COMPOST: THE BLACK GOLD

(A Farmers' Guide for Composting)

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NICRA

National Innovations in Climate Resilient Agriculture

Citation:

Singh, R. K., and Longkumer, T. E., 2018. Compost: The Black Gold, KrishiVigyan Kendra –Phek, ICAR – NRC on Mithun, Porba, Phek, Nagaland pp 112.

Published by

Krishi Vigyan Kendra Phek
ICAR – NRC on Mithun
Porba, Phek, Nagaland

Publication is funded from National Innovations in Climate Resilient Agriculture (NICRA) Project

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March 2018

Typeset and cover designed by
Dr. R. K. Singh
Printed at:
M/s Print House
Central Apartment, Nagarjan Junction
Dimapur – 797112, Nagaland

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FOREWORD

Organic farming offers the prospects of sustaining crop yields and maintaining soil health. It avoids the use of synthetic fertilisers; pesticides etc. and solely depend on the use of crop residues, animal manures, farm wastes etc. Farmyard manure, NADEP Compost, Vermicompost, Vermiwash, Azolla compost etc. are the best organic amendments that can be readily prepared by the farmers at their farmstead with least cost and the same may be used to replenish the nutrients. These organic amendments not only meet the loss of depleted nutrients but also improve the soil structure and reduce soil erosion.

The northeastern region is ideally placed for organic farming. Nowadays with increased consciousness about the ill effect of chemicals and fertilisers on human health, the demand for organic food is increasing day by day, and people are ready to pay higher prices for certified organic products. It provides ample scope for production of ORGANIC FOOD to get assured market and price advantage.

Apart from this, composting also offers clean surroundings as all the organic wastes, crop residues, animal excreta etc. may be converted into high-value compost. The present book has been prepared carefully to provide a practical guide to the farming community, hope it will serve its purpose and farmers will be benefited by adopting the recommendations.

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1st November 2018

PRELUDE

Organic wastes are generated regularly at the farm as well as at household levels, and disposal of such residues are now becoming a serious problem, specifically in urban and peri-urban areas. Most of the time these organic residues are burnt or used as landfills. However, these organic wastes such as kitchen discards, crop residues, human and animal litters may be a primary source of organic material that can be added to the soil after proper treatment. These adequately treated organic waste will not only contribute nutrient to plants but will also play an essential role in stabilising the agricultural ecosystems.

Crop residue and farm waste contain about quarter part of nitrogen (N) and phosphorus (P), half of the sulphur (S), three-quarters of potassium (K) and sufficient quantities of micronutrients uptaken by the crop during its production cycle. Other than these, carbon compounds present in the organic waste acts as food for many microorganisms present in the soil. These microbes, in turn, releases biomolecules that help in plant growth.

In the northeastern region due to the practice of jhuming, lots of organic matter is burned, which results in the loss of valuable organic nutrients and also disturbs the ecology and impacts the ecosystem. Further, this practice is also accelerating soil degradation. Organic vegetation obtained during jungle clearing can be collected and converted into quality manure along with other organic wastes.

The present book elaborates on different kinds of manures and composts, methods of composting and changes during composting, factors affecting the composting process, the enriching of organic compost and recommendation and method of application for different crops. This book will be helpful to farmers in learning the basics of composting and converting their farm and home waste to a valuable product "Compost – The Black Gold". We hope the information presented in this book will be helpful to the farmers and rural youths.

-Authors

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Chapter – I

INTRODUCTION

Soil, the uppermost crust is the earth's fragile skin that anchors all life on Earth. The fragile skin that supports the life on this planet is significantly affected by various forms of soil degradation. Half of the topsoil on the planet earth has been lost in the last 150 years. Soil degradation is estimated to be occurring on 147 million hectares (Mha) of land, including 94 Mha from water erosion, 16 Mha from acidification, 14 Mha from flooding, 9 Mha from wind erosion, 6 Mha from salinity, and 7 Mha from a combination of factors in India alone. It is very severe because India supports 18% of the world's human population and 15% livestock population, but has only 2.4% of the world's land area. Despite its low proportional land area, India ranks second worldwide in farm output (Bhattacharyya, 2015). Land degradation and poor soil quality are the major threats to our food and environmental security. Hilly terrains and high rainfall regions are more vulnerable to soil degradation. Soil erosion in these regions causes loss of top fertile soil, organic matter, nutrients and other beneficial microbes and adversely affects soil health. Organic matter helps in reducing soil vulnerability and protects nutrient loss apart from nutritional supplementation.

The practice of gathering and using wastes from animal, human and vegetable sources for improving crop productivity is as old as agriculture. These organic wastes offer the possibility of sustaining crop yields and maintenance of soil health. It also helps in evading the use of chemical fertilisers; pesticides etc. as it supplies the required nutrients. During the growth and production, crops uptake the nutrients from the soil, and the same has to be replenished to sustain the soil productivity. The best way of replenishing is to supply the nutrients received from decomposed and digested organic residues available. The process of decomposing plant residues and other non-living organic materials to make an earthy, dark, crumbly substance, which is excellent to enrich and replenish the soil is called composting and the product thus obtained is known as compost or humus. Compost is a way of returning safe, easily mineralised, organic matter, or humus, to the soil. Though the organic matter is a relatively small fraction of soil, it can have a dynamic influence on the health of the soil.Since the compost is black and can enrich the soil and it also supplies the nutrients required by the crops to enhance its performance so, it can be termed as "The Black Gold".

Figure 1: Finished Compost 'the black gold'

Compost can provide valuable nutrients and organic matter to the soil, depending upon the composting approaches and raw materials (feedstock) used. Chemical analysis of different kind of compost samples indicates its total nitrogen status, available nitrogen, phosphorus, and potassium quantities, but most of them are relatively low in one or more nutrients and are not considered good "fertilisers"; however, as soil amendments, they are good sources of organic matter.

Nitrogen and phosphorous in compost are generally found in both plant-available forms (NO_3, NH_4, and P_2O_5) and organic forms. The nutrient present in organic forms will be converted to "plant-available" form after decomposition. Therefore, readily available nutrients in compost can be much lower than in raw waste, but a "timed-release" effect occurs in compost. This slow-release of nutrients "bound" initially in organic forms makes compost nutrient efficient because it prevents the loss of nutrients, which generally occurs in fertilisers.

Why composting?

The principal advantage of making compost is utilising the nutrients available in the waste as a supplement to crop production. Primarily composting stabilises organic materials so that they can be stored safely, transported easily, and applied at a convenient time. Compost can also be converted into marketable product and may be sold in urban and peri-urban areas.

Large-scale composting is practised by municipal wastewater treatment plants, agricultural producers, industrial waste generators, and commercial composters (who are in the business of composting wastes collected from various sources). These bulk producers either sell their product to nurseries, big farms, landscaping companies, etc. or may be filled in 1-5 kg packets for retail selling to the general public. Depending upon compost production and markets, prices of commercially available compost may vary considerably.

Raw organic waste may be applied directly to farmland, but there are limitations of application timings. Further maintaining optimum moisture and temperature for proper decomposition on entire farmland may not be feasible; thus, there will be improper decomposition and nutrient loss. Apart from this scattering, the wastes to the large area may cause unhygienic environment, lousy odour and pollution. On other hands, compost is easier to handle and store than raw waste. It does not have any offensive odour and is less likely to contribute to water contamination. Simultaneously composting of organic waste also provides flexibility to the farmer and he can choose the time and mode of application. Only problem farmer may have that is storage, as compost being bulky requires vast space for storing. So the information given below may be helpful to the farmers to decide whether composting will be appropriate for them

Prerequisites of composting

The feasibility of composting depends upon the availability of raw materials (feedstock), composting space, composting equipment and labour. Composting is a biological process where microorganisms (bacteria, fungi, and actinomycetes) breaks the complex organic materials into simple and more stable forms. They feed on organic waste during their growth and development, and during the process, they decompose the organic matter into simpler compounds that can be utilised by them. Just can be said that we are feeding a balanced diet to these organisms and providing them with a comfortable environment to make them work efficiently.

So the availability of good quality feedstock having a balanced amount of nutrients for composting is of prime importance. Excreta and wastes from livestock farms are the rich sources of macro and micronutrients that can be composted as it is, but the mixing of low nutrient feedstock like straws and other crop residues can make the feedstock a balanced foodstuff for microorganisms. Moreover, livestock excreta is very rich in nitrogen, and if composted alone, the nitrogen present may convert into ammonia, which may be lost through volatilisation. Sometimes very strong and pungent odour one may feel near compost pit, this may occur due to volatilisation of ammonia. Mixing of high carbon – low nitrogen feedstock with livestock farm waste balances the carbon: nitrogen (C:N) ratio. A C:N ratio between 20:1 to 30:1 is a good ratio for proper microbial activity and making good quality compost. Compaction of feedstock during the composting restricts aerobic breakdown and creates anaerobic conditions. It may lead to the production of offensive smell and harmful gasses like methane etc. Crop residues, straws, sawmill dust, wood chips, leaves etc. can be added to increase aeration and reduce the bulk density of the composted mass.

Composting area is another essential aspect to look upon. As the compost and the feedstock are too bulky, so transportation becomes an important factor. The composting area should be near to the place where plenty of wastes and feedstuff is available, as it reduces the cost of transportation. However, the composting pit should be located sufficiently away from the residential area as the sometimes unpleasant smell is produced due to faulty decomposition. Lousy odour and flies from feedstock and compost piles may be offensive to residents of the area.

Home scale composting does not require much equipment but, it can be done with small household equipment like; spade, shovel, rakes etc. However, for commercial scale, machinery is required for transporting, mixing and composting of the feedstock. The following equipment/machinery are essential for the commercial composting unit:

1. Truck for transportation
2. Front-end loader
3. Shredder
4. Turner
5. Aerator
6. Composting thermometer
7. Shovel

Crop residue availability:

Crop residues are the remains of plants that are left in the field after harvesting and thrashing of the crops. These residues are a good source of plant nutrients, as quite a good amount of the nutrients absorbed from the soil remains in the residues. These residues can be converted into the compost of better quality, and its use can help to sustain or even improve crop yield. Therefore, efficient crop residue management can play a vital role in restoring soil productivity as well as in increasing the fertiliser use efficiency (FUE).

Organic wastes are generated regularly at the farm as well as at household levels, and disposal of such waste is a serious problem. These wastes either burnt or used as landfills, which is a poor utilisation of a very useful resource. Many times improper disposal of waste may become hazardous, and it may contaminate the ecosystem. On other hands, these organic waste can be a good source of nutrient when decomposed properly. The nutrients present in these wastes can be effectively used as organic manure for increasing the agricultural productivity besides having environmental benefits.

Burning of crop residues in fields:

Farmers use residues for their own needs or sell to other landless households. Farmers intentionally burn the surplus residues for clearing of the fields, fertility enhancement in the form of ash addition and pest and pasture management.

Figure 2: Burning of crop residues

Farmers also perceive that burning kills harmful pathogens. Residue burning increases the short-term availability of some nutrients, i.e., Calcium and potassium and reduces soil acidity but leads to loss of other nutrients like nitrogen and sulphur, organic matter and damages microflora in topsoil.

Ways to improve soil health:

An increase in biomass production improves root biomass proportionately, a significant component of which goes back into the soil. Soil organic carbon enhancement through crop residue recycling, inclusion of legumes in the cropping sequence or as intercrops, green manure crops, green leaf manuring, tank silt addition, farmyard manure, biofertilizer, composting/ vermicomposting along with fertilizers and integrated nutrient management are some of the important options to improve soil health and crop productivity in rainfed areas.

Composting of agricultural waste is an important method in which organic waste such as food, leaves and paper is turned into a material that is useful to the environment. Micro-organisms and bacteria break down the waste to form a paste-like substance. The resulting material is rich in nutrients and oxygen. Composting is becoming an effective way to increase organic matter of the soil. In addition to increasing organic matter of the soil, amending with compost also increases soil microbial populations, which leads to an improvement in the soil quality. Composting comes in many different forms.

Compost Quality

Compost quality varies with the kind of raw organic materials (feedstock), the composting process used, and the state of biological activity. Before using compost as a soil amendment, it is a good idea to evaluate its quality by determining moisture content, organic matter content, carbon to nitrogen (C: N) ratio, and pH (Table 1).

Table 1. Qualities of compost for on-farm use and methods to test (Cooperband, 2002).

S. No.	Quality	Optimum	How to test
1.	Source of organic matter	Should have a good organic matter content (40-60%)	Have organic matter tested by a soil lab
2.	Source of nitrogen	10–15:1 C:N ratio	Have C:N ratio tested by a soil lab
3.	Neutral pH	6–8	Use soil pH kit to test pH at home or have pH tested by a soil laboratory
4.	No phototoxic compounds	Good seed germination (>85%)	Plant 10 seeds in a small pot
5.	Weed-free	No or few weed seeds	Moisten compost and wait for weed seedlings to grow

Compost and Suppression of pathogens

Compost helps in developing a suppressing soil that favours the healthy growth of plants and suppresses the establishment of pathogens. The mechanisms which suppress disease organisms in these soils include induced resistance, direct parasitism (one organism consuming another), nutrient competition, and direct inhibition through antibiotics secreted by beneficial organisms (Sullivan, 2004).

Compost enhances vigour and resistance ability of the plant for any pathogenic attack. On other hands, it also favours the growth of microflora that may parasitise over the pathogens or may produce antagonistic microbial chemicals, including the production of antibiotics and parasitism, which suppresses the growthof pathogenic organisms. Organic acids and ammonia present in the compost have anantagonistic effect on pathogens.Compost also produces some compounds that stimulate premature germination of pathogens resulting in reduced pathogenic load.

Compost use and Soil Fertility

Compost is a nutrient-rich soil conditioner that improves soil quality. It not only supplies nutrients but influences the availability of nutrients to the plants and improves the soil health primarily by improving physical and biological properties of soil. Compost has along-term impact on soilnutritional status, soil texture, soil structure, soil erosion and water dynamics. It reduces water runoff, soil detachment and transfer of ammonium and nitrate ions to the water. Thus the application of compost besides supplying nutrients also increase overall soil fertility.

Compost Application

The timing of application is an important factor to get the best result. Timing greatly depends on edaphic factors. Compost supports the microbial activity, so the best time of compost application is before the onset of the monsoon is the most favourable time for the microbes. However, in an area of high rainfall, spring is the best time to apply it, to avoid leaching of some of the valuable nutrients.

Compost releases nutrient slowly, and the nutrients may not be available for uptake by the plant immediately after application. Most of the nitrogen remaining after completion of the composting process is bound into organic forms and releases slowly. Compost application rates can be calculated using fertiliser recommendations from soil tests and compost nutrient analysis. While calculating the quantity of compost based on soil test report and crop requirement, then it must also be taken into account that only 10 to 25% of Nitrogen (N), 40% of Phosphorus (P_2O_5) and 60% of Potash (K_2O) present in compost will be available to plant during the first year of application. It is important to know that the actual availability of nutrients will depend on the nature of the raw material used for composting and environmental conditions.

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Chapter –II

DEGENERATION AND DECAYING OF WASTES A NECESSARY EVIL

The common practices of disposing of waste are dumping it from out of sight of ordinary people. However, it does not solve the problem but indirectly increases the same manifold and sometimes it goes beyond the control of everybody. The consequences of this practice such as health hazards, pollution of soil, water, air & food, unpleasant surroundings, loss of precious resources that could be obtained from the solid waste, etc. are well known (Agarwal et al., 2015). Many times when we roam in any village, we may encounter the heaps of partially rotten organic residues left beside the pathways emitting some off smell and polluting the environment. The situation further darkens when the village does not has adequate sanitation facilities as a rising population, and declining vegetation cover is demanding. This scene does not create the positive image of the people residing and on other hands, it also shows the lack of awareness about the ways to convert the waste into a high-quality product the BLACK GOLD or say compost.

The decomposition of waste into constituent chemicals is a common source of local environmental pollution. This problem is quite acute in developing nations. The release of foul-smelling gases is a major environmental concern by decomposing garbage. Methane released from decomposing garbage is a by-product of the anaerobic respiration that contributes to the greenhouse effect and climate change (Alam and Ahmade, 2013). During degeneration process, the organic material is subjected to the activities of many micro-organisms. Often the disease-causing organisms find rotting garbage as a safe place to multiply, and then they spread all around causing diseases in human beings, animals and plants.

This decomposition is a necessary evil, though it looks unpleasant, it helps in cleaning. Imagine if there would not have been this decomposition and decaying process then what would have been happened. The land where we are living would have been full of residues and dead. Even the faeces would not disappear from the earth. We can easily imagine what a possible place the earth will become. No plant will be able to absorb any nutrients from the soil or synthesise any food through photosynthesis, nor can any animal or human being eat and digest any food. Therefore, decomposition or decaying is virtually a blessing in disguise, and it had made the earth a beautiful place for living and cultivating, as nature has created the process to clean the environment so the new one may have sufficient space to dwell. Since decomposition is necessary and unavoidable, so it is important to handle it properly. Therefore, decomposition of biomass/organic material may be done in the presence of oxygen using micro-organisms that will not create unsanitary conditions and even a valuable product as organic manures will be obtained.

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Chapter –III

PRINCIPLES OF COMPOSTING AND CHANGES DURING COMPOSTING

Composting is a method of aerobic decomposition of crop residues, wastes from livestock farms and other non-living organic materials and converts them to an earthy, dark, crumbly substance that can enrich and replenish the soil. In this process, various microfauna such as nematodes, mites, spiders, centipedes, earthworms, ground beetles etc.and microorganisms, including bacteria, fungi and actinomycetes break down organic matter into simpler substances in the aerated environment and give the finished product compost or humus. Efficacy of the composting is influenced by the environmental factors such as aeration, temperature, moisture, substrate, microbial populations etc.

Growth and reproduction is a feature of all the livings, so the micro-organisms present there also grow in size and increase in number and during this process they require nutrients, oxygen and moisture, which they obtain by decomposing the organic residues and surroundings. They get the large amount of energy, carbon, nitrogen, phosphorus, macro and micro minerals from the residue itself, whereas oxygen and moisture, they obtain from the surrounding atmosphere. Complex organic compounds of the residue are broken down into carbon dioxide, water vapour and energy. Some portion of this energy is utilised by the micro-organisms to carry out their life processes, but a significant portion of it is converted into heat, which increases the temperature inside the compost pit or heap. The temperature of the pit or heap goes as high as 60-70^{0}C that is sufficient enough to destroy many diseases causing agents, harmful insects and weed seeds. Carbon dioxide which is produced in a large amount leaves the pit along with some vapour, and consequently, the volume reduces. Temperature reduces again when the decomposition is over. Dark and crumbly substance remained after decomposition of the organic matter has humus, other broken-down products, and living and dead microbial cells called compost and is ready for use. Some essential conditions that are the prerequisites for obtaining quality compost are discussed below.

A. The type of organic matter

Generally, everything of plant or animal origin can be used for the composting but for achieving better results; it is important to know the combination of materials that can be used. Composting microbes use carbon as energy source and nitrogen for growth (protein synthesis). When the substrate is filled in the compost pit, it is essential to maintain a proper balance of carbon to nitrogen (C:N ratio). The ratio of the available carbon (C) and nitrogen (N) plays an important role in decomposition, the organic matter with higher nitrogen content decomposes faster than the low nitrogen containing material. The proportion may vary; at C:N ratios from 25:1 to 40:1 for proper decomposition. A mixture of materials containing 30 parts of carbon to 1 part of nitrogen is considered ideal for compost (Wilcox *et al.*, 2015).

Based on the nitrogen content, the organic matter may be grouped as low nitrogen containing or “high C:N ratio” and high nitrogen containing or “low C:N ratio” matters. The first group consists of rough materials and decomposes slowly, whereas the second group consist of dung, animal wastes and young juicy plant parts, and decomposes readily. The list of the organic residues grouped in these two broad categories is given in Table 1.

Table 1: C:N ratio or different composting materials

High C:N Ratio (> Nitrogen)	Low C:N Ratio (< Nitrogen)
Straws of paddy, wheat, oat, rye and millets etc., rice hulls	Animal Manures
Sugarcane leaves trash and baggage	Dried blood, Slaughter house wastes, Hoof and horn meal, Bonemeal
Pigeon pea stalks	Sour milk, Urine
Old green leaves, dried leaves, non-legume hay and twigs of plants	Fish cleaning/meals, chicken feathers
Mature grasses	Brewers waste
Coconut fibre waste	Kitchen scraps
Peanut hulls, Potato waste	Water hyacinth, seaweeds,
Mustard plants (after harvest)	Fresh young grass
Paper, newspaper, cardboard	Young plants
Sawdust, tree bark, wood chip	Legume Hay
Silk mill wastes	Tea/Coffee Grounds
Egg shells, ashes	Cotton, Soybean, Corn Meal

Higher nitrogen content facilitates rapid multiplication of microorganisms thus substrate decomposes at a faster rate, whereas substrate with low nitrogen decomposes slowly as multiplication of microbes remains slowly.

Table 2: Effect of C:N ratio the pace of decomposition (Adopted from Wilcox *et al.*, 2015)

Pace of decomposition	C:N Ratio
Fast	• C:N ratio between 20/1 and 40/1 • Heats up quickly • Generally, two turnings total • Ready in 2 to 3 months

Medium	• C:N ratio closer to 100/1 takes longer to mature (about three months in warm weather, nine months in cold weather). • Turning is optional but beneficial
Slow	• C:N ratio around 200/1 or higher • It generally needs to be mixed later with another pile

B. Organisms

Numerous organisms take part in the decomposition of organic residues. Depending on their size, they may be termed as macro-organisms like; mites, centipedes, snails, millipedes, springtails, spiders, slugs, beetles, ants, flies, nematodes, flatworms, rotifers and earthworms or micro-organisms such as bacteria, fungi, and actinomycetes. The macro-organisms are considered to be physical decomposers because they grind, bite, suck, tear, and chew materials into smaller pieces; however, micro-organisms are considered chemical decomposers, because they change the chemistry of organic wastes and they account for most of the decomposition that takes place in the substrate.

Aerobic bacteria are the most important decomposers among all the organisms. They are abundantly available and may count millions in a gram of soil or decaying organic matter. These bacteria are the most nutritionally diverse of all organisms and can eat nearly anything. They utilise carbon as a source of energy and nitrogen to build their protein for multiplication. They oxidise carbon fraction of the organic substrate to obtain energy. During oxidation temperature of the compost pile increases from ambient atmospheric temperature. The rate of temperature increment depends upon the composition of decomposable materials. Micro-organism can survive in an extended range of temperature from 0 to 80^0 C but, majority of them are active in decomposition within the temperature range of 30 to 40^0 C. While bacteria can survive in unfavourable environments as they can't escape but changes in pH or fluctuation in environmental factors like; oxygen, moisture, temperature etc. can make bacteria die or they become inactive. Aerobic bacteria, which are most preferred microorganism for rapid decomposition of organic matter, need oxygen levels higher than five per cent for better decomposition. When oxygen levels fall below five per cent, the population of the aerobes reduces and decomposition process slows by as much as 90 per cent. In this condition, anaerobic micro-organisms take over the process, and they start producing a lot of useless organic acids and amines that makes many nutrients including nitrogen unavailable to the plants. These products include; hydrogen sulfide (smell like rotten eggs), cadaverine, and putrescine (offensive odours) produce the rotten and stinky smell and in some cases, are toxic to plants.

Diverse kinds of aerobic bacteria act on the substrate, and their respective population varies with the temperature of the pile. Psychrophilic bacteria work at the very low-temperature range and may remain active at temperature lesser than 20^0 C. Though they produce quite a small amount of heat that is enough to enhance the temperature of the pile. As temperature increases more than 20^0 C, mesophilic bacteria, start to take over. Mesophilic bacteria rapidly decompose organic matter and produces acids, carbon dioxide and heat. Their working temperature range is generally in between 20 to 37^0 C. When the temperature of the pile increases further, the mesophilic bacteria begin to die off or they move to the outer part of the heap. At about than 40^0 C thermophilic bacteria take over as they thrive well at temperatures ranging from 45 to 70^0 C. Thermophiles continue the decomposition process, till the pile temperature reaches 65 to 70^0 C, where it usually stabilises. Feeding of new material and regular turning sustains high temperature or else this temperature lasts for three to five days. The high temperatures (above 60^0 C) have the advantage of killing pathogenic organisms and weed seeds. If the temperature exceeds than 70^0 C, then action should be taken for cooling the heap by turning it, because the temperature of the pile beyond 70^0 C, makes the composting material sterile and it loses its nutritional qualities and disease-fighting properties.

As the temperature reaches beyond 70^0 C, the population of thermophilic bacteria starts declining, and that results in the gradual reduction of the temperature of the pile. As the pile cools off, the mesophilic bacteria again become dominant, and they start consuming remaining organic material with the help of other organisms and now composting process enters in another phase where actinomycetes and fungi play their role.

While the numerous types of bacteria are at work, other micro-organisms are also contributing to the degradation process. Greyish appearing actinomycetes, a higher-form bacteria are similar to fungi and moulds. They are responsible for the pleasant earthy smell of compost. Actinomycetes decompose more resistant materials in a pile such as lignin, cellulose, starches and proteins, and reduce them to carbon, nitrogen, and ammonia, making nutrients available for higher plants. Actinomycetes occur in large clusters and become very evident during the later stages of decomposition.

Like bacteria and actinomycetes, fungi are also contributing to the decay of organic matter in a compost pile. Fungi are primitive plants that may be either single or multicellular and filamentous. They lack a photosynthetic pigment and are responsible for the breakdown cellulose and lignin. They prefer cooler temperatures (22 to 25^0 C) and easily digested food sources, so they take over the process during the final stage of composting.

Table 3: Organisms in composting

S. No.	Group	Organisms	Action
1	Macro-fauna (small soil animals)	Mites, ants, termites, millipedes, centipedes, spiders, beetles and worms.	Grind, bite, suck, tear, cut and chew materials into smaller pieces.

2	Micro-fauna (small multicellular organisms)	Rotifers	Rotifers are microscopic organisms found in films of water in the compost, and they help in controlling populations of bacteria and small protozoan
3	Micro-fauna	Microscopic animals like Protozoa	Help in consuming bacteria, fungi and micro-organic particulates.
4	Micro-flora (Single-celled)	Bacteria,	The common of all the microorganisms found in compost
5	Micro-flora (Multicellular and filamentous)	Actinomycetes,	Necessary for breaking down paper products such as newspaper, bark, etc.
6	Macro-flora (larger plants)	Fungi, moulds, yeasts, algae, viruses	Breaking down of materials that bacteria cannot, especially lignin in woody material.
7	Macro-fauna (Larger soil organisms)	Earthworms	Ingestion of partly composted material, but also continually re-create aeration and drainage tunnels as they move through the compost.

C. Aeration

Composting process accomplishes in the presence of macro and micro-organisms, and adequate supply of oxygen is essential for them to carry out respiration to sustain their life process. Therefore, the heap should be prepared in such a way that it provides adequate aeration. Anaerobic conditions (absence of air) leads to the development of different unfavourable kinds of micro-organisms, causing putrefaction of residue and degrading the quality of the compost.

D. Moisture

Every living being requires water to sustain their life and the organisms engaged in composting, too need sufficient moisture to sustain and grow. Microbial activity occurs most rapidly in thin water films on the surface of organic materials. Micro-organisms can only utilise organic molecules that are dissolved in water. The optimum moisture content for compost pile ranges from 40 to 60 per cent. If moisture reduces from 40 per cent, then bacterial activity reduces, and they may become dormant, however, if moisture increases from 60 per cent then it forces air out of pile pore spaces, suffocating the aerobic bacteria. The population of aerobic bacteria reduces and decomposition is taken over by anaerobic bacteria, resulting in putrefaction and unpleasant odours.

Special care is required to maintain adequate moisture in the composting material in tropical regions, whereas in temperate regions the chances of water losses are scanty. Wetting of the mixture initially and at each turning, using artificial windbreaks and shading may help in reducing the water losses; however during monsoon, the heap may be built above ground at an elevated site to control the excess of moisture.

E. Temperature

Soon after putting the material in a heap, rapid decomposition takes place. The heap passes through all the stages of warming-up, high temperature, cooling down and maturing. In the beginning, basic complex organic compounds like starch, sugars and fats are broken down, and the heat generated during this process warms up the heap soon after it reaches a peak of 60 to 70^{0}C. At peak stage, loss of heat from the heap is more or less equal to the amount of heat generated by the micro-organisms. The peak period of heat in a heap is essential for the destruction of pathogenic organisms and weed seeds. It generally occurs after 5-8 days of heaping or pitting. The temperature in the middle of the pile goes up to 70 to 75^{0}C and gradually cools down. However, the optimum temperature is maintained at 60^{0}C during 10-15 days after pitting, then slowly comes down to about 20^0 C.

Compost thermometer may be the best way to monitor the temperature, but one may judge the temperature of the pile by merely putting his/her fist into the pile. A metal pipe or iron bar may also be inserted in the middle of the pile, periodically pulling it out and feeling it may also give an idea about the temperature of the heap. If the bar is hot or the interior of the pile feels uncomfortably warm or hot during the first few weeks of composting, one may know that everything is fine. If the temperature inside the pile is the same as the outside that is an indication that the composting process is slow. Then adding nitrogen-rich material and turning the pile may increase the decomposition rate.

Outside air temperature also impacts the decomposition process. Warmer outside temperatures during late spring, summer and early monsoon stimulates bacteria and speeds up decomposition, whereas low winter temperature slows down or temporarily stops the composting process. As air temperature warms up in the spring, microbial activity will resume or else during winter months, compost piles can be covered with polythene or a tarp to retain heat longer.

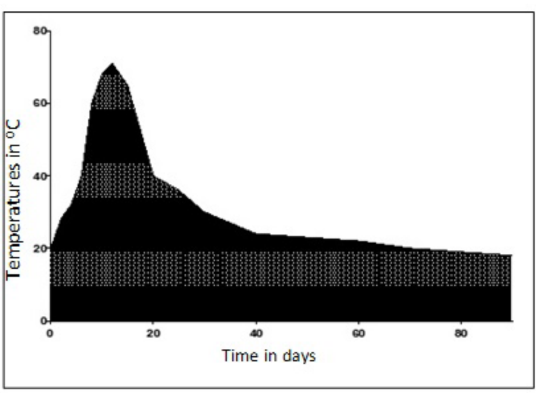

Figure 3: Temperature curve for an unturned compost pile

F. Reaction or pH

The initial pH of compost heaps is slightly acidic, i.e. around pH 6 as is found in the cell sap of most of the plants. Compost micro-organisms also operate best under neutral to slightly acidic conditions, with a pH range of 5.5 to 8. During the early stages of decomposition, organic acids are formed, and this acidic condition favours the growth of fungi and disintegration of lignin and cellulose. As composting proceeds, the organic acids become neutralised, and mature compost generally has a pH between 6 and 8.

Compost heaps are rarely too alkaline. However, in some instances when composting is highly alkaline, loss of nitrogen through volatilisation takes place. Whereas, highly acidic conditions, in the beginning, causes reduced microbial activity and the heap fails to warm up. Adding lime ($CaCO_3$) generally is not recommended because it causes loss of ammoniacal nitrogen to the atmosphere in the form of ammonia gas. This loss not only causes stringent odour but also depletes nitrogen that is better kept in the compost for future use by plants. Use of household ashes or egg shells helps in preventing too much acidity. Ashes must be used if young and succulent materials are predominately used for composting. Usually, if careful attention is paid in the making of the heap, especially in moistening the content and aeration, then acidity or alkalinity will not be a problem. If anaerobic conditions develop during composting, organic acids may accumulate rather than break down. Aerating or mixing the system reduces this acidity (Anderson *et al*., 2016).

Changes during Composting

Anything that is alive or once it was alive, constitute the organic matter, and all the sources for making compost comes from there. The plant and animal residues are primarily made up of sugars, starch, cellulose, hemicellulose, lignins, pectins, resins, proteins, fats and waxes. When these waste materials are placed in heap or pit for composting, they are attacked by a variety of macro and micro-organisms including bacteria, fungi, actinomycetes, protozoa, worms and insects larvae etc. As a result of these activities, a considerable portion of the constituent compounds available in the residues is degraded from their original complex forms to the new simple soluble forms. These degraded materials may be solids or liquids like phosphate, potassium, ammonium, nitrate, organic acids, etc. or gases like carbon dioxide, methane, hydrogen sulphide, hydrogen and ammonia. Among the organic fractions, those which readily lend themselves to decomposition are the celluloses, hemicellulose, proteins, waxes and other nitrogenous substances. Apart from this, the dark and crumbly bulk remained after decomposition of the organic matter called humus, and it forms the major portion of organic residues. The remained organic residue, or humus contains not only the remains of the organic substrate used but also dead and decomposed part of all the macro and micro-organisms which were involved in decomposition of the matter. Finally,the finished product is called the compost that may be termed as BLACK GOLD because of its nutritional advantages in replenishing the lost soil fertility.

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Chapter –IV

MANURES AND COMPOSTS

Manures and composts both contain plant nutrients in complex organic forms that release slowly into the soil after their decomposition. Their application results in the sustained supply of nutrients for longer duration besides improving soil physical properties. Manures and composts recycle the plant nutrients and they contribute back to the soil that was taken in the form of produce to consume by human being.

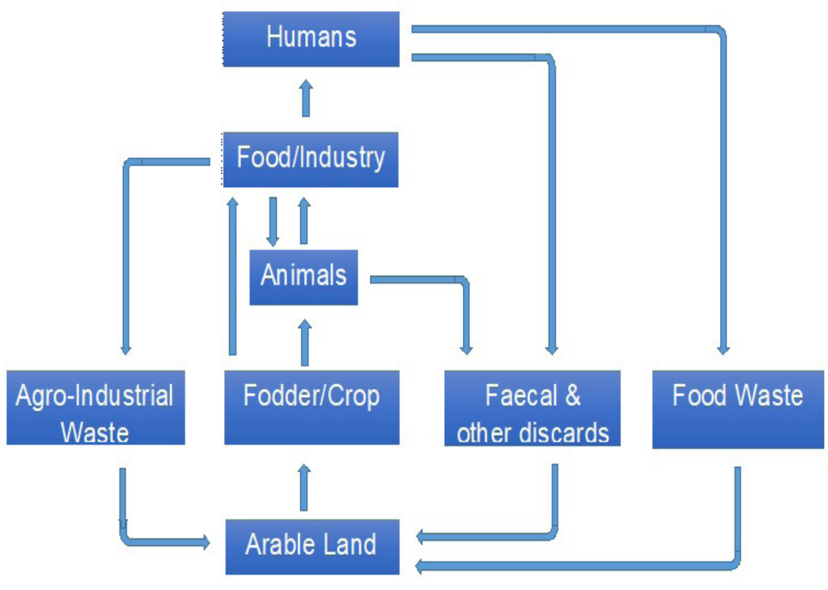

Figure 4: Recycling of nutrients

4.1 Manures:

Manures are principally excreta of farm animals mixed with plant residues offered to the animals except for cakes, brown and green manures. However, many of the slaughterhouse wastes are also utilised as manures.

Major sources of manures are (Das and Mukherjee, 2001):

i. Livestock shed wastes viz. dung, urine and slurry from biogas plants etc.

ii. Human habitation wastes viz.night soil, human urine, town refuse, sewage, sludge and sullage etc.

iii. Poultry droppings and litters etc.

iv. Slaughterhouse wastes viz. bone meal, meat meal, blood meal, horn and hoof meal, fish wastes etc.

v. Agro-industrial by-products viz. oil cakes, bagasse and press mud, fruit and vegetable processing wastes etc.

vi. Water hyacinth, weeds and tank silt etc.

vii. Brown and green manure crops and other manuring material

Manures by the concentration of the nutrients may be grouped into two major categories, bulky organic manures and concentrated organic manures based.

I. <u>Bulky organic manures:</u> Bulky organic manures are poor in nutrients, so they are required in large quantities to meet the nutritional demand of the crops. Farmyard manure (FYM), and green-manure are the most important and widely used bulky organic manures. Advantages of using bulky organic manures:

i. Bulky organic manures are required in large quantities, so they help in improving soil properties like structure, texture, porosity, water holding capacity etc.;

ii. They are a good source of micronutrients;

iii. They increase the availability of nutrients;

iv. They alter the microflora composition of the soil thus helps in controlling parasitic nematodes and fungi;

Commonly used bulky organic manures are:

a) Farmyard manure

b) Sheep and Goat Manure

c) Swine Manure

d) Poultry manure

e) Green manure

f) Green leaf manureand

g) Brown manure

Farmyard manure:

Farmyard manure (FYM) refers to the decomposed mixture of dung and urine of farm animals along with litter and leftover material from roughages or fodder fed to the cattle. On average well-decomposed farmyard manure contains 0.5 per cent N, 0.2 per cent P_2O_5 and .0.5 per cent K_2O. Urine has about 1.0 per cent nitrogen and 1.35 per cent potassium, which get wasted in the present method of preparing farmyard manure by the farmers. Nitrogen present in urine is generally in the form of urea is subjected to volatilisation losses. It is practically difficult to avoid losses altogether but can be reduced by following the improved method of preparing farmyard manure. Developing trenches to increase the absorption of nutrients available in the urine helps in increasing the nutritional status of the manure. All the available litter and refuse mixed with soil is filled and spread in the shed to absorb urine. Trenches of size 6.5 m to 7.5 m length, 1.5 m to 2.0 m width and 1.0 m to 1.25 m deep are dug. The following morning, urine soaked refuse along with dung is collected and placed in the trench. A section of the trench from one side should be taken up for filling with thedaily collection. When the section of the trench is filled up to a height of 45 cm to 60 cm above the ground then, the top of the heap is finished into a dome and plastered with cow dung and mud slurry. The process repeated for the second trench after the first trench is filled. The manure will be ready for use in about four to five months after plastering (Sankaranarayanan, 2003).

Figure 5: Finished Farm Yard Manure (FYM)

Sheep and Goat Manure

The droppings of sheep and goats have higher nutrients than farmyard manure and compost. On an average, the manure has 3 per cent N, 1 per cent P_2O_5 and 2 per cent K_2O. It is used to the field in two ways. The sweeping of sheep or goat sheds may be placed in pits for decomposition and can be applied later to the field. The nutrients available in the urine are wasted in this method. The second method is the penning of sheep, wherein sheep and goats are kept overnight in the field and urine and faecal matter added to the soil is incorporated to a shallow depth by working blade harrow or cultivator (Sankaranarayanan, 2003-04).

Swine Manure

Pig rearing is very common in the Northeastern region of India, and almost every rural household rears one or two pigs in their farm. The waste available from swine production can be converted to manure, and that can be an asset to a pork producer and agriculture when properly managed and utilised in a sustainable food production system. Swine manure contains all the essential plant nutrients that are used by plants. These include nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), copper (Cu), zinc (Zn), chlorine (Cl), boron (B), iron (Fe), and molybdenum (Mo) (Chastain, 2003). The composition and efficiency of swine manure as a source of plant nutrients depends on several factors including the feed, supplements, medications, housing system, the method of manure collection, storage and handling. An adult pig produces about 6.0 kg of waste per day having dry matter content about 10 to 12 per cent. On dry matter basis swine manure contains 8.1–11.6 per cent nitrogen, 2.58–4.38 per cent phosphorus, 2.81–5.50 per cent potash, 3.12–6.33 per cent calcium, 0.93–2.66 per cent magnesium and 1.61–3.66 per cent sodium (Evans et al.,1977). Application of swine manure increases nitrogen, phosphorus, potash, calcium, magnesium and sodium availability in soil and enhances the yields of crops and vegetables. The efficient use of swine manure can be an agronomically and economically viable management practice for sustainable in temperate regions (Choudhary,1996).

Poultry Manure

Among all animal manures, poultry manure's has long been recognised as most desirable manure because of its' high nitrogen and phosphorus content. It is mainly because solid and liquid excreta are excreted together resulting in no urine loss. Poultry excreta ferments very quickly. If left exposed, 50 per cent of its nitrogen is lost within 30 days. Poultry manure is used as a source of N, P and

K butlitter also contains Ca, Mg, S and some other micronutrients. The average nutrient content of the poultry manure is 3.03 per cent nitrogen (N); 2.63 per cent phosphate (P_2O_5) and 1.4 per cent potash (K_2O) (Kirchmann, 1985).

Green manure:

Green manure is a term commonly used to describe the group of plants or crops that are generally grown and then turned into the soil for restoring the soil fertility and increasing the organic matter content in the soil. Green manure crops usually belong to the leguminous family as the plants of this family can fix nitrogen in the soil with the help of symbiotic bacteria in their root nodules. Green manure crop can be grown *in situ* or may be brought from outside and incorporated in the soil. Green manuring crops can be cut and then tilled back into the soil or just left over the ground for degeneration. The most important green manure crops are Sunnhemp (*Crotalaria juncea*), Dhaincha (*Sesbania bispinosa*), Riverhemp (*Sesbania rostrata*), Clusterbeans (*Cyamopsis tetragonoloba*), Mung bean (*Vigna radiate*), Pillipesara (*Vignat rilobata*), and Cowpea (*Vigna unguiculata*).

Figure 6: Green manuring with Dhaincha (Sesbania)

Nutrient contribution to the soil through green manuring depends significantly on type and stage of the crop. Biomass production and N accumulation of some common green manure crops are presented in table 1, and nutrient contents are presented in table 2

Table 1: Biomass production and N accumulation of green manure crops (Organic Farming, TNAU, Agritch Portal)

Crop	Age (Days)	Dry matter (t/ha)	N accumulated
Dhaincha	60	23.2	133
Sunnhemp	60	30.6	134
Cowpea	60	23.2	74
Pillipesara	60	25.0	102
Cluster bean	50	3.2	91
New Dhaincha (*Sesbania rostrate*)	50	5.0	96

Table 2: Nutrient content and C: N ratio of major green manure crops (Sankaranarayanan, 2003)

Green manure crop	**Nutrient content (%) on an air dry basis**		
	N	**P_2O_5**	**K**
Sunnhemp (*Crotolaria juncea*)	2.30	0.50	1.80
Dhaincha (*Sesbania aculeata*)	3.50	0.60	1.20
Sesbania (*Sesbania speciosa*)	2.71	0.53	2.21

Advantages of green manuring:

1. Supplies good amount of nitrogen to the soil because most of the green manure crops belong to the leguminous family that has an association with nitrogen-fixing bacteria;
2. The deep root system of green manure crops allow cycling of nutrients that have been leached to lower layers of soil;
3. Green manuring enhances the soil aggregates stability and porosity, thus improves soil structure.

4. Green manure increases water holding capacity by covering the soil and adding organic matter;
5. Green manure also helps in reducing soil erosion as they increase the soil cover;
6. Increased soil organic matter content favours the growth of microflora and macroflora and fauna;
7. The release of organic acids during decomposition helps in solubilising stable phosphorus and make them available to the subsequent crop.
8. Green manuring helps in the reclamation of alkaline soiland minimises root-knot nematodes population;
9. They can serve as a lure crop to attract insect pests, thus helps in breaking the disease cycles;
10. Green manuring helps in reducing the weed population as they compete for resources as well some green manuring crops also releases chemicals that are allelopathic to the weeds.
11. Further, green manure crops are generally grown in the offseason, so it reduces weed proliferation and weed growth.

Disadvantages of green manuring:

1. Lack of interest of farmers;
2. Green manuring involves cost and farmers don't see any direct financial return;
3. Lesser development of breeding technologies for green manuring crops;
4. Poor availability of green manuring seeds;
5. Some green manures crops may host diseases and pests that attack the commercial crop;
6. The possibility of an adverse allelopathic effect of green manure residues on the commercial crop;
7. The possibility of competition between green manure plants and the commercial crop due to inadequate management;
8. Some green manuring crops have incompatible decomposition rates with the nutrient requirements of crops;

9. Green manure crops can utilise moisture that may otherwise be conserved during fallow;

Green leaf manure:

Application of green biomass including; green leaves and twigs of trees, shrubs and herbs collected from the vicinity are known as green leaf manuring. In the northeastern region, forest tree leaves are the main sources for green leaf manuring. Plants growing in wastelands, field bunds etc., are another source of green leaf manure. Some of the important plant species useful for green leaf manure and the nutrients available from them are summarised in table 3.

Table 3: Nutrient content of green leaf manure (Organic Farming, TNAU, Agritech Portal)

Plant	Scientific name	Nutrient content (%) on an air dry basis		
		N	P_2O_5	K
Gliricidia	*Gliricidia sepium*	2.76	0.28	4.60
Pongamia	*Pongamia glabra*	3.31	0.44	2.39
Neem	*Azadirachta indica*	2.83	0.28	0.35
Gulmohur	*Delonix regia*	2.76	0.46	0.50
Peltophorum	*Peltophorum ferrugenum*	2.63	0.37	0.50
Weeds				
Parthenium	*Parthenium hysterophorus*	2.68	0.68	1.45
Water hyacinth	*Eichhornia crassipes*	3.01	0.90	0.15
Trianthema	*Trianthema portulacastrum*	2.64	0.43	1.30
Ipomoea	*Ipomoea*	2.01	0.33	0.40
Calotrophis	*Calotropis gigantea*	2.06	0.54	0.31
Cassia	*Cassia fistula*	1.60	0.24	1.20

Brown manure:

Brown manure involves growing of a pulse crop and knocking it down by spraying any herbicide to prevent weed seed set and maximise nitrogen fixation. Brown manuring is different from green manuring. In green manuring, the crops and weeds are killed by turning them to the soil, whereas in brown manuring crops are knocked down using a herbicide. Crops suitable for brown manuring includes all the green manuring crops like; Sunnhemp, Dhaincha, Mung, Cowpea, Lentil etc.

Figure 7: Sowing of sesbania with paddy for brown manuring

Figure 8: Knocked down plants of sesbania by spraying 2,4-D

Brown manuring technique can be well adopted in directly sown rice crop where Sesbania seeds are broadcasted @ 20 kg/ha, three days after rice sowing. The crop is allowed to grow for 30 days then it is knocked down by spraying 2,4-D ethyle easter. Sesbania shreds leave in 3-5 days. These leaves supply nitrogen about 35.00 kg/ha.

Table 4. Effect of brown manuring on soil organic carbon (C) and available postharvest nitrogen (N) (Samant, 2017)

Year	Initial C content of soil (%)	C content after harvest (%)	% increase in C	Initial soil available N content (kg/ha)	Soil available N content after harvest (kg/ha)	% increase in soil available N
2014	0.54	0.69	0.15	283.0	320.2	13.1
2015	0.58	0.71	0.13	285.3	324.6	13.7
Mean	0.56	0.70	0.14	284.19	322.4	13.4

Advantages of brown manuring:

1. Enhanced soil corban status;
2. Savings in nitrogen fertiliser requirements as brown manure makes available organic nitrogen to soil;
3. Provision of organic N, which acts as a slow release form of nitrogen for following crops;
4. A manure crop fixes about 35 kilograms of nitrogen/ha;
5. Helps in water conservation, due to increasing ground cover and weed control during the growing season;
6. Other than nitrogen, available phosphorus and sulphur can also help in retaining and building soil carbon that improves soil resilience, water availability and productivity;

7. Reduces the cost of cultivation

8. After shedding the leaves, standing stems of degenerating crop acts as perch for predacious birds so helps in controlling insects.

Disadvantages of brown manuring:

1. Prolonged use of herbicide may cause herbicide tolerance in the crop;

2. Incurs additional cost as seeds of brown manure crop and herbicides.

II. Concentrated organic manures

Organic manure having higher nutrient content are termed as concentrated organic manure. In general organic manures containing nitrogen upto two per cent are included in the bulky category and those having more than two per cent nitrogen are treated as concentrated organic manure. Organic materials like oil cakes, fish meal, animal meal, poultry manures, slaughter house wastes etc. has comparatively higher contents of plant nutrients and are grouped under concentrated organic manures. These are also known as organic nitrogen fertiliser. Before the crops use their organic nitrogen, it is converted through bacterial action into readily usable ammonical nitrogen and nitrate nitrogen. These organic fertilisers are, therefore, relatively slow acting, but they supply available nitrogen for a longer period.

a) Oilseed Cakes

Oilseeds crops are cultivated for their oil content, and by-products obtained after oil extraction from the oilseeds are called oilseed cake. Oilseed cakes can be utilised either as feed for livestock and human or as a source of nutrients for the crops. Oilseed cakes are of two types, edible and non-edible. The cake obtained from edible oil-bearing seeds and has potential to meet a part of the nutritional requirement of the livestock or human are called edible oil cake, and on other hands, those cakes, which has some antinutritional factors and toxic compounds and can't be used as feedstuffs are termed as non-edible cakes.

Figure 9: Different types of edible and nonedible cakes

1. Edible oilseed cake: The cakes that can be utilised as feed stuffs for human or animals consumption are called edible cake. Oilseed cakes such as palm kernel cake, sesame cake, linseed cake and coconut cake contain 14–20 % of crude protein, where as soybean cake and groundnut cake contains 40–50 % of crude protein. These cakes are usedas feed supplements for human as well as animals; and

2. Non-edible oilseed cakes: The oilseed cakes, which has large doses of antinutritional factors and toxic compounds are not fit for feeding livestock or human consumption are called non-edible oilseed cakes; e.g., neem cake, jatropha cake, mahua cake karanja cake, castor cake, etc.

   Both edible and non-edible oil cakes may be used as manures. However, edible oil cakes are offered to cattle as feed, and non-edible oil cakes are used as manures especially for horticultural crops. Oil cakes mineralise quickly, so they release nutrients in 7 to 10 day to the crops after application. Oilcakes need to be finely powdered before application for even distribution and quicker decomposition.The average nutrient availability of different oil-cakes is presented in the following table.

Table: The average nutrient content of oil cakes (Organic Farming, TNAU, Agritch Portal)

Oil-cakes	**Nutrient content (%)**		
	N	**P_2O_5**	**K_2O**
Non-edible oil-cakes			
Castor cake	4.3	1.8	1.3
Cottonseed cake (undecorticated)	3.9	1.8	1.6
Karanj cake	3.9	0.9	1.2
Mahua cake	2.5	0.8	1.2
Safflower cake (undecorticated)	4.9	1.4	1.2
Edible oil-cakes			
Coconut cake	3.0	1.9	1.8
Cottonseed cake (decorticated)	6.4	2.9	2.2
Groundnut cake	7.3	1.5	1.3
Linseed cake	4.9	1.4	1.3
Niger cake	4.7	1.8	1.3
Rapeseed cake	5.2	1.8	1.2
Safflower cake (decorticated)	7.9	2.2	1.9
Sesame cake	6.2	2.0	1.2

Other Concentrated Organic Manures

There are many slaughterhouse byproducts; they can be utilised as manure; e.g. blood meal, meat meal, horn and hoof meal, bone meal, fish meal etc. These meals are also used in the animal feed industry. The meals unsuitable for livestock consumption can be used as manure to supplement nutrients. They are a good source of nitrogen and minerals.

Figure 10: Different (Blood, Bone, Fish & Meat) kinds of meals

The average nutrient content of animal-based concentrated organic manures is givenin the following table.

Table: The average nutrient content of animal-based concentrated organic manures (Organic Farming, TNAU, Agritch Portal).

Organic manures	**Nutrient content (%)**		
	N	**P_2O_5**	**K_2O**
Blood meal	10 - 12	1 - 2	1.0
Meat meal	10.5	2.5	0.5
Fish meal	4 - 10	3 - 9	0.3 - 1.5
Horn and Hoof meal	13	-	-
Raw bone meal	3 - 4	20 - 25	-
Steamed bone meal	1 - 2	25 - 30	-

4.2 Composts:

Compost is a mixture of properly decomposed organic matter that can be used as a supplement for soil conditioning and supplying the nutritional requirements of the crops. It helps in better plants growth and enhances the yield of the crop. Crop residues, kitchen and farm wastes currently make up about 30 to 40 per cent of our daily trash, which we throw away. If these composted then at least it can meet the half of the nutritional requirements of the crop and keepingthese materials out of the landfills will help in cutting off the production of potent greenhouse gas, the methane.

Composting is the process of physical, chemical, and biological decomposition of large, bulky, coarse organic waste of plant or animal origin to a dark brown or black coloured, homogenous, brittle particulate. The matter obtained through this is called compost that can be used as a soil conditioner and source of nutrient to the plants. It naturally fortifies the soil and helps in enhancing the productivity of the soil.

Nutritive value of the compost depends upon the substrate used for composting. The compost prepared from farm waste like sugarcane trash, paddy straw, weeds and other plants and other farm waste has average nutrient contents as 0.5 per cent nitrogen, 0.15 per cent phosphate and 0.5 per cent potash.The compost prepared from town refuses like night soil, street sweepings and dustbin refuse etc. contain 1.4 per cent nitrogen (N), 1.00 per cent phosphate (P_2O_5) and 1.4 per cent potash (K_2O).

Traditionally farm compost is made by placing farm wastes in trenches of variable sizes. Size of the trenches depends upon the quantity of the waste available for composting. Generally, 4.0 m to 5.0 m long, 1.5m to 2.0 m wide and 1.0 m to 1.5 m deep trenches are preferred. Available farm waste may be chopped to approximately 10 – 20 cm as chopping increases the surface area for microbial degradation. The chopped mass is placed in the trenches layer by layer. Each layer is moistened adequately by sprinkling cow dung slurry or water. Use of cow dung slurry adds additional nutritive value and also enhances decomposition rate. Trenches are filled up to the height of 0.5 m above the ground, and then it is left for decomposition. Sometimes water is also sprinkled over the decomposing mass for maintaining the moisture loss. In trenches improper or reduced oxygen supply restricts the decomposition process that lengthens the duration of composting.Compost becomes ready for application within five to eight months.

Composting is basically a biological decomposition of organic residues, however physical and chemical treatment is given to hasten the process. Depending upon composting methods, there are different kinds of compost and each has their advantages and disadvantages. These methods are as follows:

1. Pit Manure/Anaerobic Compost
2. Coimbatore method
3. Indore method
4. Bangalore method
5. NADEP Composting
6. Vermicompost
7. Vermiwash
8. Biodynamic composting
9. Biodung composting,
10. Padegaon method,
11. Biogas-slurry method,
12. Azolla compost
13. In-vessel composting
14. Spent Mushroom Substrate (SMS)
15. Humanure

1. Pit Manure/Anaerobic Compost

Compost making in pits is the most common method practised in rural India. Length and width of the pit vary with the quantity of refuge produced in the farm and household, but usually, depth is kept about 0.75 to 1.0 m. This method had been prevalent primarily because it requires least investment and labour and secondly all kinds of degradable waste can be dumped in the pit for making compost.

Figure 11: Pit composting

At the time of pit filling, aerobes are common micro-organisms present in the compost heap, and they need oxygen to grow, multiply and decompose the waste materials. But when there is insufficient oxygen supply in a pit, these aerobic micro-organisms can't survive, and they eventually die. After the death of aerobes, the decomposition process is taken over by micro-organisms called anaerobes, and they produce anaerobic compost. Nitrogen-rich materials are better for anaerobic composting, but almost any organic material can be processed including waste paper and cardboard, grass cuttings, left over food, animal slurries and manure, etc. The substrate with a lot of dry matter and high in corban is not preferred. In pit method decomposition is mostly anaerobic as composted mass is not turned regularly, which also leads to compaction. Usually, compost becomes ready for application in 6 to 8 months in this method but, quality of the compost is also very inferior. Presence of pathogens and weed seeds are the major disadvantage of this compost as they may not be killed, because anaerobic composting is a low temperature process. They may slowly become inactive due to a hostile environment and may not the potentially harmful.

2. Coimbatore method

In this method, pits are prepared in the shaded area. Size of the pit depends upon the volume of organic waste available for composting, however, a pit of 3.5 × 1.8× 1.0m is preferred. A layer of farm wastes such as straw, vegetable refuse, weeds and leaves are spread to a thickness of 15-20 cm, then 5 cm thick layer wet cow dung is spread over it. Water is sprinkled over it to moisten the material. The process of filling the pit alternatively with farm waste and dung is repeated till the height of the material rises 60-75 cm above ground. After filling the pit, entire mass is covered with mud and plastered to facilitate anaerobic decomposition commences. In six to eight weeks matter partially decomposes and heap flattens. At this stage mud plaster is removed and the entire mass is turned, moistenedandleft for aerobic decomposition. The compost becomes ready to use in about four to six months.

3. Indore method

Indore method was developed by Howard and Wardin (1931) in Indore (M.P) in India. Hence it is called the Indore method of composting. Length of the pit depends upon the waste available for composting; however, depth is kept as one meter, and width varies in between 1.5 to 2.0 m. The raw materials for making compost in this method includes plant residues, animal dung and urine, soil, wood ash and water. All organic wastes available on the farm; like crop residues, weeds, leaves and pruned part of the plants, and leftover fodders, are collected as a heap. Soft and succulent material are allowed to wilt to reduce moisture before stacking.

The pit is filled with 6-10 cm thick layer of organic wastes followed by 6-10 cm thick layer of urine soaked material along with dung and a thin layer of wood ash, soil and well decomposed old compost. Old compost acts as inoculum and hastens the decomposition process.These three sublayers together make a single layer and filled by 5-6 such layers fill the compost pit. At every 15 days interval, the composted material is turned to ensure proper decomposition. Water is mixed to moisten the material after each turning. Compost becomes ready for application in about four months.

4. Bangalore method

C. N. Acharya primarily develops Bangalore method of composting in 1939 for safe composting of night soil and refuge. In this method, the refuse and night soil put in the pit. Length and width of the pit depend upon the quantity of material to be composted, and depth is kept about 0.9-1.2 m. The pit is filled alternately with night soil and refuse, and its level is raised 0.5 m above the ground. It is left uncovered for 15 days. During this period the material settles down and additional refuse and night soil is placed on the top then turned, moistened and plastered with wet mud. Filled and plastered pit left undisturbed for about 4-6 months. This system of composting provides aerobic conditions during initial days, and aerobic decomposition causes the rise in temperature for the first few days, which is retained for about 15 days, which helps in killing the pathogens and controlling the foul smell. After turning and sealing with mud anaerobic decomposition starts. The anaerobic decomposition is a slow process and takes 4-6 months to complete breakdown of organic matter.

5. NADEP Compost:

The NADEP method of composting was developed by a farmer from Yavatmal district of Maharashtra, N D Pandharipande, who was popularly known as "Nadep kaka". In NADEP word NA stands for Narayan, DE for DEverao and P for Pandharipande. Being simple and ease in making compost, the method became very popular among the farmers and termed as NADEP composting method using initial letters of his name. Nadep kaka was decorated with the Ramabai Parkhe Award of Maratha Chamber of Commerce, Pune in 1983 for his contribution.

NADEP composting is aerobic decomposition of organic wastes placed in layers. The process involves filling of diverse compostable material in layers in specially designed pits. It helps in faster decomposition of organic waste as the design of the pit allows better aeration of composted waste. The quality of the compost depends basically on the type and ration of the substrate used for composting.

Figure 12: NADEP Tank

The NADEP tank can be prepared as a permanent structure using brick, cement and sand or as a temporary structure using mud instead of cement and sand. The rectangular brick tank is constructed with maintaining enough space, i.e. honeycomb structure, for aeration between the bricks. Size of the tank prepared varies in length ×breadth × height, but 3 × 1.8 × 0.9 m is the preferred size for NADEP tank. However, if more material is available for composting, then length may be further extended, but it is advisable not to increase breadth beyond 1.8 m. In making tank if mud has been used as mortar, then it is advisable that first two layers of brick should be done with cement to provide more structural stability and securing the structure from damage during filling and clearing the tank.The location of the tank is of utmost importance. Construction of the tank in the low lying area should be avoided. It can be placed at the high elevated area near some water source and preferably under the tree. The tank should be placed squarely in the direction of the wind. Old brick bats can be hammered, or a layer of bricks can be laid in the bottom of the tank to avoid seepage loss.

Materials suitable for composting include crop residues, dried husk, twigs, stalks, roots, leaves, dung, biocompost slurry, urine-soaked bedding material of livestock farm, well-filtered earth from irrigation channels, urine soaked earth form livestock farm etc. and water to moisten the organic wastes while filling them in layers.

While filling the tank care should be taken that it should be filled in one go and sealed within 24 hours. Before charging the tank with the materials, it is advisable to wet the inner walls and the tank bed with cow dung dissolved in water. After that, the first layer of plant waste of about six inches is filled. Above this, a mixture of 5-8 kg cow dung in about 80-100 litres of water is sprinkled. If biogas slurry is available then instead of cow dung, it can be used. The quantity of water utilised depends upon the season of the year and moisture percentage in plant waste being filled. If the moisture content is high in organic waste, water requirement will be less or vice-versa.

Figure 13: Filled of NADEP Tank

Further, more water is required in summers than rainy or winter season.After the layer of cow dung, organic waste is covered with alayer of about 50-60 kg clean, filtered soil. Water is again sprinkled on it to maintain the proper moister content of the filled mass. After that, the tank continues to be filled with this series of layers in the same sequence. During the process of filling, it is advisable to put 2 to 3 bamboo logs vertically in the middle of the tank having one-meter distance from each other. These logs are removed generally after a month from filling the tank. The hole created after removing the logs helps in aeration and moistening the organic mass. Level of the filled mass is raised about one and a half feet above the rim of the tank. Usually, a tank can take 8-10 such series of layers. Once the filling is completed, then the tank is sealed with either mud or mixture of mud and cow dung. Care should be taken to avoid cracking of the plaster and if cracks appear the same may be plastered again with liquid cowdung slurry.

Figure 14: Mud plastered NADEP Tank

With the commencement of microbial action decomposition of organic matter begins. This results in shrinking and material will shrink down below the tank rim is a period of 15 to 20 days. The tank should be opened and filled again in the same sequence of layers up to a height of 30 - 45 cm above the tank rim. Once again, the material should be covered with 6-8 cm thick layer of soil and sealed with liquid cowdung slurry. Level of filled mass is kept higher at the centre from the rim to avoid gathering of water in the middle either due to rains or during moistening. Accumulation of water may cause rotting instead of decomposing the mass.

Moister level of 15-20% is maintained to facilitate proper decomposition. Water may be sprayed through the holes on the tank sides and middle to maintain proper moister level. The entire tank can be covered with a thatched to prevent moister loss due to evaporation and the same time it also protects from rains. At no time compost be allowed to become dry, and cracks should not be allowed to develop and if the cracks develop same may be filled up with slurry. Grass that sprouts should be removed regularly.

Depending on the composting matter and way of preparation, the compost becomes ready in between 90 to 120 days. Status of compost can be checked from the side holes. When the composted mass turns to deep brown coloured crumbly particulate matter having a pleasant smell, then the tank may be opened as compost is ready for application. Compost may be removed for application. Each tank can be used for thrice in a year.

Figure 15: Finished and packed NADEP compost

6. Vermicompost:

Vermicomposting is a method of composting, where earthworms are used to digest and decompose the organic material. Earthworms, which generally lives is carbon-rich soils are used in making vermicompost. They eat organic biomass and excrete nutrient-rich castings, which is used as a fertiliser and soil conditioner. The digested organic matter excreted as worm casting is rich in humus and contains readily available plant nutrients. While passing from the earthworm's intestine, many of the pathogens and weed seeds also get destroyed, and same time various enzymes and digestive juices released during the digestive process also come along with the cast. Further, the remains of worms after completing their life cycle also get mixed with the final product. These all enrich the compost and makes it more worthy to farm.

There are about 4,400 identified earthworm species, but only a handful of them are ideal for recycling organic waste. Earthworms can be classified into three ecological categories – anecics, epigeics and endogeics. The anecics and endogeics are known soil dwellers and may dramatically influence thesoil properties and processes at the ecosystem level, however, the functional role of epigeics is primarily that of litter transformers, like other litter invertebrates (Lavelle 1997). Thus these epigeic earthworms are useful for vermicomposting.

Anecics (Gk-up from the earth) are dominant earthworms in many temperate region soils, (Lavelle 1983) are primarily vertically burrowing species. The burrows of these species may reach up to 3 m into the ground. They usually come to the soil surface only at night in search for decaying material like leaves.They pull their food down into their burrows and feed on it in the safety of their home. The feeding and casting habits of anecics may deeply influence soil characteristics up to >1m depth. Anecics are the largest worms on the earth and may grow several meters long. *Lumbricus terrestris* and *Apporectodea longa* are the typical examples of Anecic earthworms.

Epigeics (Gk-upon the earth) live virtually above the soil in the top 10 to 20 cm depth. They feed on decaying plant residues, dung and other animal waste.They are usually brown or red, which serves as camouflage and helps them to protect from their natural enemies. They consume, comminute and partially digest surface litter and rarely ingest soil particles. Epigeics feed purely on litter and generally have a short gut, so they greatly depend on a rapid response of gut microbes for fast digestion. Epigeic earthworm guts preferentially stimulate some microorganisms and reduce others that leads to a relative dominance of specific microorganisms that found in uningested soils. Examples of this group include *Dendrobaena octahedra, D. attemsi, D. rubidus, Eiseniella tetraedra, Eudrilus eugeniae, Heliodrilus oculatus, Lumbricus rubellus, Perionyx excavatus, Perionyx arbicola and Eisenia fetida.*

Figure 16: Earthworm *Eisenia fetida*

Endogeics (Gk-within the earth) live in the upper layers of the ground and feed on the organic matter in the topsoil. They dig horizontal burrows when moving through the soil and rarely come to the surface. They are the most common earthworms (in biomass) in most tropical environments (Lavelle 1983). Endogeics are geophagous earthworms that feed on subsurface soil horizons. Their casts generally have more clay and organic matter than uningested soil. They help is releasing significant amounts of nutrients and NH^4 in the soil. This group include *Allolobophora chlorotica, Apporectodea caliginosa, A. icterica, A. rosea, Murchieona muldali, Pontoscolex corethrurus and Lampitom auritii.*

Among all the earthworms, the epigeics are the only ones that can be used commercially in vermicomposting. *Lumbricus rubellus*, *Eudrilus eugeniae* and *Eisenia fetida* are the common worms, which are being used commercially in vermicomposting. Among them, *Eiseniafetida* can be held in captivity. It feeds heavily on the rich organic matter like kitchen scraps, garden waste or compost and multiplies rapidly, these all factors make this worm an ideal choice for vermiculture.

Almost all types of non-toxic organic matter, which are biologically degradable and decomposable can be used for vermicomposting, e.g. straws of cereals, pulses and oil crops, maize stalk, dry leaves, kitchen waste, pig manure, poultry droppings, rabbit manure, partially decomposed dung of cow, buffalo, mithun, etc. Composting materials should be screened for stone, metal, plastic, glass or any other non-decomposable materials. After cleaning the decomposable materials should be chopped into small pieces of 5-10 cm and to avoid unwanted organisms and foul smell materials are exposed to the sunshine for 1-2 days.

There is no shape, size or style specification for the vermicompost unit. It can be prepared in raised heaps above ground, in concrete tank or pits, in low-costlocal made bamboo structures, in precast cement rings, or in any such other containers, but covering with a shed over the structure is a must to avoid direct exposure to sunlight and rains.

Figure 17: Vermicompost unit made of bricks

Figure 18: Vermibag made up of polythene

The procedure adopted for vermicomposting is as follows:

- Spread 20-30 cm thick layer of composting material (tree leaves, farm or kitchen refuge etc.) for aeration.

Figure 19: Different types of substrates for vermicomposting

- Above that layer spread partially decomposed dung (20-30cm thick) of about 1-2 months old (Use of fresh dung is not advisable as it starts microbial decomposition and raises the temperature of compostable material).

Figure 20: Partially decomposed mithun dung

- Compostable material is sufficiently moistened and left for 15-20 days.
- Earthworms are introduced in it after 15-20 days at the rate of about 2-3 kg earthworms per ton of biomass or 1000 numbers of earthworms per sqm area.

Figure 21: Inoculation of earthworms

- After introducing the earthworms another layer of feeding materials, i.e., kitchen waste, crop residues, cattle dung etc. are added.
- The whole mass is covered with gunny bags to prevent birds from picking the earthworms.

Figure 22: Covering with gunny bag

- Maintaining moister up to 50-60% is advisable for the rapid growth of worms and faster decomposition. So, depending on the temperature and humidity, watering should be done to maintain proper moisture level.
- Feeding materials may be added weekly, and it should be turned fortnightly to facilitate proper aeration to the bin.

Figure 23: Weekly addition of substrate and turning

- The whole biomass is converted to vermicompost in about 2-3 months.
- When the mixture becomes brownish or blackish brown, and there does not remain any odour of dung, then the vermicompost is ready.
- Hence, adding feeding material and watering should be stopped, which will result in the migration of worms to the lower layers.
- Remove the compost, separate the worms and keep the material in the shade for drying. The final product Vermicompost is granular and looks like tea leaves.

Figure 24: Sieving of finished vermicompost

Figure 25: Finished product

- Sieve out the compost and fill in the plastic bags for use.

Figure 26: Finished and packed Vermicompost

- After sieving, the remained material has a good number of cocoons, so it can be used as inoculum for next pit or remained material may be moistened and kept separately in the shed for another 20-25 days. Each of the cocoons has 1-20 eggs, and that may develop into young earthworms in 2-3 weeks. These young ones can be separated and may be used as inoculum. Cocoons of earthworms are required to produce new young earthworms that replace the aged one. These cocoons must be saved to multiply the earthworms. Hence, the utilisation of suitable mesh size sieve is essential (Murali, 2011).

Figure 27: Cocoons and vermicules

- 3 mm mesh size sieve is better as nil or fewer numbers of cocoons can pass from the sieve during sieving (Murali, 2011).
- The number of worms shall also be increased by 20-30 times from the number introduced earlier. The same may be collected and released in other prepared bins.
- Ants, termites, flatworm, centipedes, rats, pigs, birds, etc. are important natural enemies of vermiculture, so preventive measures must be taken to avoid the loss.
- Mixing of neem cakes @ 30 g/ 1kg food while filling the beds helps in keeping away the natural enemies.
- Small furrows can be made, and water should be filled to avoid the loss from ants, termites and centipedes.
- Covering with gunny bags keeps the birds away from them.

Nutrient Content of Vermicompost (%): Though availability of nutrients greatly depends upon the kind of substrate used for making vermicompost, but the average content may as follows:

1. Nitrogen (N): 1.5-3.0
2. Phosphate (P_2O_5): 1.5-2.5
3. Potash (K_2O): 1.5-2.0

7. Vermiwash:

Vermiwash is a liquid plant growth regulator, which contains a high amount of enzymes, vitamins and hormones like auxins, gibberellins etc. along with macro and micronutrient used as a foliar spray.

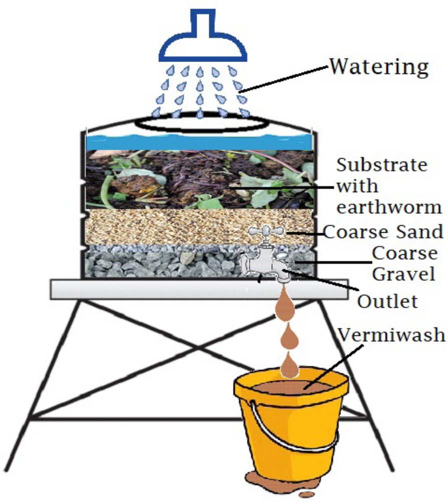

Figure 28: Diagramatic representation of a vermiwash unit

A container (concrete/plastic) with a small hole at the base is used for making vermiwash. A layer of gravel/broken pieces of bricks is placed at the bottom of the container to the height of 10-15cm above which another layer of coarse sand (10cm) is placed. A layer of farm wastes and cowdung in the ratio of 1:1 is added to the container, which is followed by the release of earthworm species like *Eisenia foetida, Eudrilus euginiae, Perionyx excavatus* etc. Above which dry straw is to be added, and watering is done. After about ten days vermiwash starts forming in the container and that can be collected through the outlet.Vermiwashcan be used fresh or may be stored for a few days. It can be diluted with water and sprayed to the plants or may be directly drenched to the plant.

8. Biodynamic composting

Biodynamics, derived from two Greek words, bios (life) and dynamos (energy). In this method of farming, farmers treat the farm as a living system, where plants interact with the cosmic energy, environment andsoilto produce food that nourishes, vitalises and helps to develop dynamic and strong societies.

Biodynamic composting is based on esoteric concepts drawn from the ideas of Rudolf Steiner developed in 1924 (Lejano et al., 2013). It emphasises on the holistic understanding of the interrelationships between soil fertility, plant growth, and livestock care. In this method fermented herbal and mineral preparations are used as compost additives and field sprays. Biodynamic preparations described by Steiner are used to make biodynamic compost. The biodynamic (BD) preparations are numbered from 500 to 508. The BD 500 and 501 are the field preparation, whereas BD 502 to 507 are compost preparations. However, BD preparation 508 had antifungal property and used as preventive and curative measures against the fungal problem.

The BD 500 preparation (cow horn-manure) is made from cow manureby filling the horn of a cattle with cow dung manure and burying it 40 to 50 cm below the surface in the ground in the autumn. It is leftfor decomposing for six months and recovered after winter. It is used as a soil spray to stimulate root growth and humus formation. The BD 501 preparation may be prepared by stuffing a horn of the cow with crushed and powdered quartz and burring the same into the ground in spring. The buried horn is taken out in autumn. One tablespoon of this quartz powder can be dissolved in100 litres of water and may be applied as a foliar spray to stimulate and regulate plant growth.

Compost preparations BD 502 to 507 are used for preparing compost. Various kinds of herbs, which are frequently used in medicinal remedies employed to make these preparations. Details are as follows:

502: Yarrow (*Achillea millefolium*) flowers are dried and stuffed into urinary bladders of the stag (*Cervus elaphus*) and placed in the sun during summer. The stuffed urinary bladder is kept in the earthen pot and buried in earth during September and retrieved in March. It helps plants for better absorption of trace elements.

503: Chamomile (*Matricaria chamomilla*) flowers are dried and stuffed into small intestines from cattle. Filled sausagesare stacked in bundle and place in earthen pot, which is buried in the humus-rich earth in October and retrieved in February/March. This preparation helps in stabilising Nitrogen (N) within the compost and stimulates plant growth.

504: Stinging nettle (*Urtica parviflora*) plants in full bloom are stuffed together into terracotta pipes or earthen pots and bury the same underground surrounded by peat for a year in September. The preparation helps in stimulating soil health and enhances the nutrient absorption capacity of the plant.

505: Oak (*Quercus glauca*) bark is crushed and placed inside the brain cavity of the skull of a domesticated animal. Bury the skull in a watery environment with weeds and plant mulch or peat in September. It is retrieved in March and on retrieval there will be foul smell and fungal growth, which goes off on drying in dark and dry place. It helps in combating harmful plant diseases.

506: Dandelion (*Taraxacum officinale*) flowers are wrapped into the mesentery of a cattle and tied with a jute thread. The wrapped parcel is placed into an earthen pot filled with the properly mixed soil and compost. The pot is buried in earth during September and retrieved in March. This preparation helps in simulating relation between Si and K.

507: Valerian (*Valeriana officinalis*) flowers are ground with a mortar and pestle. The paste obtained is mixed with water in 1:4 ratio and stored in a cool place. This preparation helps in better utilisation of Phosphorus in the soil.

Finally, there is BD preparation 508 used as a foliar spray to suppress fungal diseases in plants. It is prepared from the silica-rich horsetail plant (*Equisetum arvense*) or Casuarina.1 kg dried Horsetail herbis boiled in 10 litres of water for 2 hours and kept for two days then the decoctum obtained is filtered and stored for future application. 50 ml of decoctum/tincture is diluted in 10 litres of water and sprayed onto the soil or over the plants during the early growing stage. It is effective against mild fungus and sooty mould problems.

Composting process: The biodynamic compost is prepared as a surface heap rather than in a traditional pit. Elevated, flat, dry and away from tree shade site is selected for making the heap. A rectangular piece of land as per the quantity of compost required is marked and a set of logs or PVC pipes placed in the middle to facilitate proper aeration of the pile. A layer of 15-20 cm thick, dried and green biomass is stacked alternatively to make the pile for composting. After 2-3 layers soil from the fertile plot and cow dung slurry may also be added, along with it crushed rock phosphate and slaked lime is added in the middle layer to hasten the decomposition process and to supplement the mineral content. Stacking of the pile is done for about 1.00-1.25 meters high. After the compost pile is done, BD preparations 502−506 are tactically placed 5−7 feet inside the pile, in holes poked about 30-40 cm deep. Preparation No. 507, or say liquid valerian, is applied to the outside layer of the compost pile by spraying or hand watering.

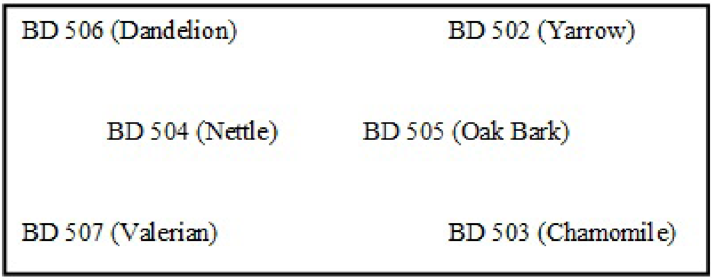

Figure 29: Placing of BD preparation in the pile

Once stacking is completed and the pile is charged with BD preparations, it is sealed with the paste made from clay and cow dung. Pile is watered regularly through the holes made for aeration and watering. If any crack appears in the plaster same is sealed to avoid rotting or drying. Piled material decomposes in about 2-3 months. At the end of this time, the compost is tested for its readiness. Readied compost smells like forest soil, which indicates that the degradation is almost complete and that the compost is ready to use. Alternatively while preparing NADEP compost BD preparations, 502−507 can also be used to get biodynamic compost.

9. Biodung composting

Biodung composting is the combination of partially aerobic and partially anaerobic decomposition. This method was developed at the Centre of Science for Villages, Datapur, Wardha by Priti Joshi in 1996. In this method, weeds were used in the preparing the biodung compost. In this method, a systematic heap of 1 x 0.5 x 1 m is prepared by stacking the biomass in definite layers. Cow dung solution is sprinkled over each layerof the biomass. 5-6 layers of biomass are place done over another to make a heap. The heap then covered with black polythene sheet for retaining optimum temperature level (40 to 55 °C for 15 days). The temperatures may reach as high as 60^0C to 65^0C as decomposition starts. At this temperature, most of the parasites and pests and viable seeds of weeds get destroyed. As temperature goes down in about 30 days, this composted material can be used for vermicomposting. Biodung composting is generally applied as a prerequisite to vermicomposting.

10. Padegaon method

The padegaon method is recommended for composting of hard to digest substrates like sugarcane trash and cotton stubbles. These materials are shredded into small pieces of about 30 cm and flattened to make a 30 cm thick and about 2 meter wide layer above the ground. Length of the layer depends upon the quantity of raw material available. The layers are drenched with the slurry prepared by mixing of wood ash, cow-dung and soil from a fertile field. Four to five such layers are added to the pile. Finally a heap of about 1.5 m high in raised and kept for decay. As the substrates used are very resistant to decay, the heap is turned each month and after turning it is trampled again. Water is added in sufficient quantity to keep the material moist. The material decays in 5-6 months and becomes ready for use. The padegaon compost compares very well in composition with farmyard manure (Arakari et al., 1962).

11. Bio-slurry method

Biogas plants anaerobically digest cow dung, farm waste and other biodegradable materials to produce preciousamounts of combustible gas, known as **'biogas'**. At the household level, this biogas can be effectively used in gas stoves for cooking and lamps for lighting. Biogas produced in large digesters can be used for running engines, motors or filling biogas cylinders. The residue emanating from the biogas plant is known as **'bio-slurry'**.

Figure 30: Bio-Slurry emanating from biogas unit

It can be easily collected and used as a potent organic fertiliser for crops and aquaculture. In India biogas has replaced dried dung cakes for cooking and the bio-slurry has a distinct added value as it can still be used as fertiliser (Bonten et al., 2014).

Bio-slurry is rich in nitrogen (N), phosphorous (P), potassium (K), and several micronutrients. The content of these plant nutrients varies with the type and nature of feedstocks used for the production of biogas. The digested slurry discharged from the biogas plants normally contains 92–94 per cent moisture whereas in the case of solid-state biogas plants, the moisture content varies between 88–90 per cent (Hazarika et al. 2015). The average nutrient and organic matter content of the bio-slurry is given in Table 1.

Table 1: Average nutrient content of bio-slurry (Hazarika et al. 2015)

S. No.	Name of Nutrient	Average Content
	N	1.8%
	P_2O_5	1.0%
	K_2O	0.90%
	Mn	188 ppm
	Zn	144 ppm
	Fe	3,550 ppm
	Cu	28 ppm

	C/N ratio	10–15
	Organic matter	65%

12. Azolla compost:

Soil health directly influences the growth and production of the crops. The health of the soil depends on anoptimum combination of organic and inorganic components of the soil. Regular use of chemical fertilisers adversely affects the soil biota and destroys them. There are many useful soil micro-organisms present in the soil, which can help plants to get nutrients. In this context in addition to all biofertilizers agents, Azolla also plays an important role. It acts as a nitrogen-fixing factory in standing crop.

Azolla, a small free-floating water fern, is available naturally on moist soils, the water surface of flooded rice fields, small ponds and canals. Its size is about 1.5-3.0 cm in length and 1.0-2.0 cm in breadth. Roots of Azollae manates from growing branches and remains suspended in water. It has some exciting attributes to be used as an aquatic green manure plant as well as animal feed.

Figure 31: Azola (*A. caroliniana*)

Azollahas a symbiotic relationship with an N-fixingblue-green alga *(Anabaena azollae)* thus can fix atmospheric nitrogen into the soil and has the potential of providing 30-60 kg N/ha under normal field conditions. It can be grown on any closed body of water. Azolla being palatable and high in protein and minerals can be used as a feed to chickens, pigs, goats, ducks and cows.

Worldwide seven different species of Azolla have been identified. Out of them, *A. pinnata* is widely available throughout the Asian subcontinent and can be easily collected from ponds and ditches. Besides this, some better species like *A. caroliniana* can also be grown successfully particularly in NE India.

Conditions for Azolla growth: Water depth of 10-15 cm is necessary for multiplication of Azolla. Slightly acidic soil having pH of 5.2 to 5.8 is good for the growth of Azolla. It prefers partial shade and can grow well at a temperature of 15-30^{0}C. All these conditions are available in rice fields, therefore as double cropping of Azolla with rice may be the most successful. Naturally, it can be seen growing in the rice field in NE region of India as soils are acidic.

Cultivation practices of *Azolla caroliniana*: Cultivation of *A. caroliniana* is detailed as follows:

- Dig out a pit of the size 2×1×0.20 meter and level the pit.
- Place a lining of good quality polythene to restrict percolation of water.
- Raise the bund all around the pit and maintain the water depth of about 10-20 cm
- Add 10 gm rock phosphate plus 200gm of dried powdered cowdung in the water
- Inoculate 300-400 gm of fresh *A. caroliniana* in the pit
- Leave it for multiplication for 15 – 20 days until a thick mat of Azollais formed.

- By this time there will be an increase in fresh biomass to the tune of 8 -10 times.

Figure 32: Azolla cultivation in LDPE/Cemented tanks

Composting of Azolla: Fresh Azolla can be collected from fields and ponds on the bunds and left for a day to drain the water. After draining the water, Azolla is stacked in a shaded area for 15-20 days. Since Azolla has an excellent carbon-nitrogen ratio, so it decomposes rapidly and converts into high-value compost within this period. On maturity Azolla compost has moisture about 20-25 per cent, Nitrogen (N) 2.60-3.50 per cent, Phosphate (P_2O_5) 0.60-0.70 per cent and Potash (K_2O) 2.80-4.00 per cent.

Figure 33: Packed Azolla compost

13. In-vessel Composting (IVC)

In-vessel Composting is a way of disposing of organic refuse in large batches. It generally defines a group of methods that confine the composting materials within a building, container, or vessels. In-vessels take up less land, process organic waste faster and can handle a much more extensive array of substrates. This technique is generally used for handling waste from food, meat, and fish processing industries, municipal sewage biosolids, field and garden waste etc. It allows large-scale organic waste processing to a safe and stable product suitable for reclamation as a soil amendment.

IVC ensures that the composting takes place in an enclosed environment, with proper temperature, moisture, and airflow control and monitoring. There are many different IVC systems, but they can be broadly categorised into six types: containers, silos, agitated bays, tunnels, rotating drums and enclosed halls. These may be comprised of metal or plastic tanks or concrete bunkers in which air flow, moister and temperature can be controlled, using the principles of a “bioreactor”. Generally, the air circulation is maintained through in via buried tubes that allow fresh air to be injected under pressure, with the exhaust being extracted through a biofilter, with temperature and moisture conditions monitored using probes in the mass to allow maintenance of optimum aerobic decomposition conditions. Decomposition occurs at a faster rate than the conventional composting processes, and the compost becomes readywithin a few weeks or month.

IVC system can also be integrated with anaerobic digestion. In this approach batches of organic material are first subjected to anaerobic digestion in the container/vessels and then later in the same bioreactor the process is switched to composting through the use of forced aeration.

14. Spent Mushroom Substrate (SMS)

Mushrooms the fleshy, spore-bearing fruiting body of the fungus are well known for their delicacy, nutritional and medicinal values, but the substrate left after the harvesting of the crop better known as ‘Spent Mushroom Substrate’ also have great importance. The substrate for mushroom growing is prepared by controlled fermentation from agricultural, poultry and industrial wastes. Primarily it is used for mushroom cultivation, and the spent substrate obtained after crop harvest possesses all essential attributes of organic manure and if this is not appropriately handled may create various environmental problems and become a nuisance.

The re-composted spent mushroom substrate has been found to be an excellent growing medium for the majority of the vegetables and the crops and has shown multifaceted utilities in improving the yield and quality of the crop, and management of the diseases, which is encouraging for the mushroom industry. The other utilities of the spent mushroom substrate, like in vermicomposting, bioremediation and as organic-mineral fertiliser are boon to the country's farming system (Ahlawat and Sagar, 2007).

Bioremediation of contaminated soil: SMS adsorbs the organic and inorganic pollutants from the soil. It also harbours diverse category of microbes that have capabilities to break down organic xenobiotic compounds biologically. The actinomycetes (*Streptomyces* spp. and *Thermomonospora* spp.) present in SPS also have strong pollutants catabolising capabilities that help in reducing pollutants level in the contaminated soil after incubation with SMS.

Nutritional composition of SMS: Nutrient status of SMS changes with withering. It contains Nitrogen (N) 1.9%, Phosphate (P) 0.4% and Potash (K) 2.4% before weathering, however after weathering for 8-16 months status changes to Nitrogen (N) 1.9%, Phosphate (P) 0.6% and Potash (K) 1.0 %.

Re-composting Methods: SMS being rich in organic matter and nutrients help in improving the soil carbon, neutralises acidic soils and support plant growth. It not only improves the fertility of the soil but also enhances water holding capacity, porosity and texture on applying as manure. Re-composting of SMS is done to improve its phyico-chemical propertiesfor using it as manure. Following three methods are generally employed for re-composting SMS.

Natural: In natural weathering process SMS is stored in the pits of about 1.25×1.25×1.25 meters and left for anatural weathering. It takes about 1 to 2 years for complete weathering.

Aerobic: A pits with the perforated base of about 1.25×1.25×1.25 meters is prepared. Generally, waste wooden logs are used in the base to achieve perforation. The perforated bottom of the pit is connected perpendicularly with 5 cm diameter hollow plastic pipes placed at a distance of 30 to 40 cm. Holes of about 2 cm diameter at a distance of 15 cm each in a circular fashion are also made on the pipe inserted perpendicularly for facilitating better aeration. The pit is filled with SMS up to the brim and left for decomposition.

Anaerobic: In this method, we fill the pit similarly as in natural method, but on the top, the pit is covered with 20-30 cm thick layer of normal soil and left as such for weathering.

15. Humanure

"Humanure" is a buzzword designated for human excrement (faeces and urine), which is recycled via composting for agricultural or other purposes. The term was first used in 1994 by Joseph Jenkins that in his book "The Humanure Handbook" where he advocates the use of humanure as a soil amendment.

Humanure is notthe "sewer sludge" or "biosolids" or "sewage compost" obtained from the sewage treatment plant as this may include various pollutant released from industries or other sources into the sewage line, instead, it is the decomposed product of faeces, urine, toilet paper and some additional carbon sources such as sawdust. Humanure also differs from night soil, which is raw human waste spread on crops. Night soil, while aiding nutrients present in faecal matter to the soil, it also contaminates the soil by spreading many human pathogens present there.

A humanure system like compost toilet works on zero energy as it does not require water or electricity. It does not smell if appropriately managed. Human excrement from compost toilet is collected and added to a hot compost heap together with sawdust and straw or other carbon-rich materials. The heat generated during the decomposition helps in destroying the pathogens. The waste is processed *in situ* in a composting toilet. Composting is the best way to dispose off the faeces and urine, the nutrients contained in them are returned to the soil. It helps in nourishing the soil and preventing soil degradation. Human faecal matter and urine have high percentages of nitrogen, phosphorus, potassium, carbon, and calcium apart from micro-nutrients.

Humanure aids in the conservation of freshwater by avoiding the use of potable water required by the typical flush toilet. It further helps in preventing the pollution of groundwater as the faecal matter decomposes before entering into the system. There should be no groundwater contamination from leachate if appropriately managed. This technology is eco-friendly, reduces energy consumption thus checks greenhouse gas emissions associated with the transportation and processing of water and wastewater.

Use of humanure is safe in the crop if it is handled appropriately and composted adequately. Because at the time of decomposition, temperature increase and sufficient heat are generated that destroys the harmful pathogens or enough time must elapse since the fresh material is added so, the biological activity should kill any pathogens present there. During the process humanure making pathogenic organisms get killed by the extreme heat of the composting, i.e. above 45 °C for weeks and the extended amount of time (1 to 2 years) that it is allowed to decompose. Complete pathogen destruction is guaranteed by arriving at a temperature of 62 °C (144 °F) for one hour, 50 °C (122 °F) for one day, 46 °C (115 °F) for one week or 43 °C (109 °F) for one month. A curing stage is needed to allow a second mesophilic phase to reduce the potential phytotoxins to make it safe for crops. Therefore, it is advisable to use the humanure after elapsing one year time.

Choosing a Composting Method

Choosing the method that best suits for composting depend upon various factors. Before selecting the method of composting following questions must be addressed.

a. Who are you?

b. Why do you want to make compost?

c. Where are you located?

d. Available technological options

e. Kind of substrate available

Who is going to make compost is an important question because one method applicable with individual small farmer may not be suitable to commercial composter? Accordingly, a small farmer may be producing for his farm use; however, large/commercial composter may be doing so for sale of compost. Where you are located is also an important factor from environmental impact and potential nuisance viewpoints. For example, composters located in rural areas need to be concerned about environmental factor and assure that composting activity shouldn't adversely affect the surface and groundwater aquifers, however, they usually may be less concerned about neighbour complaints related to odours, noise and dust so they may go for low technology composting. However,composting sites located inrural-urban and urban areas have to utilise high technology options to minimise nuisance.

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Chapter – V

FACTORS AFFECTING THE COMPOSTING PROCESS

Certain environmental factors affect the composting process, so they require food (carbon and nitrogen), air, and water to make compost. Along with this, they also require a favourable temperature and pH for rapid composting. Other physical factors affecting the pace of composting include surface area, particle size and volume. These factors affecting the process are detailed as below.

A. Organism: For every natural occurring substance, there is a corresponding microbial enzyme complex with the ability to convert it to carbon dioxide, humic material and waste. Organic waste usually is heavily contaminated with its population of micro-organisms, i.e. bacteria, fungi and actinomycetes which are derived from the atmosphere, water or soil. Micro-organisms also need the supply of nutrients, air, water and favourable conditions to work effectively. These micro-organisms can work effectively if the get large surface area to act and some macro-organisms, i.e. mites, centipedes, snails, millipedes, springtails, spiders, slugs, beetles, ants, flies, nematodes, flatworms, rotifers, and earthworms etc. play an important role in cutting, tearing and chopping the organic substrate so the micro-organisms may find suitable to act upon. Presence of asufficient number of these assures quality compost production.

The culture of cellulolytic organisms did not compete well with the native microflora during the composting of the waste. The inoculation with the one-litre slurry containing 5% each of dung, soil and well-decomposed compost is enough to introduce the microflora which can increase the decomposition rate and may bring maturation of the compost quickly (Singh, 1987).

B. Organic waste: Organic wastes are the primary substrate subjected for decomposition. It provides food for organisms in the form of carbon and nitrogen. As stated earlier, bacteria use carbon for energy and nitrogen to build protein to grow and reproduce. The level of carbon and nitrogen differs with kind of substrate. Organic materials rich in carbon tend to be dry and brown such as plant leaves, straw and wood chips.Nitrogenous materials tend to be wet and green such as fresh grass clippings, products of animal origin and food waste. There is a simple thumb rule to estimate carbon/ nitrogen content of organic matter. Any fresh and juicy materials will be usually higher in nitrogen, and older, drier, and woodier plant material will be higher in carbon.

The organic material with higher nitrogen will decompose faster than those, which are high in carbon content.

A C:N ratio between 25:1 to 30:1 is the optimum combination for rapid decomposition of organic matter. If theratio is more than 30:1 that indicates high carbon and this limits the growth and reproduction of micro-organisms thus number becomes insufficient to produce heat and decomposition slows. It happens when thepile has more of dry leaves or wood chips, and decomposition will take a year or so. When C:N ratio is less than 25:1 this indicates too much of nitrogen and pile is likely to utilise excess nitrogen in thedegenerative process and causes release malodorous ammonia gas. Too much nitrogen (N) may also cause a rise in the pH level leading to putrefaction. Any of the organic material may not have the desired C:N ratio but theblending of different materials will help in achieving a satisfactory C:N ratio. A volume-based simple thumb rule of using one-fourth to half of the organic matter as nitrogen-rich and remaining high carbon-containing materials like dry leaves and straws may be adopted for the purpose. It will provide adequate sources of carbon and nitrogen to micro-organisms for growth and cell division. C:N ratio of some of the common organic wastes used for composting is given in Table 3.

Table 3**: Carbon:Nitrogen (C:N) Ratios of some common organic wastes**

MATERIAL	C:N RATIO
Maize stalks	50-100:1
Straws of paddy, wheat, millets, etc.	40-100:1
Sugarcane leavestrash and baggage	50-100:1
Pigeon pea stalks	50-100:1
Old green leaves and twigs of plants	50-100:1
Mature grasses	40-80:1
Coconut fibre waste	50-100:1
Peanut hulls	40-80:1
Mustard plants (after harvest)	40-80:1
Paper wastes	170-200:1
Sawdust	200-500:1
Silk mill wastes	30-50:1
Potato waste	40-80:1
Fruit waste	30-35:1
Grass clippings	12-25:1
Hay, green	25-30:1
Fresh leaves from elder and elm	21-28:1
Fresh Leaves (Pine)	60-100:1
Fresh Leaves, other	30-80:1
Manure of cattle, buffalo, pig and poultry	20-25:1
Vegetable waste	12-25:1
Weeds	25-30:1
Wood chips	500-700:1

C. Aeration: Aeration refers to the amount of oxygen in the system, and it is the key environmental factor. Organisms present in the compost pile can degrade organic materials either aerobically or anaerobically. Many organisms including aerobic bacteria need oxygen to produce energy, grow and reproduce. The types of organisms active in the pile and the metabolic process used to degrade organic compounds are related to the oxygen content of the system. Aerobic degradation is preferred for rapid composting.

Aeration in a compost pile occurs naturally as the oxygen-deficient air present in a pile warmed up due to composting, it leaves the pile and replaced by the fresh air from the surrounding. The process of aeration can also be affected by wind, moisture content, and porosity (spaces between particles in the compost pile). Compaction occurs with the progression of decomposition, which reduces the porosity of the piled mass. Further, the higher ratio of fine organic material like pine needles, grass clippings, or sawdust in the substrate reduces the porosity. Air circulation can also be impeded if materials become water saturated. If poor aeration is observed then turning of the material with shovel helps in better air movement, and it also increases porosity.

D. Moisture Content: Moisture influences the rate of the microbial population which helps in faster and proper degradation of composted matter. Maintaining adequate moisture content is essential since it provides the humidity required by micro-organisms for optimal degradation. The moisture content of 50-60 per cent is generally considered optimum for composting. Microbial induced decomposition occurs most rapidly in the thin liquid films present on the surfaces of the organic particles because water dissolves the organic and inorganic nutrients present in a pile and make them available for utilisation by micro-organisms. Too little moisture (<30%) inhibits bacterial activity, whereas too much moisture (>65%) results in slow and anaerobic decomposition causing odour production and leaching of nutrient. Composting should be carried out underneath some cover to control moisture level.

E. pH: The pH of most of the composting substrate is slightly acidic, i.e. 6.0. At the early stage there is a production of organic acid hence pH goes again acidic 4.5-5.0. As the decomposition process get over and temperaturereduces and pH of the composted mass start increasing. It gets converted into alkaline pH 7.5-8.5 from acidic pH.The pH of the mature compost is 7.5-8.5 (Kakde,2017).

F. Temperature: Temperature is another important factor in the composting process and is related to proper air and moisture levels. As aerobic decomposition is an oxidative process, so considerable heat is generateddue to microbial activity, which in turn increases pile temperature. Soil micro-organisms are metabolically active over defined temperature ranges. With the increase in the temperature of the pile, different groups of organisms become active. The temperature of the compost pile with substrates of appropriate particle size may rise to 65-75^0 C if oxygen, moisture, carbon and nitrogen is present in ample amount.Temperatures in the range of 32-60^0 C are typical of a well-operated system and are indicative of rapid composting. Higher temperatures begin to limit the microbial activity and temperature beyond 70^0 C becomes lethal to most micro-organisms. At this temperature, most of the weed seeds, insect larvae and potential plant or human pathogens that may be existing in the composting materials get destroyed. Although, composting will occur without careful temperature control, but maintaining thetemperature around 32-60^0 C is necessary for rapid composting.

G. Surface area: All the microbial activity is performedon the surface of the particle, so thesurface area of the organic material exposed to soil organisms influences the rate of decomposition greatly. Composting materials should be shredded, chopped or otherwise reduced in size to increase the surface area to increase the rate of decomposition. However, on the other hand, when particles are reduced to too small and compact, air circulation through the pile is inhibited. It decreases available O_2 to micro-organisms within the pile and ultimately decreases the rate of microbial activity.

H. Size and Shape of Compost System: Size is a factor in retaining compost pile heat. A compost pile must be of adequate size to prevent faster dissipation of heat and moisture, but it may be small enough to allow good air circulation. A pile of one cubic meter is an ideal size however size largely depends upon the method of composting. Smaller composting piles will decompose the material, but there may not be sufficient heat to destroy weed seeds and kill the germs as well, and decomposition is likely to take longer time.

The shape of the pile helps in controlling its moisture content. Outdoor compost systems may be sheltered from precipitation in humid regions; whereas, in arid regions, piles with a concave top is preferred to catch precipitation and any other added water.

The shape of the compost pile helps in regulating moisture content. In most humid and temperate climates, an egg-shaped or pyramidal (triangular) shape pile will work better. Even in higher rainfall zone sheltering from precipitation is desired. If it is a dry climate, then cutting the tip-off of the pyramid and making an indentation to catch precipitation may be desired. If it is too dry, then using pit will be better option to maintain proper moisture. Decomposition process halts as the pile dries and this kills all the organisms.

I. Time of Composting

The best times to build the compost pile is autumn and spring. In the autumn, many of the weeds and grasses will be flowering or started to go to seed so substrate of much higher C/N ratio will be available. In the spring, there will be again fresh green growth, which will have a lot more nitrogen (N). If the pile is built in mid-Summer, then it is likely to get too hot, and enough amount of organic matter may be lost, or if built in mid-Winter, it is more likely to stay too cold/wet and may result in anaerobic that may result in leaching of valuable nitrogen. In the summer, keeping the pile in the shade and adding more carbonaceous materials helps in keeping it cool, while in the winter making the pile on the south-facing side of a building and keeping the pilemay keep it warm.

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Chapter –VI

ENRICHMENT OF ORGANIC COMPOST

Enrichment of the compost is a way of fortifying naturally produced compost. It is an excellent way of enhancing the quality of compost. Most of the Indian soil is deficient in Phosphorus, and continuous cropping further drains it. Yearly removal of phosphorus from soil is more than the addition. Similarly, other nutrients are also drained from the soil. If the traditional technology of composting is improved in the term of its nutritional status, then it can help significantly in checking the nutritional depletion.

Figure 34: Enrichment of compost/manure

Common additives and methods to produce enriched compost

a) Clay soil: Addition of 10% clay soil in the compost pile helps in reducing nitrogen losses and makes the end-product more stable. Clay acts as a "colloidal trap," and help in retaining nitrogen. Microbes present into the pile convertsthis nitrogenfrom agaseous form to a usable form. Adding thin and repetitive layers of clay soil works better.

b) Rock phosphate: Rock phosphate can increase the availability of usable phosphorus to cropsand help in reducingvolatilisation of ammonia. In India, about 160 million tons of rock phosphate deposits are available, but they are of low-grade and contains less than 20% P_2O_5, which are considered unsuitable for manufacturing commercial phosphaticfertilisers. However, this low-grade indigenously available rock phosphate works well in acid soils, however, modifications required to use in neutral and alkaline soils (Biswas, 2008).

The Indian Institute of Soil Science (IISS), Bhopal has developed technology to utilise the rock phosphate in combination with phosphate solubilising bacteria (*Aspergillus awamori*,*Pseudomonas straita*, and *Bacillus megatheriu*m), pyrite and bio-solids. The phospho-compost/N-enriched phospho-compost technology enriches the manurial value of the compost compared to FYM and other ordinary compost.

Material Required: 1900 kg organic waste, 200 kg cow dung (on dry basis) and 250 kg of rock phosphate (18% P_2O_5)are used to produce one ton of phospho-compost through this method. The final product contains about 2—3% phosphate, and it becomes ready for application in about 90-100 days.

Methods: Base of the heap is prepared from hard and woody materials like woody sticks, bamboos etc. Size of the base depends upon the quantity of the substrate available for composting. Generally, a base of 3×3×0.15 m is preferred. Above the base, 30-40 cm thick layer of bio-solids is placed. Over the bio-solid layer slurry prepared by mixing cow dung, rock phosphate and microbes are sprinkled. Another layer of the substrate is added and moisten with slurry. Stacking of the material continues with the alternate layer of crop residue and slurry until the heap is 1.5 m high. Area of each layer is reduced to taper the heap. Water is added to the heap to maintain moisture about 60 to 70% to facilitate proper bacterial activity and decomposition. Heap is covered with mud or polythene. The material is turnedafter 30 & 45 days. Add water at each turning to maintain the moisture content about 60-70%.The compost becomes ready for field application within 90-100 days period.

Table: Nutrient composition of manure and phosphocompost

Manure	Total N (%)	Total P (%)	C: N ratio
FYM	0.5-0.8	0.32-0.55	22.0-25.0
Compost	0.6-0.8	0.55-0.60	22.0-25.0
Phospho-compost	1.2-1.4	2.00-3.50	17.0-18.0

c) Enriching compost with waste-mica: Along with rock phosphate waste mica generated during cleaning of raw mica can be used to enrich the compost as it is a good source of potash and other micronutrients. The world's largest deposits of muscovite mica, potash (K) bearing mineral containing 9-10% K_2O, are distributed over a total area of about 4,000 km^2in Munger district of Bihar and Koderma and Giridih districts of Jharkhand. Huge quantities of waste mica are generated during cleaning of raw mica, which is dumped near mica mines. This waste may be utilised along with a considerable quantity of biomass available mainly rice straw, which is generally burnt in the field for sowing wheat in northern India (Biswas, 2008).

This enriched compost can reduce dependency on costly inorganic P and K fertilisers and save precious foreign exchange, besides providing an environmentally sound and economically feasible solution to problems of waste management.

Rock phosphate and waste-mica enriched compost can be prepared by trench or pit method as discussed earlier.

d) Use of Microbes and Biofertilizers: Microbes and biofertilizer can also be used to hasten the decomposition process and to enrich the compost as well. Inoculation of the substrates with cellulolytic and lignolytic microorganisms like *Trichoderma harzianum*, *Aspergillus niger*, *Aspergillus terreus*etc. may accelerate the decomposition during composting (Chandra, 2005).

Nitrogen-fixing bacteria like *Azotobacter*and*Azospirillum*@ 2 kg/ton each if solid or 1litre/ton if the liquid is enough to inoculate the compost to get a good result. Further, phosphorus solubilising bacteria*Bacillus polymyxa*and potash mobilising bacteria *Fraturiaaurantia* may be added @ 4kg/ton if solid, 2litres/ton.

Some Bio-Control agents like *Trichoderma viride* and *Pseudomonas fluorescence* at the rate of 2kg/ton of each if solid or 500ml/tone ifliquid form may help in improving the quality of compost and help in controlling soil-borne diseases.

Biofertilisers may be added either during composting or after harvesting the compost. Biofertilisers mentioned above may be dissolved in 50 litres water and poured inholes previously made in compost piles. Enrichment can also be done by mixing biofertilisers withthe harvested compost and heap of the treated compost should be stored in the shed for at least two weeks before application to increase the population of inoculated microbes.

e) Other biological inoculants or "activators": Generally, most of the compost organisms are present in manures, soils, and on the plant materials, but the use of aged compost as an inoculant helps in hastening the ratedecomposition if the composting area is new or it is done in concrete pits. It may also be useful if the substrate hashigh oil content plant residues.

f) Wood ash: Adding a small amount of ash helps in enhancing the potassium content of the compost. It also eliminates the possibility of the adverse effect of high pH.

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Chapter: VII

RECOMMENDATION FOR DIFFERENT CROPS

Manure use recommendations are based on observations and trails carried out at our KVK. We have also taken the feedback and experiences of farmers in preparing the recommendations. These recommendations are averages, not tailored to specific crop needs in a specific area. Therefore farmers are advised to adjust the quantity of the manure based on soil test recommendations.

Major crops cultivated in the Northeastern regions are listed below, and recommendation thereof for major kind of manure is given in the table.

7.1. Cereal crops-Rice, maize, pea, groundnut, soybean.
7.2. Vegetable crops-cabbage, potato, chow-chow, beans, Brassica spp.
7.3. Fruit crops-Kiwi, passion fruit, orange, peach, plum, pear.
7.4. Flowers-Begonia, chrysanthemum, rose, dahlia, impatiens

Table: Manure recommendation for various crops

S. No.	Crops	FYM	NA-DEP	Vermi-compost	Azolla	SMS	When to incorporate	Nurs-ery
1.	Field crops							
	Rice	10-20t/ha	5-10t/ha	5-6t/ha	300kg/ha	100t/ha	Land preparation	10kg/m^2
	Maize	10-15t/ha	10-12t/ha	2t/ha	1.5-2.2t/ha		Land preparation	-
	Pea	20t/ha	-	2t/ha	-	20t/ha	Land preparation	-
	Grou-ndnut	10-15t/ha	-	3-5t/acre	-	-	15-20days before sowing	-
	Soya bean	15-20t/ha	-	2t/ha	-	-	Land preparation	-

2	Vegetable Crops							
	Cab-bage	15-20t/ha	-	4-6t/ha or 50gms/ plant	10gms/ plant or 2t/ ha	25t/ ha	Land preparation	5-10kg/ m^2
	Potato	10-15t/ ha	-	4-6t/ha or 50gms/ plant	10gms/ plant or 2t/ ha	-	While planting in the furrow	-
	Chow-chow	15-20t/ ha	-	4-6t/ha or 50gms/ plant	10gms/ plant or 2t/ ha	-	Land preparation	-
	French beans	25t/ha	-	2.5t/ha or 50gms/ plant	10gms/ plant or 2t/ ha	-	Land preparation	-
	Brassi-ca spp	25t/ha	10-12t/ ha	4-6t/ha or 50gms/ plant	10gms/ plant or 2t/ ha	-	Land preparation	10kg/m^2
3	Fruit crops							
	Kiwi	20kg	-	2-3kg/ plant	-	-	-	3-5kg/ m^2
	Or-ange	3kg/ plant/yr	-	2-3kg/ plant	-	-	After ev-ery 3years	
	Pas-sion-fruit	15kg/ vine/ year Or 2000kg/ ha	-	2-3kg/ plant	-	-	Before final ploughing	-
	Plum	10kg/ plant/ year	-	2-3kg/ plant	-	-	-	-
	Peach	5kg/ plant/ year	-	2-3kg/ plant	-	-	-	-

4	Flowers							
	Bego-nia	5kg/m ^{2}	-	50gms/ plant (pot)	-	-	Soil prepa-ration	-
	Chry-santhe-mum	25t/ha 5kg/m ^{2}-sucker	-	50gms/ plant (pot)	-	-	Soil prepa-ration	-
	Rose	5kg/ plant/ year 10kg/pl	-	50gms/ plant (pot)	-	-	After pruning	-
	Impa-tiens	5kg/m^2	-	50gms/ plant (pot)	-	-	Soil prepa-ration	-
	Dahlia	5kg/m ^{2}	-	50gms/ plant (pot)	-	-	Soil prepa-ration	-

Chapter: VIII

METHODS OF APPLICATION

According to the recommendation of different compost for different crops, compost are applied in solid and liquid form Gypsum is spread in the cattle shed, which absorbs urine and prevents volatilisation loss of urea present in the urine. It also adds calcium and sulphur to the compost. Superphosphate also acts similarly in reducing the losses and also increases the availability of phosphorus.
Partially rotten farmyard manure may be applied three to four weeks before sowing, whereas well rotted manure can be applied just before sowing. Nutritional, requirements of the vegetable and fodder crops are higher, so more than 20 t/ha compost is applied. Further, a dose of 10 to 20 t/ha is reasonably good for other cereal crops. Application of FYM is preferred 15 days before the sowing of transplanting to avoid immobilisation of nitrogen. The present practice of leaving manure in small heaps in the field for a prolonged period results in loss of nutrients. These losses can be minimised by spreading the manure and incorporating it by ploughing immediately after application.

Vegetable crops like potato, tomato, sweetpotato, carrot, radish, onion etc., respond well to the farmyard manure (FYM). The other responsive crops are sugarcane, rice, fodder crops like Napier grass, sorghum, and orchard crops like mango, banana, oranges, and plantation crop like coconut.

The entire amount of nutrients present in the compost is not available immediately to the crop. Nutrients from the compost are released slowly, and only about 30 per cent of nitrogen (N), 60 to 70 per cent of phosphorus (P2O5) and 70 per cent of potassium (K2O) are available to the first crop. However, rest nutrients will be available for the succeeding crops. Availability of nutrients depends upon the nature of the raw material used for composting. Estimated first-year nutrient availability of various manuresis given the table.

Table: Estimated nutrient availability of various manures during the first year of application (Peters, 2010)

Species	N	P_2O_5	K_2O	S
Dairy surface applied	30%	60%	80%	60%
Dairy incorporated	40%	60%	80%	60%
Swine solid surface applied	50%	60%	80%	60%
Swine solid incorporated	65%	60%	80%	60%
Poultry solid surface applied	50%	60%	80%	60%
Poultry solid incorporated	60%	60%	80%	60%

If manure has been applied to the same field at similar rates for two consecutive years, increase the nutrient values an additional 10%. If manure has been applied to the same field at similar rates for three or more consecutive years, increase the nutrient values by 15% (Peters, 2010).

Common methods of manure application are as follows:

Broadcasting: Broadcasting is the most common method applied in field crops. Compost is broadcasted 1-2 weeks before the sowing or planting of the crop. Compost is mixed with the soil thoroughly by ploughing after broadcasting.

Top Dressing: Fully matured and fine grounded compost also can be used as top dressing in some crops like paddy and maize. It is also preferred for top dressing to maintain grasses in lawns. Top dressingwith a 1/8 to 1/2 inch layer of well decomposed compost is advocated at least twice ayear in the gardens. Care should be taken to continue with the routine watering of the lawn asexcessively dry condition prevents decomposition of compost (Bordoloi et al., 2015).

Placing manure in pits: Compost may be applied in pits during planting of crops. This method is found to be effective for vegetable crops like ginger, turmeric, potato tubers, cucurbits, seedlings of vegetables such as cabbage, cauliflower, knolkholetc.

Compost as a potting mixture: Compost is mixed with soil as a potting mixture for application is flowering pot and small gardens. Generally, compost, sand and garden soil ratio is maintained as 1:1:1.Transferring seedlings along with pot mixture to the field help avoid stress to the seedlings besides other benefits (Bordoloi et al., 2015).

Compost as mulch: Various kinds of mulches are used to conserve moisture, improve water balance and soil structure, control of weeds, minimise soil temperature fluctuations, increase soil fertility and reduce water erosion of soil. Three to four inches thick layer of finished or unfinished compost can be utilised as mulching material (Bordoloi et al., 2015).

Use of Compost Tea: Water extract of compost is termed as compost Tea. It is rich in soluble micronutrients, humic acids and growth promoting substances. This tea can be sprayed to crops as a growth booster. Spraying compost tea is an excellent way to nourish indoor or outdoor potted plants. It can be prepared by placing a cloth bag filled with mature compost in a bucket of water for an hour and subsequently harvesting the liquid as compost tea. The remaining content of the bag can be utilised as a soil amendment, whereas compost tea for spraying.

References:

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John Peters. 2010. Manure Analysis Update: 1998-2010. Department of Soil Science University of Wisconsin – Madison. Retrieved from http://www.soils.wisc.edu/extension/area/2010/Manure_summary_Peters.pdf

Chapter: IX

CONCERNS WITH COMPOST AND MANURE

Compost helps in improving soil structure and nutritional status but sometimes it may also source in spreading of disease and weeds. Therefore it is always advisable to be precautious in producing and using the compost. Properly cured and produced compost is considered to be free for any harmful organism and weed seeds as during composting temperature of the composted mass rise as high as 65^0C, and that kills all the disease-causing microbes and weed seeds. However, during the process, it is possible that certain organism and weed seeds may escape due to faulty composting.

Further, one should not eat crops grown in areas where manure has been applied recently. It takes at least three months to neutralise the ill effect. Generally, pathogens present in manure, such as Salmonella, Listeria and E.coli, may contaminate the food. The risk of pathogens contaminating food is highest for root crops and leafy vegetables. The edible portions of these vegetables come in contact with contaminated soil thus passes the pathogens. Careful washing or peeling eliminates the risks, and cooking also effectively kills the pathogens. Also, raw or poorly decomposed manure should not be applied under the fruit trees because the fruit may fall there and get contaminated as it comes into contact with the manure.

Sometimes, poultry, rabbit and pigs are fed organoarsenicals to control coccidiosis and growth promotion, but the compost prepared form the faecal matter obtained from such farms may contain Arsenic (As). Repeated use of such compost for the extended period may result in arsenic buildup in the soil. Such soils become sick and may lead to uptake of arsenic by plants. It may also leach to groundwater, thus polluting the water and find the way in the human food chain (Makriset al. 2008).

Reference:

Makris, K. C., S. Quazi, Punamiya, P., Sarkar, D. and Datta R. 2008. Fate of Arsenic in Swine Waste from Concentrated Animal Feeding Operations, J. Environ. Qual.;37(4):1626-33 doi:10.2134/jeq2007.0479

Chapter: X

ACTIVITIES OF KVK PHEK PERTAINING TO COMPOSTING

Training: Training imparted to farmers, rural youth and SHG's- Altogether 117 nos. of training under vermicomposting and different composting methods and importance of composting have been imparted to different group comprising of practicing farmer, rural youth, SHG's, NGO's extension functionaries etc. in villages i.e. Porba, Sakraba, Gidemi, Pholami, Khomi, Pfutsero, Pfutseromi, Phek, Thipuzu, Rihuba, Kami, K. Basa, Lekromi, Phusachodu, Tsufame, Mesulumi, Rukizu, Kikruma, Runguzu Nasa, Enhulumi, Lasumi, Chizami, Zapami, etc. (1261 participants)

Figure 35: Vocational training programme for the farm women

Demonstration:

Method demonstration of vermicomposting and aerobic composting has been demonstrated to farmers at different villages. Under ATMA programme, method demonstrations have been conducted at Zhavame, K. Bawe village and Lekromi.

Figure 36: Demonstration on Vermicomposting under ATMA

On Farm Trial (OFT):

Under OFT, trials consisting of using different composting like vermicompost, NADEP compost and azolla compost were used in various crops i.e. French bean, maize.

i. Effect of vermicompost on maize yield: A trial on the effect of vermicompost on maize yield was conducted at Porba village where maize variety was HQPM. The results showed that application of vermicompost in maize increased the yield over the control. Yield recorded in vermicompost application (70.6 qt/ha), Average no. of cob per plant (2.73/plant), test weight (37.82g) compared to control (67.83qtl/ha), Average no.of cob per plant (2.2/plant), test weight (33.24g)

ii. Effect of composting methods on the nutrient availability of mithun dung on tomato: Vermicompost and NADEP compostwere used for the trial. Yield recorded were 21.02 t/ha and 19.70 t/ha in NADEP compost and vermicompost respectively, whereas, 18.00 t/hayield was recorded in control plot.

Front Line Demonstration (FLD):

i. Application of vermicompost in groundnut. Var. JL-24: Front Line demonstration on application of vermicompost in groundnut Var. JL-24 was conducted in Gidemi village of Phek district of Nagaland. Vermicompost was applied @ 5.0 t/ha during the final land preparation. Vermicompost treated plot recorded a pod yield of 8953.2 kg/ha as compared to 8520 kg/ha in control plot. The net return in the treated plot was Rs.86068/ha with a B: C ratio of 2.78.

Vocational training:

Vocational training on vermicompost production was conducted at Porba village for 113 beneficiaries for 4 days. Activities involving classroom training, video show, and method demonstration on vermicomposting were imparted during the vocational training. Vermibeds, earthworms species *Eisenia fetida* were distributed to the beneficiaries. (113)

Programmes under different projects and with NGOs:

Under Tribal Sub Plan (TSP), three concrete vermicomposting unit have been constructed in three khels at Porba village.

Training and method demonstrations were conducted on low-cost vermicomposting in Thipuzu village under NICRA project. The farmers were also given vermibed and *Eisenia fetida* species of earthworms.

Figure 37: Training and demonstration organized under NICRA

Under Tribal Development Fund Project sponsored by NABARD and organized by Chakesang Women Welfare Society, Pfutsero, training was given to SHGs in different villages, viz. Pfutsero, Losami, Thenezu. Method demonstrations on vermicomposting were also conducted for the beneficiaries under this project. North East Network (NEN) Chizami, is a prominent NGO working in this region and KVK has collaborative programmes with them. Lectures and demonstrations on Vermicomposting were imparted during Summer Farm School programme organized by NEN for the school children.

Epilogue

Compost and manure use is not new to us; they were in use since time immemorial. The scripts of Ramayan describes that all the dead things, rotting corpse or stinking garbage returned to earth are transformed into wholesome things that nourish life. The Mahabharata (5500 BC) mentions of Kamadhenu, the celestial cow and its role on human life and soil fertility. Kautilya has mentioned about manures like oil cakes, excreta of animalsin Arthashastra (300 BC). Brihad-Sanhita by Varahmihir described how to choose manures for different crops and methods of manuring. Rig Veda (2500-1500 BC) mention of organic manure in verses 1.161.10 shows its use during the period.

Similarly, Atharva Veda II (1000 BC) describes green Manure and in Sukr (IV, V, 94, 107-112) it is stated that to cause healthy growth, the plant should be nourished by dung of goat, sheep, cow, water as well as meat. A reference of manure is also made in Vrksayurveda by Surpala (Behera et al., 2012). These instances indicate that our forefathers used all those techniques that we are now reverting. It will not be wrong to say that we are reinventing our traditions (Sofia et al., 2006).

We were practising the traditional farming till mid of the twentieth century, but the population explosion has triggered enhanced demand for the food. During such time Green Revaluation Technologies (GRT) was introduced as a boon. The GRT encouraged greater use of synthetic agrochemicals like fertilisers and pesticides, adoption of nutrient-responsive, high-yielding varieties of crops, greater exploitation of irrigation potentials etc. and that has boosted the production. Without proper choice and continuous use of this high energy, inputs lead to a decline in production and productivity after prolonged practice. It has also led to the deterioration of soil health and environmental degradation (Behera et al., 2012).

Indiscriminate use of chemicals has brought changes in soil reaction and triggered nutritional imbalance. These chemicals have swept away the organic matter from the soiland damaged the soil flora and fauna. Use of chemicals for the prolonged period have destructed the soil structure, aeration and water holding capacity and adversely affected the soil health resulting in sick soils. The final impact is being observed as a reduction in productivity and deterioration in the quality of the produce.

Now again we are reverting to our traditional system of agriculture and various new concepts of farming such asorganic farming, natural farming, bio-dynamic Agriculture, do-nothing agriculture, eco-farming etc. are being introduced. However, the basic concept of all the practices is “Giving back to nature”, where the philosophy is feeding the soil rather than feeding the crop to maintain the soil health (Behera *et al.*, 2012).

References

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Table: List of Organic Manures and their nutritional status

Manure	Percentage content		
	Nitrogen (N)	**Phosphoric acid (P_2O5)**	**Potash (K_2O)**
Blood meal	10-12	1.2	1.0
Press mud	1-1.5	4-5	2-7
Bone meal			
1)Raw bone meal	3-4	20-25	-
2)Steamed bone meal	1-2	25-30	-
Fish meal	4-10	3.9	0.3-1.5
Animal refuse	0.3-0.4	0.1-0.2	0.1-0.3
Cattle dung, fresh	0.4-0.5	0.3-0.4	0.3-0.4
Horse dung, fresh	0.5 -0.5	0.4-0.6	0.3-1.0
Poultry manure, fresh	1.0-1.8	1.4-1.8	0.8-0.9
Sewage sludge, dry	2.0-3.5	1.0-5.0	0.2-0.5
Sewage sludge, activate dry	4.0-7.0	2.1-4.2	0.5-0.7
Cattle urine	0.9-1.2	trace	0.5-1.0
Horse urine	1.2-1.5	trace	1.3-1.5
Human urine	0.6-1.0	0.1-0.2	0.2-0.3
Sheep urine	1.5-1.7	trace	1.8-2.0
Ash, coal	0.73	0.45	0.53
Ash, household	0.5-1.9	1.6-4.2	2.3-12.0
Ash, wood	0.1-0.2	0.8-5.9	1.5-36.0
Rural compost, dry	0.5-1.0	0.4-0.8	0.8-1.2
Urban compost, dry	0.7-2.0	0.9-3.0	1.0-2.0
Farmyard manure, dry	0.4-1.5	0.3-0.9	0.3-1.9
Filter-press cake	1.0-1.5	4.0-5.0	2.0-7.0
Rice Hulls	0.3-0.5	0.2-0.5	0.3-0.5
Groundnut husks	1.6-1.8	0.3-0.5	1.1-1.7

Banana, dry	0.61	0.12	1.00
Cotton	0.44	0.10	0.66
Maize	0.42	1.57	1.65
Paddy	0.36	0.08	0.71
Tobacco	1.12	0.84	0.80
Pigeon pea	1.10	0.58	1.28
Wheat	0.53	0.10	1.10
Sugarcane trash	0.35	0.10	0.60
Tobacco dust	1.10	0.31	0.93
Coir Pith	1.20	1.20	1.20
Tree leaves, dry			
Calotropis gigantea	0.35	0.12	0.36
Careya arborea	1.67	0.40	2.20
Cassia ariculata	0.98	0.12	0.67
Dillenia pentagyna	1.34	O.50	3.20
Madhuca indica	1.66	0.50	2.00
Pongamia pinnata	3.69	2.41	2.42
Pterocarpus marsupium	1.97	0.40	2.90
Terimalia chebula	1.46	0.35	1.35
Terminalia paniculata	1.70	0.40	1.60
Terminalia tomentosa	1.39	0.40	1.80
Xylia dolabriformis	1.37	0.30	1.61
Green manures, fresh			
Cowpea (*Vigna unguiculata*)	0.71	0.15	0.58
Sesbaniaaculeata	0.62	-	-
Cluster-bean *(Cyamopsis tetragonoloba)*	0.34	-	-
Horse-gram *(Dolichos biflorus*)	0.33	-	-
Mothbean	0.80	-	-
Green gram *(Vigna radiate)*	0.72	0.18	0.53

Sunnhemp(*Crotalaria juncea*)	0.75	0.12	0.51
Blackgram(*Vigna mungo*)	0.85	0.18	0.53
Non-edible Oil Cakes			
Castor cake	4.3	1.8	1.3
Cotton cake	3.9	1.8	1.6
Karanj cake	3.9	0.9	1.2
Mahua cake	2.5	0.8	1.8
Neem cake	5.2	1.0	1.4
Safflower cake	4.9	1.4	1.2
Edible Oil Cakes			
Coconut cake	3.0	1.9	1.8
Groundnut cake	7.3	1.5	1.3
Niger cake	4.7	1.8	1.3
Rapeseed cake	5.2	1.8	1.2
Sesame cake	6.2	2.0	1.2

Source:Source: "Handbook of Manures and Fertilizers" 1964. Indian Council of Agriculture Research, New Delhi

Table: Nutrient content (%) of weed biomass, crop residues, livestock excreta and compost.

	Nitrogen (N)	**Phosphorus (P)**	**Potassium (K)**
WEED BIOMASS			
Eupatorium odoratum	3.36	0.10	0.82
Lantana camara	2.41	0.08	1.37
Mikania micrantha	2.94	0.18	1.71
Azolla	2.38	0.51	2.75
Ipomea spp.	2.01	0.33	0.44
CROP RESIDUES			
Rice straw	0.36	0.08	0.71
Maize stover	0.42	1.57	1.65

Pulse stover	0.72	0.18	0.53
Oilseed stover	0.30	0.13	0.33
Groundnut stover	1.6	0.23	1.37
LIVESTOCK EXCRETA			
Cow dung	0.4	0.2	0.1
Pig manure	1.19	0.39	1.01
Rabbit manure	1.82	0.47	1.07
Poultry manure	1.87	0.54	2.15
Sheep manure	1.6	0.2	0.95
COMPOST			
Ordinary compost/ farm litter compost	0.5	0.15	0.5
Azolla compost	2.73	0.67	2.93
Vermicompost	1.68	1.06	1.57

Parameters to assess the quality of compost (Bordoloi et al. 2015)

Sl. No.	Compost quality parameter	What to look for
1.	Gradation (Refers to particle size)	All the particles should pass through a 1-inch sieve, and at least 90% of the materials should pass through ½ inch screen under pressure sieving. Excessive dust fraction (<500µ size) is indicative of low organic matter content.
2.	Organic content	High-quality compost will have at least 50% organic content on the dry weight basis.
3.	C: N ratio	Above 30:1 is harmful. Enriched composts viz., PSN compost should have C: N ratio well below 20:1

4.	pH	Mostly preferred between 6 and 8. Might vary a little with substrates and additives. Too low pH is indicative of wrong composting practices and should not be used.
5.	Soluble salts (Salinity) Expressed as electrical conductivity (EC).	EC varies widely depending on substrate and composting method, but most commonly preferred EC level should be below 4.0 dS/m. Sodium (Na) should ideally account for less than 25% of the total soluble salts in compost.
6.	Moisture content	The ideal moisture content is between 35-50%. The product should be neither too wet and sticky nor dusty.
7.	Contaminants	Compost should be free from all sorts of contaminants viz., glass, stones, metal, plastics etc.
8.	Maturity and stability	Maturity and stability refer to complete degradation of the organic matter and neutralisation of all the phytotoxic substances that may adversely affect the seed germination and plant growth. It also relates to the level of biological activity present in the compost. Stable compost consumes almost no nitrogen or oxygen and generates little carbon dioxide or heat.
9.	Heavy metals	Should preferably be free of arsenic, cadmium, chromium, copper, lead, mercury, nickel and selenium.

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State-wise crop residue generated, residue surplus and burned
(Crop residue in Million Tonne)

S.N.	States	Residue generation*	Residue surplus*	Residue burned$
1.	Andhra Pradesh	43.89	6.96	2.73
2.	Arunachal Pradesh	0.40	0.07	0.04
3.	Assam	11.43	2.34	0.73
4.	Bihar	25.29	5.08	3.19
5.	Chhattisgarh	11.25	2.12	0.83
6.	Goa	0.57	0.14	0.04
7.	Gujarat	28.73	8.90	3.81
8.	Haryana	27.83	11.22	9.08
9.	Himachal Pradesh	2.85	1.03	0.41
10.	Jammu &Kashmir	1.59	0.28	0.89
11.	Jharkhand	3.61	0.89	1.10
12.	Karnataka	33.94	8.98	5.66
13.	Kerala	9.74	5.07	0.22
14.	Madhya Pradesh	33.18	10.22	1.91
15.	Maharashtra	46.45	14.67	7.42
16.	Manipur	0.90	0.11	0.07
17.	Meghalaya	0.51	0.09	0.05
18.	Mizoram	0.06	0.01	0.01
19.	Nagaland	0.49	0.09	0.08
20.	Orissa	20.07	3.68	1.34
21.	Punjab	50.75	24.83	19.65
22.	Rajasthan	29.32	8.52	1.78
23.	Sikkim	0.15	0.02	0.01
24.	Tamil Nadu	19.93	7.05	4.08
25.	Tripura	0.04	0.02	0.02
26.	Uttarakhand	2.86	0.63	0.78
27.	Uttar Pradesh	59.97	13.53	21.92
28.	West Bengal	35.93	4.29	4.96

Total		**501.73**	**140.84**	**92.81**

Source: * Ministry of New & Renewable Energy (MNRE, 2009), Govt. of India, New Delhi and $ Pathak Himanshu et al. (2010), Senior Scientist, C.E.S. & C.R., IARI, New Delhi

State-wise major cropped area under rice, wheat and sugarcane -Crops prone to residue burning

Sl. No.	**Name of States**	**Area under major cereal crops and sugarcane**			
		Rice	Wheat	Sugar-cane	Crops prone to residue burning
1.	Andhra Pradesh	3628.0	8.0	196.0	Rice & Sugarcane
2.	Assam	2488.2	33.9	28.9	In jhum areas, plants, & bushes are burnt
3.	Bihar	3298.9	2207.7	250.3	Rice, wheat and Sugarcane
4.	Chhattisgarh	3784.8	101.2	13.5	Rice
5.	Gujarat	701.0	1024.0	176.0	Rice and wheat
6.	Haryana	1215.0	2497.0	101.0	Rice, Wheat & Sugarcane
7.	Himachal Pradesh	76.9	364.2	1.9	No crop residue is burnt
8.	Jammu & Kashmir	261.7	290.0	0.0	No crop residue is burnt
9.	Jharkhand	1414.5	164.3	6.7	No crop residue is burnt
10.	Karnataka	1278.0	225.0	425.0	Rice and Sugarcane
11.	Kerala	197.3	0.0	1.7	No crop residue is burnt
12.	Madhya Pradesh	1882.6	5300.0	59.5	Rice and wheat
13.	Maharashtra	1557.0	773.0	933.0	Rice and Sugarcane

14.	Odisha	4022.8	1.0	14.5	No crop residue is burnt
15.	Punjab	2845.0	3512.0	83.0	Rice, Wheat and Sugarcane
16.	Rajasthan	125.6	3063.2	5.5	No crop residue is burnt
17.	Tamil Nadu	1493.1	0.0	347.2	Rice and Sugarcane
18.	Uttarakhand	262.8	358.1	109.9	Rice and wheat
19.	Uttar Pradesh	5861.0	9734.0	2212.0	Rice, Wheat and Sugarcane
20.	West Bengal	5444.3	321.6	16.1	Rice
21.	Others	915.4	25.1	17.2	No crop residue is burnt
Total		**42753.9**	**30003.3**	**4998.9**	
Total (million ha.)		**42.75**	**30.00**	**4.99**	

Source: Directorate of Economics & Statistics, MOA, DAC, New Delhi (final estimate-2012-13).

Losses of nutrients from Farm Yard Manure during collection and storage

Losses during handling

$CO(NH)_2 + 2H_2O \rightarrow (NH_4)_2CO_3$

Urea in urine Ammonium carbonate

$(NH_4)_2CO_3 + 2H_2O \rightarrow 2\ NH_4OH + H_2CO_3$

Carbonic acid

$NH_4OH \rightarrow NH_3 \uparrow + H_2O$

Ammonium hydroxideAmmonia

Losses during preparation and storage

By leaching and volatilisation

- Microbial decomposition of urea and other nitrogenous compounds in urine and dung liberates Ammonia (NH_3).
- Ammonia reacts with carbonic acid and forms Ammonium carbonate

  $2NH_3 + H_2CO_3 \rightarrow (NH_4)_2CO_3$
- Ammonium carbonate combines with water and converts to Ammonium hydroxide and carbonic acid

  $(NH_4)_2CO_3 + 2H_2O \rightarrow 2NH_4OH + H_2CO_3$
- Ammonium hydroxide breaks again to ammonia and water. This ammonia escapes in air

  $NH_4OH \rightarrow NH_3\uparrow + H_2O$

Ways to minimise losses from FYM during handling

- Adoption of pit/trench method for composting and storage.
- Use of Gobar gas plant to produce biogas and slurry should be stored in pits.
- Prepared compost and FYM should be stored in pits ant top of the pit should be covered.
- If compost and FYM are stored heaps, then the heaps must be secured with polythene to avoid the loss.
- Composts must not be kept in heaps in the fields too long as it may cause loss; instead, it should be mixed to the soil as earliest possible.
- Chemical preservatives: 1) Gypsum 450 g to 900 g of rock phosphate per day per animal in the cattle shed. 2) Rock phosphate.
- Application of gypsum and rock phosphate in livestock sheds helps in reducing nitrogen loss and enhances the quality of FYM.

$(NH_4)_2 CO_3 + CaSO_4 \rightarrow CaCO_3 + (NH_4)_2SO_4$

$2CaSO_4 + Ca (H_2PO_4) + 2(NH_4)_2 CO_3 \rightarrow Ca_3 (PO_4)_2$ (TCP)

$+2(NH_4)_2SO_4 + 2H_2O + 2CO_2$

Tricalcium phosphate (TCP) formed in this reaction does not react with ammonium sulphate when manure becomes dry as such there will be no loss of ammonia.

ISBN 978-81-937862-2-2