Organic Manuring in Agriculture and Its Management

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There are many different types of organic matters or humus which perform different functions in the improvement of soil and ultimately the crop growth, and these are:

i) Fresh and incompletely decomposed plant and animal residues "active organic matter";
ii) Products of advanced decomposition of organic residues and products, which are re-synthesized thoroughly by microorganisms present in the soil (protein like substances, organic acid, carbohydrates, gum, waxes, fats, tannins, lignins, etc;
iii) High molecular humic substances, fulvic acids, humic acids and humin, which are relatively resistant to further biological decomposition.

Aims of organic manuring

- Organic manuring phenomenon aims to improve the biological, chemical and physical properties of the soil and is important as a source of energy and nutrient elements for the soil ecosystem.
- Organic matter influences productivity of soils through the mineralization of nutrients, its high cation exchange and water holding capacities, and its ability to improve soil physical properties. Many measurements are used to denote soil structure, including porosity, bulk density, and soil aggregation.
- The impact of the structure of a soil may be expressed in terms of the content and transmission of water, air and heat as well as soil strength.
- Some organic substances are combined with the clay fraction in aggregates so that they are not accessible to microbial decomposition.

Types of organic manures

1. Bulky Organic Manure
    - Compost
    - Farm Yard Manure (FYM)
    - Poultry manures
2. Concentrated Organic Manure
    - Oil Cakes:Richest source of plant nutrient of all organic manure.
    - Edible oil cakes 9 (i.e., used for cattle feeding)
    - Non-edible oil cakes (i.e., used as manure)

Compost

Compost is an organic manure artificially prepared from plant residues and animal waste products. The process of making compost is known as composting. It is largely a biological process in which aerobic (which require air or oxygen for their development) and anaerobic (which function in absence of air or free oxygen) micro-organisms decompose organic matter and lower the carbon-nitrogen ratio of the refuse.

Compost is prepared from waste vegetables and other refuse mixed with cow-dung and urine and also from town waste and night-soil. The compost becomes ready in about three to four months without any further attention. Composts are of two types and they differ in nature and composition. Sometimes composing materials are supplemented with little amount of fertilizers.

(i) Rural/village compost

This type of compost is prepared from farm waste products, e.g. straws, crop stubbles, crop residues such as sugarcane trash, groundnut husks and leaves, cotton stalks, etc. Weeds, waste folder, urine soaked earth, litter from cowshed and hedge clippings. This type of compost contain 0.4-0.8% Nitrogen (N), 0.3-0.65 P_2O_5 and 0.7-1.0% K_2O.

(ii) Urban compost or town compost

This type of compost is prepared from town waste and night soil. This type of compost contains 1.0-2.0% nitrogen, 1.0% P_2O_5 and 1.5 per cent K_2O.

The Composting Process

Under controlled conditions, composting is accomplished in two main stages: an active stage and a curing stage. In the active composting stage, microorganisms consume oxygen (O_2) while feeding on organic matter in manure and produce heat, carbon dioxide (CO_2) and water vapour. During this stage, most of the degradable organic matter is decomposed. It is important to maintain proper temperature, oxygen and moisture for the organisms. In the curing phase, microbial activity slows down and as the process nears completion, the material approaches ambient air temperature. Finished compost takes on many of the characteristics of humus, the organic fraction of soil. The material will have been reduced in volume by 20 to 60%, the moisture content by 40% and the weight by up to 50%. One of the key challenges in composting is to retain as much nitrogen as possible. Composting may contribute to the greenhouse effect because carbon dioxide (CO_2), methane (NH_4) and nitrous oxide (NO_2) will be emitted to the atmosphere during composting.

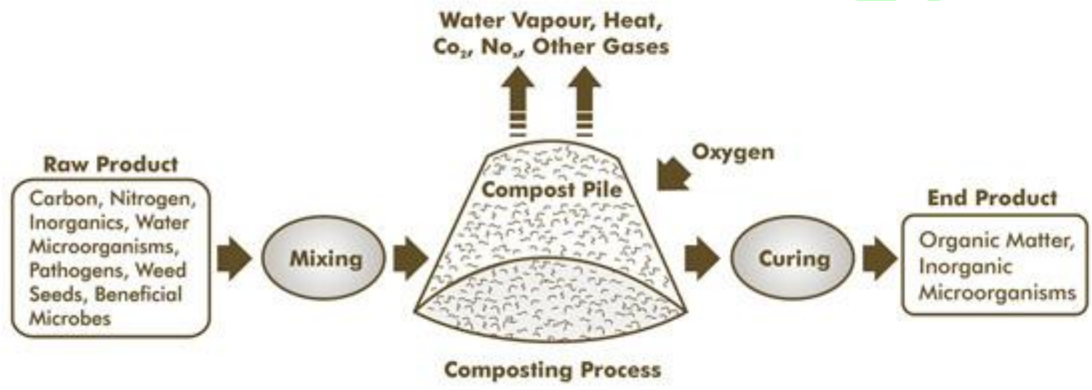

Figure: Material flow for the conventional composting process.

Factors Affecting the Composting Process

Controlling the process factors can accelerate the natural composting process. Each of these factors has the potential to significantly affect the composting process. Some of the important factors in the composting process are shown in **Table** with their acceptable ranges.

Table: Factors affecting the composting process and acceptable ranges

Factor	Acceptable Range
Temperature	54 – 60 °C
Carbon to Nitrogen ratio (C:N)	25:1 – 30:1
Aeration, percent oxygen	> 5%
Moisture Content	50 – 60%
Porosity	30 - 36
pH	6.5 – 7.5

1. Temperature

Temperature is a very good indicator of the process occurring within the composting material. The temperature usually increases rapidly to 50−60°C where it is maintained for several weeks. This is called the active composting stage. Biochemical reaction rates approximately double with each 10°C increase in temperature, yet higher temperatures will increase ammonia loss during the composting process. The temperature gradually drops to 40°C as the active composting slows down and the curing stage begins. Eventually, the temperature will become that of the surrounding air.

The highest rates of decomposition occur when temperatures are in the range of 43 - 66°C. When the temperatures can exceed 70°C, many microorganisms begin to die, which stops the active composting stage. However, the temperature should be maintained at 55°C or higher for a minimum of 14 days to destroy the viability of many pathogens and weed seeds.

2. Carbon to Nitrogen Ratio

The carbon to nitrogen ratio (C:N) of manure is a very important factor that affects the whole composting process because microbes need 20 to 25 times more carbon than nitrogen to remain active. The ratio should be between 25:1 and 30:1 at the beginning. The microorganisms digest carbon as an energy source and ingest nitrogen for protein and reproduction. If the ratio is too high (insufficient nitrogen), the decomposition slows. If the ratio is too low (too much nitrogen), it will likely be lost to the atmosphere in the form of ammonia gas. Most materials available for composting do not fit the ideal ratio so different materials must be blended.

3. Aeration

The minimum desirable oxygen concentration in the composting material is 5%. Greater than 10% is ideal to avoid anaerobic conditions. Aeration adds fresh air in the center of the composting material. Rapid aerobic decomposition can only occur in the presence of sufficient oxygen. Good aeration during composting will encourage complete decomposition of carbon (C) to carbon dioxide (CO_2) rather than releasing carbon as methane (CH_4). Too much aeration, however, can actually reduce the rate of decomposition by cooling the composting material and may cause the release of too much CO_2. Excessive air flow can remove a lot of moisture. Another consequence of excessive aeration is ammonia loss, especially with high nitrogen (low C:N ratio) mixes. As the material dries out, more ammonia volatilizes and consequently, more nitrogen is lost.

4. Moisture Content

Moisture plays an essential role in the metabolism of microorganisms and indirectly in the supply of oxygen. Microorganisms can utilize only those organic molecules that are dissolved in water. Moisture content between 50 and 60% (by weight) provides adequate moisture without limiting aeration. If the moisture content falls below 40%, bacterial activity will slow down and will cease entirely below 15%. When the moisture content exceeds 60%, nutrients are leached, porosity is reduced, odours are produced (due to anaerobic conditions) and decomposition slows.

5. Porosity

Porosity refers to the spaces between particles in the compost material. These spaces are partially filled with air that can supply oxygen to the organisms and provide a path for air circulation. As the material becomes water saturated, the space available for air decreases, thus slowing the composting process. Compacting the composting material reduces the porosity. Adding coarse materials such as straw or woodchips can increase the overall porosity, although some coarse materials will be slow to decompose.

6. pH of Materials

The optimum pH for microorganisms involved in composting lies between 6.5 and 7.5. The pH of most animal manures is approximately 6.8 to 7.4. Composting alone leads to major changes in materials and their pH as decomposition occurs. For example, release of organic acids may, temporarily, lower the pH (increase acidity), and production of ammonia from nitrogenous compounds may raise the pH (increase alkalinity) during early stages of composting.

Farm Yard Manure (FYM)

The main types of livestock wastes which are found in farms are farmyard manure, either fresh or stockpiled, slurry, liquid manures (urine). Farmyard manure consists of three main groups of components; bedding or litter, solid of the animals and liquid urine. Urine is high in nitrogen and minerals. Solid excrete contains considerable amounts of proteins, and thus tend to give a more balanced medium for the growth of microorganisms. The chemical composition of FYM is nitrogen: 0.5%, P_2O_5: 0.2 %, K_2O: 0.5 %.

Poultry Manure

The excreta of birds ferment very quickly. If left exposed, 50 percent of its nitrogen is lost within 30 days. Poultry manure contains higher nitrogen and phosphorus compared to other bulky organic manures. The average nutrient content is around 3% N; 2.5% P_2O_5 and 1.5% K_2O.

Oil Cakes

Oil cakes are the by-products of oil seeds crops. Oil cakes are the important and quick acting organic nitrogenous manure. It also contain small amount of phosphorous and potassium.

(i) Edible Oil Cakes

This type of oil cake is used for feeding cattle in the form of concentrations, e.g. mustard oil cakes, groundnut cake, sesame or til cake, linseed cake, coconut cake, etc.

(ii) Non-edible oil cakes

This type of oil cake is not suitable for feeding to cattle and mainly used for manuring crops, e.g., castor cake, neem cake, etc. The non-edible oil cakes contain a harmful toxic substance, which make them unsuitable for feeding to cattle. But these are a good source of nitrogenous manure. The amount of nitrogen varies with the type of oil cake. It ranges from 2.5 to 7.9%. In addition to nitrogen, all oil cakes contain small quantities of phosphoric acid (0.8 to 2.9%) and potash (1.1 to 2.2%). Oil cakes are insoluble in water. But their nitrogen becomes quickly available in about a week or ten days after application to crops.

Green Manure

Green manures comprise plant crops grown on a given soil to a certain stage of development before being ploughed under, while still green. Both leguminous and non-leguminous plants are utilized for this purpose. Leguminous crops are cultivated widely in a variety of agro- climatic zones in the tropics and subtropics.

Green manures serve several distinct purposes for plant growth and soil improvement. They increased the supply of total and available nitrogen in the soil and various leguminous plants are utilized for this purpose. Green manures prevent the nutrient elements of the soil, especially the nitrates from being leached out during the season of the year when no cultivated crops are being grown in the soil. They also increase the supply of organic matter in the soil and protect it against possible erosion.

Green manuring crops should be quick growing and contains high amount of biomass. The plants used for green manuring are also high in water-soluble constituents, in nitrogen and other nutrient elements, but are comparatively low in cellulose and lignin. As a result, decomposition of a green manure ploughed into the soil and reaction sets in very rapidly. This is accompanied by rapid liberation of the nitrogen and other nutrient elements in available forms. Green manuring crops should be incorporated as soon as flowering. As the plants grow older, their ash and nitrogen contents decrease and their cellulose and lignin contents increase. Young plants, low in lignin and cellulose, but high in water-soluble minerals and nitrogen decompose much more rapidly than do mature plants. The age of the plants used for green manuring exerts an important influence upon the amount and the rate of liberation of nutrient elements in available forms.

The main benefits of green manuring are:

i) Maintaining carbon and nitrogen accumulation;
ii) Reduction of nutrient elements leaching;

iii) Reduction of soil erosion;
iv) improving water utilization;
v) Providing aeration of the soil;
vi) Weed and pest control;
vii) Providing cost savings in the crop rotation as a result of lowering fertilizer use, improving nutrient elements utilization, easier cultivation and reducing plant protection requirements.

Sewage Sludge

Sewage sludge and other municipal and agricultural wastes hold promise of benefiting soil organic matter and contains N and P, but little potash, must of which and some of the N are lost in the liquid during separation. The organic matter obtained through such process can make useful contribution to soil improvement. If sewage sludge is used in bio-fortified farming, then it must be applied with extreme caution. Large quantities of these materials have traditionally been incinerated or deposited in landfills.

The composition of waste materials must be determined before land application, though to avoid potentially hazardous high levels of trace metals and toxic compounds.

Forms of available nitrogen in manures

About half of the nitrogen in manure is in the form of ammonium and about half is in the form of organic material. Microbes that consume the organic compounds excrete ammonium. One of the four things will happen to the ammonium - regardless of whether it comes directly from the manure or from microbes consuming the organic compounds. The ammonium may either be used by plants immediately, converted to ammonia and lost to the air (as volatilization) or converted to nitrate which will be used by plants or microbes. The "immobilized" nutrients become available to plants when the microbes are consumed by other organisms that release ammonium as a waste product. Some of the nitrates are lost through denitrification or leaching.

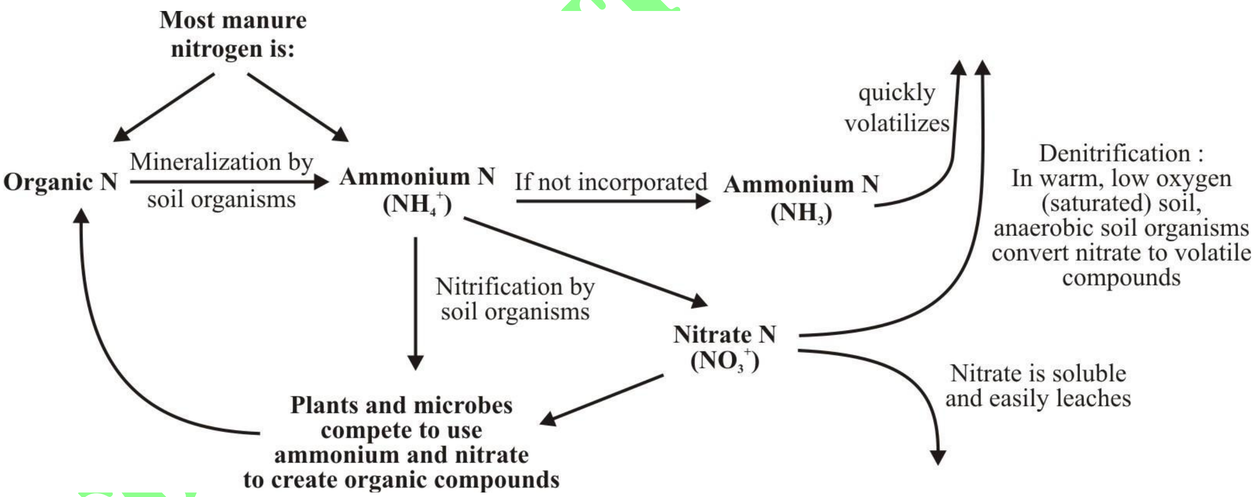

Figure: Forms of available nitrogen in manure

Vermicompost

Earthworms in History

- Aristotle described them as the “intestines of the earth”
- Cleopatra declared earthworms sacred and established laws to protect them
- Charles Darwin demonstrated they improved soil and plant productivity

Vermicompost is the product or process of composting using various worms, usually red wigglers, white worms, and other earthworms to create a heterogeneous mixture of decomposing vegetable or food waste, bedding materials, and vermicast. Vermicast, also called worm castings, worm humus or worm manure, is the end-product of the breakdown of organic matter by an earthworm. These castings have been shown to contain reduced levels of contaminants and a higher saturation of nutrients than do organic materials before vermicomposting.

Containing water-soluble nutrients, vermicompost is an excellent, nutrient-rich organic fertilizer and soil conditioner. This process of producing vermicompost is called vermicomposting.
Vermicomposting food waste offers several advantages:

- It reduces household garbage disposal costs;
- It produces less odor and attracts fewer pests than putting food wastes into a garbage container;
- It saves the water and electricity that kitchen sink garbage disposal units consume;
- It produces a free, high-quality soil amendment (compost);
- It requires little space, labor, or maintenance;
- It spawns free worms for fishing.

Effects of organic manures in crop, soil and environment

Effects on crops

Manure is applied to agricultural land chiefly because of its fertilizing value. Animal manure supplies all major nutrients (N, P, K, Ca, Mg, S,) necessary for plant growth, as well as micronutrients (trace elements), hence it acts as a mixed fertilizer. Manure application in a given year will influence not only crops grown that year, but also crops in subsequent years, because decomposition of the organic matter is not completed within one year. Therefore, the application of manure, thus, saves mineral fertilizers for various nutrients. This illustrates that nutrients from animal manure can be substituted for mineral fertilizers and which is far better for the environment.

A disadvantageous aspect of the uptake of components from manure by the crop is over-dosage, which can lead to the absorption by plants of non-degradable components such as heavy metals (Cu, Zn) and organo-chlorines. These components can accumulate in the food chain and become a health hazard.

Effects on soil quality

On the other hand, manuring almost always has a positive influence on the build up of soil organic matter and thus improves the "intrinsic" fertility of the soil, as well as the soil structure. Negative impacts, that could be defined as soil pollution, have to do with the addition of heavy metals, organo-chlorines and too many salts. Also, weed seeds could be spread through manuring the land.

After application of manure, decomposition by microorganisms of the organic material will start into carbon dioxide (CO_2), water (H_2O) and minerals of plant nutrients such as N, P, S and metals. The transformation of organically bound elements into plant available nutrients during microbiological decomposition is called mineralization. Humus contributes to soil fertility by retaining plant nutrients through adsorption. In addition, humus increases the water holding capacity and the cation exchange capacity (CEC) of any type of soil.

Effects on ground water and surface water quality

The main dangers of the application of manure are runoff of manure or manure components into surface water and leaching of nitrate (NO_3) and P into the ground water. Mineral N in manure is largely present as NH_3. If, upon application of the manure, it does not volatilize, it will be quickly nitrified, i.e. transformed through microbial action into NO_3. As NO_3 is an anion that is not adsorbed by clay minerals or soil organic matter, it is easily leached in case of a precipitation surplus. If ground water concentrations of NO_3 become too high, it is unsuitable for drinking water. Under certain conditions this may lead to excessive growth of algae, causing oxygen shortage and consequently the death of fish. Phosphorus, however, is not nearly as mobile in the soil as NO_3 and therefore much less susceptible to leaching. Nevertheless, leaching of P can occur under certain conditions (sandy soils). If P flows into the ground water and subsequently into surface water, the same problems as described above for NO_3 will occur. For example, P causes eutrophication in freshwater bodies.

Effects on air quality

Two processes involving N and one involving carbon (C) from manuring have an important effect on air quality. First, surface application of manure, particularly liquid manure, may cause substantial losses of NH_3 by volatilization which may lead a major contributor to acid deposition. Acidification may lead to mobilization of Al^{3+}, which are very toxic to fish, disturbs the nutrient uptake of plants and trees, and enhances sensitivity to stress factors. Second, denitrification of NO_3 by microorganisms is possible under anaerobic conditions when N_2 is formed, but giving off a by-product N_2O, a gas that affects the ozone layer. Animal excreta and arable land may be important sources of N_2O globally.

A third important air pollutant is methane (CH_4), formed upon decomposition of manure under anaerobic conditions. If stored manure is disturbed, CH_4 will escape into the atmosphere and eventually, like N_2O, affect the ozone layer. In addition to CH_4 formation in manure storage, the use of manure in flooded rice production (anaerobic conditions) and CH_4 formation in the rumen of ruminants are important sources of CH_4 emission. Methane and its consequences are discussed in detail in one of the other reports.

Odour has a negative effect on the air quality, affecting animals and people in closed stables as well as people near farms producing or applying manure. Especially in combination with dust odour may cause serious health problems.

Parameters influencing effects of manure on the environment

1. Climate

The most important climatic characteristics affecting processes such as emission, leaching and decomposition of organic material are temperature, precipitation and evapotranspiration. Temperature strongly influences all microbiological processes. Higher temperatures, therefore, lead to higher rates of nitrification, denitrification and decomposition of organic material, but also to faster crop growth and the associated uptake of nutrients from manure.

The extent of nutrients leaching to the ground water is largely determined by the balance of precipitation and evapotranspiration. Potential evapotranspiration (PET) also strongly influences the rate of NH_3 volatilization; high PET leading to high rates of volatilization.

2. Soil

Of the soil characteristics, only texture and pH will be discussed. The water and nutrient holding capacity of clay soils is higher than that of sandy and silty soils, therefore leaching of NO_3, P, other nutrients and organo-chlorines is dependent on soil texture. Conversely the risk of accumulation of harmful components in the root zone following repeated application of large doses of manure is higher in heavier textured soils than in light soils. Clay soils become more easily waterlogged after heavy rainfall because of a lower hydraulic conductivity, i.e. the possible rate of water transport through the soil. Under waterlogged conditions, denitrification can occur and harmful N_2O may be formed. Under extreme acid or alkaline conditions ($pH<4$ or >9), the structure is destroyed and leaching of many organic and inorganic components becomes inevitable. Volatilization of NH_3 from soils with higher pH values is greater than from those with lower pH values.

3. Hydrological conditions

The hydrological conditions strongly influence the leaching process. Pollutant containing topsoil can come into contact with deep aquifers via old ground water wells. The flow from ground water to surface water is usually direct in areas with a shallow ground water level. In this way, leached nutrients/pollutants can flow rapidly from the soil via the ground water to the surface water and cause eutrophication and toxicity problems.