ON-FARM COMPOSTING METHODS

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EXECUTIVE SUMMARY

On-farm composting methods

Growing concerns relating to land degradation, threat to eco-systems from over and inappropriate use of inorganic fertilizers, atmospheric pollution, soil health, soil biodiversity and sanitation have rekindled the global interest in organic recycling practices like composting. The potential of composting to turn on-farm waste materials into a farm resource makes it an attractive proposition. Composting offers several benefits such as enhanced soil fertility and soil health – thereby increased agricultural productivity, improved soil biodiversity, reduced ecological risks and a better environment.

Even though the practice is well known, farmers in many parts of the world especially in developing countries find themselves at a disadvantage by not making the best use of organic recycling opportunities available to them, due to various constraints which among others include absence of efficient expeditious technology, long time span, intense labour, land and investment requirements, and economic aspects.

There is an extensive literature on composting methodology. However, the background paper presents only a selective and brief account of the salient approaches. A broad distinction as *"Traditional"* and *'Rapid'* composting practices has been made, based mainly on the considerations of the practices being adopted as a convention; and the recent introductions for expediting the process, involving individual or combined application of treatments like shredding and frequent turning, mineral nitrogen compounds, effective micro-organisms, use of worms, cellulolytic organisms, forced aeration, forced aeration and mechanical turnings and so on.

By and large, '*Traditional Methods'* adopt an approach of anaerobic decomposition, or aerobic decomposition based on passive aeration through measures like little and infrequent turnings or static aeration provisions like perforated poles/pipes, and are time taking processes involving several months. On the other hand, '*Rapid Methods'* make use of the treatments introduced recently such as those mentioned above to expedite the aerobic decomposition process and bring down the composting period around four to five weeks.

Besides, there are certain other recently introduced approaches like '*Vermi-Composting'*, which though bring down the process duration to a good extent as compared to the conventional methods besides producing a far-superior quality product, have a lower turn-over and longer time taken as compared to other '*Rapid Methods'*.

Traditional methods based on passive composting approach involve simply stacking the material in piles or pits to decompose over a long period with little agitation and management. '*Indian Bangalore method'* relying on this approach permits anaerobic decomposition for a larger part of operations and requires six to eight months for the operations to complete. The method is still in use in the urban areas of the developing world, mostly for treatment of urban wastes. A method similar in approach involving anaerobic decomposition and followed in western globe with large farms, is the '*Passive Composting of*

Manure Piles'. The active composting period in this process may range from one to two years.

'Indian Indore method', which slightly enhances passive aeration through a few turnings - thereby permitting aerobic decomposition; reduces the time requirement; and enables production in a time-span of around four months. *Chinese rural composting* methods, based on passive aeration approach through turnings/ aeration holes, provide output in two to three months. The methods are extensively used in developing world. Though the labour requirements for these methods are high, they are not capital intensive and do not require sophisticated infrastructure and machinery. Small farmers find them easy to practice, especially in those situations where manual labour is not a constraint. However, the low turnover and longer time span are the major bottlenecks.

'Turned Windrows' have been in use with the large farms especially in the developed parts of the world. The windrows are periodically turned using a bucket loader or special turning machine, commonly available on these farms. The turning operation mixes the composting materials, enhances passive aeration and provides conditions congenial for aerobic decomposition. Composting operations may take upto eight weeks.*'Passively Aerated Windrows'* eliminate the need for turning by providing air to the materials via pipes, which serve as air ducts. Active composting period could range between ten to twelve weeks.

Rapid methods like *'Berkley Rapid Composting' and 'North Dakota State University Hot Composting'* involve accelerated aerobic decomposition through measures like chopping of raw materials to small size; use of mineral compounds like ammonium sulphate, chicken manure, urine; and turning of the material on daily basis. While chopping without much machinery support may be possible at smaller scales, mechanisation may be necessary at large scale applications. Whereas *'Berkley Rapid Composting'* methods claims an active composting period of two to three weeks only, *'North Dakota State University Hot Composting'* may take four to six weeks.

'EM based Quick Compost Process' involves aerobic decomposition of rice husk/bran and cow dung as raw materials in pits as enabled through turnings; and uses effective micro-organisms as activator for expediting the decomposition process. The use of EM as activator brings down the composting period requirement from twelve weeks to four weeks.

An example of cellulolytic culture based method is the*'IBS Rapid Composting'* which is a development of windrow type of composting. Salient process features include chopping of vegetative organic materials, passive aeration provisions through air ducts and use of cellulose decomposer fungus (*Trichoderma harzianum*).The process requires about four weeks.

Mechanical forced aeration based methods like *'Aerated Static Pile'* reduce the composting time period further, allow for higher, broader piles and have lower land requirements as well in comparison to *'Windrow' or 'Passively Aerated Windrow'* methods. However, there is little experience using *'Aerated Static Piles'* with agricultural wastes.The technology is commonly used for treatment of municipal sewage sludges. Active composting period may range between three to five weeks.

Mechanical forced aeration and acclerated mechanical turning methods like *'In-vessel composting '* are specially designed commercial systems, with potential advantages like reduced labour, weather proofing, effective process control, faster composting, reduced land requirement, and quality output. However, high investment and recurring costs related to operation and maintenance could be a bottleneck for adoption especially in economically backward areas. Among the systems, '*Bins*' and '*Rectangular Agitated Beds*', in particular, have found place on several large farms in developed world. *Bin composting* involves provisions for forced aeration in the bin floor; little turning of the composting material; and movement of material from one bin to another. '*Agitated Bed Systems*' appear to have promise for on-farm rapid composting. However, the cost for the system is expensive. Commercially manufactured large systems (150 tons/day or larger) reportedly available though; small systems (20 tons/day or less) likely to interest the majority of farmers, are lacking.

'*Vermicomposting*' based on the use of worms results in high quality compost. The process does not require physical turning of the material. To maintain aerobic conditions and limit the temperature rise, the bed or pile of materials needs to be of limited size. Temperatures should be regulated so as to favour growth and activity of worms. Composting period is longer as compared to other rapid methods and varies between six weeks to twelve weeks.

The brief review is intended to provide food for thought and serve as stimulant for idea generation.

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ON-FARM COMPOSTING METHODS

A. TRADITIONAL METHODS

Anaerobic Decomposition

A.1 The Indian Bangalore Method[1]

This method of composting was developed at Bangalore in India by Acharya (1939). The method is basically recommended when night soil and refuse are used for preparing the compost. The method overcomes many of the disadvantages of the Indore method such as problem of heap protection from adverse weather, nutrient losses due to high winds / strong sun rays, frequent turning requirements, fly nuisance etc. but the time involved in production of a finished compost is much longer. The method is suitable for areas with scanty rainfall.

Preparation of the pit

Trenches or pits about one metre 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 are put in alternate layers and, after filling, the pit is covered with a 15-20 cm thick layer of refuse. The materials are allowed to remain in the pit without turning and watering for three months. During this period, the material settles down due to reduction in volume of the biomass and additional night soil and refuse are placed on top in alternate layers 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 takes about six to eight months to obtain the finished product.

A.2 Passive Composting of Manure Piles[2]

Passive composting involves simply stacking the materials in piles to decompose over a long time period with little agitation and management. The process has been used for composting of animal wastes. Needless to mention that simple placement of manure in a pile does not satisfy the requirements for continuous *aerobic* composting. Without considerable *bedding* material, the *moisture content* of manure exceeds the level, which enables an open porous *structure* to exist in the pile. Little, if any, air passes through it. Under these circumstances, the anaerobic micro-organisms dominate the degradation. All of the unde-

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[1] Source : FAO 1980 A Manual of Rural Composting. FAO/UNDP Regional Project RAS/75/004 Field Document 15

[2] Source: NRAES 1992 On-farm composting (Ed. Rynk, Robert). Natural Resource, Agriculture, and Engineering Service, Cooperative Extension, Ithaka, New York

sirable effects associated with anaerobic degradation occur including low temperatures, slow decomposition, and the release of hydrogen sulphide and other malodorous compounds.

When a livestock management system relies on bedding to add to livestock comfort and cleanliness, the bedding becomes mixed with the manure and creates a drier, more porous mixture. This provides some structure and, depending on the amount of bedding, enables the mixture to be stacked in true piles. The bedding also tends to raise the *C:N ratio* of the manure.

A mixture of manure and bedding requires a considerable proportion of bedding to provide the *porosity* necessary for composting. At least equal volumes of bedding and manure are required. If the amount of bedding is too low to provide a porous mix, then additional dry *amendments* must be provided by either increasing the bedding used in the barn or adding amendments when piles are formed. Manure from horse stables or bedded manure packs can often compost in piles alone, whereas non-bedded manure from dairy, swine, and many poultry barns needs drying or additional amendments.

The pile must also be small enough to allow passive air movement, generally less than 6 feet high and 12 feet wide. This passive method of composting is essentially windrow composting but with a much less frequent turning schedule. It is a common method used for composting leaves. It demands minimal labour and equipment. Passive composting is slow because of its low *aeration* rate, and the potential for odour problems is greater.

Aerobic Decomposition through Passive Aeration

A.3 The Indian Indore Method[3]

An important advance in the practice of composting was made at Indore in India by Howard during the period 1924 to 1926. The traditional procedure was systematized into a method of composting now known as the 'Indore method'.

Raw materials

The raw materials used are mixed plant residues, animal dung and urine, earth, wood ash and water. All organic material wastes available on a farm such as weeds, stalks, stems, fallen leaves, prunings, chaff, fodder leftovers 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 case not exceed ten percent of the total plant residues. Green materials, which are soft and succulent, are allowed to wilt for two to three days to remove excess moisture before stacking; they tend to pack closely if they are stacked in the fresh state. The mixture of different kinds of organic material residues ensures a more efficient decomposition. While stacking, each type of material is spread in layers about 15 centimetres thick until the heap is about one and a half metres high. The heap is then cut into vertical slices and about 20-25 kilograms are 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 pits where the composting is to be done.

[3] Source : FAO 1980 A Manual of Rural Composting. FAO/UNDP Regional Project RAS/75/004 Field Document 15

A.3.1 Pit method

Site and pit dimension:

The site selected for the compost pit should be at high level so that no rainwater gets in during the monsoon season; it should be near to the cattle shed and a water source. A temporary shed may be constructed over it to protect the compost from heavy rainfall. The pit should be about 1 m deep, 1.5-2 m wide and of any suitable length.

Filling the pit:

The material brought from the cattle shed is spread evenly in the pit in layers of 10-15 cm. On each layer is spread a slurry made with 4.5 kg dung, 3.5 kg urine-earth and 4.5 kg of inoculum taken from a 15 day-old composting pit. Sufficient quantity of water 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.

Turning:

The material is turned three times during the whole period of composting; the first time 15 days after filling the pit, the second after another 15 days and the third after another month. At each turning, the material is mixed thoroughly, moistened with water and replaced in the pit.

A.3.2 Heap method

Site and heap dimensions:

During rainy seasons or in regions with heavy rainfall, the compost may be prepared in heaps above ground and protected by a shed. 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 the 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 started 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, weeds or garden plant residues, fresh or dry manure or digested sewage sludge. The pattern of 20 cm carbonaceous material and 10 cm of nitrogenous material is followed until the pile is 1.5 m high and the material is normally wetted so that it may 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. In the Republic of Korea, heaps are covered with thin plastic sheets to retain heat and prevent insect breeding.

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 speeds up decomposition considerably; most materials can be shredded by running over them several times a rotary mower. 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 second mixing. The process takes about four months to complete.

A.4 Chinese rural composting[4]

A.4.1 The pit method

Generally, composting is carried out in a corner of a field and in a circular or rectangular pit. Rice straw, animal dung (usually pig), aquatic weeds or green manure crops are used and often silt pumped from river beds is mixed with the crop residues. The pits are filled layer by layer, each layer being 15 cm thick. Usually, the first layer is of a green manure crop or water hyacinth, the second layer is a straw mixture and the third layer is of animal dung. These layers are alternated until the pit is full, when a top layer of mud is added; a water layer of about 4 cm depth is maintained on the surface to create anaerobic conditions which help to reduce losses of nitrogen. Approximate quantities of the different residues in tons per pit are: river silt 7.5, rice straw 0.15, animal dung 1.0, aquatic plants or green manure 0.75 and superphosphate 0.02. Three turnings are given in all, the first one month after filling the pit and, at this time, the superphosphate is added and thoroughly mixed in. Water is added as necessary. The second turning is done after another month and the third two weeks later. The material is allowed to decompose for three months and produces about eight tons of compost per pit.

A.4.2 High temperature compost

This form of compost is prepared mainly from night soil, urine, sewage, animal dung, and chopped plant residues at a ratio of 1:4. The materials are heaped in alternate layers starting with chopped plant stalks and followed by human and animal wastes; water is added to optimum 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 on the second day of composting leaving the holes for aeration of the heap. Within four to five days, the temperature rises to 60-70^{o}C and the holes are then sealed. The first turning is usually done after two weeks and the moisture is made up with water or animal or human excreta; the turned heap is again sealed with mud. The compost is ready for use within two months.

In some locations, a modified method of high temperature composting is used. The raw materials, crop stalks (30%), night soil (30%) and silt (30%) are mixed with superphosphate at the rate of 20 kg superphosphate per ton of organic material. The compost heaps have aerating holes made by inserting bundles of maize stalks instead of bamboo poles.

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[4] Source: FAO 1980 A manual of rural composting. FAO/UNDP Regional Project RAS/75/004 Field Doc. 15

Large Scale Passive Aeration

A.5 Windrow Composting[5]

A.5.1 Turned Windrows

Windrow composting consists of placing the mixture of raw materials in long narrow piles or windrows which are agitated or turned on a regular basis. The turning operation mixes the composting materials and enhances *passive aeration.* Typically the windrows are initially from 3 feet high for dense materials like manures to 12 feet high for fluffy materials like leaves. The width varies from 10 to 20 feet. The equipment used for turning determines the size, shape, and spacing of the windrows. Bucket loaders with a long reach can build high windrows. Turning machines produce low, wide windrows.

Windrows aerate primarily by natural or passive air movement (convection and gaseous diffusion). The rate of air exchange depends on the porosity of the windrow. Therefore, the size of a windrow that can be effectively aerated is determined by its porosity. A light fluffy windrow of leaves can be much larger than a wet dense windrow containing manure. If the windrow is too large, anaerobic zones occur near its centre which release odours when the windrow is turned. On the other hand, small windrows lose heat quickly and may not achieve temperatures high enough to evaporate moisture and kill *pathogens* and weed seeds.

For small to moderate scale operations, turning can be accomplished with a front end loader or a bucket loader on a tractor. The loader simply lifts the materials from the windrow and spills them down again, mixing the materials and reforming the mixture into a loose windrow. The loader can exchange material from the bottom of the windrow with material on the top by forming a new windrow next to the old one. This needs to be done without driving onto the windrow in order to minimize compaction. Windrows turned with a bucket loader are often constructed in closely spaced pairs and then combined after the windrows shrink in size. If additional mixing of the materials is desired, a loader can also be used in combination with a manure spreader.

A number of specialized machines have been developed for turning windrows. These machines greatly reduce the time and labour involved, mix the materials thoroughly, and produce a more uniform *compost.* Some of these machines are designed to attach to farm tractors or front-end loaders; others are self-propelled. A few machines also have the capability of loading trucks or wagons from the windrow.

It is very important to maintain a schedule of turning. The frequency of turning depends on the rate of decomposition, the moisture content and porosity of the materials, and the desired composting time. Because the decomposition rate is greatest at the start of the process, the frequency of turning decreases as the windrow ages. Easily degradable or high-nitrogen mixes may require daily turnings at the start of the process. As the process continues, the turning frequency can be reduced to a single turning per week.

By the end of the first week of composting, the windrow height diminishes appreciably and by the end of the second week it may be as low as 2 feet. It may be prudent to

[5] Source: NRAES 1992 On-farm composting (Ed. Rynk, Robert). Natural Resource, Agriculture, and Engineering Service, Cooperative Extension, Ithaka, New York

combine two windrows at this stage and continue the turning schedule as before. Consolidation of windrows is a good wintertime practice to retain the heat generated during composting. This is one of the advantages of windrow composting. It is a versatile system that can be adjusted to different conditions caused by seasonal changes.

With the windrow method, the active composting stage generally lasts three to nine weeks depending upon the nature of the materials and the frequency of turning. Eight weeks is a common period for manure composting operations. If three weeks is the goal, the windrow requires turning once or twice per day during the first week and every three to five days thereafter.

A.5.2 Passively Aerated Windrows

The method, *passively aerated windrow* system, eliminates the need for turning by supplying air to the composting materials through perforated pipes embedded in each windrow. The pipe ends are open. Air flows into the pipes and through the windrow because of the chimney effect created as the hot gases rise upward out of the windrow.

The windrows should be 3-4 feet high, built on top of a base of straw, *peat* moss, or finished compost to absorb moisture and insulate the windrow. The covering layer of peat or compost also insulates the windrow; discourages flies; and helps to retain moisture, odour, and *ammonia*. The plastic pipe is similar to that used for septic system leach fields with two rows of 1/2-inch diameter holes drilled in the pipe. In many aerated pile applications, the pipe holes are oriented downward to minimize plugging and allow condensate to drain. However, some researchers recommend that the holes face upwards.

Windrows are generally formed by the procedures described for the aerated static pile method. Because the raw materials are not turned after the windrows are formed, they must be thoroughly mixed before they are placed in the windrow. Avoid compacting the mix of materials while constructing the windrow. Aeration pipes are placed on top of the peat/compost base. When the composting period is completed, the pipes are simply pulled out, and the base material is mixed with the compost.

This method of composting has been studied and used in Canada for composting seafood wastes with peat moss, *manure slurries* with peat moss, and *solid manure* with straw or wood shavings. Manure from dairy, beef, swine, and sheep operations has been used.

B. RAPID COMPOSTING METHODS

While traditional composting procedures take as long as 4-8 months to produce finished compost, rapid composting methods offer possibilities for reducing the processing period up to three weeks. A variety of approaches and their combinations have been used to hasten the composting process, which include the following:

- *Shredding and frequent turnings*
- *Use of chemical nitrogen activators*
- *Use of Effective Micro-organisms (EM)*
- *Use of worms*
- *Use of celluloytic cultures*

- *Use of forced aeration*
- *Use of forced aeration and mechanical turnings*

The following paragraphs deal with the rapid composting methodologies based on the above-mentioned approaches.

Shredding and Frequent Turnings

B.1 The Berkley Rapid Composting Method[6]

The method corrects some of the problems associated with the old type of composting. With this process, compost can be made in two to three weeks. There are several important factors essential to the rapid composting method as given below:

- Material will compost best if it is between 1/2 to 1 1/2 inches in size. Soft, succulent tissues need not be chopped in very small pieces because they decompose rapidly. The harder or the more woody the tissues the smaller they need to be divided to decompose rapidly. Woody material should be put through a grinder, but most grinders chop herbaceous materials too finely for good composting. Chopping material with a sharp shovel is effective. When pruning plants, cut material into small pieces with the pruning shears -- it takes a little effort but the results are good.

- For the composting process to work most effectively, material to be composted should have a carbon to nitrogen ratio of 30:1. Mixing equal volumes of green plant material with equal volumes of naturally dry plant material will give approximately a 30:1 carbon to nitrogen (C/N) ratio. Green material can be grass clippings, old flowers, green prunings, weeds, fresh garbage and fruit and vegetable wastes. Dried material can be dead, fallen leaves, dried grass, straw and somewhat woody materials from prunings.

- Materials, which should not be added to a composting pile, include soil, ashes from a stove or fireplace, and manure from carnivorous (meat-eating) animals. Manures from herbivorous animals such as rabbits, goats, cattle, horses, elephants or fowl can be used. Once a pile is started, do not add anything. The reason is that it takes a certain length of time for the material to break down and anything added has to start at the beginning, thus lengthening the decomposition time for the whole pile. Excess material should be as dry as possible during storage until a new pile is started. Moist stored materials will start to decompose and if this occurs, they will not do a good job in the compost pile. Nothing needs to be added to the organic materials to make them decompose. The micro-organisms active in the decomposition process are ubiquitous where plant materials are found and will develop rapidly in any compost piles.

- Composting works best if the moisture content of materials in the pile is about 50 percent. Too much moisture will make a soggy mass, and decomposition will be slow and will smell. If the organic material is too dry, decomposition will be very slow or will not occur at all.

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[6] Source: Raabe,R.D. 2001 The Rapid Composting Method. Co-operative Extension, Division of Agriculture and Natural Resources, University of California

- Heat, which is very important in rapid composting, is supplied by the respiration of the micro-organisms as they break down the organic materials. To prevent heat loss and to build up the amount of heat necessary, a minimum volume of material is essential: a pile at least 36” X 36” X 36” is recommended. If less than 32 inches, the rapid process will not occur. Heat retention is better in bins than in open piles, so rapid composting is more effective if bins are used. In addition, the use of bins is much neater. High temperatures favour the micro-organisms which are the most rapid decomposers; these micro-organisms function at about 160^{o}F (71^{o}C) and a good pile will maintain itself at about that temperature. A thermometer to measure temperatures inside the pile is helpful although not necessary.

- The compost pile needs to be turned to prevent the pile from getting too hot. If it gets much above 160^{0}F, the micro-organisms will be killed, the pile will cool, and the whole process will have to start from the beginning. By turning the pile it will not overheat, and it will be aerated also, both of which are necessary to keep the most active decomposers functioning. The pile should be turned so that material which is on the outside is moved to the centre. In this way, all the material will reach optimum temperatures at various times. Due to heat loss around the margins, only the central portion of the pile is at the optimum temperature. Because of the necessity for turning, it is desirable to have two bins so the material can be turned from one into another. Bins made with removable slats in the front make the turning process easier. Bins with covers retain the heat better than do those having no covers. Once the decomposition process starts, the pile becomes smaller and because the bin is no longer full, some heat will be lost at the top. This can be prevented by using a piece of polyethylene plastic slightly larger than the top area of the bins. After the compost is turned, the plastic is placed directly on the top of the compost and is tucked in around the edges. If the material in the pile is turned every day, it will take 2 weeks or a little longer to compost. If turned every other day, it will take about 3 weeks. The longer the interval between turning the longer it will take for the composting to finish.

- If done correctly, a pile will heat to high temperatures within 24 to 48 hours. If it doesn’t, the pile is too wet or too dry or there is not enough green material (or nitrogen) present. If too wet, the material should be spread out to dry. If too dry, add moisture. If neither of these, then the nitrogen is low (a high C/N ratio) and this can be corrected by adding materials high in nitrogen (such as ammonium sulphate, grass clippings, fresh chicken manure or urine diluted 1 to 5).

- If the C/N ratio is less than 30:1, the organic matter will decompose very rapidly but there will be a loss of nitrogen. This will be given off as ammonia and if this odour is present in or around a composting pile, it means that valuable nitrogen is being lost in the air. This can be counteracted by the addition of some sawdust to that part of the pile where there is an ammonia odour -- sawdust is very high in carbon and low in nitrogen (a high C/N ratio) and therefore will counteract the excess nitrogen. Other than adding water should the pile become dry, this is the only thing, which should be added to a pile once it’s started. Because composting can be done anytime, during the rainy season some covering the pile may be necessary to keep the composting materials from becoming too wet.

- The rapid decomposition can be detected by a pleasant odour, by the heat produced (this is even visible in the form of water vapour given off during the turning of the pile), by the growth of white fungi on the decomposing organic material, by a reduction of volume, and by the change in colour of the materials to dark brown. As composting nears completion the temperature drops and, finally, little or no heat is produced. The compost is then ready to use. If in the preparation of the compost the material was not chopped in small pieces, screening the material through 1-inch-mesh chicken wire will hold back such pieces. These can be added to the next pile and eventually they will decompose.

Use of Mineral Nitrogen Activators

B.2 North Dakota State University Hot Composting [7]

Compost piles with a height of 6 feet (1.8 m) are raised. The maximum size of the organic matter pieces should be 6-9 inches (15-23 cm) long. If bins are constructed, the dimensions of 5x5x6 feet will yield 150 cubic feet (4.3 cu.m) of compost. This is a respectable volume of compost to produce in a four- to six-week time period.

To keep the aerobic bacteria population high and active, 0.12 kg of actual nitrogenous fertilizer should be added per cubic foot of dry matter and holes punched (four to five) into the centre of the pile. This is best done in phases or stages as the compost pile is building up. For example for a 150 cubic feet volume of dry matter, if the pile is built up over a period of three stages - at 2 feet , 4 feet and 6 feet , 5.7 kg of a nitrogen fertilizer should be added at each step. The total should be about 17-18 kg of fertilizer for the entire pile.

In this high-temperature, bacterially active system, it is best to turn the composting material every three to four days. Once activated, expect the temperature to range between 120-160°F (49-71°C). The decomposition will go faster in summer (as short as three to four weeks) and take more time in the spring and fall. No measurable activity occurs during typical North Dakota winters. Once the compost is no longer hot and is an odour-free, crumbling material, it is ready for use.

Use of Effective Micro-organisms (EM)

B.3 EM based Quick Compost Production Process [8]

Since 1999 seven small-scale organic fertilizer plants, using the EM based quick production process have been in operation in Myanmar. They are owned and operated by Women's Income Generation Groups (WIGG). A unit plant consists of nine pits of 6 ft (l) x 4 ft (w) x 3 ft (d) , enclosed by low walls and covered with roof.

Raw Materials

The raw materials for organic fertilizer production are as follows:

- Cow dung 2 portions
- Rice husk 1 portion

[7] Source: Smith, R.C.1995 Composting Practices. NDSU Extension Service, North Dakota State University of Agriculture and Applied Science, and USDA

[8] Source: Hiraoka, H. 2002 Biofertilizer Production Plant, Myanmar (FAO/UNDP Project), Back to Office Report, Feb. 2002, FAO- RAP, Bangkok

- Rice husk/charcoal 1 portion
- Rice bran, milled 1 portion
- Accelerator 33 litres of EM solution or Trichoderma solution per pit.

Preparation of EM solution (accelerator)

Firstly one litre of 'instant solution' is made by mixing 10 ml EM, 40 ml molasses and 950 ml water and leaving it for five to seven days, depending on temperature. Then the solution is added to one litre of molasses and 98 litres of water to obtain 100 litres of ready-to-use EM solution. This amount is enough for three pits. The EM solution functioning as accelerator reduces the composting period from three months to one month.

Procedure

Firstly, mix all the ingredients, except accelerator. Then make 0.5 ft layer of mixture in the pit and sprinkle accelerator over. Repeat the same procedure until the pit is full. Cover with plastic sheet. Two or three weeks later, mix the whole pit to boost aerobic decomposition. The fertilizer is ready to use a couple of weeks later. . A pit turns out 900 kg of final product per batch, which are usually packed in 30 kg plastic bags. Assuming that it takes 30 days on average to produce a batch and only eight pits may be used for technical reasons, the annual potential production capacity works out to 86.4 tons (0.9 t x 8 pits x 12 months).

Use of Celluloytic Cultures

B.4 IBS Rapid Composting Technology [9]

B.4.1 IBS Rapid Composting

IBS rapid composting technology involves inoculating the plant substrates used for composting with cultures of Trichoderma harzianum, a cellulose decomposer fungus. The fungus, grown in a medium of sawdust mixed with the leaves of ipil ipil (*Leucaena leucocephala)*, a leguminous tree, is termed as compost fungus activator (CFA). The technology is a development of the windrow type of composting. The composting time, using this procedure, ranges from 21 to 45 days, depending on the plant substrates used.

The procedure consists of two parts: the production of the compost fungus activator, and the composting process.

Preparation of substrates

Substrates such as rice straw, weeds and grasses should be chopped. Chopping helps speed up decomposition by increasing the surface area available for microbial action, and providing better aeration. If large quantities of substrates are to be used (i.e. several tons), a forage cutter/chopper is needed. Chopping can be dispensed with if the compost is not needed in the near future.

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[9] Source: Virginia,C.C. 1997 Rapid Composting Technology in Philippines: its role in producing good quality organic fertilizers. Extension Bulletin, FFTC, Taiwan

Adjustment of moisture content

Substrates should be moistened with water. Plant substrates can be soaked overnight in a pond, which cuts down on the need for water. If a large volume of substrates are to be composted, a sprinkler is more convenient.

The compost mixture

Carbonaceous substrates should be mixed with nitrogenous ones at a ratio of 4:1 or less, but never lower than 1:1 (on a dry weight basis). Some possible combinations are:

- 3 parts rice straw - 1 part ipil-ipil
- 4 parts rice straw - 1 part chicken manure
- 4 parts grasses - 1 part legume materials + 1 part manure
- 4 parts grasses - 1 part Chromolaena odorata or Mikania cordata [10]+ 1 part animal manure

Composting procedure

- The substrates should be piled loosely in a compost pen to provide better aeration within the heap. The material should not be too compact and no heavy weights should be put on top. Compost heaps should be located in shady areas such as under big trees. The platform should be raised about 30 cm from the ground, to provide adequate aeration at the bottom. Alternatively, aeration can be provided by placing perforated bamboo trunks horizontally and vertically at regular intervals, to carry air through the compost heap.

- The compost activator, consisting of a cellulolytic fungus, is broadcast onto the substrates during piling. The amount of activator used is usually 1% of the total weight of the substrates (i.e. about 1 kg compost activator per 100 kg substrate). Decomposition is faster if the activator is mixed thoroughly with the substrate. A greater amount of activator can be used if faster decomposition is desired.

- The heap should be covered over completely. This maintains the heat of decomposition, and minimizes water evaporation and ammonia volatilization. White plastic sheets, or plastic sacks with their seams opened and sewn together, can serve as a cover. The compost heap usually heats up in 24 - 48 hours.

- Heat should be maintained at 50°C or higher, and the heap should be turned over every 5-7 days for the first two weeks, and thereafter once every two weeks. After the first week, the volume of the pile should be reduced by one-third. After two weeks, the volume of the pile should be reduced to one half the original.

[10] Note: Chromolaena odorata is a common broad-leaf weed. Mikania cordata is an herbaceous climbing plant, a common weed in the Philippines. It is important to use grasses and weeds, which do not have any flowers or seeds.

- The mature compost should be removed from the pen, and dried in the sun for two days. It should then be put into sacks and stored in a shaded area. Decomposition will continue until the substrate is finely fragmented, so that the finished product has a powdery texture. Then, once decomposition is complete, the compost should be sun-dried again until the moisture content is at 10-20%.

- If mature compost is needed at once, it should be sun-dried for one day, as soon as its temperature drops to 30°C. Drying removes excess moisture, and makes the compost much easier to handle. Although the compost still retain some fibres, it can be applied immediately as fertilizer.

B.4.2 IBS Rapid Commercial Compost Production

In the large-scale commercial production of compost, the following operations need to be mechanized, other steps remaining the same:

- Chopping of substrates.
- Mixing/Turning - when there are several tons of substrate, a pay loader will make mixing of substrates or turning of heaps much easier.
- A hammer mill should be used to break up big lumps of mature compost before drying.
- During rainy months, it is more economical to dry compost mechanically than try to sun dry it.

B.4.3 IBS Rapid Rice Straw Composting

At harvest time, rice straw is heaped on to one side of the paddy field. It saves labour to have one compost pile for each paddy field instead of one central pile. Various steps are as follows:

- Rice straw is soaked overnight in water or in the rain until saturated.
- A simple platform is made in the middle of the field
- A layer of saturated rice straw 10-15 cm thick is loosely piled on the platform.
- On top of the layer, one or two handfuls of the activator is broadcast (25 kg /ha).
- Straw is alternately layered with the activator until all the straw has been used.
- Manure and nitrogenous plants are put on top of the straw layers. The nitrogen substrate is 15-25% of total composition.
- The compost is covered (with plastic, banana leaves, or coconut fronds) and heats up within 25 hours.
- The compost must be moistened frequently to compensate for evaporation.
- The compost is left unturned and matures within one month. It is ready for use when the pile has cooled and is 30% of its original size.

Use of Forced Aeration

B.5 Aerated Static Pile[11]

The aerated static pile method takes the piped aeration system a step further, using a blower to supply air to the composting materials. The blower provides direct control of the process and allows larger piles. No turning or agitation of the materials occurs once the pile is formed. When the pile has been properly formed and if the air supply is sufficient and the distribution is uniform, the active composting period will be completed in approximately three to five weeks.

With the aerated static pile technique, the raw material mixture is piled over a base of wood chips, chopped straw, or other very porous material. The porous base material contains a perforated aeration pipe. The pipe is connected to a blower, which either pulls or pushes air through the pile.

The initial height of piles should be 5-8 feet high, depending on the material porosity, weather conditions, and the reach of the equipment used to build the pile. Extra height is advantageous in the wintertime to retain heat. It may be necessary to top off the pile with 6 inches of finished compost or *bulking agent*. The layer of finished compost protects the surface of the pile from drying, insulates it from heat loss, discourages flies, and filters ammonia and potential odours generated within the pile.

Two forms of aerated static piles are common: individual piles and *extended piles*. Individual piles are long triangular piles with a width (10-16 feet, not including the cover) equal to about twice the pile height. The aeration pipe runs lengthwise beneath the ridge of the pile. Individual piles hold a single large batch of material or a few batches of roughly the same *recipe* and age (within three days, for example). Individual piles are practical when raw materials are available for composting at intervals rather than continuously.

Since the pile does not receive additional turnings, the selection and initial mixing of raw materials are critical. Otherwise, poor air distribution and uneven composting occur. The pile must have good structure as well as to maintain porosity through the entire composting period. This generally requires a fairly stiff bulking agent such as straw or wood chips. Wood chips are commonly used for composting *sewage sludge* by this method. Because of their large size, wood chips pass through the process only partially composted. They are usually screened from the finished compost and reused as bulking agents for an additional two or three cycles. Since straw decomposes over the composting period, a pile with straw as an amendment can gradually lose structure. This is partially compensated by the drying which takes place as composting proceeds. Other possible bulking agents and amendments for static pile composting include recycled compost, peat moss, corn cobs, crop residues, bark, leaves, shellfish shells, waste paper, and *shredded* tires. Uncomposted material like shredded tires and mollusc shells must eventually be screened from the compost and reused. To obtain good air distribution, manure or sludge must be thoroughly blended with the bulking agent before the pile is established.

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[11] Source: NRAES 1992 On-farm composting (Ed. Rynk, Robert). Natural Resource, Agriculture, and Engineering Service, Cooperative Extension, Ithaka, New York

The required airflow rates and the choice of blowers and aeration pipe depend on how aeration is managed - that is, how the blower is controlled. The blower can be controlled in several different modes. It can be run continuously or intermittently. In the latter case, the control mechanism can be either a programmed time clock or a temperature sensor.

The airflow rates are based on the dry weight of the primary raw material, such as sludge or manure. They should take into account the presence of typical amendments like wood chips, straw, and compost. In practice, it may be necessary to adjust the timer cycle, pile size, or blower, to suit the specific conditions and materials.

For static pile composting, the air can be supplied in two ways: a suction system with the air drawn through the pile or a pressure system with the blower pushing the air into the pile. Suction draws air into the pile from the outer surface and collects it in the aeration pipe. Since the exhaust air is contained in the discharge pipe, it can be easily filtered if odours are occurring during the composting process.

With positive pressure aeration, the exhaust air leaves the compost pile over the entire pile surface. Therefore, it is difficult to collect the air for odour treatment. If better odour control is desired, a thicker outer layer of compost can be used. Pressure aeration provides better airflow than suction aeration, largely because of the lack of an odour filter. The lower pressure loss results in greater airflow at the same blower power. Therefore, pressure systems can be more effective at cooling the pile and are preferred when temperature control is the overriding concern.

Controlled Systems with Forced Aeration and Accelerated Mechanical Turnings

B.6 In-Vessel Composting[12]

In-vessel composting refers to a group of methods which confine the composting materials within a building, container, or vessel. In-vessel methods rely on a variety of forced aeration and mechanical turning techniques to speed up the composting process. Many methods combine techniques from the windrow and aerated pile methods in an attempt to overcome the deficiencies and exploit the attributes of each method.

There are a variety of in-vessel methods with different combinations of vessels, aeration devices, and turning mechanisms. The few methods discussed here have either been used or proposed for farm composting. They also serve as good examples of the types of in-vessel systems available.

B.6.1 Bin Composting

Bin composting is perhaps the simplest in-vessel method. The materials are contained by walls and usually a roof. The bin itself may simply be wooden slatted walls (with or without a roof), a grain bin, or a bulk storage building. The buildings or bins allow higher stacking of materials and better use of floor space than free-standing piles. Bins can also eliminate weather problems, contain odours, and provide better temperature control.

[12] Source: NRAES 1992 On-farm composting (Ed. Rynk, Robert). Natural Resource, Agriculture, and Engineering Service, Co-operative Extension, Ithaka, New York

Essentially, bin composting methods operate like the aerated static pile method. They include some means of forced aeration in floor of the bin and little or no turning the materials. Occasional remixing of material in the bins can invigorate the process. If several bins are used, the composting materials can be periodically moved from one bin to the next in succession. Most of the principles and guidelines suggested for the aerated pile should apply to bin composting as well. One exception relates to relatively high bins. In this case, there is a greater degree of compaction and a greater depth of materials for air to pass through. Both factors increase the material's resistance to airflow (pressure loss). A raw material with a stronger structure and/or a higher pressure blower may be required, compared to the aerated static pile method.

B.6.2 Rectangular Agitated Beds

The *agitated bed* system combines controlled aeration and periodic turning. In this system, composting takes place between walls which form long, narrow channels referred to as beds. A rail or channel on top of each wall supports and guides a compost-turning machine.

Raw materials are placed at the front end of the bed by a loader. As the turning machine moves forward on the rails, it mixes the compost and discharges the compost behind itself. With each turning, the machine moves the compost a set distance toward the end of the bed. The turning machines work much like windrow turners, using rotating paddles or flails to agitate the materials, break up clumps of particles, and maintain porosity. Some machines include a conveyor to move the compost. The machines work automatically without an operator and are controlled with limit switches.

Most commercial systems include a set of aeration pipes or an aeration plenum recessed in the floor of the bed and covered with a screen and/or gravel. Between turnings, aeration is supplied by blowers to aerate and cool the composting materials. Since the materials along the length of the bed are at different stages of composting, the bed is divided into different aeration zones along its length. Several blowers are used for one bed. Each blower supplies air to one zone of a bed and is individually controlled by a temperature sensor or time clock.

The capacity of the system is dependent on the number and the dimensions of the beds. The width of the beds in commercially available systems ranges from 6 to 20 feet, and bed depths are between 3 and 10 feet. The beds must conform to the size of the turning machine, and the walls must be especially straight. To protect equipment and control composting conditions, the beds are housed in a building or a greenhouse or, in warm climates, just covered by a roof.

The length of a bed and frequency of turning determine the composting period. If the machine moves the materials 10 feet at each turning and the bed is 100 feet long, the composting period is ten days with daily turning. It increases to twenty days if turning occurs every other day. Suggested composting periods for commercial agitated bed systems range from two to four weeks, though a long *curing* period may be necessary.

B.6.3 Silos

Another in-vessel technique resembles a bottom-unloading silo. Each day an auger removes composted material from the bottom of the silo and a mixture of raw materials is loaded at the top. The aeration system blows air up from the base of the silo through the composting materials. The exhaust air can be collected at the top of the silo for odour treatment. A typical composting time for this method might be fourteen days, so one-fourteenth of the silo volume must be removed and replaced daily. After leaving the silo, the compost is cured, often in a second aerated silo. This system minimizes the area needed for composting because the materials are stacked vertically. However, the stacking also presents compaction, temperature control, and airflow challenges which must be overcome. Because materials receive little mixing in the vessel, raw materials must be well mixed when loaded into the silo.

B.6.4 Rotating Drums

A different system uses a horizontal rotary drum to mix, aerate, and move the material through the system. The drum is mounted on large bearings and turned through a bull gear. A drum 11 feet in diameter and 120 feet long has a daily capacity of approximately 50 tons with a residence time of three days. In the drum, the composting process starts quickly; and the highly degradable, oxygen-demanding materials are decomposed. Further decomposition of the material is necessary and is accomplished through a second stage of composting, usually in windrows or aerated static piles. In some commercial systems, the composting materials spend less than one day in the drum. In this case, the drum primarily serves as a mixing device.

Air is supplied through the discharge end and is incorporated into the material as it tumbles. The air moves in the opposite direction as the material. The compost near the discharge is cooled by the fresh air. In the middle, it receives the warmed air, which encourages the process; and the newly loaded material receives the warmest air to initiate the process.

The drum can be either open or partitioned. An open drum moves all the material through continuously in the same sequence as it entered. The speed of rotation of the drum and the inclination of the axis of rotation determine the residence time. A partitioned drum can be used to manage the composting process more closely than the open drum. The drum is divided into two or three chambers by partitions. Each partition contains a transfer box equipped with an operable transfer door. At the end of each day's operation, the transfer door at the discharge end of the drum is opened and the compartment emptied. The other compartments are then opened and transferred in sequence, and finally a new batch is introduced into the first compartment. A sill in place at each of the transfer doors retains 15% of the previous charge to act as an *inoculum* for the succeeding batch. Upon discharge, the compost can go directly into a screen to remove oversized particles which can be returned to the drum for further composting.

On a smaller scale, composting drums can be adapted from used equipment such as concrete mixers, feed mixers, and old cement kilns. Although less sophisticated than the commercial models, the functions remain the same: to mix, aerate, and get the composting process started rapidly.

B.6.5 Transportable Containers

A different type of in-vessel system, relies on a transportable vessel and a central composting facility. A number of local farms participate and provide manure as a raw material. Each farm receives a transportable vessel, which resembles a solid waste roll-off container. The container has aeration pipes in its base, which are connected to a blower. At the farm, the manure and dry amendments are loaded daily into the container and aerated for several days until the container is picked up and delivered to the central facility to finish composting. When the composting container is picked up, the farm is provided with another empty container to continue the cycle. The farm supplies the manure and receives bulking agent, compost, and/or revenue in return.

Use of Worms

B.7 Vermicomposting

The term "vermicomposting" had recently been coined to mean the use of earthworms for composting organic residues. Earthworms can consume practically all kinds of organic matter and they can eat their own body weight per day; thus, for example, one kilogram of worms can consume one kilogram of residues every day. The excreta or "castings" of the worms are rich in nitrate, available forms of phosphorus, potassium, calcium and magnesium. The passage of soil through earthworms promotes bacterial and actinomycetes growth; actinomycetes thrive well in the presence of worms and their content in worm casts is over six times more than in the original soil.

Kind of worms

A moist compost heap of 2.4 m by 1.2 m and 0.6 m high can support a population of more than 50 000 worms. The introduction of worms into a compost heap has been found to mix the materials, aerate the heap and hasten decomposition. Turning the heaps is not necessary if earthworms are present to do the mixing and aeration. The ideal environment for the worms is a shallow pit and the right sort of worms are necessary. *Lumbricus rubellus* (the red worm) and *Eisenia foetida* are thermo-tolerant and so particularly useful. Field worms *Allolobophora caliginosa* and night crawlers (*Lumbricus terrestris*) will attack organic matter from below but the latter do not thrive during active composting, being killed more easily than the others at high temperature.

European Night Crawlers (Dendrabaena veneta) or (Eisenia hortensis) are commercially produced as well and have been successfully used in most climates. This night crawler grows to about 4 inches and up to about 8 inches. The African Night crawler (*Eudrilus eugeniae),* is a large, tropical worm species. It does tolerate heats a bit higher than does *E. foetida*, provided there is ample humidity, but has a narrow temperature tolerance range. However, it cannot survive at temperatures below 45 degrees F.

B.7.1 Vermicomposting in Philippines[13]

The worms used are *Lumbricus rubellus* and/or *Perionyx excavator*. The worms are reared and multiplied from a commercially-obtained breeder stock in shallow wooden boxes stored in a shed. The boxes are approximately 45 cm x 60 cm x 20 cm and have drainage holes; they are stored on shelves in rows and tiers.

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[13] Source: FAO 1980 A manual of rural composting. FAO/UNDP Regional Project RAS/75/004 Field Document 15

A bedding material is compounded from miscellaneous organic residues such as sawdust, cereal straw, rice husks, bagasse, cardboard and so on, and is moistened well with water. The wet mixture is stored for about one month, being covered with a damp sack to minimize evaporation, and is thoroughly mixed several times. When fermentation is complete, chicken manure and green matter such as ipil ipil leaves or water hyacinth is added. The material is placed in the boxes and should be sufficiently loose for the worms to burrow and should be able to retain moisture. The proportions of the different materials will vary according to the nature of the material but a final protein content of about 15% should be aimed at. A pH value as near neutral as possible is necessary and the boxes should be kept at temperatures between 20^{o}C and 27^{o}C. At higher temperatures, the worms will aestivate and, at lower temperatures, they hibernate.

In spite of their being able to eat the bedding material, the worms at this stage are fed regularly; for every kilogram of worms a kilogram of feed is given every 24 hours. For each 0.1 m^2 of surface area, 100 g of breeder worms are added to the boxes. The feedstuffs used are again various and include chicken manure, ipil ipil, vegetable wastes and so on. At one farm, water hyacinth is grown specifically and used fresh (chopped up) as the sole source of feed.

Some form of protection against predators is necessary; predators can include birds, ants, leeches, rats, frogs and centipedes.

Composting procedure

- A series of pits (the number depending on available space) are dug approximately 3 m x 4 m x 1 m deep, with sloping sides. Bamboo poles are laid in a parallel row on the pit floor and covered with a lattice of wood strips. This provides the necessary drainage as the worms cannot survive in a waterlogged environment.

- The pit is then lined with a suitable material to keep the worms from escaping into the surrounding soil (although, with the abundant feed provided in the compost heap, this may not happen) and yet permit drainage of excess water. At the farm under consideration, old animal feedstuff sacks were used.

- The pit can now be filled with rural organic residues such as straw and other crop residues, animal manure, green weeds, leaves and so on. The filled pit is covered loosely with soil and kept moist for a week or so. During this period, another pit can be filled as necessary.

- One or two spots on the heap are then well watered and worms from the breeding boxes are place on top; the worms immediately burrow down into the damp soil.

- To harvest the worms from the boxes, two-thirds of the box is emptied into a new box lined with banana leaf or old newspaper. The original box can now be provided with fresh bedding material and those worms remaining will again multiply. The worms emptied from the box are picked out by hand for adding to the heap.

- The compost pit is left for a period of two months; ideally it should be shaded from hot sunshine and it must be kept moist. Within two months, about 10 kg of castings will have been produced per kilogramme of worms. The pit is then excavated to an extent of about two-thirds to three-quarters and the bulk of the worms removed – by hand or by sieving. This leaves sufficient worms in the pit for further composting and the pit can be refilled with fresh organic residues. The compost can be sun-dried and sieved to give a very good quality material. A typical analysis is: Organic matter 9.3%, Nitrogen 8.3%, Phosphorus 4.5%, Potassium 1.0% (water-soluble), Calcium 0.4%, Magnesium 0.1%.

- The excess worms that have been harvested from the pit can be used in other pits, sold to other farmers for the same purpose, used or sold for use as animal feed supplement, used or sold for use as fish food or, if there is no social taboo, used in certain human food preparations.

B.7.2 Vermicomposting in Cuba[14]

In Cuba, different methods are used for worm propagation and vermicomposting.

B.7.2.1 Worm troughs in a row

The first and most common is cement troughs, two feet wide and six feet long, much like livestock watering troughs, used to raise worms and create worm compost. Because of the climate, they are watered by hand every day. In these beds, the only feedstock for the worms is manure, which is aged for about one week before being added to the trough.

First, a layer of three to four inches of manure is placed in the empty trough, then worms are added. As the worms consume the manure, more manure is layered on top, roughly every ten days, until the worm compost reaches within a couple inches of the top of the trough, about two months. Then the worms are separated from the compost and transferred to another trough.

B.7.2.2 Windrows

The second method of vermicomposting is windrows. Cow manure is piled about three feet across and three feet wide. Then it is seeded with worms. As the worms work their way through it, fresh manure is added to the end of the row, and the worms move forward. The rows are covered with fronds or palm leaves to keep them shaded and cool. Some of these rows have a drip system - a hose running alongside the row with holes in it. But mostly, the rows are watered by hand. Some of these rows are hundreds of feet long. The compost is gathered from the opposite end when the worms have moved forward. Then it is bagged and sold. Fresh manure, seeded with worms, begins the row and the process again.

Some of the windrows have bricks running along their sides, but most are simply piles of manure without sides or protection. Manure is static composted for 30 days, then transferred to rows for worms to be added. After 90 days, the piles reach three feet high. Worm populations, they say, can double in 60 to 90 days. Windrows are also used to compost rice hulls and sugar cake (cake is what is left after sugar cane is processed), but this too is mixed with animal manure. Sometimes food scraps added to worm beds.

[14] Source: Cracas, Paula 2000 Vermicomposting Cuban Style. Worm Digest Issue 25 – online articles

B.7.3 Vermiculture in India[15]

Preparing vermicompost

- Materials - breeder worms, a wooden bed and organic wastes.
- The bed should be 2 1/2 ft. high x 4 ft. wide x any length desired. Apply worms for every part of waste.
- Sieving and shredding- Decomposition can be accelerated by shredding raw materials into small pieces.
- Blending- Carbonaceous substances like sawdust, paper and straw can be mixed with nitrogen rich materials such as sewage sludge, biogas slurry and fish scraps to obtain a near optimum C/N ratio of 30:1 / 40:1. A varied mixture of substances produces good quality compost, rich in major and micro nutrients.
- Half digestion- The raw materials should be kept in piles and the temperature allowed to reach 50-55^{o}C. The piles should remain at this temperature for 7 to 10 days.
- Moisture, temperature and pH- The optimum moisture level for maintaining aerobic conditions is 40-45%. Proper moisture and aeration can be maintained by mixing fibrous with nitrogen rich materials. The temperature of the piles should be within 28-30^{o}C. Higher or lower temperatures will reduce the activity of micro flora and earthworms. The height of the bed can help control the rise in temperature. The pH of the raw material should not exceed 6.5 to 7.

After about a month the compost is ready. It will be black, granular, lightweight and humus-rich. To facilitate separating the worms from the compost, stop watering two to three days before emptying the beds. This will force about 80% of the worms to the bottom of the bed. The rest of the worms can be removed by hand. The vermicompost is then ready for application.

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[15] Source: Jambhhekar, Hemangee 2002 Vermiculture in India –on line training material, Maharashtra Agricultural Bioteks, Pune, India