Soil organic matter – composition, decomposition, mineralization and immobilization

SOIL ORGANIC MATTER

Substances containing carbon are organic matter. Soil organic matter consists of decomposing plant and animal residues. It also includes substances of organic origin either leaving or dead.

Soil organic matter plays an important role in deciding / maintaining soil physical conditions. It also influences soil chemical properties especially cation exchange capacity. Organic matters supply the energy sources for soil micro organisms. Soil development is another aspect which is influenced by the soil organic matter.

Plant tissue is the major source. Animals are considered as the secondary sources. They attack original plant tissues, contribute waste products and leave their own bodies after death.

Factors affecting soil organic matter

1. Climate

2. Natural vegetation

3. Texture

4. Drainage

5. Cropping and Tillage

6. Crop rotations, residues and plant nutrients.

1. Climate: Temperature and rainfall exert a dominant influence on the amounts of N and organic matter found in soils.

a) Temperature: The organic matter and N content of comparable soils tend to increase if one moves from warmer to cooler areas. The decomposition of organic matter is accelerated in warm climates as compared to cooler climates. For each 10°C decline in mean annual temperature, the total organic matter and N increases by two to three times.

b) Rainfall: There is an increase in organic matter with an increase in rainfall. Under comparable conditions, the N and organic matter increase as the effective moisture becomes greater.

2. Natural Vegetation: The total organic matter is higher in soils developed under grasslands than those under forests.

3. Texture: Fine textured soils are generally higher in organic matter than coarse textured soils.

4. Drainage: Poorly drained soils because of their high moisture content and relatively poor aeration are much higher in organic matter and N than well drained soils.

5. Cropping and Tillage: The cropped lands have much low N and organic matter than comparable virgin soils. Modern conservation tillage practices helps to maintain high OM levels as compared to conventional tillage.

6. Rotations, residues and plant nutrients: Crop rotations of cereals with legumes results in higher soil organic matter. Higher organic matter levels, preferably where a crop rotation is followed.

Composition of organic residues:

Plant residues contain 75% moisture and 25% dry matter. This 25% is made up of Carbon (10-12%), Oxygen (9-10%) , Hydrogen (1.5-2.5%) , N(1-2%) and mineral matter (1-3%).

Composition of plant tissues:

Carbohydrates

Celluloses 20-50%

Hemicellulose 10-30%

Starch, Sugar 1-5%

Proteins 1-15%

Fats, waxes, tannins 1-10%

Lignins 10-30%

Inorganic residues (mineral matter)

Nitrogenous

1. Water insolubles

Proteins, Peptides

Peptones and S containing materials

2. Water solubles

(No_3, NH4 compounds)

Soil organic residues

Non Nitrogenous Carbohydrates (celluloses Hemicellulose, ,Starch, Sugar etc)

Ether solubles (Fats, oils, waxes, resins etc) Lignins

The organic matter is also classified on the basis of their rate of decomposition

1. Rapidly decomposed : Sugars, starches, proteins etc.

2. Less rapidly decomposed : Hemicelluloses, celluloses etc.

3. Very slowly decomposed : Fats, waxes, resins, lignins etc

Decomposition of soil organic matter:

Different organic residues contain different organic compounds. There is great variation in the rate of decomposition of organic residues. Sugars, starches and simple proteins are very rapidly decomposed. On the other hand Fats, waxes and lignins are very slowly decomposed. Hemicellulose, celluloses and protein are intermediate. Even though the composition may vary the end products are more or less the same. The general reactions taking place during decomposition are

1. Enzymatic oxidation of the bulk with the release of Co_2 , water, energy and heat
2. Essential elements are released (N, P, S etc) and immobilized by a series of reactions.
3. Formation of compounds which are resistant to microbial action.

Molecules very resistant to microbial action is formed either through modification of compounds or by microbial synthesis

Under aerobic conditions the products formed are

Co_2, NH_4, NO_3 , H_2PO_4, SO_4, H_2O and essential plant nutrients like Ca, Mg, Fe, Cu, Zn etc.

Under anaerobic conditions

CH_4, organic acids like lactic, propionic, butyric, NH_4, various amine residues (R-NH_2) H_2S, ethylene (CH_2=CH_2) and humic substances.

A. Decomposition of soluble substances: When glucose is decomposed under aerobic conditions the reaction is as under:

$$\textbf{Sugar + Oxygen} \rightarrow \textbf{CO}_2 + \textbf{H}_2\textbf{O}$$

Under partially oxidized conditions,

Sugar + Oxygen → Aliphatic acids (Acetic, formic *etc*.) or Hydroxy acids (Citric, lactic etc.) or Alcohols (ethyl alcohol etc.)

Some of the reactions involved may be represented as under:

$$C_6H_{12}O_6 + 2O_2 \rightarrow 2CH_3.COOH + 2CO_2 + 2H_2O$$

$$2C_6H_{12}O_6 + 3O_2 \rightarrow C_6H_8O_7 + 4H_2O$$

$$C_6H_{12}O_6 + 2O_2 \rightarrow 2C_2H_5OH + 2CO_2$$

Ammonification – organic N - Polypeptides – Peptides – amonoacids – NH_3 or NH_4

i) Ammonification: The transformation of organic nitrogenous compounds (amino acids, amides, ammonium compounds, nitrates etc.) into ammonia is called ammonification. This process occurs as a result of hydrolytic and oxidative enzymatic reaction under aerobic conditions by heterotrophic microbes.

ii)Nitrification: The process of conversion of ammonia to nitrites (NO_2) and then to nitrate (NO_3^-) is known as nitrification. It is an aerobic process by autotrophic bacteria.

$$\underset{\text{Ammonia}}{NH_3} \xrightarrow{\text{Nitrosomonas}} \underset{\text{Nitrite}}{NO_2} \xrightarrow{\text{Nitrobacter}} \underset{\text{Nitrate}}{NO_3^-}$$

The net reactions are as follows:

$$\mathbf{NH_4 + O_2 \rightarrow NO_2 + 2H^+ + H_2O + energy}$$

$$\mathbf{NO_2 + O_2 \rightarrow NO_3^- + energy}$$

iii) Denitrification: The process, which involves conversion of soil nitrate into gaseous nitrogen or nitrous oxide, is called Denitrification. Water logging and high pH will increase N loss by Denitrification.

$$\text{Nitrate} \xrightarrow{\text{Pseudomonas / Bacillus}} N_2\text{gas}$$

2. Under anaerobic conditions:

$C6H_{12}O_6$ (Glucose) - Lactic acid, butyric acid Ethyl alcohol are formed

Protein and other N compounds are converted into elemental N.

B. Decomposition of Insoluble Substances

i) Breakdown of Protein: During the course of decomposition of plant materials, the proteins are first hydrolyzed to a number of intermediate products.

Aminization: The process of conversion of proteins to aminoacids.

Ammonification: The process of conversion of aminoacids and amides to ammonia.

ii) Breakdown of cellulose: The decomposition of the most abundant carbohydrates.

Hydrolysis hydrolysis oxidation

Cellulose ⇒ Cellobiose ⇒ Glucose⇒ Organic acids ⇒ $CO_2 + H_2O$

(cellulase) (cellobiase)

This reaction proceeds more slowly in acid soils than in neutral and alkaline soils. It is quite rapid in well aerated soils and comparatively slow in poorly aerated soils.

iii) Breakdown of Hemicellulose: Decompose faster than cellulose and are first hydrolyzed to their components sugars and uronic acids. Sugars are attacked by microbes and are converted to organic acids, alcohols, carbon dioxide and water. The uronic acids are broken down to pentose and CO_2. The newly synthesized hemicelluloses thus form a part of the humus.

iv) Breakdown of Starch: It is chemically a glucose polymer and is first hydrolyzed to maltose by the action of amylases. Maltose is next converted to glucose by maltase. The process is represented as under:

$$(C_6H_{10}O_5)n + nH_2O \Rightarrow n(C_6H_{12}O_6)$$

C. Decomposition of ether soluble substances:

Fats →glycerol + fatty acids

Glycerol →CO_2 + water

D. Decomposition of lignin: Lignin decomposes slowly, much slower than cellulose. Complete oxidation gives rise to CO_2 and H_2O.

Sulphur containing organic compounds:

Converted to SO_4^{-2} + H^+ + energy by sulphur oxidizing bacteria.

P containing organic compounds:

Various micro organisms mineralize phospholipids and other organic P compounds in the presence of phosphates enzymets H_2PO_4 and HPO_4^{-2} depending on soil P^H.

Mineralisation: The biological conversion of organic forms of C, N, P and S to inorganic or mineral forms is called mineralization.

Immobilization: The conversion of inorganic forms of C, N, P and S by the soil organism into organic forms is called Immobilization.

Factors affecting decomposition

1. Temperature: Cold periods retard plant growth and organic matter decomposition. Warm summers may permit plant growth and humus accumulation.

2. Soil moisture: Extremes of both arid and anaerobic conditions reduce plant growth and microbial decomposition. Near or slightly wetter than field capacity moisture conditions are most favorable for both processes.

3. Nutrients: Lack of nutrients particularly N slows decomposition.

4. Soil pH: Most of the microbes grow best at pH 6 to 8, but are severely inhibited below pH 4.5 and above pH 8.5.

5. Soil Texture: Soils higher in clays tend to retain larger amounts of humus.

6. Other Factors: Toxic levels of elements (Al, Mn, B, Se, Cl), excessive soluble salts, shade and organic phytotoxins in plant materials.

Role of organic matter

1. Organic matte creates a granular condition of soil which maintains favorable condition of aeration and permeability.
2. Water holding capacity of soil is increased and surface runoff, erosion etc., are reduced as there is good infiltration due to the addition of organic matter.
3. Surface mulching with coarse organic matter lowers wind erosion and lowers soil temperatures in the summer and keeps the soil warmer in winter.
4. Organic matter serves as a source of energy for the microbes and as a reservoir of nutrients that are essential for plant growth and also hormones, antibiotics.
5. Fresh Organic matter supplies food for earthworms, ants and rodents and makes soil P readily available in acid soils.
6. Organic acids released from decomposing organic matter help to reduce alkalinity in soils; organic acids along with released CO_2 dissolve minerals and make them more available.
7. Humus (a highly decomposed organic matter) provides a storehouse for the exchangeable and available cations.
8. It acts as a buffering agent which checks rapid chemical changes in pH and soil reaction.

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