UNIT-1

"Biofertilizers are substances that contain microorganisms, which when added to the soil increase its fertility and promotes plant growth."

What is Biofertilizer?

Biofertilizers are the substance that contains microbes, which helps in promoting the growth of plants and trees by increasing the supply of essential nutrients to the plants. It comprises living organisms which include mycorrhizal fungi, blue-green algae, and bacteria. Mycorrhizal fungi preferentially withdraw minerals from organic matter for the plant whereas cyanobacteria are characterized by the property of nitrogen fixation.

Nitrogen fixation is defined as a process of converting the di-nitrogen molecules into nitrogen compounds. For instance, some bacteria convert insoluble forms of soil phosphorus into soluble forms. As a result, phosphorus will be available for plants.

Types of Biofertilizers

Following are the important types of biofertilizers:

Symbiotic Nitrogen-Fixing Bacteria

Rhizobium is one of the vital symbiotic nitrogen-fixing bacteria. Here bacteria seek shelter and obtain food from plants. In return, they help by providing fixed nitrogen to the plants.

Loose Association of Nitrogen-Fixing Bacteria

Azospirillum is a nitrogen-fixing bacteria that live around the roots of higher plants but do not develop an intimate relationship with plants. It is often termed as rhizosphere association as this bacteria collect plant exudate and the same is used as a food by them. This process is termed as associative mutualism.

Symbiotic Nitrogen-Fixing Cyanobacteria

Blue-Green algae or Cyanobacteria from the symbiotic association with several plants. Liverworts, cycad roots, fern, and lichens are some of the Nitrogen-fixing cyanobacteria. Anabaena is found at the leaf cavities of the fern. It is responsible for nitrogen fixation. The fern plants decay and release the same for utilization of the rice plants. Azolla pinnate is a fern that resides in rice fields but they do not regulate the growth of the plant.

Free-Living Nitrogen-Fixing Bacteria

They are free-living soil bacteria which perform nitrogen fixation. They are saprotrophic anaerobes such as *Clostridium beijerinckii*, Azotobacter, etc.

Among all the types of biofertilizers, Rhizobium and Azospirillum are most widely used.

Components of Biofertilizers

The components of biofertilizers include:

Bio Compost

It is one of the eco-friendly product composed of waste material released from sugar industries which are decomposed. It is magnified with human-friendly bacteria, fungi, and various plants.

Tricho-Card

It is an eco-friendly and nonpathogenic product used in a variety of crops as well as in horticultural and ornamental plants, such as paddy apple, sugar cane, brinjal, corn, cotton, vegetables, citrus, etc. It acts as a productive destroyer and antagonistic hyper parasitic against eggs of several bores, shoot, fruit, leaves, flower eaters and other pathogens in the field.

Azotobacter

It protects the roots from pathogens present in the soil and plays a crucial role in fixing the atmospheric nitrogen. Nitrogen is a very important nutrient for the plant and about 78% of the total atmosphere comprises of nitrogen.

Phosphorus

Phosphorus is one of the essential nutrients for plants growth and development. Phosphate solubilizing microorganisms, hydrolyze insoluble phosphorus compounds to the soluble form for uptake by plants. Many fungi and bacteria are used for the purpose such as *Penicillium, Aspergillus, Bacillus, Pseudomonas, etc.*

It is an Eco-friendly organic fertilizer comprises of vitamins, hormones, organic carbon, sulfur, antibiotics that help to increase the quantity and quality of yield. Vermicompost is one of the quick fixes to improve the fertility of the soil.

Also refer: Vermicomposting

Importance of Biofertilizers

Biofertilizers are important for the following reasons:

- Biofertilizers improve soil texture and yield of plants.
- They do not allow pathogens to flourish.
- They are eco-friendly and cost-effective.
- Biofertilizers protect the environment from pollutants since they are natural fertilizers.
- They destroy many harmful substances present in the soil that can cause plant diseases.
- Biofertilizers are proved to be effective even under semi-arid conditions.

Applications of Biofertilizers

Following are the important applications of biofertilizers:

Seedling root dip

This method is applicable to rice crops. The seedlings are planted in the bed of water for 8-10 hours.

Seed Treatment

The seeds are dipped in the mixture of nitrogen and phosphorus fertilizers. These seeds are then dried and sown as soon as possible.

Soil Treatment

The biofertilizers along with the compost fertilizers are mixed and kept for one night. This mixture is then spread on the soil where the seeds have to be sown.

Discover more about what is biofertilizer, types of biofertilizers and applications of biofertilizers, only at

Organic fertilizers:

Organic fertilizers are fertilizers derived from animal matter, animal excreta (manure), human excreta, and vegetable matter (e.g. compost and crop residues).[1] Naturally occurring organic fertilizers include animal wastes from meat processing, peat, manure, slurry, and guano.

In contrast, the majority of fertilizers used in commercial farming are extracted from minerals (e.g., phosphate rock) or produced industrially (e.g., ammonia). Organic agriculture, a system of farming, allows for certain fertilizers and amendments and disallows others; that is also distinct from this topic.

Examples and sources

Compost bin for small-scale production of organic fertilizer

A large commercial compost operation

The main organic fertilizers are, peat, animal wastes (often from slaughter houses), plant wastes from agriculture, and treated sewage sludge.[1]

Mineral

By many definitions, minerals are separate from organic materials. However, certain organic fertilizers and amendments are mined, specifically guano and peat. Other mined minerals are fossil products of animal activity, such as greensand (anaerobic marine deposits), some limestones (fossil shell deposits), and some rock phosphates (fossil guano).

Peat, a precursor to coal, offers no nutritional value to the plants, but improves the soil by aeration and absorbing water. It is sometimes credited as being the most widely use organic fertilizer and by volume is the top organic amendment.

Peat is the most widely used organic amendment.

Animal sources

Animal sourced materials include both animal manures and residues from the slaughter of animals. Manures are derived from milk-producing dairy animals, egg-producing poultry, and animals raised for meat and hide production. When any animal is butchered, only about 40% to 60% of the live animal is converted to market product, with the remaining 40% to 60% classed as by-products. These by-products of animal slaughter, mostly inedible -- blood, bone, feathers, hides, hoofs, horns, -- can be refined into agricultural fertilizers including bloodmeal, bone meal[1] fish meal, and feather meal.

Chicken litter, which consists of chicken manure mixed with sawdust, is an organic fertilizer that has been proposed to be superior for conditioning soil for harvest than synthetic fertilizers.[2]

Plant

Processed organic fertilizers include compost, humic acid, amino acids, and seaweed extracts. Other examples are natural enzyme-digested proteins. Decomposing crop residue (green manure) from prior years is another source of fertility.

Other ARS studies have found that algae used to capture nitrogen and phosphorus runoff from agricultural fields can not only prevent water contamination of these nutrients, but also can be used as an organic fertilizer. ARS scientists originally developed the "algal turf scrubber" to reduce nutrient runoff and increase quality of water flowing into streams, rivers, and lakes. They found that this nutrient-rich algae, once dried, can be applied to cucumber and corn seedlings and result in growth comparable to that seen using synthetic fertilizers.[3] :>

Treated sewage sludge

Sewage sludge, also known as biosolids, is effluent that has been treated, blended, composted, and sometimes dried until deemed biologically safe. As a fertilzer it is most commonly used on non-agricultural crops such as in silviculture or in soil remediation. Use of biosolids in agricultural production is less common, and the National Organic Program of the USDA (NOP) has ruled that biosolids are not permitted in organic food production in the U.S.; while biologic in origin (vs mineral), sludge is unacceptable due to toxic metal accumulation, pharmaceuticals, hormones, and other factors.[4]

With concerns about human borne pathogens coupled with a growing preference for flush toilets and centralized sewage treatment, biosolids have been replacing night soil (from human excreta), a traditional organic fertilizer that is minimally processed.

Manures

Manures are plant and animal wastes that are used as sources of plant nutrients. They release nutrients after their decomposition. The art of collecting and using wastes from animal, human and vegetable sources for improving crop productivity is as old as agriculture. Manures are the organic materials derived from animal, human and plant residues which contain plant nutrients in complex organic forms. Naturally occurring or synthetic chemicals containing plant nutrients are called fertilizers. Manures with low nutrient, content per unit quantity have longer residual effect besides improving soil physical properties compared to fertilizer with high nutrient content. Major sources of manures are:

1. Cattle shed wastes-dung, urine and slurry from biogas plants
2. Human habitation wastes-night soil, human urine, town refuse, sewage, sludge and sullage
3. Poultry Jitter, droppings of sheep and goat
4. Slaughterhouse wastes-bone meal, meat meal, blood meal, horn and hoof meal, Fish wastes
5. Byproducts of agro industries-oil cakes, bagasse and press mud, fruit and vegetable processing wastes etc
6. Crop wastes-sugarcane trash, stubbles and other related material
7. Water hyacinth, weeds and tank silt, and
8. Green manure crops and green leaf manuring material

Manures can also be grouped, into bulky organic manures and concentrated organic manures based on concentration of the nutrients.

Bulky organic manures

Bulky organic manures contain small percentage of nutrients and they are applied in large quantities. Farmyard manure (FYM), compost and green-manure are the most important and widely used bulky organic manures. Use of bulky organic manures has several advantages:

- They supply plant nutrients including micronutrients
- They improve soil physical properties like structure, water holding capacity etc.,
- They increase the availability of nutrients
- Carbon dioxide released during decomposition acts as a CO_2 fertilizer and
- Plant parasitic nematodes and fungi are controlled to some extent by altering the balance of microorganisms in the soil.

Farmyard manure

Farmyard manure refers to the decomposed mixture of dung and urine of farm animals along with litter and left over material from roughages or fodder fed to the cattle. On an 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.The present method of preparing farmyard manure by the farmers is defective. Urine, which is wasted, contains one per cent nitrogen and 1.35 per cent potassium. Nitrogen present in urine is mostly in the form of urea which is subjected to volatilization losses. Even during storage, nutrients are lost due to leaching and volatilization. However, it is practically impossible to avoid losses altogether, but can be reduced by following improved method of preparation of farmyard manure. Trenches of size 6 m to 7.5 m length, 1.5 m to 2.0 m width and 1.0 m deep are dug.

All available litter and refuse is mixed with soil and spread in the shed so as to absorb urine. The next morning, urine soaked refuse along with dung is collected and placed in the trench. A section of the trench from one end should be taken up for filling with daily collection. When the section is filled up to a height of 45 cm to 60 cm above the ground level, the top of the heap is made into a dome and plastered with cow dung earth slurry. The process is continued and when the first trench is completely filled, second trench is prepared.

The manure becomes ready for use in about four to five months after plastering. If urine is not collected in the bedding, it can be collected along with washings of the cattle shed in a cemented pit from which it is later added to the farmyard manure pit. Chemical preservatives can also be used to reduce losses and enrich farmyard manure. The commonly used chemicals are gypsum and superphosphate. Gypsum is spread in the cattle shed which absorbs urine and prevents volatilization loss of urea present in the urine and also adds calcium and sulphur. Superphosphate also acts similarly in reducing losses and also increases phosphorus content.

Partially rotten farmyard manure has to be applied three to four weeks before sowing while well rotten manure can be applied immediately before sowing. Generally 10 to 20 t/ha is applied, but more than 20 t/ha is applied to fodder grasses and vegetables. In such cases farmyard manure should be applied at least 15 days in advance to avoid immobilization of nitrogen. The existing practice of leaving manure in small heaps scattered in the field for a very long period leads toloss of nutrients. These losses can be reduced by spreading the manure and incorporating by ploughing immediately after application.

Vegetable crops like potato, tomato, sweet-potato, carrot, raddish, onion etc., respond well to the farmyard manure. The other responsive crops are sugarcane, rice, napier grass and orchard crops like oranges, banana, mango and plantation crop like coconut.

The entire amount of nutrients present in farmyard manure is not available immediately. About 30 per cent of nitrogen, 60 to 70 per cent of phosphorus and 70 per cent of potassium are available to the first crop.

Farm yard manure

Sheep and Goat Manure

The droppings of sheep and goats contain higher nutrients than farmyard manure and compost. On an average, the manure contains 3 per cent N, 1 per cent P2O5 and 2 per cent K2O.It is applied to the field in two ways. The sweeping of sheep or goat sheds are placed in pits for decomposition and it is applied later to the field. The nutrients present in the urine are *wasted* in this method. The second method is sheep penning, wherein sheep and goats are kept overnight in the field and urine and fecal matter added to the soil is incorporated to a shallow depth by working blade harrow or cultivator or cultivator.

Poultry Manure

The excreta of birds ferment very quickly. If left exposed, 50 percent of its nitrogen is lost within 30 days. Poultry manure contains higher nitrogen and phosphorus compared to other bulky organic manures. The average nutrient content is 3.03 per cent N; 2.63 per cent P2O5 and 1.4 per cent K2O.

Concentrated organic manures

Concentrated organic manures have higher nutrient content than bulky organic manure. The important concentrated organic manures are oilcakes, blood meal, fish manure etc. These are also known as organic nitrogen fertilizer. Before their organic nitrogen is used by the crops, it is converted through bacterial action into readily usable ammoniacal nitrogen and nitrate nitrogen. These organic fertilizers are, therefore, relatively slow acting, but they supply available nitrogen for a longer period.

Compost is a mixture of organic residues (manure, animal carcasses, straw, etc.) that have been piled, mixed and moistened to undergo thermophilic (high heat 113 to 160 degrees Fahrenheit) decomposition (SSSA, 1997).

This publication pertains to composting animal manures. For information on composting animal carcasses, refer to NDSU Extension publication “Animal Carcass Disposal Options” (NM1422).

Composting requires routine introduction of oxygen, which stimulates aerobic microorganisms that feed on the organic components and convert the piled organic material to a fairly stable nutrient-rich soil amendment (Larney and Blackshaw, 2003). Compost can be applied to agricultural fields as a fertilizer, added to improve soil structure, substituted for peat in horticulture and used as a microbial additive to increase enzyme activities (Steger et al., 2007).

Compost Benefits

The soil benefits greatly from the addition of compost. Fertility, water-holding capacity, bulk density and biological properties are improved (Flavel and Murphy, 2006). Odors are reduced and fly eggs die due to the high temperatures occurring during microbial decomposition (Larney et al., 2006).

Certain weed seeds can pass through livestock and grow in manure applied on cropland. Few weed seeds remain viable in properly composted manure, which can reduce the amount of herbicide or tillage needed for weed control. Larney and Blackshaw (2003) studied weed seed viability in composted livestock manures. After 21 days of composting downy brome, false cleavers, foxtail barley, scentless chamomile, wild mustard and wild oat, weed seeds did not germinate. Some weed seeds were more difficult to kill. Those were green foxtail, redroot pigweed, round-leaved mallow, stinkweed and wild buckwheat. After 42 days of composting, those weeds did not germinate.

Composting reduces the volume and density of manure approximately 50 to 65 percent (Figures 1 and 2). The decrease in volume reduces hauling costs. Wiederholt et al., (2009) conducted a case study that compared the energy required of a 180-head feedlot operation that applied raw manure and composted manure to agricultural fields. They concluded that composting and applying livestock compost is more energy efficient than hauling raw manure. The decrease in volume and mass from composting reduced the hauling requirements enough to offset the energy required to compost The energy ratio of raw manure to composted manure was 1.56-to-1 energy units.

Figure 1. Initial windrows of bedded feedlot manure. The west pile cannot be seen in this picture and note the initial height of the middle pile.
(photo NDSU Carrington Research Extension Center)

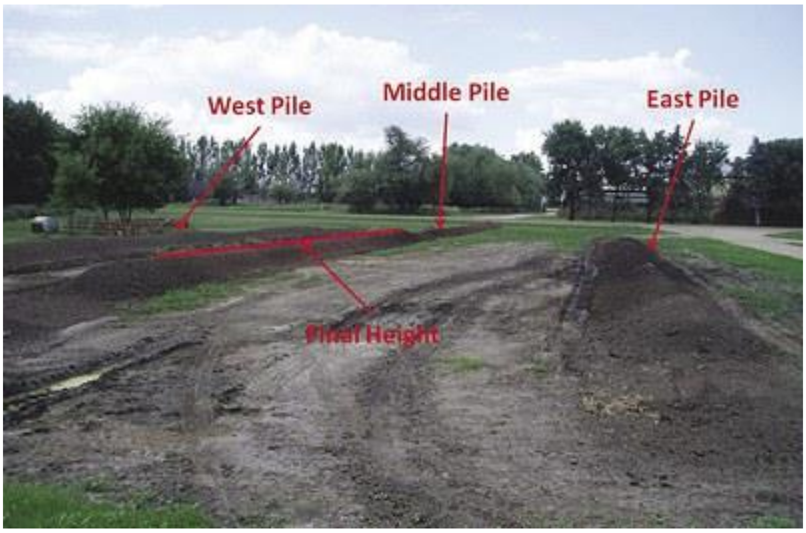

Figure 2. Composted bedded feedlot manure. The west pile can be seen and the final height of the middle pile is greatly reduced.
(photo NDSU Carrington Research Extension Center)

Composting animal manures is an effective way to kill pathogens. Grewal (2006) studied and compared the length of time that pathogens lived in simulated composted dairy manure, a simulated dairy manure pack and a simulated liquid dairy lagoon. Grewal found that after three days of composting at 131 F, Escherichia coli, Salmonella and Listeria monocytogenes were not detected. However, Salmonella still was detected after 28 days in the manure pack and lagoon simulations. Escherichia coli and Listeria monocytogenes were found in the lagoon after 14 days, and Listeria was not found after seven days in the bedded pack simulations.

Site Selection

Composting should take place on an area that drains well but where runoff or leachate will not reach waters of the state. The pad ideally should drain into a containment pond. The site may not be located along surface waters of the state, on soil textures coarser than a sandy loam or within a flood plain. Ideal areas are well-drained, have slopes of 2 to 4 percent, consist of concrete or packed soil or gravel and drain into a containment pond. Windrows should be constructed parallel to the slope. This prevents the windrow from blocking runoff and allows implement access to the pad. Slopes exceeding 6 percent may be prone to erosion and can cause pad issues.

Composting Manure Process

The microorganisms responsible for composting are indigenous to manures. By properly managing compost, the producer facilitates these decomposing microbes. The manure must be piled, the carbon-to-nitrogen (C/N) ratio should be 30-to-1, 50 percent of the pore space should contain water and the pile must be aerobic (having oxygen) (Rynk et al., 1992).

Manure usually is piled into a windrow. The pile commonly is 10 to 12 feet wide and 4 to 6 feet high (Figure 1). The windrow dimensions are dictated by the length of the pad and size of the turning implement. After a day or two, the pile should reach temperatures in excess of 120 F (Figures 3 and 6).

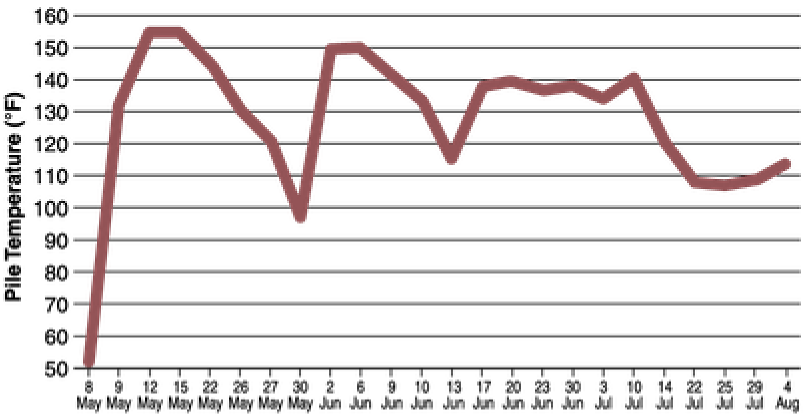

Figure 3. Average temperatures of a straw-bedded beef feedlot manure compost pile. The manure was piled into windrows on May 8. The pile was turned on May 30, June 13, June 23 and July 29. The pile did not pass the wet-rag test on June 11 and was watered the same day. This pile may be piled for curing after Aug. 4.

Figure 6. Twenty-four hours after raw straw-bedded feedlot manure was piled in early May, temperatures already have reached 132 F.
(photo NDSU Carrington Research Extension Center)

The C/N ratio in a composting pile needs to range from 20-to-1 (20 parts of carbon for every part of nitrogen) to 40-to-1 (40 parts of carbon for every part of nitrogen). Decomposing microorganisms typically have a C/N ratio of 5-to-1 to 10-to-1. The C/N ratio needs to be higher because approximately 50 percent of the metabolized carbon is released as carbon dioxide (Miller, 1996). Nitrogen can be lost when too much (C/N ratio below 20-to-1) is present, and the pile might smell of volatizing ammonia. Adding carbon (straw or woodchips) can help alleviate this. Too much carbon (C/N ratio more than 40-to-1) in a compost pile can immobilize nitrogen and slows the composting process (Coyne and Thompson, 2006).

Composting material's C/N ratio varies greatly. Differences in manure can be from species, feeding rations, climate, storage facility, etc. The C/N ratio of bulking materials of plant origin varies greatly as well and for the same reasons as manures. Table 1 outlines many of the properties that various composting materials possess. Figure 4 and Table 2 illustrate the process of determining the C/N ratio.

Table 1. Carbon-to-nitrogen (C/N) ratio of common composting materials.

Material	C/N Ratio	Material	C/N Ratio
Cattle Manure	19:1	Poultry Carcass	4:1
Cattle Carcass	10:1	Sawdust	442:1
Corn Silage	40:1	Sheep Manure	16:1
Corn Stalk	68:1	Swine Carcass	14:1
Dairy Manure	20:1	Swine Manure	12:1
Grass Clippings	17:1	Turkey Litter	16:1
Horse Manure	30:1	Wheat Straw	127:1
Leaves	54:1	Wood Chips	600:1

(Rynk et al., 1992)

Table 2. A worksheet to determine C/N ratio mixture of composting materials.

Material	C/N Ratio	Minus	Desired C/N Ratio	Equals	Adjusted C/N Ratio (Absolute Value)	Materials C/N Ratio Difference	Equals	Dividing Factor*	Equals	Adjusted C/N Ratio (Absolute Value)	Divide	Dividing Factor*	Equals	Multiply by 100 Equals	Recom-mended Co-product (%)	Minus 100% Equals	Recommended Mixture (%)
Swine Manure	12:1	–	30:1	=	18	127–12	=	115	=	18	÷	115	= 0.157	X 100 =	15.7%	– 100% =	84.3% Swine Manure
Wheat Straw	127:1	–	30:1	=	97	127–12	=	115	=	97	÷	115	= 0.843	X 100 =	84.3%	– 100% =	15.7% Wheat Straw
		–		=			=		=		÷		=	X 100 =		– 100% =	
		–		=			=		=		÷		=	X 100 =		– 100% =	
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*Dividing Factor is the difference of C/N ratios of different composting materials. The value used is the absolute value.

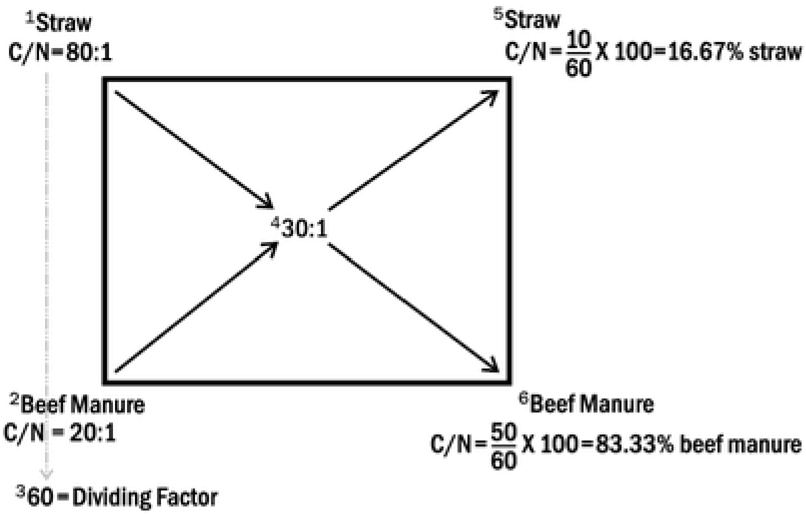

Figure 4. An example of using the Pearson Square method for proper compost mixture determination.

Pearson Square Procedure: 1 is the C/N ratio of a typical straw. 2 is the C/N ratio of typical beef manure. 3 is the difference of straw and beef manure. 4 is the desired C/N ratio. 5 is the difference of beef manure C:N ratio and desired C:N ratio. Multiplying this value by 100 reveals that 16.67% of straw is needed for the desired C/N ratio. 6 is the difference of straw C/N ratio and desired C/N ratio. Multiplying this value by 100 reveals that 83.33% of manure is needed for the desired C/N ratio.

Water management is important in compost because 40 to 65 percent of the pore space in composting materials should have water. Measuring devices can be used to monitor the moisture, but they can be costly.

One way to test moisture is the simple hand test called the "wet rag test." Squeeze the compost and feel for moisture. If water drips out, then it is too wet. But if the compost feels like a wrung-out wet rag, the compost has sufficient amounts of moisture (Rynk et al., 1992). Remember to wash your hands after working with compost.

Moisture usually is not an issue in central and eastern North Dakota. However, water may have to be added in western North Dakota or during prolonged dry events. Some turners have water tanks plumbed into nozzles that add water while turning. Water also may be added by spraying it directly on the pile (Figure 5).

Figure 5. Watering compost at the Carrington Research Extension Center during an extremely dry period. (photo NDSU Carrington Research Extension Center)

The microorganisms that transform manure into compost require oxygen for their energy-deriving chemical reactions. Less than 5 percent of oxygen within the pore space will turn the pile anaerobic (without oxygen), may create a rotten-egg smell and will slow the composting process. Aerobic conditions can be replenished by turning the pile (Rynk et al., 1992).

Monitoring the pile temperature with a probe-type thermometer can indicate when to turn the pile (Figure 6). To efficiently compost manure, turn the pile when temperatures drop below 110 F. After three to five turns, the manure should be composted. Temperatures should be taken at various locations and depths. According to Michel (2009), compost windrows can be turned every 10 days or two weeks. This can minimize labor while creating a good-quality product.

Organic operations must meet certain temperature and turning frequency requirements. The National Organic Program requires pile temperatures to exceed 131 F for 15 days and piles to be turned at least five times (The Organic Center, 2006).

Piles may exceed 160 F, which can destroy the beneficial microbes, causing a decline in microbial activity and slowing the process. If this occurs, chances are the piles have too much nitrogen. Adding carbon, making the piles smaller and digging holes in the pile are ways of cooling the pile (Carpenter-Boggs, 1999).

Compost Aeration Methods

Turning manure is essential to composting manure. Turning compost incorporates oxygen into the system, homogenizes the pile and breaks up clumps. Mixing allows more contact of manure with microbes. Producers have various ways to turn the pile. The two most common methods for turning compost are with a windrow turner (Figures 7 and 8) or bucket tractor. Turners may be self-propelled or attached to a tractor or skid steer. Turners mix the compost by an auger, rotary drum with flails or an elevating conveyor. Some turners require power from the attached implement, while others are self-powered.

Figure 7. Front-mount composter. This compost turner cleans pens, windrows and turns the pile in the same pass.

(photo NDSU Carrington Research Extension Center)

Figure 8. A pull-type compost turner that is turning windrowed bedded feedlot manure for the first time. (photo NDSU Carrington Research Extension Center)

Producers have many factors to consider when selecting a turner. Determining the amount of manure to turn is a good starting point. Bucket tractors or skid steers work well for small operations or testing if compost fits into your operation. However, turner implements work better for larger operations.

Turners range in various sizes from 6 feet wide to as much as 20 feet wide. A 10-foot-wide turner may turn 1,500 yards per hour, while a 14-foot turner may turn as much as 2,600 yards per hour. Implements that run a turner must have a creeper gear and go as slowly as 20 feet per minute.

Turning becomes easier throughout the composting process. Some front-mount turners clean pens and windrow the manure in the same pass. The benefit of this is that space and time are saved by eliminating the external pad and not hauling the manure out of the pen.

Other ways to incorporate oxygen include using passively aerated windrows and aerated static piles. Passively aerated windrow systems require peat moss, wood chips or some type of material to be added to increase porosity. Perforated pipes are placed within the pile to allow airflow. No mechanical mixing is required, but the windrow should be constructed above 6 to 12 inches of compost or peat moss and covered by a layer of compost or peat moss. This covering insulates the pile and absorbs excess moisture. An aerated static compost pile is similar to passively aerated windrows but has fans that force air through the perforated pipes. (Rynk et al., 1992).

After the heating cycles have subsided, compost usually is piled for storage while awaiting field applications. This month long or longer process is known as curing. Applying immature compost can cause issues that include malodors, insect swarms, nitrogen immobilization and phytotoxicity (Mathur et al., 1993; Francou et al, 2005; Steger et al., 2007).

Compost maturity is strongly related to microbial activities during the composting process. Producers have many options to assess compost maturity. Options include sending samples to laboratories, checking pile temperatures to ensure that the pile is near the ambient temperature (Figure 3) and kits that give colormetric readings of carbon dioxide and ammonia emissions.

Nutrient Management of Compost

Manure composts not only improve soil physical and chemical characteristics; they also are a good source of fertilizer for crop production. However, much of the nitrogen is tied up in complex organic compounds (immobilized) and is not immediately ready for plant uptake, whereas commercial fertilizers are predominantly plant-available. Cropland soils and compost should be tested for nutrients. Nitrogen, phosphorus and potassium tend to be the most limiting nutrients required by crops (Coyne and Thompson, 2006).

Applications of compost must be based on crop needs. Manure applications usually are based on nitrogen needs for that crop (North Dakota Department of Health, 2005). Most crops have a nitrogren-to-phosphorus (N/P) ratio of 7-to-1 to 10-to-1, whereas composted manure commonly has an N/P ratio of 1-to-2. Because of this, nutrient management plans may need to be based upon phosphorus management. This change in management can prevent nutrient loading and high levels of phosphorus that can accumulate when not properly managed and monitored (Spargo et al., 2006). Sampling and testing soil for nutrients can alleviate nutrient loading. Refer to NDSU Extension publications “North Dakota Fertilizer Recommendation Tables and Equations” (SF882) and “Soil Sampling as a Basis for Fertilizer Application” (SF990) for more information on soil sampling and nutrient requirements.

Crop and environmental benefits may not occur if the finished composted product is not tested and properly applied. Once cured, compost samples should be taken within the pile at various points and mixed thoroughly to account for variability. Samples should be tested as soon as possible or kept in cold storage until they can be sent to a laboratory for analysis. Refer to NDSU Extension publication “Manure Sampling for Nutrient Management Planning” (NM-1259) for more sampling methods and interpretation of test results.

Keep in mind that many testing labs treat compost nutrient availability as if it were raw manure (approximately 50 percent nitrogen, 80 percent phosphorus and 90 percent potassium of the total nutrients are plant-available the first growing season). Compost nutrient availability is different and producers need to account for the differences. This difference is due to the increased stability of compost. Eghball and Power (1999) found in a four-year study that 15 percent of the total nitrogen in beef feedlot compost was plant-available the first year and 8 percent of the nitrogen was mineralized the second year. Wen et al. (1997) found in a two-year study that 30 percent and 70 percent of the total phosphorus in composted livestock manure was mineralized the first and second year, respectively. A greenhouse study conducted by Bar-Tall et al. (2004) showed that 31 percent of the total potassium in compost is mineralized.

Because of immobilization and the possibility of nutrient loading, compost fertilizer applications may need to be supplemented with conventional fertilizers. Eghball and Power (1999) tested different management strategies (compost applications based on nitrogen or phosphorus and conventional fertilizer). They found that managing composts based on phosphorus and supplementing the other nutrient requirements with conventional fertilizers yielded equal or greater corn yields.

Compost should be applied with a calibrated spreader. This ensures that the proper amount of nutrients is applied and also lessens the chance of polluting. Manure spreaders can be calibrated various ways. Refer to NDSU Extension publication “Manure Spreader Calibration for Nutrient Management Planning” (NM1418) for spreader calibration procedures.

Summary

Manure needs to be managed properly to be composted properly. Carbon/nitrogen ratios should be about 30-to-1, moisture content should be around 50 percent and air needs to be incorporated routinely by turning. This ensures that the pile will heat and convert to compost effectively.

Surface and ground water proximity are important for compost site selection. The compost site needs to be in an area not prone to contamination of groundwater by leaching or where leachate can run off to surface water.

Instead of viewing manure as a waste, producers can begin to view it as a product that can be substituted for commercial fertilizer and as an economic resource

Composting is an effective manure management tool that reduces volume, kills pathogens and weed seeds, and also improves soil health and fertility. However, soil and compost should be tested for nutrients. Applying compost with a calibrated spreader ensures that crop yield goals will be met and reduces the chance of pollution. The volume reduction of composting manure can save producers money.

Effective microorganisms technology’

Effective microorganisms technology’ is a method developed by Professor T. Higa of Japan in which a mixed culture of beneficial microorganisms (primarily photosynthetic and lactic acid bacteria, yeasts, actinomycetes, and fermenting fungi) is applied as an innoculant to increase the microbial diversity of soils. This improves the soil quality and health, which improves the growth, yield, and quality of crops. In the variant being tested at ICIMOD it is combined with composting, to make an easy to prepare and very effective organic fertiliser.

Composting is a largely biological process in which microorganisms (both aerobic and anaerobic) decompose organic matter and lower the carbon-nitrogen ratio of refuse resulting in a final product of well-rotted compost. Compost has a high content of organic matter and important nutrients and is very useful for soil conservation and improving and maintaining soil fertility. In cooler climates, however, and with coarse material, the process of composting can be quite slow.

The EM composting method uses effective microorganisms and molasses to speed up the composting process and provide an improved compost product. Vegetation, especially weeds from cropping alleys and unwanted (exotic) forest weeds like banmara (Euphatoriumadenophorum), is chopped and mixed with a small amount of goat manure and fermented organic matter containing beneficial microorganisms, and 1% of a solution of EM in molasses. The mixture is placed in piles on the ground. In the summer, it transforms into mature compost in 5-6 weeks.

hat is meant by Effective Microorganisms (EM)?

E.M. is an abbreviation for Effective Microorganisms

Microorganisms are tiny units of life that are too small to be seen with the naked eye and they exist everywhere in nature. Microorganisms are crucial for maintaining the ecological balance. They carry out chemical processes that make it possible for all other organisms including humans to live. There are friendly guys of the microbial worlds known as beneficial microorganisms and a not so friendly group called pathogens that are harmful and capable of producing disease, decay and pollution.

EM origin

In 1982 Dr.Higa at the University of Ryukyus, Okinawa Japan, discovered a specific group of naturally occurring beneficial microorganisms with an amazing ability to revive, restore, and preserve. He named this group E.M. (Effective microorganisms).

Using EM to make an Insect Repellent

This mix will make a non-toxic chemical free insect repellent. It can be used to prevent pest and disease problems in the garden. It acts by creating a barrier around the plant thereby protecting it from insects. The mix can be enhanced by including garlic, hot peppers or aloe vera . These are chopped or mashed prior to adding to the mix.

Mixing

Warm water (chlorine free)	:	300 ml
Molasses	:	50 ml
Natural vinegar	:	50 ml
Whiskey or ethyl alcohol	:	50 ml
EM liquid concentrate	:	50 ml

Select a suitable sized container for mixing, some plastic bottles with caps for storage and a funnel. Add the molasses to the warm water and stir till thoroughly mixed. Then add the vinegar, whiskey and EM concentrate. Pour the mix into the plastic bottles and add small quantities of chopped garlic etc. Seal as tightly as possible and leave in a warm dark place. Release any gas produced at least twice daily by releasing the cap. The EM is ready for use when the production of gas has stopped and the product has a sweet fruity smell. The mix can be stored in a dark cool place which has a uniform temperature for up to 3 months. If garlic extract has been used, filter this out before storage. Do not store in the refrigerator.

Using EM insect repellent mix

Dilute 20 mls of the mix in 2 litres of clean water in a sprayer and spray enough of the mix to wet the crop. Spraying can begin from seed germination or plant establishment and before pests and diseases can be seen. If an attack occurs use up to 30 mls of solution in 2 litres of water Spray weekly either in the morning or after heavy rains for best results.

EM the natural product

- EM is the trade mark used to identify this particular mixture of beneficial organisms
- E.M. is a combined culture of aerobic microorganisms (requiring oxygen to survive) and anaerobic (requires no oxygen to survive) that co-exist together to the mutual advantage of both (symbiosis).
- E.M combines with the existing microorganisms within the soil. They work together to build a healthy living soil.
- E.M is not toxic or pathogenic and is safe for humans, animals and the environment.

EM in action

Current research indicates that EM cultures can suppress soil-borne pathogens, accelerate the decomposition of organic wastes, increase the availability of mineral nutrients and useful organic compounds to plants, enhance the activities of beneficial micro-organisms, e.g., mycorrhizae, nitrogen fixing bacteria, and reduce the need for chemical fertilisers and pesticides. EM helps to increase beneficial soil micro-organisms and supression of harmful ones.

Using EM Liquid

Concentrate

As a foliage application

Apply weekly using a clean sprayer and spray directly onto the plants ensuring through wetting. This should be done in early morning or late afternoon for best results and to prevent leaf scorch.

As a soil application

Give a good watering ensuring the solution fully drenches / wets the soil. Apply as required around mature plants or on open ground. When incorporating organic matter/compost into the soil, apply EM dilution to the organic matter before digging in.

No dig gardening

Cut any annual weeds, grass, or crop residues at least 5 cm from the ground and place the material on the soil as a mulch. Spray EM liquid weekly on the mulch and plants.

As a compost application

Apply to the compost heap to reduce troublesome odours and flies as well as improving the compost process and quality. Preferably spray on with a hand sprayer to prevent over wetting the compost heap and apply at each addition of fresh material if possible.

EM for the garden

EM is a liquid concentrate and in this form the micro organisms are alive but dormant. It is a dark brown liquid with a pleasant vinegary yeasty type smell. The pH of this liquid is approx. 3.5. To activate the EM simply dilute the concentrated solution with clean chlorine free water. The EM solution which is then produced is a yellowish brown in colour with a pleasant smell.

Where to use EM Liquid

Concentrate

EM Liquid Concentrate can be used as a pre planting treatment, as a foliar spray, or for actively growing fruit and veggie crops, and for all ornamental plants. In fact anywhere in the garden including your compost heap or areas of poor or stagnant soil.

Applying EM Liquid Concentrate

Use EM liquid concentrate in the garden at the rate of 5ml EM concentrated solution diluted in 1 litre of clean chlorine free water. Apply at the rate of one litre per square metre. These are minimum recommended rates for use.

How to improve the performance of EM concentrate

(This following procedure is optional)
You will need

- 10 litre watering can
- 10 litres of chlorine free water (water can be left to stand for 24hrs to allow the chlorine to evaporate)
- 10-20 ml EM Concentrate
- 10-20 ml Molasses

If necessary, dissolve the molasses or brown sugar in a little warm water first. Then pour the molasses or brown sugar into the 10 litres of water and stir thoroughly. Add the EM Concentrate into the molasses, water mix and stir well. The EM then uses the molasses as a food source, so kick starting it into action quicker.

Leave the mix to stand in a warm place out of direct sunlight for 1-2 hours to allow the EM to activate more fully. Apply at the rate of one litre per square m etre. Do not store any of the made up solution. These are minimum recommended rates for use.

EM in the soil

Most organics including animal manures and composts have populations of micro-organisms. Many of these are beneficial upon introduction to the soil, however they are soon overwhelmed by the existing soil microorganisms. Thus, the beneficial effects of micro-organisms introduced with the application of composts are often short lived. On application EM cultures are subject to the same fate when applied to the soil environment. But the advantage of EM is that beneficial microorganisms are in much greater numbers, and in optimally-balanced populations when introduced, so remain dominant in the soil for a much longer time.

The effectiveness of EM can be extended in soils by three applications of EM at 8 - 10 day intervals during the first 3 to 4 weeks after planting a crop. This will insure that EM populations remain high throughout a critical a period when young seedlings and plants are vulnerable to environmental stresses (drought, heat, weeds, and pathogens). It is at this stage when the greatest loss in crop yield and quality occurs.

EM cultures and organics

EM cultures have been used effectively to inoculate both farm wastes as well as urban wastes to reduce odours and hasten the treatment process. EM has also been used with great success as an inoculant for composting a wide variety of organic wastes. An EM culture known as EM Bokashi can be used for composting food organics and other compostable materials. EM Bokashi is a fermented compost starter made from sawdust and wheat bran. When the correct conditions are provided EM sets in motion a fermentation process to transform food and other organic materials into compost.

EM effects on soils and crops

EM has been used on many different soils and crops over a wide range of conditions. Results show that in most cases EM gives positive results. EM is not a substitute for other management practices. EM technology is an added dimension for optimising our best soil.

and crop management practices such as crop rotations, use of composts, crop residue recycling, and biological control of pests. If used properly EM enhances soil fertility and promotes growth, flowering, fruit development and ripening in crops. It can increase crop yields and improve crop quality as well as accelerating the breakdown of organic matter from crop residues. The population of beneficial micro- organisms in the soil is also increased helping to control soil diseases through competitive exclusion. In New Zealand EM has Bio-Gro certification as an "Approved organic product".

EM for weeds pests and diseases

EM is not a pesticide and contains no inorganic chemicals. EM is a microbial inoculant that works as a bio-control measure in suppressing and/or controlling pests through the introduction of beneficial microorganisms to soils and plants. Pests and pathogens are suppressed or controlled through natural processes by enhancing the competitive and antagonistic activities of the microorganisms in the EM inoculants.

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2. EM-based quick composting

Effective micro-organisms (EM) consist of common and food-grade aerobic and anaerobic micro-organisms: photosynthetic bacteria, lactobacillus, streptomyces, actinomycetes, yeast, etc. The strains of the micro-organisms are commonly available from microbe banks or from the environment. There are no genetically engineered strains that are in use. Since 1999, seven small-scale organic fertilizer units have been using the EM-based quick production process in Myanmar. They are owned and operated by women's income generation groups. A unit consists of nine pits measuring about 180 cm (length) × 120 cm (width) × 90 cm (depth), enclosed by low walls and covered with a roof .

Raw materials

The raw materials for organic fertilizer production are:

Cow dung	:	2 portions
Rice husk	:	1 portion
Rice husk-charcoal	:	1 portion
Rice bran, milled	:	1 portion
Accelerator	:	33 litres of EM solution or *Trichoderma* solution per pit

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3. Preparation of EM solution

One litre of 'instant solution' is made by mixing 10 ml of EM, 40 ml of molasses and 950 ml of water and leaving it for five to seven days, depending on temperature. The solution is then added to 1 litre of molasses and 98 litres of water to obtain 100 litres of ready-to-use EM solution. This amount is enough for three pits. The EM solution functioning as accelerator reduces the composting period from three months to one month.

Procedure

All the ingredients are mixed together, except accelerator. A 15 cm layer of mixture is spread in the pit and accelerator is sprinkled on it. This procedure is repeated until the pit is full. The pit is covered with a plastic sheet. Two or three weeks later, the whole pit is mixed in order to boost aerobic decomposition. The compost is ready to use a couple of weeks later. A pit produces 900 kg of final product per batch. The product is usually packed in 30-kg plastic bags. Assuming that it takes 30 days on average to produce a batch and that only eight pits may be used for technical reasons, the annual potential production capacity is 86.4 tonnes (0.9 tonnes × 8 pits × 12 months). Within the framework of the FAO Technical Cooperation Programme project on promotion of organic fertilizers in Lao PDR (TCP/LAO/2901), a simple EM-based quick composting method, as detailed below, is promoted.

Raw materials

The raw materials for compost production are:

- Rice straw
- Farmyard manure
- Urea fertilizer
- EM solution

Procedure

Straw is stacked in layers of 20 cm height, 1 m width, and 5 m length to form a pile. A unit pile is about 5 m (length) × 1 m (width) × 1 m (height) in size. The pile is sprinkled with water for adequate moisture content, followed by addition of a manure layer 5 cm high, and the sprinkling of a few handfuls of urea (100-200 g). EM solution, prepared in the same way as described in the Myanmar example, is sprinkled to accelerate aerobic decomposition.

This procedure is repeated until the pile is about 1 m high and then it is covered with a plastic sheet. The pile is turned after two weeks and then again after another week. Normally, the compost is ready two weeks later when the heap has cooled down and the height of the pile has fallen to about 70 cm.

Effective microorganisms