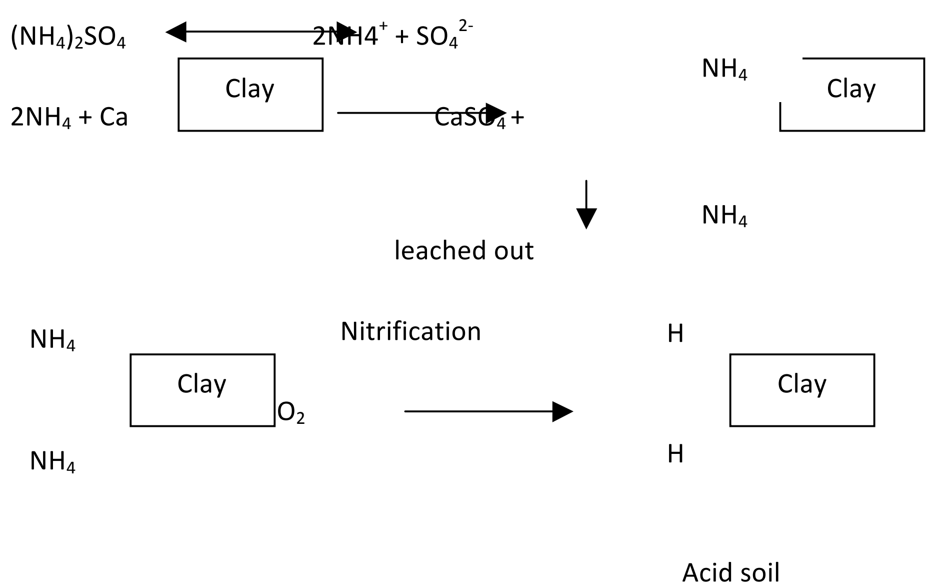
Leachable

Acidic parent material

Some soils have developed from parent materials which are acid such as granite and that may contribute to some extent soil acidity.

Acid forming fertilizers and soluble salts

The use of ammonium sulphate and ammonium nitrate increases soil acidity. Ammonium ions from ammonium sulphate when applied to the soil replace calcium ions from the exchange complex and the calcium sulphate is formed and finally leached out.



Besides, basic portion of ammonium sulphate is NH_4^+ and it undergoes biological transformation in the soil and form acid forming nitrate ions. Similarly, sulphur also produces acid forming sulphate ions through oxidation. Divalent cations of soluble salts usually have a greater effect on lowering soil pH than monovalent metal cations.

Humus and other organic acids

During organic matter decomposition, humus, organic acids and different acid slats may also be produced and also concentration of CO_2 increased. The increased concentration of CO_2, hydrolysis of acid salts and various organic acids increased the total acidity of soil.

Aluminosilicate minerals

At low pH values most of the Al is present as the hydrated Aluminium ions, which undergoes hydrolysis and release hydrogen ions in the soil solution.

Carbon dioxide

Soil containing high concentration of CO_2, the pH value of such soil will be low and the soil becomes acidic. Root activity and metabolism may also serve as sources of CO_2, which ultimately helps the soil to become acidic.

Hydrous oxides

These are mainly oxides of iron and aluminium. Under favourable conditions they undergo stepwise hydrolysis with the release of hydrogen ions in the soil solution and develop soil acidity.

Production constraints

- Increased solubility and toxicity of Al, Mn and Fe
- Deficiency of Ca and Mg,
- Reduced availability of P and Mo and
- Reduced microbial activity

Management of acid soils

Management of the acid soils should be directed towards enhanced crop productivity either through addition of amendments to correct the soil abnormalities or by manipulating the agronomic practices depending upon the climatic and edaphic conditions.

Soil amelioration

Lime has been recognized as an effective soil ameliorant as it reduces Al, Fe and Mn toxicity and increases base saturation, P and Mo availability of acid soils. Liming also increases atmospheric N fixation as well as N mineralization in acid soils through enhanced microbial activity.

Liming materials

Source of lime material is an important aspect of acid soil management and the economics of application of different sources need to be given due importance. Commercial limestone and dolomite limestone are the most widely used amendments. Carbonates, oxides and hydroxides of calcium and magnesium are referred to as agricultural lime.

Among, the naturally occurring lime sources calcitic, dolomitic and stromatolitic limestones are important carbonates. The other liming sources are marl, oyster shells and several industrial wastes like steel mill slag, blast furnace slag, lime sludge from paper mills, pressmud from sugar mills, cement wastes, precipitated calcium carbonate, etc were found to be equally effective as ground limestone and are also cheaper. Considering the efficiency of limestone as 100%, efficiencies of basic slag and dolomite were found to be 110 and 94 % respectively.

Burnt lime is the oxide of lime or quick lime. Quick lime is produced in large kilns. Its reactions in soil are much faster compared to those of carbonates.

$$CaCO_3 + heat \longrightarrow CaO + CO_2\uparrow$$

$$CaMg(CO_3)_2 + heat \longrightarrow CaO + MgO + 2\ CO_2\uparrow$$

Addition of water to burnt lime makes hydroxide or hydrated lime (slaked lime), which is more caustic than burnt lime.

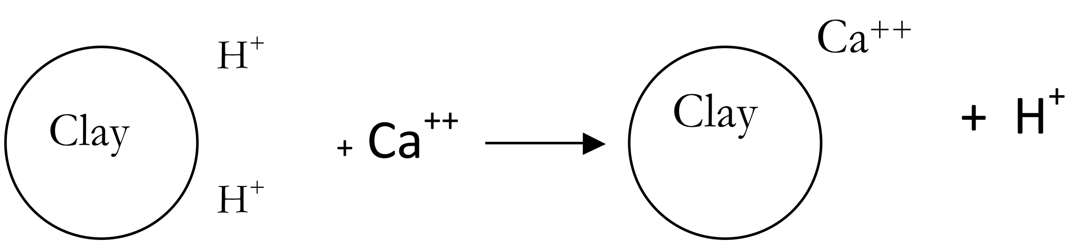
Lime when applied to acidic soils either in the form of oxide, hydroxide or carbonate reacts with carbon dioxide and water to form bicarbonate.

$$CaO + H_2O + 2\ CO_2 \longrightarrow Ca\ (HCO_3)_2$$

$$Ca\ (OH)_2 + 2\ CO_2 \longrightarrow Ca\ (HCO_3)_2$$

$$CaCO_3 + H_2O + CO_2 \longrightarrow Ca\ (HCO_3)_2$$

These liming materials on reaction with soil colloid, replace hydrogen and aluminium ions from the colloidal phase to soil solution.



Lime requirement:

Four important factors govern the lime requirement, *viz.,*

- The required change in pH
- The buffer capacity of the soil to be limed
- The chemical composition of the liming materials used
- The fineness of the liming materials.

A fine textured acid soil requires much larger quantity of lime than does a sandy soil or a loamy soil with the same pH value. Calcitic or dolomitic limestone reacts slowly with soil colloids, whereas burnt lime and hydrated lime react faster and bring about changes in soil pH within a few days.

Lime requirement of an acid soil may be defined as the amount of liming material that must be added to raise the pH to some prescribed value. Shoemaker *et al*. (1961) buffer method is used for the determination of lime requirement of an acid soil. Lime requirement interms of pure $CaCO_3$ can be observed from the following table.

Lime requirement of an acid soil

pH of soil buffer suspension (Field soil sample)	**lime required to bring pH down to indicated level ($CaCO_3$) in tonnes per acre**		
	pH 6.0	**pH 6.4**	**pH 6.8**
6.7	1.0	1.2	1.4
6.6	1.4	1.7	1.9
6.5	1.8	2.2	2.5
6.4	2.3	2.7	3.1
6.3	2.7	3.2	3.7
6.2	3.1	3.7	4.2
6.1	3.5	4.2	4.8
6.0	3.9	4.7	5.4
5.9	4.4	5.2	6.0
5.8	4.8	5.7	6.5
5.7	5.2	6.2	7.1
5.6	5.6	6.7	7.7
5.5	6.0	7.2	8.3

5.4	6.5	7.7	8.9
5.3	6.9	8.2	9.4
5.2	7.4	8.4	10.0
5.1	7.8	9.1	10.6
5.0	8.2	9.6	11.2
4.9	8.6	10.1	11.8
4.8	9.1	10.6	12.4

Benefits:

The most conspicuous effect of liming was on the exchangeable acidity, which registered a decrease up to 95 %. A decrease of 70-74% in pH dependent and total acidity was recorded by liming. An average yield improvement of 30 % could be obtained.

Crop choice:

Selection of crops tolerant to acidity is an effective tool to counter this soil problem and breeding of such varieties is of specific importance for attaining higher productivity, particularly in areas where liming is not an economic proposition. The crops can be grouped on the basis of their performance in different soil pH range.

Relative tolerance of crops to soil acidity

Crops	**Optimum pH range**
Cereals	
Maize, sorghum, wheat, barley	6.0-7.5
Millets	5.0-6.5
Rice	4.0-6.0
Oats	5.0-7.7
Legumes	
Field beans, soybean, pea, lentil etc.	5.5-7.0
Groundnut	5.3-6.6
Other crops	

Sugarcane	6.0-7.5
Cotton	5.0-6.5
Potato	5.0-5.5
Tea	4.0-6.0

Occurrence in India:

95% of soils of Assam and 30% of geographical area of Jammu and Kashmir are acidic. In West Bengal, 2.2 Mha, in Himachal Pradesh, 0.33 Mha, in Bihar, 2 Mha and all hill soils of erstwhile U.P. come under acid soils. About 80% of soils in Orissa, 88% in Kerala, 45% in Karnataka and 20% in Maharastra are acidic. The laterite zone in Tamil Nadu is covered with acid soil and about 40,000 ha are acidic in Andhra Pradesh.

References

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4. Soil Acidity and liming by Adams, F. (Ed) (1984). 2nd Edn, American Soiciety of Agronony, Madison, U.S.A.

Questions to Ponder

1)What ions are the principal sources of soil acidity?

2) is soil pH altered by fertilizer application?

3) what is agricultural lime?

4)what are the factors that determine the frequency and rate of liming?

5)What is fluid lime?