MATTER AND HUMUS CYCLE

Soil is comprised of inorganic (mineral) and organic components. A notable characteristic of soil is surface accumulation of organic matter, from the overlying floral and faunal communities. Humus, a dark coloured amorphous product of plant and animal matter decomposition is an integral component of the soil system. It is vital for most biological and physico-chemical process happens in soil. The term humus is used to describe both incorporated humus (soil organic matter) and surface humus layers (or surface accumulations). Humus or humic substances persist in soils throughout its profile development. It is composed of slow decomposing products of decomposition and is complex and rather resistant mixture of brown or dark brown amorphous and colloidal substances modified from the original tissues (plants as well as animals) or synthesized by various soil organisms.

FORMATION OF HUMUS

Humus is a product of decomposition of organic matter. In the soil, microorganisms act on the dead plant and animal remains, degrade, and decompose them into simpler organic compounds. A product of this microbial decomposition is humus, which is a dark coloured, amorphous substance, composed of residual organic matters not readily decomposed by the organisms. When detrital carbon (carbon from plant, microbial and animal residues) is processed by decomposer organisms (largely microbes) in the soil, the carbon is either lost as carbon dioxide, incorporated into the cells of the decomposer organisms, or enters a carbon pool that is relatively stable either as a result of physical protection from attack by decomposers or chemical protection. It seems that physically protected organic matter is related to the structural characteristics of the soil, whereas chemically protected organic matter is related to the chemical processes in the soil and referred to as soil humus. Incomplete decomposition of detritus (dead and decaying plant and animal matters) leads to production of humus in an ecosystem. Under less than ideal conditions for decomposition, a portion of the litter entering the soil system is not completely decomposed, but is modified into humus, which may decompose slowly and hence accumulate. The first and most important aspect of humus formation is shredding of organic matter (detritus), which will be performed by saprophagous fauna (earthworms, potworms, millipedes, snails, etc.) followed by microorganisms, which will subsequently be subjected to further chemical transformations. It is found that around 90% of the organic matter has been processed by two of these animal groups, potworms and earthworms. According to Aber and Melillo (1991), the decomposition process from litter to humus has two stages. In the first stage, there is rapid loss of solubles (sugars, starches, proteins) followed by cellulose, but a little loss or sometimes-even gain of lignin (insoluble decay products). During this stage, carbon is relatively available and nutrients are limiting, and there is immobilization of the nutrients such as nitrogen. Once the litter reaches the second stage, it can be considered as humus, it has stabilized contents and slow decomposition rate. During the late stage of decay, there is net loss of lignin and nitrogen mineralization. The critical determining factor for the rate of humus accumulation on a site is how much of the original litter mass remains at a point at which the materials gets converted to humus and decomposition slows down.

FACTORS CONTROLLING HUMIFICATION

The major factors that influence the rate of humification are nature of plants, animals or soil organisms, rate of decomposition, temperature and aeration and moisture. All these aforesaid factors are more or less interrelated. The participation of the plant cover in humus formation is determined by the amount and nature of the plant residues, their mode of admission into the soil and the nature of their decomposition. Litter is the main source of humus in forest soils (in the absence of grass cover), and organic matter enters the soil layers in the form of leachates from litter. The quantum of humus formed by woody species is less than that of grass vegetation, as the roots of woods species are thick and long living. Local micrometeorological conditions are considered good predictors of decomposition rates and good relationships exist between temperature or actual evapotranspiration and rates of litter decomposition. Temperature is directly proportional to the rate of humification upto a certain extent as an increase in temperature increases the rate. Good aeration and moisture content in soil also stimulates the humification process. The chemical nature of litter is probably the most significant factor influencing the proportion that becomes humus. The availability of microorganisms and the extent of their activity influence the process of humification to a maximum extent, as these are the main drivers of the process. The whole complex of processes by which plant residues are transformed and finally converted into humus is the result of combined activity of associations of microbes exhibiting diverse biochemical functions. The humus reserve of the soil is determined by the rate of the two processes – the new formation and decomposition of humus substances. The interaction among various factors controlling the decomposition, and the humification rate is presented in fig 1.

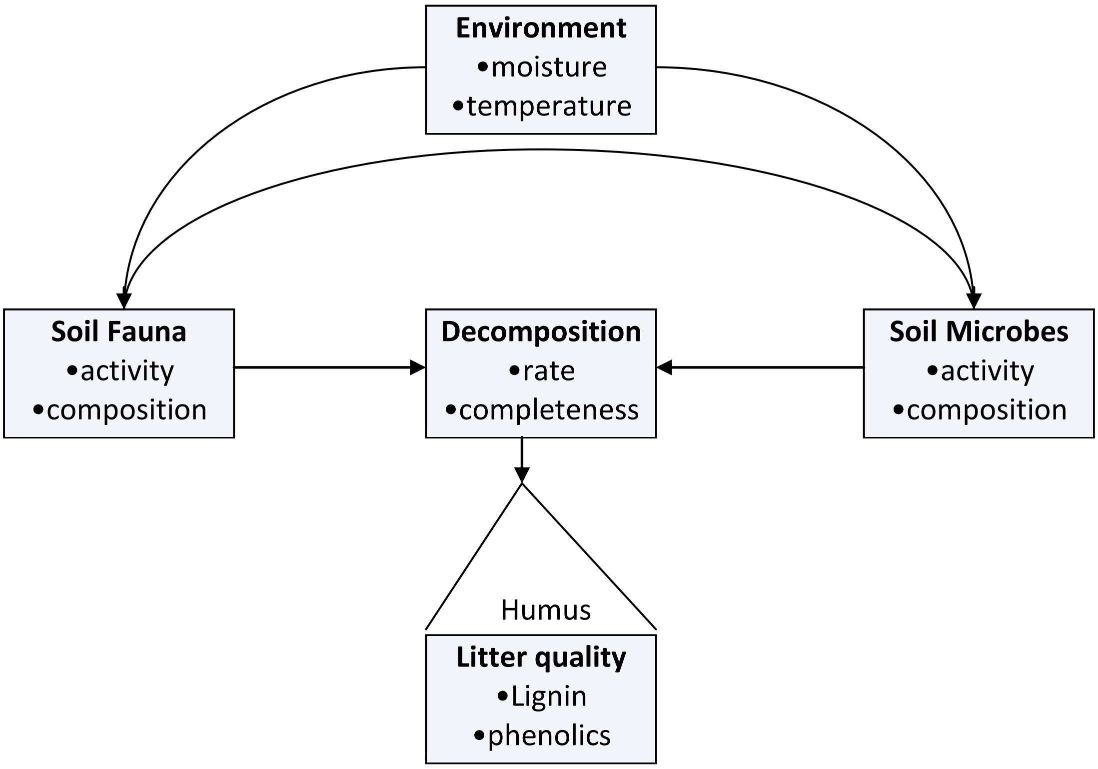

Fig 1. Interactions among climate, litter quality and soil organisms in controlling humification.

The amount of humus in different soils varies greatly depending on the factors as discussed above. It shows spatial as well as temporal variations. It is less in arid soils and very high in humid soils. Even in the same soil type, it varies through different horizons of the soil profile. In the top layer of the soil, humus quantity is greater than that in the deeper layers, as the availability of fresh or partly decayed detrital matter is higher in the top layer of the soil. In humid areas with dense forest or vegetal cover, the humus may be found in the three stages of degradation.

- The top floor is covered with dead organic parts at a low degree of decomposition that form litter.
- Below the litter may be found a layer of partially decomposed organic matter, which is known as duff layer.
- When the duff is decomposed, the simpler decomposition products generally called leaf moulds are accumulated below duff layer.

Sometimes under anaerobic conditions, the dead remains are not at all acted upon by microorganisms. Accumulation of such undecomposed organic remains is termed as peat.

ROLE OF HUMUS IN SOIL

Soil organic matter has been extensively examined because of its importance for soil fertility and productivity. Moreover, its importance for establishing favourable physical conditions and architecture in soil is well known. It contributes a lot to chemical, physical as well as biological properties of soil. Humus is known to fulfill multiple functions in soil formation and soil fertility. The humus makes the soil fertile, provides nutrients to the plants and microorganisms, increases availability of minerals in dissolved state to plants on complete decomposition and it forms several organic acids that serve as solvents for soil materials. Humus has got high capacity for retaining water, because it is porous, thus increasing the water retention capacity of soils. It acts as a cementing agent for binding the sand particles and increases the rate of nutrient uptake by plants. Optimum humus content in soil assures an agronomically valuable structure, a favourable water-air regime, and provides better progressive warming-up of soil. Most important physico-chemical soil indices such as high cation exchange capacity, acid-base buffering capacity of soils, etc are related to humus. Besides all these important roles, humus plays some limiting roles. According to Romell (1935), humus has been regarded as “the very essence of soil fertility” and also“ a necessary evil”. Humus may also be viewed as a nutrient sink that competes with trees for growth-limiting resources. Especially in the case of surface accumulations, the progressive immobilization of nutrients into humus may over time deplete the supply of available nutrients and reduce site productivity. Surface humus accumulations may also hinder seedling germination and growth. Humus can also be an energy trap because of its long residence time in the soil. In addition to agronomic as well as pedologic importance, humus is equally important ecologically. Being a part of the detritus based food chain; it plays a key role in energy as well as material circulation in the ecosystem (as detritus food chain is very important for the circulation of materials). Detritus based food chain is less dependent on direct solar energy; it depend chiefly on the influx of organic matter produced in another trophic system. Hence, availability of nutrients and energy locked up in the falling detritus to the soil depends on the rate of decomposition, and humification. As decomposition rate gets speeded up, mineralisation takes place releasing nutrients as well as energy into the soil system, which will be available for recirculation in the entire cycle.

HUMUS-NATURE AND CHARACTERISTICS

Humus is not soluble in water. It is present in soil in the form of organic colloids. The colloidal nature and other major characteristics of humus, the important soil component, are listed below:

- It is black colour distinguishing it from most other colloidal constituents in soils.
- The tiny colloidal humus particles (micelles) are composed of carbon, hydrogen and oxygen, probably in the form of modified lignin, polyuronides and polysaccharides.
- The humus colloidal particles have very high surface area generally exceeding that of silicate clays.
- The colloidal surfaces of humus are negatively charged, the sources of the charge being phenolic (-OH) or carboxylic (-COOH) groups. The extent of the negative charge is pH dependent (high at high pH).
- The cation exchange capacity of humus far exceeds that of most silicate clays at high pH values.
- Cation exchange reactions with humus are qualitatively similar to those occurring with silicate clays.
- Humus has a high water holding capacity (on a weight basis), i.e. approximately 4-5 times that of the silicate clays (humus will adsorb from a saturated atmosphere water equivalent to 80-90% of its weight).
- Humus has low plasticity and cohesion, which account for its very favourable effect on aggregate formation and stability.