



Rural Composting for Improvement of Soil Health and Sustainable Agriculture

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Abstract

Rural composting means a biochemical process in which diverse and mixed groups of micro-organisms breakdown organic materials to a humus-like substance which is similar in properties to farmyard manure. Rural compost has a lower bulk volume than the original raw organic material, is stable in nature, has a slow decomposition rate and can be returned to the soil without destruction of its high energy value. The process of composting poses neither hazard to human health nor to the environment, it is therefore, a desirable method of recycling rural organic residues. In other words, composting is the process by which organic materials are transformed into soil building substances for the farm, orchard or garden.

Keywords: Soil; Sustainable agriculture; Composting

Main Objectives of Rural Composting

The broad objectives of rural composting are conserving and recycling farm residue resources, safeguarding rural public health and maintaining or improving the quality of the environment, all at a low cost and involving microbiological processes. There are several reasons for using compost but its main contribution is as a supplier of humus substances to soil, thus supplementing major plant nutrients (NPK) and being a good source for providing micronutrients whose deficiencies are showing up with intensive cropping and high productivity targets Sidhu et al. [1]. An appropriate rural compost technology will make the recycling of farm wastes feasible and will minimize the pollution of water and land resources. The farmer has to recognize the need to maintain the marginal organic content of his soil by following a mixed agriculture system leading to resources moving from soil to crops, from crops to animals or back to soil and finally from animals to land Sidhu & Beri [2].

Principles of composting and affecting factors

Organic materials: Rural compost is prepared from organic residues such as crop residues (straw, leaves, rice husk, groundnut shell, sugarcane trash and bagasse), water hyacinth and other weeds, cattle dung, cattle urine and other animal

wastes, the organic substance undergo intensive decomposition under thermophilic and mesophilic conditions in heaps or pits with adequate moisture and finally yield a dark colored humified material in three to six months which is more stable in form, valuable for replenishment of plant nutrients, maintenance of soil organic matter and in improving and maintenance of soil fertility. Alexander M [3].

Factors affecting composting and their control

The most important factors in the composting of rural residues are carbon-nitrogen ratios, shredding of material, blending of material, moisture, aeration, temperature, reaction, microorganisms involved, use of inoculants, amendments and destruction of pathogenic organisms.

Carbon/Nitrogen ratio: The carbon-nitrogen ratio of the organic materials is the most important factor in composting. The transformation of rural organic residues into manure is predominantly a microbiological process and so is influenced by the proportions of carbonaceous and nitrogenous materials present in the residues to be composted. Microorganisms need carbon for growth and nitrogen for protein synthesis. A C/N ratio of 30 to 40 is optimal for efficient composting and ratios between 25 and 40 have been found satisfactory. If the organic material

is poor in Nitrogen i.e. if C/N ratio is wide, biological activity decreases and several successions or cycles of microbial activities would be required to accomplish degradation of the carbonaceous material. Immobilized nitrogen is recycled on the death of some of the organisms and the limited nitrogen is thus recycled for reducing the carbon content of the residues. The completion of the process is therefore delayed and finished compost takes longer to produce. Chanyasak & Kubota [4]. High C/N ratios are generally caused by organic materials poor in nitrogen such as straw of cereals, sugarcane trash, maize stalks, cotton stalks, jute stems and sawdust. Rural residues have been found to vary widely in C/N ratio-from 30 to 300. As the available nitrogen is exhausted, under favorable C/N conditions the activity of nitrogen-fixing organisms predominates and there is a gain of nitrogen from the atmosphere. With a C/N ratio of raw materials less than 30:1, the proportion of nitrogen is in excess of the requirements of the microorganisms. In such cases although the process of decomposition goes on, the unassailable nitrogen is lost by volatilization as ammonia or by denitrification. At low C/N ratio, ammonia is formed under favorable conditions and can be further oxidized to nitrite and nitrate but low C/N ratio under unfavorable conditions causes loss of ammonia.

About 20 to 40% of nitrogen may be lost as ammonia during preparation of compost from animal dung and water hyacinth. This implies that a thorough mixing of these fractions with the carbonaceous material of residues cannot be attained in practice and there are always pockets of concentration of nitrogenous material which causes an imbalance in the decomposition process with loss of nitrogen. It has been seen that simple nitrogenous compounds are more susceptible to loss and control of this loss with a greater retention of nitrogen in the final compost is of practical value in obtaining better quality compost. Beri et al. [5]. The time of composting high C/N residues can be reduced by adding a nitrogen source or by blending with organic residues richer in nitrogen like legume residues, grass cuttings, aquatic weeds, green leaves.

Shredding of materials: The process of composting can be accelerated if raw materials are shredded into small pieces since it then becomes more susceptible to bacterial action due to greater surface area exposure. The most desirable particle size for composting is less than 5cm although larger sizes can be composted satisfactorily. However, the advantage of shredding on farms or by individuals is doubtful when one considers the additional cost involved. Ajay K & Jawaid SM [6].

Blending of materials: The C/N ratio and moisture percentage are two important parameters to be considered when mixing together different kinds of material for composting. There may not be any need of blending if the C/N ratio of the materials is between 25 and 50, although a desirable range is 30 to 40. Substances poor in nitrogen such as sawdust, straw, paper can be mixed with comparatively nitrogen-rich materials such as biogas slurry, leguminous plants, and so on to obtain a near optimum ratio of 30 to 40. Similarly, wet and dry materials can be mixed

together to obtain a desirable proportion of moisture and to avoid anaerobic conditions. Soil at the rate of 5 to 10% can be added to moist materials to reduce the moisture content and to absorb ammonia while composting materials of low C/N ratio. Dry soil may be added if sufficient dry organic materials are not available. Soil may also be added to high C/N ratio organic material to buffer acid conditions and to act as a diluents (for retarding anaerobic processes). It can also be used for improving the appearance of the finished compost by giving it a more granular structure.

Moisture and aeration: Moisture content and degree of aeration are important factors in composting. If the amount of moisture in the compost pile is below forty percent (W/W), decomposition will be aerobic but slow. Aerobic decomposition will occur at any moisture content between 30 and 100% if adequate turning is provided but higher moisture contents should be avoided. The optimum moisture level for aerobic composting is 50-60% however; a range of 40-80% is quite satisfactory depending upon the nature of the material to be composted. In case of anaerobic composting, moisture level is not important. Experiments with straw (a fibrous material) have resulted for the maintenance of 80-85% moisture content Das K & Keener HM [7].

Temperature

As the microorganisms multiply in the composting mass, the heat of exothermic biochemical reactions is retained due to the larger mass, when the temperature rises above 40°C the mesophilic microorganisms are replaced by thermophilic organisms. High temperature is essential for destruction of pathogenic organisms and weed seeds. This generally occurs within 2 to 7 days of the start of operations. The temperature in the middle of the pile goes up to 55-70°C after which it gradually cools to ambient values. Decomposition is fastest in the thermophilic range. The optimum temperature for organic matter decomposition into carbon dioxide and water has been found to be 60°C and although higher temperature is desirable but it should not exceed 71°C for long as decomposition will be slowed due to the thermal kill of microorganisms. Only a few thermophilic organisms actively carry on decomposition above 70°C.

Reaction

The initial pH value in compost heaps is generally slightly acidic to neutral, around [6,7]. Lime may be applied for counteracting acidity but nitrogen can be conserved without using limestone. It has been seen that when calcium carbonate is added to compost significant losses of nitrogen occur as the alkaline conditions favors volatilization of ammonia.

Microorganisms involved: The microbial population fluctuates during aerobic composting. There is a typical pattern-the fungi and acid producing bacteria appear during the mesophilic stage. As the temperature increases above 40°C these organisms are replaced by thermophilic bacteria, actinomycetes and fungi. Spore-forming bacteria develop at still higher temperatures and finally, mesophilic bacteria and fungi reappear as the temperature

again falls. The role of mesophilic bacteria involved in the raising of temperature of the compost for the development of the thermophilic bacteria which colonies the mass. Mesophilic bacteria, which flourish during a limited time, consume most of the readily degradable carbohydrates and proteins. *Bacillus sp.* is especially involved in degradation of proteins, amino-acids, peptones. Actinomycetes degrade starch very actively and also bring about large losses of water soluble fractions. Thermophilic bacteria attack lipids and hemicelluloses. Lipids are degraded to great extent whereas degradation of celluloses and hemicelluloses is comparatively slow and intermediate. Lignin is most resistant compounds to decomposition. Division of Microbiology has developed a consortium of four fungi *Aspergillus awamori*, *Aspergillus nidulans*, *Phaenerochaete chrysosporium* and *Trichoderma viride* for composting crop residues. Inoculants are being sold at Rs. 30 per packet. A packet of 300g is enough to decompose one tone of organic matter within 90 days. Singh et al. [8].

Microbial inoculants: If the C/N ratio is too high adding nitrogen can speed up the composting process by lowering the ratio and thus leading to greater biodegradation. Addition of microorganisms is also beneficial when compost heaps/pits are poor in microbial content.

Destruction of pathogens and parasites

The destruction of animal and human pathogens and parasites should be taken into consideration while composting materials containing sewage sludge or night soil.

Nature and quality of raw materials

There are diverse types of raw materials available in rural areas which can be utilized for preparation of compost. They can be classified into five broad groups - Crop residues and weeds, animal shed wastes, human wastes, kitchen wastes and forest residues (Table 1).

Table 1: Most commonly available materials in rural areas.

Crop Residues	Human Habitation Wastes
Rice husks	Solid wastes (e.g; excreta)
Rice straw	Liquid wastes (e.g.; urine)
Barley Straw	Garbage
Maize cobs	Kitchen wastes
Maize stalks	Vegetable residues
Millet stalks	Fruit residues
Banana stems	Meat waste
Coconut stem	Fish waste
Castor stem	Forest Residues
Castor stem	Non-edible seeds
Cotton stick	Pine needles

Sugarcane trash	Leaves
Cotton leaves	Sawdust
Jamun leaves	
Coconut leaves	
Coconut husks	
Cassava leaves	
Tamarind leaves	
Animal shed Wastes	
Dung	
Vrine	
Biogas slurry	

The farm wastes and residues are scattered organic resources and include readily available materials such as rice straw, wheat straw, maize stalks, millet residues, banana, cotton, coconut, red gram sticks and sugarcane trash. The leaves of cotton, jute, cassava, coconut, papaya, tamarind, mango, guava and other crops are available in different and specific seasons in large quantities. The various kinds of farm weeds can be dried and composted or the green weeds can be composted together with dry organic materials from other sources. Water hyacinth is an aquatic weed that grows luxuriantly in water and is often a nuisance, but the plant can be harvested and composted into valuable manure. Animal shed wastes are produced in large quantities in villages and small towns and are either composted or burnt as fuel. These materials are potential resources for blending with crops residues when composting Hall J M & Sansoucy R [9].

Kitchen wastes and forest residues are equally important groups of materials for rural composting. Kitchen wastes can serve as a good blending material when composting dry and high C/N ratio farm residues. Nitrogen content and carbon-nitrogen ratio-one of the most critical factors in successful composting is the nitrogen content and its ratio to carbon in the raw materials. Therefore, these values should be known if possible and made available to the farmer. In due course, a farmer will be able to predict and identify the range of C/N ratio of organic materials commonly available in rural areas for blending or proportioning different types of raw materials for composting. As a general rule, crop residues and particularly straw, stems, and so on, are wide C/N ratio materials ranging from 50 to 120 whereas the green succulent materials (green manure crops, leguminous residues), animal shed wastes and vegetable and kitchen wastes are narrow to medium C/N ratio materials generally ranging between 10 and 25. Sawdust and rice husk have very wide ratio between 130 and 500. Sawdust contains a high quantity of lignin and this coupled with its high C/N ratio causes a very slow rate of decomposition. However, sawdust has good urine and water holding properties and can be used in composting at up to ten percent of the total biomass of raw material (Table 2,3).

Table 2: The NPK contents of commonly available organic materials.

Material	N	P	K
Blood meal	10-12	0.53	-
Bone meal (raw)	3-4	9-11	-
Bone meal (steamed)	1-2	11-13	-
Meat meal	10.5	1.1	0.3-1.3
Fish meal	4-10	1.7	0.3-1.3
Coffee grounds	2.08	0.14	0.2
Eggshells	1.19	0.17	0.12
Garbage	2.0-2.9	0.5-0.6	0.7-1.8
Grass clippings	2.41	-	-
Leaves (fresh)	0.5-1.0	0.04-0.06	0.3-0.6
Dry horse dung	1.2	0.4	1.3
Dry cattle dung	2.0	0.4	1.7
Dry poultry dung	5.0	0.8	1.0
Dry sea weed	1.68	0.33	4.1
Sewage sludge	1.5-3.5	0.07-1.76	0.3-0.7
Wood ash	-	0.5-0.8	3.3-8.3
Rice straw	8.0	-	-
Wheat straw	0.5-0.6	0.1	1.3
Water hyacinth	2.4	0.3	4.4

% composition on dry weight basis

Table 3: Nitrogen content and C/N ratio of various available compostable residues.

Material	N%	C:N
Wheat straw	0.3-0.5	80-130
Rice straw	0.3-0.5	80-130
Barley straw	0.3-0.4	100-120
Cotton stalks	0.6	70
Maize stalks and leaves	0.8	50-60
Sugarcane trash	0.3-0.4	110-120
Lucerne residues	2.55	19
Green weeds	2.45	13
Water hyacinth	2.38	17.6
Seaweed	2.10	-
Azolla	2-5	-
Ferns	1.5	25
Fallen leaves	0.5-1.0	40-80
Grass clippings	2.15	20
Neem cake	6.05	4.5
Sesbania sp.	2.83	17.9

Cow dung	2.0	19
Buffalo dung	-	19
Horse dung	2.4	-
Poultry	5.0	-
Sheep dung	3.75	-
Pig dung	3.75	-
Human night soil	4.0-6.0	6-10
Human urine	15-18	0.8
Digested sludge	5.0-6.0	6
Biogas slurry	2.0	20.4
Potato tops	1.6	27
Amaranthus	3.6	11
Tobacco	3.0	13
Carrot (whole)	1.6	27
Tomato	3.3	12
Onion	2.6	15
Lettuce	3.7	-
Cabbage	3.6	12
Pepper	2.6	15
Fruit wastes	1.5	35
Turnip top	2.3	19

Methods of Composting

An important advance in the practice of composting was made at Indore in India by Howard in collaboration with Jackson and Wad during the period 1924 to 1926. The traditional procedure was systematized into a method of composting now known as the 'Indore method'. The materials needed are mixed plant residues, animal dung and urine, earth, wood ash and water. All vegetable wastes available on a farm such as weeds, stalks, stems, fallen leaves, pruning, chaff, fodder remnants, green matter and so on, are collected and stacked in a pile. Hard woody material like cotton or Pigeon pea stalks and stubble are first spread on the farm road and crushed under vehicles such as tractors or bullock carts before being piled. Such hard materials should in any in any case not exceed 10% of the total plant residues. Green materials which are soft and succulent are allowed to wilt for 2 or 3 days to remove excess moisture before being piled. Such hard materials should in any case not exceed 10% of the total plant residues. Green materials which are soft and succulent are allowed to wilt for 2 or 3 days to remove excess moisture before stacking, they tend to pack closely if they are stacked in the fresh state while stacking, each material is spread in layers of about 15 centimeters thickness until the heap is about one and a half meters high. The mixture of different kinds of vegetable residues ensures a more efficient decomposition Goluekem C [10]. The heap is then cut into vertical slices and about 20-25 kilogram is put under the feet of cattle in the shed as bedding for the night. The next morning the bedding, along with the dung and urine and urine-earth is taken to the pit where the composting is to be done BSI [11].

Pit method

Site and size of pit: The site selected for the compost pit should be at high level so that no rain water gets in during the monsoon season; it should be near to cattle and shed may be constructed over it to protect the compost from heavy rainfall. The pit should be about 1 m deep, 1.5 to 2.0 m wide and of any suitable length. Open Pit Surface Mine Mine Engineer Community (2000) accessed 19 December [12].

Filling pit: The material brought from the cattle shed is spread and a slurry of dung made with 4.5 kg dung, 3.5 kg urine-earth and 4.5 kg of inoculums taken from a fifteen days old composting pit. A sufficient quantity of water/nearly 90% is sprinkled over the material in the pit to wet it. The pit is filled in this way layer by layer and it should not take longer than one week to fill. Care should be taken to avoid compacting the material in any way.

Heap method

During rainy season or in region with heavy rainfall the compost may be prepared in heaps above ground and protected by shed. When sufficient nitrogenous material is not available a green manure or leguminous crop like sun hemp is grown on the fermenting heap by sowing seeds after the first turning. The green matter is then turned in at the time of the record mixing.

Dimensions: The basic Indore pile is about 2 m wide at the base, 1.5 m high and 2 m long. The sides are tapered so that top is about 0.5 m narrower in width than the base. A small bund is sometimes built around the pile to protect it from wind which tends to dry the heap.

Forming the heap: The heap is usually commenced with a 20 cm layer of carbonaceous material such as leaves, hay, straw, sawdust, wood chips and chopped corn stalks. This is then covered with 10 cm of nitrogenous material such as fresh grass, weed or garden plant residues, garbage, fresh or dry manure or digested sewage sludge. The pattern of 20 cm carbonaceous material and 10 cm nitrogenous material is followed until the pile is 1.5 m high and they are normally wilted so that they feel damp but not soggy. The pile is sometimes covered with soil or hay to retain heat and is turned at six and twelve week intervals. If materials are limited, the alternate layers can be added as they become available. Also, all materials may be mixed together in the pile if one is careful to maintain the proper proportions. Shredding the material speed up decomposition considerably, most materials can be shredded by running over it several times with a rotary mower.

Advantage and limitation: This method of composting is recommended where land and labor are easily available. The process can also be partially mechanized to make it economical when large quantities of material are to be handled. The labor requirements are relatively high but compost preparation can help the unemployed in villages to earn a living. Preparation on a large scale can be done through community composting. There is lack of protection from rain and wind. A considerable amount of

water is needed and so the method is not suitable in areas of scanty rainfall. The intense aerobic decomposition to which material is subjected no doubt shortens the period of composting but it leads to heavy losses of organic matter and nitrogen. Therefore the C/N ratio should be maintained about 30 to 40 to reduce such losses.

Windrow method

Large scale compost preparation by windrow method involves the creation of windrows with a length of 40 m each consists of mainly paddy straw and leaf litter in a ratio of (1:3) volume basis. Each windrows consisting of paddy straw mix, cow dung, good quality soil, old compost in the ratio of 8: 1: 0.5: 0.5. All the biomass ingredients along with compost inoculants are mixed thoroughly with 3-4 days' old cow dung before forming windrow. The compost mechanical loader is use for making windrows. Windrows are kept in trapezoidal shape with a bottom width of 2 m and a top width of 1.5 m to match the width of the rotor of the Turner-cum-Mixer. To enhance the process of composting, PUSA Compost Inoculants developed at IARI is added at a rate of 1000 ml per tone of the material. In practice, 27 liters of culture is mixed with 100 liters of water and sprayed on the top of the windrows manually. The manual spraying is preferred as bigger fungal mats creates problem while passing through the nozzle of the regular sprayer.

Machines for windrow composting: A set of machines namely Compost Turner-cum-Mixer, Automatic Compost Sieving machine and a tractor front-mounted loader are useful for quality compost making and handling. Compost Turner-cum-Mixer is a trailing and offset type machine used for thoroughly mixing the cow dung, farm residues and biomass for manure preparation. The main components of the equipment are a mixing rotor, a hydraulic system to operate the rotor, and a water tank to store water and culture and the machine also has a side tank for weight balancing. Blades arranged in a helical path on rotor in order to facilitate thorough mixing and turning of the material. Rubber pads are also provided for partially covering the mixing unit to check the spillage of compost while mixing. Automatic Compost Sieving Machine is suitable for sieving and separating the finer grade material from the coarse grade one. Sieving machine is provided with an automatic belt feeding mechanism, a compost separator unit and hopper for safe feeding, and a belt conveyor based unit for conveying the finished quality compost. Separation in different sizes is done for value addition. A tractor front-mounted loader is useful for the purpose of handling of materials i.e. loading, shifting and shaping of the raw materials. The mechanization of the windrow compost making process has provided the avenue for a large scale production of good quality compost in a much rapid manner without drudgery to laborers.

Advantage and limitation: Windrow method is economical for large scale commercial compost preparation. Compost preparation by manual method is labor intensive. Also, handling cow dung manually is full of drudgery. The use of machines

overcomes the labor problem and fastens the compost preparation process while imparting dignity to labor. The technology facilitates compost making in 45-60 days, whereas in traditional pit method it takes almost 120-140 days depending upon the ingredients and seasonal variations.

The bangalore method

The method of composting was developed at Bangalore in India by Acharya [13]. The method is basically recommending when night soil and refuse are used for preparing the compost. The method over come many of a disadvantage of the Indore method but the time involved in production of finished compost is much longer. The method is suitable for areas with a scanty rainfall.

Preparation of the pit: Trenches or pits about one meter deep are dug; the breadth and length of the trenches can be made depending on the availability of land and the type of material to be composted. The selection of site for the pits is made as in the Indore method. The trenches should preferably have sloping walls and a floor of 90 cm slope to prevent water logging.

Filling the pit: Organic residues and night soil or animal dung are put in alternate layer and after filling. The pit is covered with a 15 cm to 20 cm thick layer of refuse. The materials are allowed to remain the pit without turning and watering for three months. During the period material settles down due to reduction in volume of the biomass and additional night soil and refuse in alternate layer are placed on top and plastered or covered with mud or earth to prevent loss of moisture and breeding of flies. After the initial, aerobic composting which is for about eight to ten days, the material undergoes anaerobic decomposition at a very slow rate and it take about six to eight months to obtain the finished product.

Advantage and limitation: The recovery of the finished product is much greater as compared to aerobic composting; loss of nitrogen is negligible. Labor requirement is less than the Indore method as turning of materials is not done; labor is needed only for digging and filling the pits. The method requires a long time to produce finished compost and so takes up more land use. A uniform high temperature is not assured in the biomass. Problems of odor and fly breeding need to be attended to.

Rural composting in india

The digging and preparation of a compost pit: The pits can be partitioned into two with partitions made from hardy straw materials. The sources are generally cattle dung mixed with straw and stubble and used as bedding for the animals, different kinds of farm weeds in addition to crops residues. The straw material, rural garbage and so on are spread in the pit layer by layer and rock phosphate or superphosphate added.

High temperature compost: This form of compost is prepared mainly from night soil, urine, sewage, animal dung and chopped residues at ratio 1:4. The material are heaped in alternate layer starting with chopped plant stalk and followed by human

and animal waste, water is added to optimum plant amount. At the time of making the heap a number of bamboo poles are inserted for aeration purposes. After the heap formation is complete, it is sealed with 3 cm of mud plaster. The bamboo poles are withdrawn after one day of composting clearing the holes for aeration of the heap. Within four or five days the temperature rises to 60-70°C and the holes are then sealed with mud. The compost is ready for use within two months and is considered free from pathogen.

The berkley method

This method of compost was developed at the University of California at Berkley (1953). Compost can be prepared within two week by the method.

Raw materials: For rapid decomposition a mixture of organic residues in the proportion of two part of cellulose-rich material to one part of nitrogen-rich materials should be used. However, pure cellulose material such as paper waste should not form more than ten percent of the raw material to be composted. It is recommended that the leaves of all kinds, grass clipping and dry manure should be mixed and shredded with a mechanical device before the heaps are made. The C/N ratio of the mixed Berkley organic wastes average 30:1.

Dimensions of the berkley composting heap and procedure: The material is composted in heaps of 2.4 m by 2.2 m with a height of about 1.5 m and it is composted for two weeks. By the second or third day thermophilic temperature develops and the heap should be turned with thorough mixing on the fourth day. The turning and mixing is repeated on the seventh and tenth days. At this stage the temperature normally starts to decrease and within two weeks the compost is ready for use. The original raw material will be somewhat recognizable but the appearance should be coarse, crumbly and dark brown. If finer compost is required it may be allowed to decompose further or it could be sieved and stored.

Advantages and limitation: The main advantages of the Berkley method is speed since large quantities of compost can be prepared in a relatively short time. The turning schedule is tight and labor intensive. There is a limitation of using material with a narrow C/N ratio.

Nature and properties of finished compost

Composted organic material that is applied to agricultural land should be sufficiently decomposed and should not have a detrimental effect on the growth of plant. The finished compost is designated by the general name humus. Humus may be described as a complex aggregate, dark brown to black in color of amorphous colloidal substances resulting from the microbiological breakdown of plant and animal residues under aerobic or anaerobic condition chemically, humus is heterogeneous material composed of different type of polymerized substances such as aromatic molecule. Polysaccharides of several kinds, bound amino-acids, polymer of uronic acids and phosphorus-containing

substance synthesized by microorganisms, complex resulting from decomposition, substances still undergoing decomposition and plant material resistant of further breakdown. The principal constituents are derivative of certain hemicelluloses, cellulose, lignin and proteins.

In general, finished compost is characterized by following features:

- (i) Dark brown to black in color.
- (ii) Practically insoluble in water, although a part may go in to colloidal suspension.
- (iii) Dissolves to a large extent in dilute alkali, sodium pyrophosphate or ammonium oxalate solution to give dark colored extract which can be further fractionated into humic, fulvic and humin fraction.
- (iv) Has a C/N ratio ranging 10 to 20 depending upon the original material and the degree of humification.
- (v) Is not in a biochemical stable state but change in composition through the activities of microorganisms as long as environmental conditions such as moisture and temperature are suitable until it is oxidized to inorganic salts, carbon dioxide and water. Many specific humic and fulvic acid decomposing bacteria and fungi have been found to be involved in the biodegradation of humic substrates.
- (vi) Exhibits a high capacity for cation exchange and for water absorption with consequent swelling.
- (vii) When compost is applied to the soil it has beneficial effects both on the soil and on the growing vegetation. Its fertilizer values include nitrogen. Phosphorus, potassium, calcium and magnesium. In addition it also contains essential trace elements for plant growth.

Its favorable effects upon soil fertility are greatly enhanced if it is used in conjunction with mineral fertilizers.

Methods for determining the condition of compost

Criteria: There are several tests by which the various stages of the composting process and the condition of the compost can be judged but no single method appears completely adequate. From the point of view of the overall judgment of the final product following test are useful:

- (i) Physical characteristics such as temperature, color, texture and so on and the extent of solubility in sodium hydroxide or sodium pyrophosphate solution.
- (ii) C/N ratio, status of plant nutrient content and compost value as shown by crop returns or plant test.
- (iii) Absence of flies and odour and the sanitary quality, i.e. free from pathogens, parasites and weeds seed.

The farm, the garden or the rural compost operator generally will not be interested in detailed tests other than those to confirm that the material is safe from the health point of view and this

can be judged from the temperature of the compost pile and that it is satisfactory for soil improvement which is judged by the physical appearance of the finished product for routine day to day monitoring temperature, appearance odour and presence of flies are the important observation to be made.

Temperature change: Temperature is the best indicator of the process, aerobic composting and as to whether or not the pathogen parasites and weed and seed have been destroyed. When aerobic composting progresses there is a rapid rise from ambient temperature to 55°C to 65°C in the first three to five days. High temperature maintained several days during the active period of decomposition provided that proper aeration and moisture condition are maintained. The failure to attain thermophilic temperature within three to six days shows that either the heap is too small to retain the heat or moisture is excessive or insufficient or carbon nitrogen relationships of the organic materials is too wide or nutrient may not be present in correct amounts. Cooling is reliable indicator of finished compost only if the material does not re-heat after turning and moistening. The temperature of the compost pile can be determined by accurate or approximate method.

Accurate determination of temperature with in a thermometer: The checking of the temperature inside a compost pile can be accurately done with the use of a long stem dial thermometer with provision for recording composting mass. The procedure is quite satisfactory for rural community compost operation and metal dial thermometer with a stem of 0.5 to 0.75 m length is satisfactory and will not easily break.

Approximate determination of temperature

(a) The compost heap is dug into at several places and temperature inside felt by hand. If thermophilic temperature has been developed the material will feel very hot to the hand and will be too hot if the hand is kept in the heap for very long. In winter or at low ambient temperature when the pile is opened during period of high temperature, steam will be seen emerging.

(b) The temperature inside compost can also be approximated by inserting a metal rod about 0.75 m long into it for about five or ten minutes. On removing the rod it will be hot to the touch and thermophilic temperatures may be too hot to hold.

These approximate testing measures for temperature will be satisfactory for small rural composting or for individual farmers composting small amounts of organic residues. However, temperature alone cannot indicate the progress of composting because sometimes the drop in temperature may result from the development of unfavorable environmental condition such as moisture, aeration and thermal kill of organisms.

Physical characteristics of finished compost:

Structure: The material should be crumbly it should be medium loose not packed and not lumpy.

a) **Color:** A blackish brown color is the best. A pure black color shows unfavorable fermentation with too much moisture and lack of air. A grayish, yellowish color indicates an excess of soil or ash. When the material inside the biomass decomposes anaerobically, it turns pale green and shows little change with progressive composting. Aerobic composting is characterized by a progressive darkening of color.

b) **Moisture Status:** The approximate moisture status of the compost can be judged by inserting an iron rod to different depths in the pile. The rod should become quite moist if sufficient moisture is being maintained. The moisture status can also be judged simply by visual observation. No water should drip from a sample of compost if pressed by hand.

c) **Odour:** The odour should be like humus or soil. Any foul smell is a sign that decomposition is not yet complete and that breakdown processes are still going on. Anaerobic condition can easily be detected by disturbing the heap.

d) **Acidity:** A neutral to slightly acid reaction is the best although slight alkalinity is acceptable. A too acidic reaction indicates lack of aeration and too much moisture. The pH range for good compost is between 6.0 and 7.5. Nitrogen-fixing bacteria can thrive well at this pH range.

Carbon-Nitrogen relationships and fertilizer value

The proper moisture and proportion of raw material determines the C/N ratio and fertilizer value of compost. A compost with an organic matter content as low as 8% is little more than a soil rich in humus as generally found in temperate region. On average, compost should have about 30% to 60% organic matter in the final material. Chemical tests such as determination of carbon and nitrogen and the C/N ratio are more reliable indicators of the finished product, however, if a C/N ratio of 20 or less is attained, normal compost is considered as ready for use. However, the C/N ratio of a well composted material may vary between 5, 10 and 20.

Future Prospects

Novel approaches to improve the process of composting, including reducing generation time, inclusion of fecal residues/animal litter, organic/inorganic compounds and consortia of effective microorganisms has revolutionized the use of compost in diverse spheres of agriculture and made it an essential component in crop-production, crop-protection and natural resource management. Keeping in view the different agro-climatic zones, tailor made bioinoculants and technologies are needed

to suit the demands of the local farmers for quality compost production. Although lot of work has been done on microbiology of composting, there is lack of sufficient knowledge about microbial diversity and their exact role during various stages of composting. There is a strong need to carry out work on the unculturable microorganisms and their activities during the composting processes using advanced techniques like denaturing gradient gel electrophoresis (DGGE) and other cultivation independent techniques. Extension workers and KVKs need to play a major role in popularizing different compost technologies among farmers. Besides composting, agro wastes may be utilized as a useful resource for production of animal feed, biofuel and enzymes to generate additional income from bioconversion process.

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