Rejuvenating Soil Health with Manures and Composts

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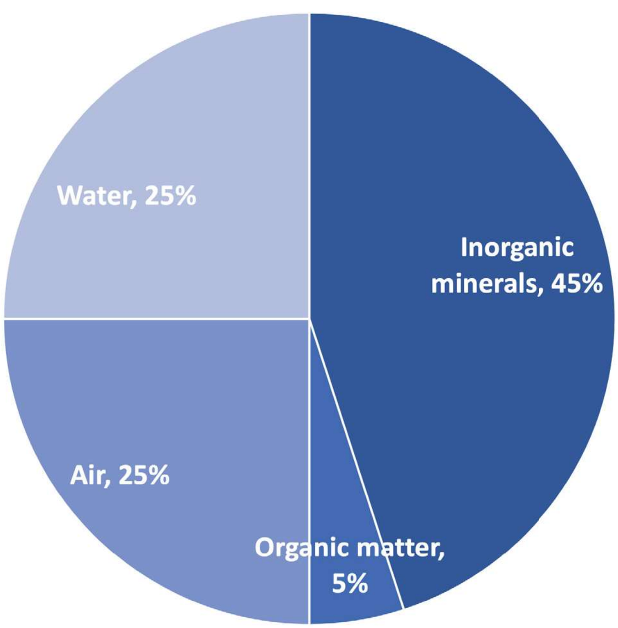
INTRODUCTION

Sustainable farming depends on healthy soils. Soil health depends on its organic soil content. Application of manures and composts leads to improvement in soil organic matter, so the structure is improved. Manures and composts provide nutrients and improve the soil biological, physical and chemical properties. Soil structure is important for microorganisms to survive and multiply. Soils that are rich with a structured food web of microorganisms such as amoebae, fungi, algae, bacteria, protozoans and other organisms such as micro-arthropods, insects, nematodes, earthworms, vertebrates add life to soils and make them healthy with decomposed organic matter. Soils rich with decomposed organic matter are fertile and contribute to better soil health and plant health.

A healthy soil is expected to contain about 25% air, 25% water, 45% minerals and 5% organic matter. Soils that have higher levels of organic matter have better aeration to allow better infiltration of rainwater and a higher water holding capacity. Manures and composts provide the complete set of nutrients that plants need. They provide nutrients for a longer period. Organic matter also checks soil erosion, The biggest advantage of manures and composts is that they can be prepared easily and are eco-friendly.

Figure-1. Composition of healthy soils.



TYPES OF MANURES

There are different kinds of manures and composts that can be prepared in the farm and applied to the soil to increase its organic carbon content and fertility.

There are two main categories of manures.

1. **Bulky manures:** The first category is called bulky manure, because these manures have a large organic biomass with less macro nutrients such as nitrogen (N), phosphorus (P) and potassium (K). Examples of bulky manures are farmyard manure, compost, vermi-compost and green manure.
2. **Concentrated manures:** The second category is called 'concentrated manures' because these manures have higher quantities of macro nutrients compared to bulky manures. Examples of concentrated manures are seed-oil cakes and animal-based manures such as blood-meal, fish-manure and bonemeal.

Bulky organic manures improve soil structure. They provide carbon to earthworms, soil insects and microorganisms to build carbon reserves and soil health. Bulk manures are mostly prepared by using cattle dung or chicken dung. Farmyard manure and rural compost have very low quantities of macronutrients such as N, P and K. For example, one tonne of farmyard manure, rural compost, buffalo dung and urban compost provide only 5 to 10 kg of nitrogen, 2 to 8 Kg of phosphorus and 5 to 15 Kg of potassium. Vermi-compost has higher levels of nutrients at 12 Kg nitrogen, 13 Kg phosphorus and 10 Kg potassium per tonne. Chicken manures have higher quantities of nutrients. One tonne of chicken manure provides more than 32 kg of nitrogen, 33 Kg of phosphorus and about 24 Kg potassium.

Table-1. Nutrient content (Kg) in one tonne of bulk manure

Type of Manure	Nitrogen (N) Kg	Phosphorus (P_2O_5) Kg	Potash (K_2O) Kg
Farmyard manure	5	3	5
Compost (rural)	5	2	5
Buffalo dung	10	8	7
Compost (urban)	10	5	15
Vermicompost	12	13	10
Swine dung	21	24	10
Cattle dung	24	7	9
Chicken - broilers dung	32	33	24

Table-2. Nutrient content (Kg) in one tonne of seed-cake manure

Type of Manure	Nitrogen (N) Kg	Phosphorus (P_2O_5) Kg	Potash (K_2O) Kg
Mahua cake	25	8	12
Karanj cake	39	9	12
Castor cake	43	18	13
Linseed cake	49	14	13
Rape seed cake	52	18	12
Sesamum cake	62	20	12
Cotton seed cake	64	29	22
Groundnut cake	73	15	13
Safflower cake	79	22	19

Table-3. Nutrient content (Kg) in one tonne of concentrated manure

Type of Manure	Nitrogen (N) Kg	Phosphorus (P_2O_5) Kg	Potash (K_2O) Kg
Steamed bone meal	20	300	-
Raw bone meal	40	250	-
Fish meal	80	70	20
Meat meal	105	25	5
Blood meal	120	20	10
Horn and Hoof meal	130	-	-

Farmyard manure

Farmyard manure is a bulk manure that is obtained from decomposed mixture of dung and urine of farm animals obtained from cattle sheds. Farmyard manure also contains residues of leftover fodder, litter or roughages. It contains low quantities of macro nutrients such as nitrogen phosphorus and potassium but is rich in organic matter that helps to improve soil structure and microbial life.

Figure-2. Farmyard manure

Green manure

Crops such as alfalfa, sesbania, hairy vetch, beans, mustard, etc. are used as green manure crops. One tonne of the green manure biomass provides about 20-30 Kg nitrogen, 5-10Kg phosphorus, 10-40 Kg potassium and other micronutrients.

Figure-3. Sunn hemp green manure

Oil-seed cakes

Seed cakes are a good source of organic matter and macronutrients (NPK). Seed cakes are obtained after extracting oil from seeds. In most cases edible seed cakes are fed to animals. The non-edible seed cakes can be converted to manures. One tonne of seed cake contains 25 to 79 Kg nitrogen, 8 to 29 Kg phosphorus and 12 to 22 Kg potassium. Cotton seed cake is rich in all the three major nutrients (NPK). It provides about 64 Kg nitrogen, 29 Kg phosphorus and 22 Kg potassium.

Figure-4. Seed cake manure

Animal manures

Animal based manures are prepared from dried meat or decomposed horns and animal blood. Animal based manures are generally rich in phosphorus. While meat-meal, horn-meal and hoof-meal have higher levels of nitrogen, bone-meals are an excellent source of phosphorus. Horn and hoof-meals have higher levels of nitrogen and bonemeal provide very high quantities of phosphorus at about 250 Kg apart from providing 40 Kg nitrogen per tonne.

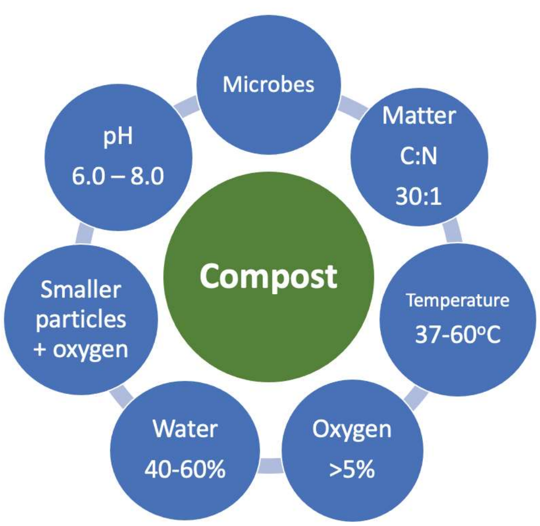
Figure-5. Bone-meal manure

COMPOSTING

Principles of composting

Organic matter contains nutrients. But it must be decomposed by microorganisms first so that the nutrients are available to plants easily. Composting is a process wherein organic matter is degraded by soil microorganism to produce compost that can be used to improve soil health.

Figure-6. Principles of composting

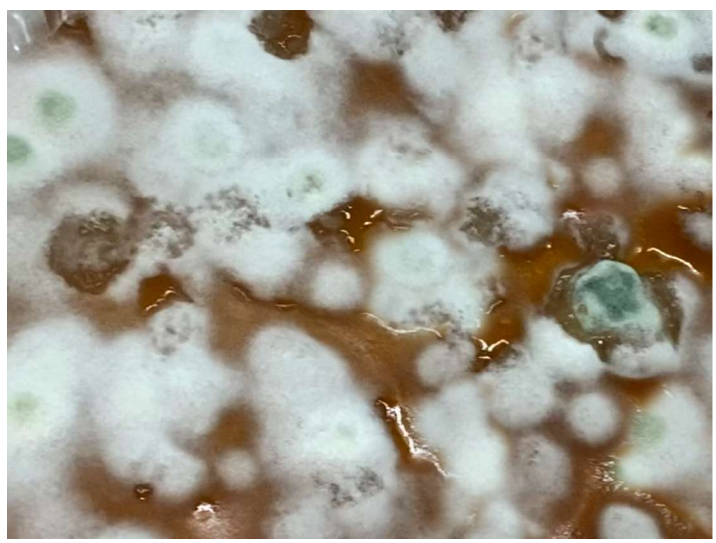


Soil microorganisms such as bacteria, actinomycetes and fungi, feed and decompose organic matter. These microorganisms need oxygen, water, air, warmth, carbon, nitrogen and other minerals for their survival. The efficiency of composting depends on the population and composition of different types of microorganisms, the carbon to nitrogen ration in the feedstock material, oxygen levels, moisture levels, temperature, the physical structure of the material and pH. Microorganisms degrade organic matter to produce compost that contains dark brown humus-like material which is an excellent soil conditioner.

Decomposers

Organic matter is degraded by billions of microorganisms present in the soil. These microorganisms are mainly fungus, actinomycetes and bacteria. Fungus feeds on tough dry organic waste that could be acidic and not usable as feed by bacteria. Actinomycetes bacteria degrade complex organic material that contains chitin, cellulose, lignin and proteins. Finally, bacteria play a major role by decomposing simpler forms of organic material. Thus, these three groups of microorganisms feed on plant and animal debris to convert the organic matter into compost. In this process of preparing compost, the microorganisms utilize oxygen and organic matter to release heat, carbon dioxide and water vapor.

Figure-7. Decomposers: Soil microorganisms



Nutrients: Carbon to Nitrogen Ratio

For efficient composting, the preferred ratio of carbon:nitrogen (C:N) should be about 30:1 within a range of 25:1 to 35:1 in the organic matter compost-feedstock. Though different microorganisms have different C:N ratios in their bodies, the average C:N ratio is considered to be 8:1 for the general pool of microorganisms, wherein carbon content could be eight times higher than the content of nitrogen. For rapid decomposition of organic matter into compost, the feedstock material must contain carbon and nitrogen in appropriate ratios to help microorganisms survive and multiply. From 30 units of carbon in the feedstock, microorganisms use 24 units of carbon of which

16 units are used as the source of energy, 8 units of carbon to be assimilated into their body biomass and the remaining 6 units of carbon being left in organic matter residues. The 16 units of carbon used for metabolism get converted to carbon dioxide. From the C:N ratio at 30:1 in the feedstock, microorganisms use the one unit of nitrogen for the synthesis of essential molecules such as DNA and protein. If the organic matter has more carbon and less nitrogen for example of C:N ratio at 60:1, decomposition will be very slow because microorganisms will excess carbon but an inadequate proportion of nitrogen for protein synthesis. The resultant compost will also be deficient in nitrogen because all of the nitrogen in the feedstock will be rapidly depleted. On the contrary, if the organic matter has a C:N ratio at 20:1, decomposition will be fast because microorganisms will use the excess nitrogen for DNA and protein synthesis but will rapidly exhaust oxygen to create anaerobic conditions. The excess nitrogen is also converted to nitrate and ammonia and creates compost with odour and consequently deficient nitrogen. In general, dry hay such as wheat straw contains more carbon to nitrogen and wet grass, or green leaf biomass contains less carbon to nitrogen. The time of composting can be as slow as 2 to 3 years if the organic material contains high levels of carbon to nitrogen. Composting will be efficient and faster within 6 months, if different organic materials are mixed to get the desired ratio of 30 carbon is to 1 nitrogen.

Oxygen

Composting is an aerobic process. The microorganisms that prepare compost are aerobic and need oxygen to survive. Therefore, adequate amounts of oxygen generally more than 6 per cent with a desired range of 16% to 18% are critical for efficient composting. When the oxygen levels fall below 6%, the aerobic microorganisms die to be rapidly replaced by other anaerobic microorganisms. The anaerobic microorganisms do not need oxygen to survive but are very slow and inefficient in composting. They produce gases such as methane, ammonia and hydrogen sulphide which have an unpleasant odour. Proper oxygen levels at more than 6% result in efficient composting and prevent odours and unpleasant smell.

Moisture

For efficient and rapid composting, the moisture level in the total organic material must be at 40% to 65% per cent of the total weight. Microorganisms use water to create a suitable living environment and to dissolve nutrients and consume them to grow and multiply. Moisture levels in excess of 65% restrict the flow of oxygen to create anaerobic conditions. This slows down the rate of composting. If the moisture levels go below 40% per cent, bacterial populations decline because their nutrient solubility becomes restricted.

Temperature

Temperature is a good indicator of the rate of degradation of organic matter in a compost pile. Therefore, regular monitoring helps to understand the rate and efficiency of composting. The optimum temperature for composting is 50°C to 60°C. Microorganisms generate heat in the composting material when they degrade organic matter. The organic pile insulates temperatures and heat is maintained within the heap. Consistent temperatures of 56°C to 58°C maintained for 2 to 3 days destroy plant disease causing pathogens and weed seeds. At temperatures above 42°C, heat loving microorganisms dominate and increase the rate of composting. However, when the temperature exceeds 60°C, the rate of composting slows down. Temperatures move away from the optimum range if oxygen levels drop below 6% or when moisture levels are less than 40% or above 60%.

Physical structure

Microorganisms prefer smaller organic material for degradation. Therefore, composting is faster with finely chopped organic matter. Accelerated composting in the shredded material leads to higher demand for oxygen and a greater need for air. However, smaller sized particles lead to compaction of the material which results in deficiency of oxygen. Care must be ensured to provide proper aeration in shredded organic material used as feedstock for composting.

pH

Microbial degradation of organic matter is most efficient between a pH of 6.5 and 8.0. If the pH drops below 6.0 towards acidity, most microorganisms die, and the process of composting becomes slow. If the pH increases above 8.0 towards alkalinity, nitrogen in the organic matter gets converted to ammonia and is lost. Low nitrogen levels lead to slow rate of composting. Generally, at the initial stage of decomposition the compost becomes slightly acidic but reaches a neutral pH at final stabilization stage.

METHODS OF COMPOSTING

Farmers across the world prepare manures and composts using different methods. It is interesting that most farmers prepare excellent manures and composts without knowing a few basic principles that help in faster and efficient composting.

Heap method

The most common method is called heap composting. In this method, different organic materials are laid out over each other to prepare a heap that is finally covered with a mixture of soil and cattle dung. The main ingredients of heap composting are green matter that is mostly grasses or green leaves, dry matter that can be obtained from hay of crops, cattle dung, water and soil. Apart from these main ingredients, farmers also use small quantities of lime to prevent acidity that builds up initially during composting. Gypsum is also added to prevent nitrogen losses. Gypsum converts ammonium carbonate into ammonium sulfate and calcium carbonate to reduce nitrogen losses. Ammonium carbonate is easily lost as ammonia compared to ammonium sulfate. Small quantities of compost are also added to serve as an initial source of inoculum of microorganisms.

Figure-8. Heap method

The most common size of a heap is 5 meters in length, 2 metres in width and about 1.5 metres in height. Different types of materials such as green matter and brown dry matter are spread and layered over one another alternately. Each layer is generally covered with a layer of soil containing dung and small quantities of lime, gypsum and compost. The layers are watered to provide moisture. Dry material is spread first followed by pouring of dung water and spreading of soil over the dry matter. Green matter is layered over the layer of dry matter. subsequently, soil plus dung plus gypsum is spread over the green matter. Some farmers also add rock phosphate to this layer. Generally, there are several layers of dry and wet material sandwiched with soil and dung till the heap reaches a height of about 1.5 metres above the soil. In the fifth step fine soil plus compost is layered on the top. The final layer is a paste of dung plus soil. The heap is left for a few months to a year before applied on the farm.

Pit method

The pit method of manure preparation or composting is also followed commonly across the world. This method is also like the heap method, but the layers are built one over the other first inside the pit. The pit can be of any size, but the general dimensions are three metres length, 2 metres breadth and 1 metre depth. The height of the heap layered in the pit reaches about half metre above ground. It is very common that the height of the heap gets lowered down as the composting progresses.

Open brick method

The open brick method is built as a tub of bricks with open spaces in between brick for aeration. The dimensions of the brick tub are generally 4 metres in length, 3 metres in breadth and 1 metre in height. This method provides aeration for efficient composting, without having the need to turn the composting material at regular intervals, generally every fortnight as is commonly done with the pit method or heap method of composting. The method of layering of different materials is almost the same as in any composting method. The bottom-most layer has farm waste up to 15cm thick. This layer is covered with dung water and a fine layer of soil. The process is repeated with alternate layers of farm waste, dung water and soil until the heap reaches a dome shape. Composting takes about four to ten months. Each tub can produce about 2.5 tonnes of compost.

VERMICOMPOST

Vermicomposting is prepared by using earthworms for faster and efficient conversion of organic matter into compost. Vermicompost is a good organic fertilizer that is rich in water soluble nutrients. It also serves as a good soil conditioner. Vermicompost promotes plant growth because it also contains plant growth promoting hormones secreted by soil microorganisms and earthworms. Structures of cement or plastic are made to prevent earthworms from escaping or burrowing into soil. The structures are about 5 metres in length or longer, one metre in breadth and 0.6 metres in depth. Two species of earthworms, namely *Esinia foetida* and *Udrilus uginii* are use very commonly for vermicomposting.

Figure-9. Earthworms

There are about five main stages in the production of vermicompost. The first step is the collection of biodegradable waste. The second step is mixing of the dung and organic waste in an equal ratio by weight. The third step is preparation of earthworm bed with the waste and dung mixture. The fourth step is generally at 60 to 70 days when vermicompost is collected and sieved. The final step is storage of vermicompost in conditions that ensures proper moisture to encourage microbial growth.

Figure-10. Vermicomposting unit

Vermicompost bed is prepared by using organic materials of dry straw (sorghum, wheat, maize etc.) layered as a 4 inches bed at the bottom of the bed, covered by a 4 inches farmyard manure. The second later comprises of 10 to 12 inches of farm waste, which is again covered by a 6 inches layer of farmyard manure. Earthworms are released over the top layer at about 1 kg worms per square metre. The layers are repeated until the heap covers the full depth of the structure. The bed is watered daily to keep it wet. Earthworms are most efficient when the organic matter is wet, but not too wet above 60% moisture. After 60 to 70 days, watering must be stopped for 3 to 4 days so that the upper part of the bed becomes dry, and earthworms will move down to the lower wet layers of the bed.

Vermicompost is harvested from the upper 3 to 4 inches of the bed and sieved to get finer particles and return any recovered worms back to the bed. Generally, a 2.0mm to 3.0mm sieve is used to get finer particles of compost. The sieved vermicompost is stored under shade and maintained to contain 15-20% moisture. First harvesting of compost is possible 25-30 days or more, after releasing the worms, depending on the management. Subsequently vermicompost is harvested at weekly intervals by withdrawing water for 3-4 days and scraping vermicompost from the top 3 to 4 inches of the bed. The duration for one cycle is 70-80 days.

VERMI-WASH

Vermi-wash is a liquid form of compost produced in a drum containing earthworms, cattle dung, organic matter and sand. Materials that are used in vermicomposting beds are the same materials that are used to prepare a vermi-wash drum. The materials are farm waste, farmyard manure, earthworms, water, small stones and coconut coir or dry hay.

Figure-11. Ms. Madhuri describing a vermiwash unit

The vermi-wash tub is first layered with small stones up to 4 inches. The second layer has 2 inches of coconut coir of 4 inches of dry hay. The tub is them filled with farmyard manure, a mixture of farm waste mixture. The drum is watered daily for 4 to 5 days, and earthworms are released. The drum is watered regularly to keep the contents wet. A vermi-wash unit can be prepared in plastic drum or earthern pots of various sizes ranging from 10 to 100 litres. The drum has a tap at the bottom to facilitate collection of the vermi-wash liquid. Excess water is provided after 20 to 30 days and vermi-wash liquid is collected through the tap at weekly intervals. The vermi-wash liquid is diluted 10 times with water and sprayed over plants. The spray fluid is rich in microorganisms and has soluble nutrients and hormones that promote plant growth. The vermi-wash liquid has a near neutral pH. It contains less quantities of nutrients and carbon, but is rich in soil microorganisms such as Nitrosomonas, Nitrobacter and fungi that can be used to inoculate farm soils or composting units.

Composts and manures are important sources of nutrients for plants and organic matter for soils. Composts when prepared properly can serve as an inoculum of microorganisms to rejuvenate soil health on a long-term basis. The principles of regenerative agriculture include increasing organic matter in soils and maintaining live root systems of diverse crops to ensure microorganism diversity in soils. Composts not only inoculate soils with a diverse range of microorganisms, but they also provide good amount or organic matter for microorganisms to multiply and survive in soils to build soil health for good crop health and high yields.

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