THEORY NOTES

ON

Course Title : **Manures, Fertilizers and Agrochemicals**

Course No. : **SSAC-243 (New Course)**

Course : **B.Sc. (Agri.)**

Semester : **IV**

PREPARED BY

Dr. H.K. Kausadikar

Dr. S.L. Waikar

Dept. of Soil Science and Agril. Chemistry
College of Agriculture,
Parbhani – 431 402

MAHARATHWADA AGRICULTURAL UNIVERSITY,

PARBHANI : 431 402

Theory Notes
on

Course Title : **Manures, Fertilizers and Agro-chemicals**
Course No. : **SSAC – 243** (New Course) Semester : IV
Course : **B.Sc. (Agri.)**

INDEX

Chapter 1

Sources and Soil Organic Matter

Soil organic matter comprises an accumulation of partially disintegrated and decomposed plant and animal residues and other organic compounds synthesized by the soil microbes as the decay occurs. Such material is continually being broken down and resynthesized by soil microorganisms. Consequently organic matter is a rather transitory soil constituent, lasting from a few hours to several hundred years. This constituent requires maintenance by the regular addition of plant and/or animal residues to the soil.

The organic matter content of a typically well drained mineral soil is low varying from 1 to 6 % by weight in the topsoil and even less in the sub soils. The influence of organic matter on soil properties, and consequently, on plant growth is far greater even though the percentage of organic matter is less in the soil.

Sources of Soil Organic Matter :

a) The primary sources of soil organic matter is plant tissue are :

i) The tops and roots of trees
ii) Shrubs
iii) Grasses
iv) Remains of harvested crops
v) Soil organisms.

b) Animals usually are considered as secondary source of organic matter :

i) Waste products of animals
ii) remains of animals after completion of life cycle.

Composition of Organic residues

Organic residues consist of both organic and inorganic fractions. A simple outline for the presence of different compounds in organic residues are given below :

Organic residues

- Organic
  - Nitrogenous organic compounds
    - Water insoluble) protein, peptides, Peptones) and other carrying sulphur
    - Water soluble (nitrates, ammonical compounds etc.)
  - Non-nitrogenous organic compounds
    - Carbohydrates (cellulose, hemi cellulose starch, pectin sugars etc.)
    - Ether soluble (fats, oils, waxes, resins steroids etc.)
    - Lignin (tannin, organic acids, essential oils etc.)
- Inorganic (mineral constituents or ash) Ca, Mg, Na, K, Fe, Mn, Zn, Cu, etc.

On an average the green plant materials contain mainly contain water and dry matter. The dry matter content of the material also contains various substances like different elements and organic compounds which are shown below :

Since various types of plant tissues are found in manure, their composition also varies accordingly. However, the most tentative composition of a plant material has shown in the above scheme. From the scheme it is found that various organic compounds are present consisting of carbohydrates, proteins, legnins etc. Of which carbohydrate group of organic compounds are predominant. Lignin containing carbon, hydrogen and oxygen are very resistant to microbial decomposition. The crude protein are perhaps the most complicated which contain carbon, hydrogen, oxygen, nitrogen, sulphur iron and phosphorus. All these plant and animal remains are of no importance until and unless they are subjected to decomposition by different soil microorganisms. The decomposition of such residues in soil constitutes a basic biological aprocess in that carbon is recirculated to the atmosphere as CO_2, nitrogen is made available as NH_4^+ and NO_3^- and other associated plant nutrients like P, S and various micronutrient (fe, Mn, Cu, Zn etc.) appear in forms which will be available plants.

Organic Recycling

Generally crop residues should be left on or returned to the soil. This guideline takes advantage of the benefits of organic matter in soil, its aggregation of soil particles, improvement of aeration status, infiltration and permeability of soil, its reservoir of plant nutrients and energy for microorganisms etc. Such major benefits of organic residues are derived only if the material is somewhat easily and rapidly decomposing, a condition that exists only if fresh sorganic residues are incorporated into the soil regularly. This rapidly decomposing organic materials cana be recognized as "active organic matter", If only the humus residues (decompose very slow) are left, the release of different nutrient elements is slow. Slower decomposing organic matter produces a much less amount of gums or polysaccharides (long chain sugars), which can bind the soil particles forming aggregates and subsequently improves soil structure. If the supply of organic materials to the soil stops, polysaccharides like substances continue to decompose and within a very short period structural improvement of soil can be lost. Thus, new supplies of fresh organic waste materials must be continuously available to maintain the production of polysaccharide substances as well as to provide additional plant nutrients. .

Conservation tillage (fewer tillage operations and less disturbance of plant residues) is an another economic practice for recycling of organic residues as well as for maintenance of organic matter in the soil. Because it provides less opportunity for mixing organic residues with the soil and as a result the soil organic matter remains in large amounts than where sufficient tillage operation is done.

Newly applied plant residues can either stimulate or retard decomposition of native soil organic matter. This change in decomposition rate is described as "priming" and is usually positive. The priming action is defined as the loss of native soil organic matter through the application of fresh organic residues in the soil.

The amount of native C through "priming" was taken as the differences between the amount of soil CO_2 evolved in the presence and absence of fresh organic residues.

The loss of native soil organic matter due to priming action may be attributed that there is a building of a large and vigorous population of microorganisms when energy material (fresh is added to soil and that these microorganisms subsequently produce enzymes which attack the native soil organic matter).

Composition of Plant Material :

The no. of organic substances is immense, and they are as variable in composition as they are numerous. Organic matter is composed of about half carbon with lesser amounts of oxygen and hydrogen plus small quantities of nitrogen, phosphorus, sulfur, and many other elements. Carbon atems joined together into carbon chains of many lengths and linkage are the basic skeleton of organic compounds. The remaining elements fill out the skeletons to make different groups of organic matter, substances called proteins, lignins, carbohydrates, oils, fats, waxes, and many other materials.

The moisture content of plant residues is high, varying from 60-90 % with 75 % a representative figure. On a weight basis, the dry matter is mostly carbon and oxygen, with less than 10 % each of hydrogen and inorganic elements (ash). However, on an elemental basis (no. of atoms of the elements), hydrogen predominates in a representative plant residues there are 8 hydrogen atoms for every 3.7 carbon atoms and 2.5 oxygen atoms. These three elements dominate the bulk of organic tissue in the soil.

The general composition of representative green plant materials added to the soils can be booked in to **figure**. Note that all inorganic elements, including nitrogen, are represented in the ash . Common ranges in the percentages of compounds present are shown in parentheses.

Carbon cycle :

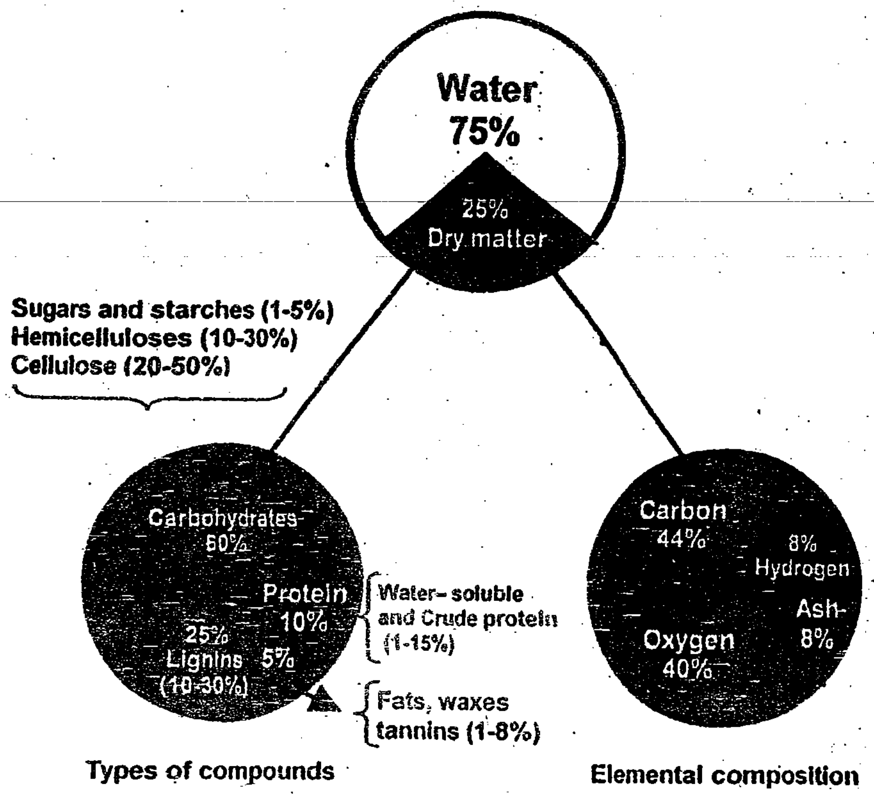
Carbon is a common constituent of all organic matter)plant and animal residues). Carbon is continually being fixed into organic form by photosynthetic organisms under the influence of light and once bound, the carbon becomes unavailable for use in the generation of new plant life. Therefore, it is essential for the carbonaceous materials to be decomposed and returned to the atmosphere for the survival of the higher organisms.

The decomposition of plant and animal remains in soil constitutes a basic biological process in that carbon © is recirculated to the atmosphere as CO2, Nitrogen is made available as NH_4^+ and NO_3^- and other associated nutrient elements like P, S, Fe, Mn, Cu and Zn etc appear in plant available forms. In the process part of the nutrient elements is assimilated by microorganisms and incorporated into microbial tissues (soil biomass). The conversion of organic forms of C, N, P and S to inorganic or mineral forms is called **mineralization** and the conversion of inorganic forms of thsose elements to their organic forms is known as **immobilization**.

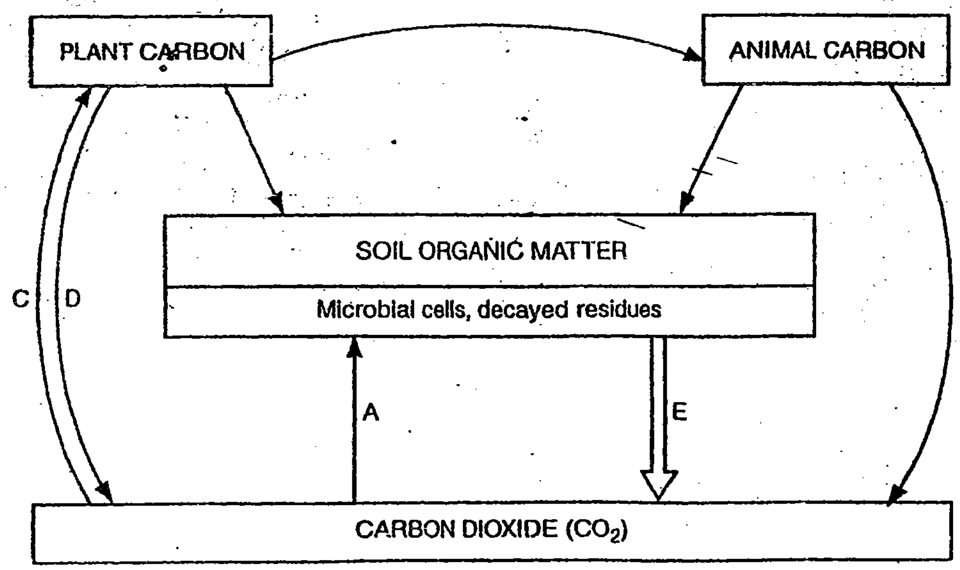
The carbon cycle revolves about CO_2 and its fixation and regeneration. Chlorophyll containing plants utilize the gas as their sole carbon source, and the carbonaceous matter thus synthesized serves to supply the animal world with preformed organic carbon. Upon the death of the plant or animal, microbial metabolism assumes the dominant role in the cyclic sequence. The dead tissues undergo decay and are transformed into microbial cells and a large amount of heterogeneous carbonaceous compounds togetherly known as humus or as the soil organic fraction. The cycle is completed and carbon made available with the final decomposition and production of CO_2 from humus and the rotting tissues. The carbon cycle is shown in figure.

Carbon : Nitrogen (C:N) ratio :

It is the intimate relationship between organic matter and nitrogen contents of soils. The ratio of the weight of organic carbon to the weight of total nitrogen in a soil or organic material is known as C:N ratio. The importance of C:N ratio in controlling the available nitrogen, total organic matter and the rate of organic materials decomposition is recognized in developing appropriate soil management practices.



Composition of representative green plant materials



A - AUTOTROPHIC MICRO-ORGANISMS
B - RESPIRATION, ANIMAL
C - PHOTOSYNTHESIS
D - RESPIRATION, PLANT
E - RESPIRATION, MICROBIAL

The Carbon Cycle

Ratio in soils :

The C:N ratio of soil is one of its characteristic equilibrium values, the figure for humus being roughly 10:1 although values from 5:1 to 15:1 are generally found in most arable soils. This critical ratio (10:1) is a reflection of the dynamic equilibrium that results from the dominating presence of a microbial population, the ratio being similar to the average chemical composition of microbial cells. As a rule microbial protoplasm contains 5 to 15 parts of carbon to 1 part of nitrogen, but 10:1 is a reasonable average for the predominant aerobic flora. A change in the microbial population brought about by anaerobiosis or the accumulation of fractions resistant to further decomposition can modify the C:N equilibrium value of humus. Such C:N ratio of soils can vary with the climates i.e. rainfall, temperature etc. The C:N ratio is generally lower in warmer regions than that of cooler ones inspite of having the same rainfall under both the the soil conditions. The ratio is also narrower for sub soils as compared to surface soil horizons.

Ratio in plants and microbes :

The carbon and nitrogen ratio in plant material is variable and ranges from 20:1 to 30:1 to legumes and farm yard manure to as high as 100:1 in certain straw residues. On the other hand C:N ratio of the bodies of microorganisations is not only more constant but much narrower between 4:1 and 9:1. Bacterial tissue in general is somewhat richer in protein than fungi and consequently has a narrow C:N ratio.

Therefore, it is usually found that most of the applied fresh organic materials in soils carry large amounts of carbon with relatively very small amounts of total nitrogen. As a result, the value of C:N ratio is wide and the values of C:N ratio for soils are in between those of higher plants and the microbes.

Practical implications of the C:N ratio :

The C:N ratio in soil organic matter is important for two major reasons : (i) keen competition for available nitrogen results when organic residues of high C:N ratio are added to soils and (ii) because this C:N (10:1) is relatively constant in soils, the maintenance of carbon and hence soil organic matter is dependent to no small degree on the level of soil nitrogen. So the C:N ratio obviously has practical implications on the availability of nitrogen in soils as well as in plants. As for example, large amount of fresh organic materials having wide C:N ratio (50:1) are incorporated into the soil under favourable soil conditions for decomposition. A rapid change will found. The heterotrophic microorganisms – bacteria, fungi and actinomycetes become active and increases their population with the production of large amounts of CO_2. Under these conditions nitrate nitrogen (NO_3-N) disappears from the soil because of the urgent needs by the microorganisms. And for the time being, little or no nitrogen is available to plants. As the decomposition proceeds, the C:N ratio of the organic materials decreases with the loss of carbon and conservation of nitrogen.

Reasons for the stabilization of C:N ratio to a constant value :

As the decay process proceeds, both carbon and nitrogen are now subject to loss as CO_2 and nitrates respectively. It is only a question of time until their percentage rate of disappearance from the soil becomes more or less the same i.e. the percentage of the total nitrogen being removed equals the percentage of the total carbon being lost. At this point the C:N ratio becomes more or less constant 10:1 to 12:1 always being somewhat greater than that of the ratio in microbial tissue.

C:N ratio and the level of organic matter :

Since carbon and nitrogen are reduced to almost a definite ration, the amount of soil nitrogen largely determines the amount of organic carbon present when stabilization occurs. Thus, the greater the amount of nitrogen present in the original organic material, the greater will be the possibility of an accumulation of organically bound carbon. Since a definite ratio (1:1.7) exists between the organic carbon and the soil humus, the amount of organic matter to be maintained in any soil is largely conditional on the amount of organic nitrogen present. The ratio between nitrogen and organic matter is thus constant (organic matter : Nitrogen, 20:1 for most soils).

....

Chapter 2

Decomposition of Soil Organic Matter

The organic materials (plant and animal residues) incorporated in the soil do not remain as such very long. They are at once attacked by a great variety of micro organisms, worms and insects present in the soil especially if the soil is moist. The microorganism for obtaining their food, break up the various constituents of which the organic residues are composed, and convert them into new substances. Some of these substances are very simple in composition and others highly complex. The whole of the organic residues is not decomposed all at once or as a whole. Some of the constituents are decomposed very rapidly, some less readily, and others very slow. They may be listed in terms of ease of decomposition as follows :

1.	Sugars, starches and simple proteins	Rapid decomposition
2.	Crude proteins	
3.	Hemicelluloses	↑
4.	Cellulose	↓
5.	Fats, waxes and resins	
6.	Lignins	Very slow decomposition

The organic matter is also classified on the basis of their rate of cecomposition as given below :

* Rapidly decomposed	:	Sugars, starches, proteins etc.
* Less rapidly decomposed	:	Hemicelluloses, celluloses etc.
* Very slowly decomposed	:	fats, waxes, resins, lignins etc.
* Simple decomposition products	:	Aerobic – CO_2, H_2O, NO_3, SO_4, PO_4 etc.
		Anaerobic – CH_4, H_2, N_2O, N_2 etc.

When organic material is added to soil, three general reactions take place.

1. the bulk of the material undergoes enzymatic oxidation with carbon dioxide, water, energy, and heat as the major products.
2. the essential elements such as nitrogen, phosphorus and sulphur are released and / or immobilized by a series of specific reactions relatively unique for each element.
3. Compounds very resistant to microbial action are formed either through modification of compounds in the original plant tissue or by microbial synthesis.

A) Decomposition of soluble substances :

Sugars and water soluble nitrogenous compounds are the first to be decomposed as they offer a very readily available source of carbon, nitrogen and energy for the microorganisms. Thus when glucose is decomposed under aerobic conditions the reaction is as under :

Sugar + Oxygen → Carbon dioxide + water

When the nutrient or oxygen supplies are restricted, partially oxidized different compounds are formed :

Sugar + Oxygen → Aliphatic acids (acetic, formic etc.) OR
Sugar + Oxygen → Hydroxy acids (Citric, lactic etc.) OR
Sugar + Oxygen → Alcohols (ethyl alcohol etc)

Some of the reactions involved may be represented as under :

$C_4H_{12}O_6 + 2O_2 \rightarrow 2CH_2.COOH + 2CO_2 + 2H_2O$
(Acetic acid)

$2C_6H_{12}O_6 + 3O_2 \rightarrow 2C_6H_8O_2 + 4H_2O$
(citric acid)

$C_6H_{12}O_6 + 2O_2 \rightarrow 2CH_2H_6OH+ 2CO_2$
(Ethyl alcohol)

i) Ammonification :

Soluble nitrogenous compounds, viz. amino acids, amides, ammonium compounds, nitrates etc are also attacked by the microorganisms. The transformation of organic nitrogenous compounds into ammonia is called ammonification. During the course of action under aerobic conditions by heterotrophic organisms, oxygen is taken up and carbon dioxide is released. Ammonification process involves a gradual simplication of complex compounds.

Protein → Polypeptides → amino acids → ammonia or ammonium salt
OR
Organic nitrogen → NH_3

The ammonification orrurs as a result of acition of enzymes produced by microorganisms. Their action is chiefly hydrolytic and oxidative (in presence of air).

ii) Nitrification :

the process of conversion of ammonia to nitrates and then to nitrate is known as nitrification. The production of nitrate is more rapid than that of nitrite, while the formation of ammonia is the slowest process. That is why soil usually contains more nitrate nitrogen than nitrite at any time. Nitrification is an aerobic process involving the production of nitrates from ammonium salts. It is the work of autotrophic bacteria.

$$NH_3 \xrightarrow{\text{Nitrosomonas}} NO_2^- \xrightarrow{\text{Nitrobacter}} NO_3^-$$

Ammonia → Nitrite → Nitrate

The net reactions are as follows :

$NH_4^+ + O_2 \longrightarrow NO_2^- + 2H^+ + H_2O$ + energy (66 k cal)

$NO_2^- + O_2 \longrightarrow NO_3^-$ + energy (18 k cal)

The process, which involves conversion of soil nitrate into gaseous nitrogen or nitrous oxide, is called denitrification.

Pseudomonas / bacteria

Nitrates ----------------------------------→ Nitrogen gas

Water logging (e.g. rice field) and high pH will increase nitrogen loss by denitrification.

B) Decomposition of insoluble substances :

i) Breakdown of protein :

Proteins are complex organic substances containing nitrogen, sulphur and sometimes phosphorus, in addition to carbon, hydrogen and oxygen. During the course of decomposition of plant materials, the proteins are first hydrolyzed to a no. of intermediate products e.g. proteoses, peptones, peptides etc. collectively known as polypeptides. The changes may be represented as under :

Proteins → Proteoses, peptones, peptides → Aminoacids, amides → ammonia

Aminization   Ammonification

The process of conversion of proteins to amino acids is known as aminization and the conversion of amino acids and amides to ammonia is known as ammonification.

ii) Breakdown of cellulose :

Cellulose is the most abundant carbohydrate present in plant residues. The microorganisms break up cellulose into cellobiose and glucose. Glucose is further attacked by organisms and converted into organic acids.

The decomposition of cellulose in acid soils proceeds more slowly than in neutral and alkaline soils. It is quite rapid in well aerated soils and comparatively slow in those poorly aerated.

Hydrolysis   Hydrolysis

Cellucose --------- → cellobiose ----------→ Glucose

(cellulase)   (cellobiase)

Oxidation   oxidation

------------→ Organic acids ------------→ $CO_2 + H_2O$

iii) Breakdown of hemicellulose :

When subjected to microbial decomposition, hemicelluloses are first hydrolysed to their components sugars and uronic acids. The sugars are further attacked by microorganisms. They are converted to organic acids, alcohols, carbon dioxide and water. The uronic acids are broken down to pentose and carbon dioxide. The newly synthesized hemicelluloses thus form a part of the humus. Hemicelluloses decompose faster than cellulose.

iv) Breakdown of starch :

Chemically it is glucose polymer. It is first hydrolysed to maltose by the action of enzymes. Maltose is next converted to glucose by another enzyme. Glucose being soluble in water is utilized for growth and other metabolic activities. The process may be represented as under :

$$(C_6H_{10}O_5 + nH_2O \rightarrow n(C_6H_{12}O_6))$$

C) Decomposition of ether soluble substances :

Fats are first broken down by micro-organisms through the agency of enzymes lipase into glycerol and fatty acids. Glycerol is further oxidized to organic acids which along with the other fatty acids are finally oxidized to carbon dioxide and water.

$$\text{Fats} \xrightarrow{\text{lipase}} \text{glycerol} + \text{fatty acids}$$

$$\text{Glycerol} \xrightarrow{\text{Oxidation}} \text{Corbon dioxide} + \text{Water}$$

D) Decomposition of lignin :

Lignin is deposited on the cell wall to impart strength to the skeleton framework of plant. Lignin decomposes slowly, much slower than cellulose. Complete oxidation of lignin gives rise to carbon dioxide and water.

Simple Decomposition products :

As the enzymic changes of the soil organic matter proceed, simple products begin to manifest themselves. Some of these, especially carbon dioxide and water, appear immediately. Others, such as nitrate nitrogen, accumulate only after the peak of the vigorous decomposition is over. The more common simple products resulting from the activity of the soil micro organisms are as follows :

Carbon	:	CO_2, CO_3^{--}, HCO_3^-, elemental carbon
Nitrogen	:	NH_4^+, NO_2^-, NO_3^-, gaseous nitrogen
Sulphur	:	S, H_2S, SO_3^-, SO_4^-, CS_2
Phosphorus	:	H_2PO_4, HPO_4^-
Others	:	H_2O, O_2, H_2, H^+, OH^-, K^+, Ca^{++}, Mg^{++}, etc.

i) Mineralisation of organic sulphur :

Many organic compounds, especially those of a nitrogenous nature, carry sulphur. Heterotrophic bacteria simplify the complex organic compounds, then autotrophic bacteria (sulphur bacteria) oxidize it into sulphate form.

$$\underset{\text{Sulphur}}{S + 2O_2} \xrightarrow[\text{Oxidation}]{\text{Enzymic}} SO_4^{=}$$

ii) Mineralisation of organic phosphorus :

A large proportion of the soil phosphorus is carried in organic combinations. Upon attack by microorganisms the organic phosphorus compounds are mineralized, that is they are changed to inorganic combinations. It depends upon soil pH. As the pH goes up from 5.5 to 7.5 the available phosphorus changes from H_2PO_4 to $HPO_4^{=}$. Both of these forms are available to higher plants.

Factors affection decomposition :

The most important factors that alter the rate of decomposition of organic matter are :

1) Temperature :

Cold periods retard plant growth and organic matter decomposition. If temperatures are warm enough to produce considerable vegetation during the growing season, but are cold for long periods at other times of the year, organic matter accumulation in and on the soil will be high. Continuous cold temperatures lower soil humus because of less plant material is grown. Warm summers may permit plant growth and humus accumulation. Continuous warm temperatures not only aid high plant production, but also promote faster decomposition.

2) Soil moisture :

Both plant growth and organic matter decomposition require moisture, near or slightly wetter than field capacity moisture conditions are most favourable for both processes. Extremes of both arid and anaerobic conditions reduce plant growth and microbial decomposition. Poorly drained soils with growing soils vegetation usually have relatively high humus contents, such conditions have been the cause of formation of some organic soils.

3) Nutrients :

Lack of nutrients, particularly nitrogen, usually reduces plant growth, more than it slows decomposition because microorganisms use the nutrients in the dead organic material before plant roots can absorb it..

4) Soil pH :

Most common microorganisms grow best at pH 6-8, but are severely inhibited below pH 4.5 and above pH 8.5. Strontly acid soils are even more inhibiting to microbe growth than are strongly alkaline ones.

5) Soil texture :

Soils higher in clays tend to retain larger amounts of humus, other conditions being equal. Most organic substances adsorb to mineral surfaces by many kinds of bonds, particularly to clays. The many active bonding sites of minerals and humus include the –O, -OH, -Al-OH, -Fe-OH, and cation exchange sites of minerals, and the –NH_3^+, -SH, -OH, and –COOH portions of organic materials. When oily or waxy molecules are absorbed, the soil may become water repellent as these materials coat soil solids.

Other factors :

Other decomposition inhibitors include toxic levels of elements (aluminum, manganese, boron, selenium, chloride), excessive soluble salts, shade, and organic phytotoxins (toxic to plants) in plant materials. The type of plant is also important, as legumes are more readily decomposed than grasses.

Role of organic manures :

The effect of organic manure on soil fertility are as follows :

1. It binds soil particles into structural units called aggregates. These aggregates help to maintain a loose, open, granular condition. Water infiltrate and percolate more readily. The granular condition of soil maintains favourable condition of aeration and permeability.
2. Water holding capacity of soil is increased by organic matter. Organic matter definitely increases the amount of available water in sandy and loamy soils. Further, the granular soil resulting from organic matter additions, supplies more water than sticky and impervious soil.
3. Surface runoff and erosion are reduced by organic matter as there is good infiltration.
4. Organic matter on the soil surface reduces looses of soil by wind erosion.
5. Surface mulching with coarse organic matter, lowers soil temperatures in the summer and keep the soil warmer in winter.
6. The organic matter serves as a source of energy for the growth of soil microorganisms.

7. Organic manure serves as a reservoir of chemical elements that are essential for plant growth. Most of the soil nitrogen occurs in organic combination. Also a considerable quantity of phosphorus and sulphur exist in organic forms. Upon decomposition, organic matter supplies the nutrients as well as many harmones and antibiotics needed by growing plants..
8. Fresh organic manure has a special function in making soil phosphorus more readily available in acid soils.
9. Organic acids released from decomposing organic matter help to reduce alkalinity in soils.
10. Fresh organic manure supplies food for such soil life such as earthworms, ants and rodents. These micro-organisms improve drainage and aeration. Earth worms can flourish only in soils that is well provided with organic matter.
11. organic matter upon decomposition produces organic acids and carbon dioxide which helps to dissolve minerals such as potassium and make them more available to growing plants.
12. It acts as a buffering agent. Buffering checks rapid chemical changes in pH and in soil reaction.

....

Chapter 3

Organic Manures

Generally, manures are added to the soil in order to increase the soil fertility and yield of the crop. To distinguish organic and inorganic substances used for the purpose, the organics are specifically called **'Manures'** and inorganics are called **'Fertilizers'**.

Organic Manures - The organic manures are made up of dead plant and animals remains. They are bulky in nature and poor in plant food. They supply almost all the ingredients of plant food. Bulky, organic manures are farm yard manure, compost and green manure.

Substances like oilseed cakes, blood meal, bone meal etc. are rich in particular nutrients, and they are referred as concentrated organic manures. Synthetic organic product like urea is also coming into use for supply of nitrogen.

Average percentage composition of different organic manures.

S.N.	Organic manure	Nitrogen (N)	Phosphorus (P_2O_5)	Potash (K_2O)
(A)	**Bulky organic manure**			
1	Farm Yard Manure	0.50	0.25	0.60
2	Compost	0.89	0.51	3.05
3	Manure of night soil	1.00	0.80	0.40
(B)	**Concentrated organic Manure**			
1	Groundnut cake	7.29	1.53	1.33
2	Linseed cake	5.56	1.44	1.28
3	Castor cake	4.37	1.85	1.39
4	Neem cake	5.22	1.08	1.48

Bulky organic manures :

Preparation of Farm Yard Manure (F.Y.M.) :

Trench Method :

1) The manure preparation should be carried out in trench of 20-25 ft long, 5-6 ft breadth and 3 - 3.5 ft deep.
2) Dry litter should be spread under each animal in the evening for absorption of urine.
3) Each morning urine-soaked litter and dung should be well-mixed and filled in the one section of 3 ft length of the trench (length wise trench is sub-divided into 7-8 pits with partitions).

4) When the one section is filled to a height of 1 ½ - 2 ft above ground level, the dome-shaped top surface is plastered with a cowdung + soil slurry.

5) After filling the one section (3 ft) of trench, the next 3 ft length of the trench is filled. In about 3 months the FYM manure is ready for use.

Heap method of storing manure is also recommended. The heaps are prepared on the upland. Each day's material is arranged, layer by layer in dome-shaped structure. When the heap is about 6 ft high, it is rounded on the top and plastered with mud.

FACTORS AFFECTING NUTRITIONAL BUILD UP OF F.Y.M. :

The following factors affect the composition of F.Y.M.

1) Age of Animal : Growing animals and cows producing milk retain in their system nitrogen and phosphorous required for productive purposes like making growth and producing milk and the excreta do not contain all the ingredients of plant food given in the feed. Old animals on the down grade waste their body tissues and excrete more than what they do ingest.

2) Feed : When the feed is rich in plant food ingredients, the excreta produced is correspondingly enriched.

3) Nature of Litter used : Cereal straw and leguminous plant refuse used as litter enriched the manure with nitrogen.

4) Ageing of Manure : The manure gets richer and less bulky with ageing.

5) Manner of Making and Storage : In making and storage losses are in various ways.

LOSSES IN F.Y.M.

There are two types of losses in F.Y.M. (a) losses during handling, and (b) losses during making and storage.

(a) Losses During Handling.

(i) Loss of Dung - A part of the dung is often dried and used as fuel. The dung is valuable as manure and should be used as such.

(ii) Loss of Urine – Urine is not collected by the farmers in this country. Urine containing nitrogen and potash in good quantity is therefore, wasteful. The loss of urine may be minimized by spreading litter under the cattle and by making pucca floor.

(b) Losses During Making and Storage.

(i) Oxidation or Fermentation Loss : The fermentation being highly aerobic, it is unfavorable for the accumulation of organic acids; due to this the ammonia that is evolved remains unfixed and escapes. The loss increases further with the looseness of the heap and exposure to the atmosphere. The loss is reduced by compacting the manure and keeping it moist, which results in the reduction of aerobic condition (aerobic bacteria become inactive) and anaerobic bacteria bring about the decomposition of manure. The anaerobic decomposition is comparatively slower, loss of carbonaceous material kept down and humus formation takes place partly in the manure pit and this is the type of fermentation that is desired in manure pits.

(ii) Volatilization Loss - Gaseous nitrogen evolved as urea is broken down to ammonia and carbon dioxide. The volatilization is increased by an increase in temperature and drying. This loss can be minimized by addition of water to keep down the temperature and by having two or three small storage pits rather than one larger one, so that the manure may not lie uncovered for too long a time.

(iii) Leaching Loss- Another source of loss of nutrients is through leaching in the form of liquid that oozes out from the manure heap or pit. This liquid contains not only soluble nitrogen but also phosphorus and potash. The oozing of the liquid is very often due to over watering. Such loss should be prevented by erecting a roof over the pit and further by putting a low bund all round the rim of the pit.

....

Chapter 4

Composting

Composting is a bio-chemical process in which microorganisms of both aerobic (which require air or oxygen gas for development) and anaerobic(which function in the absence of air or free-oxygen) types, decompose organic matters into a final product which is well rotten manure known as **compost.**

Compost is prepared form refuses collected from the farm or in towns or villages. The ingredients of composts that are commonly prepared in India, are mainly from the following two sources.

1.Compost from farm refuse :

This utilizes weeds, stubbles, bhusa, crop residues, remnants of fodder, hedge clippings etc.

2. Compost from town-refuse :

The main components of town compost are night-soil and street and dust-bin refuses, commonly known as kachara.

Selection of Site :

The site selected for the pit should be easily approachable for inspection.

Pit should be at a comparatively higher level so that neither rain water gets into it nor the water table rises and causes water stagnation in the pit during monsoon.

It should be near the cattle shade and the source of water supply.

Compost pit should be located at a distance form the road or else to prevent contamination of lead due to automobile exhausts. Compost containing toxic metal lead contaminates even food grain, affected health of animals & human beings.

Three different methods of compost making viz. **Indore method, Bangalore method and NADEP method** are described here in detail, one can adopt them according to the availability of ingredients and convenience.

1. Indore method

This method was developed by A.Howard and Y.D Wad at the Instiutte of Plant Industry, Indore, between 1924 and 1931. In this method animal dung is used (as catalytic agent), alongwith all other plant residues and wastes available on the farm. In fact, this is the first aerobic method of composting in which manure is ready within four months.

The size of the pit :

Breadth	-	6 to 8 ft.
Depth	-	2 to 3 ft. (not more than 3 ft.)
Length	-	10 ft. or more as per requirement

In regions of heavy rainfall compost should be prepared at safer places and protected by shed. Compost making should be avoided between the months of June and September.

1) Bangalore or Acharya Method :

The composting of the vegetative waste is done in pits. The size of pit (9 x 2.1 x 0.9 meter) varies with the quantity of material available for composting. A 22 cm thick layer of waste material is first laid in the pit. On each layer is spread a slurry made of dung, urine, earth. A sufficient quantity of water is sprinkled over the material in the pit to make it moist but not too wet. The pit is filled in this way layer by layer, the layer of bedding material alternating with that of slurry and water, till it rises 2 ft above ground level. At the end dome-shaped heap is plastered over with wet mud. It is left undisturbed. The compost is ready in about 4 to 5 months. This method overcomes many of disadvantages of the Indore-method like turning etc. After the initial aerobic decomposition during the first eight to ten days (i.e. filing of pit is going on) the material undergoes semi-anaerobic decomposition. Under these conditions, the decomposition is more gradual and slow. Under this process, there is less loss of organic matter and nitrogen and hence there is a greater production of compost. Therefore, this method is called developed or superior.

Requirements of Composting :

For making good compost the following conditions should exist :

1.Moisture. Decomposition is due to the activity of microorganism. For the proper development of microorganism there should be sufficient moisture.
2.Temperature. Optimum temperature is conducive for the growth and activities of microorganism.
3. Nutrients. Straw material such as wheat stubble, cotton stalks etc. are the source of nutrients.
4. Starter Material. To hasten decomposition, dung, urine, nitrogenous fertilizer is added.

(3) NADEP method :

According to Shri Narayan Rao Panda, "we have about 100 crore units of city compost which provide 60 lac tons of N, 24 lac tons of P and 45 lac tons of K. in view of scarcity of organic manure in the country, we can provide required nutrients to the soil by utilizing available organic resources by adopting ' Nadep Method' of composting.

This method envisages lot of composting through minimum use of cattle dung. this requires compost materials like dung, farm residues, soil, waste productsof agriculture and water, decomposition process follows through 'aerobic' method and it requires about 90 to 120 days for obtaining the final product. The nitrogen, phosphorus and potash contents of the compost prepared by NAPED method are as follows :

The sides of the pit should be sloppy and should have sufficient space between them for the carts to move freely.

The materials needed for composting :

Mix plant residues, weeds, sugarcane leaves, grass, wood ashes, bran etc. Hard woody materials are chopped into small pieces and are crushed.

1. Animal dung : Dung of all the farm animals like cows, buffaloes, bullocks, horses, goats etc. is collected with beddings.
2. Urine soaked mud : the urine soaked mud of the cattle shed should also be utilized for composting.
3. Wood ashes : This reduces acidity of the compost and adds potassium.
4. Water and air : Both are necessary for bacterial and fungal activity.

Methods of Filling the Pits :

The material brought from the cattle shed is spread evenly in the pit in layers of 3 inches with the help of racks. Wood ash, if available, will also be spread over, along with urine and mud. After this, 2 inch layer of bedding with cattle dung and soil is spread evenly. Sufficient amount of water is sprinkled over the material to make it moist. The pit is filled in this way layer-by-layer, the layer of bedding, material is placed along with slurry and water. The pit is filled till the material is 1 foot, above ground level. It should not take more than six or seven days to fill the ¾ length of the pit, leaving about one fourth of the pit empty to facilitate subsequent turnings. At the end, one more layer of bedding material with wood ash and urinated mud should be provided. Water is sprinkled in the evening and the next morning and the process should be repeated 3 times. In this way sufficient water is soaked by the trash material and dung and the process of decomposition starts, resulting in shrinkin go the heap. Heaps in the pit are turned once in a week and at the time of first, second and third turning are moistened with water.

Turning

Decomposition through bacterial activity needs proper mixing as well as circulation of water and air. The material is turned up three times.

(1) First turning : 10-15 days after tilling he pit.
(2) Second turning : 15 days after first turning.
(3) Third turning : after 2 months. The black granular material should be sprinkled with water and be dept in a rectangular shape out of the pit in a heap of 10' x 9' x 3.5' or 3 x 3 x 1 m. Heaps thus prepared should be left for decomposition for a month. This helps the bacteria in fixing atmospheric nitrogen in a large quantity.

In rainy season the compost may be prepared in heaps above ground in the areas with average rainfall the size of the heaps may 8' x 8' broader at the base and 7' x 7' at the top and not more than 2' high.

Nigrogen (N)	-	0.5 to 1.5 %
Phosphate (P)	-	0.5 to 0.9 %
Potash (K)	-	1.2 to 1.4 %

Selection of site and compost making by NADEP method :

With the help of bricks or locally available materials in the villages, tanks, (hodi) are constructed on the soil surface. These tanks should be located near cattle shade or on easily approachable farm sites. The tank, each 10' x 6' x 3' are prepared with 9 inch thick wall. Lining of the bricks is made with the help of mud which saves expenditure on cement. If upper layer is lined with cement construction it may last long. For circulation of air, proper blocks/holes of 7 inches are left on all the four sides of the tank wall. Plastering of inner-outer walls and floor of the tank should be by dung and mud mixture.

Materials required for NADEP Compost :

Farm residues, refuses like weeds, grasses, leaves, sugarcane trash, stubbles and all kinds of wastes, stalks, roots, stems, prunings, chaff, cotton and pigeon pea stalks etc. 1400 to 1500 kg.

Cattle dung 90 to 100 kg. (8-10 baskets.)

Dry sieved-soil 1750 kg. (120 baskets)(urinated earth more effective.)

Water-according to season (less during rains and in abundance during dry spells.) 1500 to 2000 liters.

Methods of filling the tank :

Before filling the tank, slurry of cow dung and water should be sprinkled on the floor and the walls.

First layer :

Plant residues available on the farm are spread evenly in layers to a thickness of 6 inches (100 to 110 kg.)

Second layer :

Cattle dung or 'Gobargas-slurry' 4 to 5 kg. in 125 to 150 liters of water on the first layer of the trash.

Third year :

It consists of clean dry sieved soil (keeping apart stones, pebbles, glass, plastic etc.) then 50 to 60 kg. (4 to 5 baskets) of soil are spread on moist layer of farm refuses. Sprinkling of water is repeated. The tank is filled in this way layer by layer. It is filled till the material is 1 ½ feet above the brick level. A hut like shape may be given at the top. The whole tank is to be filled within 1 or 2 days. Eleven to twelve layers are required for filling the tank to its capacity. In case cattle dung is not available in desired quantity, collection of the same is done for 8-10 days under a shade by covering it with a light layer of soil. As an alternative practice, tank can be filled 1/3 or ½ of its capacity in parts. Full tank should be covered and sealed by 3 inch layer of soil. (300 to 400 kg.) it should be pasted with a mixture of dung and soil. Craks should not be allowed to develop on the heaps, the check gas leakages, for that the pasting can be repeated.

Second filling :

After 15 to 20 days the trash contracts and becomes more compact and goes down in the tank by 8-9 inches. The procedure described in the first filling is repeated and again sealed and pasted with mud and dung. it takes about 3 to 4 months in compost making by NADEP method. In order to maintain 15 to 20% moisture, the compost is sprinkled with cattle dung and water. This helps in conservation of the nutrients.

Normally from one tank about 160-175 cubic ft. of manure and 40 to 50 cubic ft. of undecomposed raw material, weighing about 3 tons are obtained. According to an estimate, from annual collection of dung from one cow 80 tons of manure can be prepared which contains 800 kg N, 560 kg P and 1040 kg K. The market value and worth of the nutrients derived from this manure can easily be estimated. It takes one thousand rupees to construct a tank. Eight Man days are required for filling the pits to get it emptied and transported to the field.

In Indore method of composting two inch thick dung layer is spread over the trashes while in 'Nadep' method only 5 kg. solution (water + dung) of dung is sprinkled. In this way with a little amount of dung more manure can be prepared. In Indore Method, 3 turnings are required as the manure is prepared in the pits, whereas in NADEP method no turning is required.

The microorganisms live in soils spreading of soil layers are essential. This can be situated at any corner of the farm which save transportation and labour. The collection of dung only will have to be carried out. Soil mixed compost which is derived from the NADEP Method, keeps on absorbing air and is believed to be the best method of composting.

Production of Composts : General

Production of compost is the heart of the organic method. Dying and decaying matter, whether the falling leaves of the forest or the decaying bodies of more complex life forms, is constantly being used as the raw material of new life. In nature, the forest floor is the workshop for a continuous compost production operation. In gardens, we interrupt this normal cycle by taking out some of the organic material produced. In setting up a compost-making operation, we are restoring the cycle and returning to the soil the humus which is the single most important element in its fertility. The process of compost of life renewal is achieved by a remarkably complex interaction of billions of microscopic life forms with biological materials.

Compost bin as factory :

Compost bin works as factory in which suitable mixture of carbonaceous and nitrogenous materials act as the raw materials, and the workforce is supplied by an army of bacteria, fungi, and various other microscopic life forms. The end product of this factory has desired, sweet-smelling, brown crumbly compost which enriches the soil fertility.

Transformation Agents :

Transformation of biological material is carried out by microbial flora. They requires moisture, heat and, depending on the type of production operation chose, air. A single gram of compost will contain up to a billion bacteria, 100 million actinomycetes, a million fungi, algae, protozoa and other in their hundreds of thousands,. Moreover, different bacteria with differing skills take over, depending on whether the heap is an aerobic (air-using) or anaerobic (airless) production line, the temperature, the pH level and the mineral content. Bacteria utilize nitrogen to break down the carbon materials and form compost.

Compost factory makes the end-product by two processes: one hot and quick, the other warm and slow. The hot method is the aerobic on in which, all other conditions being met, there will be a rapid rise in temperature, possibly to 140^0 F (60^0 C), within four days (a hot bath is bout 110^0 F or 40^0 C), declining over the next fortnight or so. The bacteria which survive at these temperatures get through a lot of decomposing work, so that, after two to four weeks, you already have a rough sort of compost. For improvement, the heap is turned, and fresh supply of air is introduced. It stimulates the bacterial activity once more so that a second heating a achieved.

The slower method is the anaerobic (for abut 12 months), relatively cool one. Oxygen is not introduced, and a different set of bacteria take over, producing decomposition and the resulting compost at a munch more leisurely pace. Within around twelve months you should have a dark, crumbly compost.

What to put in heap ?

The proposed materials for heap are of biological origin, for example cardboard, woolen carpets and ash all pass this test. The alternative layers of various possible organic materials in a compost bin built up in layer system.

Ensure that the materials present the right mix of carbon and nitrogen. If carbon level is higher in the heap, it will remain cold and the decomposition process will be protracted. The are of making successful compost is largely associated with achieving a correct C:N balance. 30 part, carbon to 1 part nitrogen, is ideal which reduces to 10-15:1 when turned into mature content. Fine grass mowing on their own will produce a treacle mass result, so straw leaves or, possibly, cardboard would be good companions. If you include too much woody material such as bark and pruning without balancing this with sufficient green matter, the pile may not heat up at all.

A compost heap, in fact, is somewhere between a bonfire and nature's own method of decomposition. method of decomposition, which is a slow rotting process culminating in incorporation by worms into the soil when breakdown is completed. By speeding up the decomposition process we can increase a soil's fertility very quickly, especially by making a well aerated heap where oxygen-loving organisms can flourish.

Materials for the Compost bin

Material	Conversion ratio	Comments
Urine	2:1	Excellent activator and source of potash; ideally mix it with water before putting on heap
Dried blood	4:1	Highly effective activator
Pig manure	5:1	
Poultry manure	10:1	Use sparingly; a powerful activator. Also source of phosphates
Lawn trimmings	12:1	Too nitrogenous to use on their own, especially if soggy. Mix with damp straw, weeds or leaves
Kitchen waste	12:1	Ideal, balanced ingredients. Exclude meat and bones which may rot and attract rodents
Farmyard manure	14:1	E.g. animal excretion plus straw. Almost a balanced compost in itself after decomposition. Used fresh, when the straw is still quite yellow, it makes a good activator.
Seaweed	19:1	Superb source of trace elements; no fiber or structure.
Garden waste	20:1	Pea, bean, tomato, potato haulms provide valuable nutrients, also useful for holding air in the heap
Horse manure	25:1	See farmyard manure
Weeds	30:1	Can range form sappy to fibrus, good source of nutrients. Avoid pernicious perennials. Note stinging nettles are high in nitrogen and make an effective activator, if used in quantity, best treated in same way as lawn trimmings.
Straw	80:1	Must be damp before use and , preferably, part-rotted to avoid robbing too many nutrients form heap
Woody prunings	100:1	Shred first, or else use as mulch
Bark	100:1	See woody prunings
Newspaper, cardboard	200-500:1	Use sparingly, shredded or torn up. Dampen beore use; avoid materials with coloured inks
sawdust	500:1	Too demanding of nutrients in their breakdown and too slow, unless first stacked for two to three years.

Note :

C:N values should be regarded only as approximations and will vary according to age precise make-up, etc. they are best used for comparative purposes to balance high C:N and low C:N materials at opposite ends of the table. A wide range of ingredients is the safest bet and will ensure a nutrient rich compost, especially if seaweed and comfrey are added, even in small amounts. Wood ash, supplying potash and lime, may also be used. Lime need not normally be added to the compost pile, unless you have an acid soil. Care should be taken with pet manure: cat and dog feces can sometimes be hazardous if handled.

Factors for decomposition :

A heap should contain enough bulk of food for the heat-loving bacteria for their growth and activity. If the pile is too small, there will be insufficient heat build-up. To obtain a suitable C:N mix on a garden scale, the materials may first need to be assembled over a period of time. This can best be achieved by creating a preliminary stockpile. Garden debris, mowing, weds and so forth can be loosely stacked and covered in one pile or placed in plastic bags; likewise kitchen waste.

Temperature :

Sufficient air is required to sustain the temperature build-up. Non special air channels are required. Simply ensure that the material does not get compacted by forking through it and that grass mowing or the like, which are prone to settle into a solid, airless mass, are mixed with woody materials. Temperature is related to the weather, therefore composting is more reliable and fast in summertime. Compost which may be ready in two summer months may require six months in winter.

Moisture :

Moisture is essential for microbial activity. In a dry summer the heap will definitely need some, preferably, added every so often while you are constructing it. Ingredients should be pretty damp. Too much moisture is unlikely at the time of making the heap, but it should be protected form rain with polythene on top.

The final consideration in making quick compost is the right mixture of ingredients. There are many variations. A good balancing material is straw. It is best to leave this outside first to get wet and begin the rotting process on its own, so that when you include it in your heap you will not need to wet it and it will already be a much richer plant food, with more nitrogen (from the air) and pro-portionately less carbon.

Ingredients to avoid

Para toxics:

Materials which definitely should not find their way into your heap include all metals, rubbers, glass and plastics- even so – called biodegradable plastic will endure for many years. Large quantities of newspaper and cardboard will greatly slow the rotting process. Also inadvisable is diseased plant material, such as brassica stalks infected with club root, or white rot on onions, leeks or garlic. Potato blight, however, can be safely composed. If your heap does not meet these criteria it is safest to burn suspicious material.

Activators of bio-degradation :

Animal manure is used to enhance the heating process; it must be fresh rather then already rotted. Fresh manure activates by seeding the heap with bacteria. If enough is added it will also bring a lot of heat into the compost heap. This can be very useful in winter when it is cold and there is a shortage of green matter to engender heat.

The right bacteria can also be introduced by adding some of last time's compost as the heap is constructed. Commercial activators are unnecessary if the above conditions are met, but you might find it interesting to experiment with herbal products, which definitely make a difference. Packaged bacterial activators are also available but since the types of bacteria at work vary with activators are also available but since the types of bacteria at work vary with the temperature, air conditions and other factors, these may be of limited use.

When and where to spread waste / manure ?

Waste cannot be spread at some stages of crop growth: it is usually not possible to spread wastes on crops near harvesting time. It is also true that some crops are more suitable for waste application than are others. From a fertilizer point of view, spring application in USA and Europe and *kharif* (rainy season) application in India usually gives best results, supplying maximum benefit from the nitrogen in the waste. However, it is not always possible to spread all waste in the above sections. In pig production, for example, the manure is produced throughout the year, so adequate storage for twelve months would be necessary if all the manure was spread in spring. This would be vary costly. In practice, it is customary that manure produced during water be spread during spring and summer and that produced in autumn be spread dung late autumn. In some situations, where soil conditions are suitable, manure is sometimes spread throughout the year so that very little storage is required.

The pattern of agriculture determines when and where wastes can be spread. Traditionally, most waste was spread on tilled land. With intensive agriculture, in areas like the British Isles- waste is spread on grassland. In countries such as Denmark, where most of the land is tilled, and high proportion of the waste is spread for tillage corps. In India agricultural waste is incorporated in soil for crops.

Time of application of waste is often determined by when soil conditions are dry enough to carry manure spreading equipment. Under some soil and climatic conditions, there may be six months of the year when manure spreading equipment could cause serious damage to the soil surface. Under other conditions, it is possible to spread manure throughout the year without serious soil damage to grass than the same quantity applied in spring or summer. It appears that slurry can depelete the already low oxygen levels in the soil near the grass roots, killing the better yielding grasses, which will be replaced by weeds. It is therefore advisable that if slurry grases, which will be replaced by weeds. It is therefore advisable that if slurry has to be spread on grassland in winter, low rates.(say not more than 20 tonnes/ha) should be used.

Rate of application :

The quantities of plant nutrients required for different crop and soil conditions are reasonably well established for most countries. Where soil fertility is adequate, **maintenance dressings** of phosphorus and potassium are applied annually.. Maintenance dressings are rates that will maintain soil fertility over the year and should equal the difference between losses and the nutrient supplying power of the soil. The main nutrient losses are corp removal and loss in drainage water. Niterogen is more complex because there are many sources of losses and inputs and it is the primary nutrient influencing yield in conditions of high soil fertility. With low soil fertility, extea rates of nutrients, above maintenance dressings, may have to be applied

....

Chapter 5

Green manuring

Green manuring is the practice of applying as manure large quantities of green material such as leaves and twigs of plants or crops grown for this purpose. Growing of a crop or applying of leaves and twigs of plant and incorporating it with the soil is called 'green manuring'.

Methods of Green manuring :

There are two methods **(A) Green mauring in situ** and **(B) Green leaf manuring.**

(A) Green Manuring in Situ - Growing a crop and incorporating (ploughing) it in the same field with the soil is called situ method of green manuring.

Green manure crops :

Leguminous (pulse) crops used for Green manuring :

(1) Sannhemp (*Crotalaria juncea*). Adapted to well-drained soil, suitable for upland condition, quick growing, relatively resistant to pest and diseases, have deep root system.
(2) Dhaincha (*Sesbania aculeate*)- Resistant to drought, salt and water-logging, ideal for rice soil (clay), generally grown in lowland, suitable for saline and alkaline soil, have deep root system.
(3) Dhaincha (*Sesbania rostrata*) - A newly introduced green manure crop which can also grow in water-logged condition. In this crop nodules formation is on the roots and also in large number on the stem. So that it fixes more nitrogen than Sesbania aculeata.
(4) Mung (*Phaseolus aureus* mung)- It is quick growing, drought resistant.
(5) Indigo (*Indigofera tinctoria*) - Suited to heavy soil (clay), slow growing.
(6) Khesari (*Lathyrus sativus*) - Winter season crop.

Non-Leguminous Green manure Crops
1.Bhang (*Cannabis sativa*)
2.Kodogira (*Vernonia cenerea*)

(B) Green Leaf Manuring - When green leafy material is collected from other places and ploughed in the field it is known as green leaf manuring.

Green Leaf Manuring Crops :

1. Glyricida (*Glyricida maculata*)
2. Karanj (*Pongamia glabra*)
3. Ipomoea (*Ipomoea carnea*)

Green manuring Procedure :

The green manuring practices are given below :

1. Green manure crop can be grown in any type of soil, provided there is sufficient rainfall or alternatively irrigation available.
2. To ensure success with a leguminous green manure crop is to inoculate the seed with the proper strain of bacteria.
3. The green manure crop should be sown with a higher seed rate than usual so that there will be a good canopy produced very quickly. The usual seed rate for sannhemp is about 40 to 50 kg. per hectare.
4. The production of green manures is limited by the plant food elements (plant nutrients) deficient in the soil. Leguminous green manure plants are able to fix atmospheric nitrogen. When the soil is rich in nitrogen, leguminous plants do not fix nitrogen so well, as when grown in poor soils. The application of phosphatic fertilizers improves the growth of leguminous crop markedly and promotes the fixation of nitrogen by profuse nodulation.
5. The best stage at which the crop should incorporated in the soil as a green manure is when it reaches the flowering stage. Sannhemp crop is ready for turning- in at the age of 7 to 8 weeks whereas dhaincha crop is ready for incorporation when 5 to 6 weeks old.
6. Burying of green manure crop is done in the different ways. In some cases the plants are cut close to the ground and the green material is put in the furrows opened by a mould board plough, and is later buried. One of the method is to plank the material down with a heavy plank or log, and then plough the field. The other method is to mix the uprooted or cut plant material (green leaf manure) by means of disc harrow. In drier areas this method has been proved to be better than ploughing in.
7. Immediately after ploughing the material, careful packing of the soil should be done by suitable implements to ensure proper decomposition. Packing (compacting) is especially necessary if the soil moisture supply is deficient.
8. Under certain favourable circumstances, green manure crop such as dhaincha can be sown in between the rows of cotton or Jowar. When the dhaincha is sufficiently tall it can be uprooted and mixed with the soil by inter-cultivations.
9. Under limited moisture supply condition, it may be advisable to grow the green manure crops in one field and add the green material to another field. By doing this the moisture required for growing the green manure crop is saved.
10. For proper decomposition, in light soils the crop should be buried deeper than that in the heavy ones.

Decomposition of Green manure :

A host of microorganisms affect the complete disintegration of organic matter leading up to ammonification and, finally nitrate production. The factors for complete decomposition are the varying moisture conditions of the soil. The desired results would follow if moisture contents are high in the beginning, leading to semi-anaerobic fermentation of resistant material and low(moisture) afterwards for inducing aerobic condition under which nitrification can take place. Decomposition also depends on other factors such as composition of green matter (crop) and presence of available inorganic nutrients.

Advantages of Green manuring : Green manuring has the following advantages :

1. Green manuring adds organic matter and nitrogen to the soil. Fresh organic matter (leaves, twigs, roots etc.) decomposes and liberates plant nutrients. Leguminous green manure crop fixes nitrogen in the soil.
2. Green manuring checks weed growth. The plants used for green manuring are usually, grow very quickly and thus, tend to suppress the growth of weeds.
3. Green manuring crops aid in the reclamation of saline and alkaline soils by the release of organic acids.
4. Green manuring increases the availability of plant nutrients. When fresh organic matter decomposes, carbondioxide is evolved, more organic acids are formed and as a result, plant nutrients become more soluble in organic acids and therefore, more readily available to crops.

Disadvantages of Green Manuring :

The limitations of green manuring are as follows :

1. Growing green manuring crops in rainfed area where annual rainfall is less than 30 inches, there is a likelihood of harmful effects. The reason for this is because the green material added to the soil does not decompose readily due to lack of sufficient water. Retarded decomposition results in nitrogen starvation of the following crop.
2. Due to improper decomposition, problems of insect-pests and diseases may come up.
3. Sometime the cost of green manuring is more than chemical fertilizers.
4. Green manuring crop may be taken as a catch crop between the main crops. Due to late sowing of green manure crop and insufficient moisture, burying of green manure crop became late. Therefore, showing of main crop may not be done or delayed.
5. If rainfall is scanty, growth of green manure crops would be less vivorous which results in less production of green matter.

Selection of Green manure Crops :

The characteristics of good green manuring crops are given below :

1. It should be quick growing, so that timely incorporation of green manure crops may be done. For example, sannhemp and mung.
2. It should yield large quantities of green material in a short period. For example, dhaincha.
3. It should be preferably from the legume family so that nitrogen would be fixed in addition to green matter production. For example, dhaincha and sannhemp.

4. It should be tender (move leafy growth than woody growth) so that itws decomposition will be rapid. For example, berseem and lobia.
5. It should have a deep root system so that it would penetrate deep layers of the soil. Thus, it utilizes nurtuents and water from deeper layers and also helps in developing good soil structure. For example, sannhemp and dhaincha.

Principles of Green manuring :

1. Green manuring crop should be grown in irrigated area or where annual rainfall is more than 30 inches. Lack of moisture is harmful for the growth of the crop as well as for decomposition. An undecomposed crop may harm the subsequent crop by upsetting the balance of carbon and nitrogen.
2. After green manuring subsequent crops should be sown in well decomposed crops. Undecomposed green manure may cause poor germination, and problem of diseases and insects.
3. In the irrigated area, the best stage at which the crop should incorporated in the soil as a green manure is when it reaches the flowering stage. In rainfed or dry region, green manure crop should be incorporated before flowering stage (tender or leafy stage.)
4. Green manure crop should be quick growing.
5. It should be preferably from the legume family.
6. It should have deep root system.
7. One tonne green manure = 2.8 t FYM = 4.3 kg N = 9.3 kg urea.

Green Manure crops, their yield and nitrogen added in the field

Sr.no.	Name of green manure crop	Botanical name	Growing season	Average yield of green matter kg per hectare	Nitrogen added kg per hectare
1	Sannhemp	*Crotalaria juncea*	Summer and *Kharif*	194.7	84.2
2	Dhaincha	*Sesbania aculeate*	-do-	183.6	76.9
3	Urd	*Phaseolus mungo*	-do-	100.1	42.2
4	Mung	*Phaseous aureus*	-do-	37.4	38.6
5	Khesari	*Lathyrus sativus*	*Rabi*	123.0	54.9
6	Bersem	*Trifolium alexandrinum*	-do-	155.0	54.2

Role of Organic Manure : Function of organic manure are given below :

1. Organic manure binds soil particles into structural units called **aggregates**. These aggregates help to maintain a loose, open, granular condition. Water infiltrates and percolates more readily. The granular condition of soil maintains favorable condition of aeration and permeability.
2. Water-holding capacity is increased by organic matter. Organic matter definitely increases the amount of available water in sandy and loamy soils. Further, the granular soil resulting from organic matter additions, supplies more water than sticky and impervious soil.
3. Surface run off and erosion are reduced by organic matter as there is good infilatration.
4. Organic matter or organic manure on the soil surface reduces losses of soil by wind erosion.
5. Surface mulching with coarse organic matter lowers soil temperatures in the summer and keeps soil warmer in winter.
6. The organic matter serves as a source of energy for the growth of soil microorganisms.
7. Organic matter serves as a reservoir of chemical elements that are essential for plant growth. Most of the soil nitrogen occurs in organic combinations. Also a considerable quantity of phosphorus and sulphur exist in organic forms upon decomposition, organic matter supplies the nutrients needed by growing plant, as well as many hormones ad antibiotics.
8. French organic matter has a special function making soil phosphorus more readily available in acid soils.
9. Organic acids released from decomposing organic matter help to refuce alkalinity in soils.
10. Fresh organic matter supplies food for such soil life as earthworms, ants and rodents. These microorganism improves drainage and aeration. Earthwo4rrms can flourish only in soils that are well provided with organic matter.
11. Organic matter upon decomposition produces organic acids and carbon dioxide which helps to dissolves minerals such as potassium and make them more available to growing plants.
12. Humus (highly decomposed organic matter) provides a storehouse for the exchangeable and available action- potassium, calcium and magnesium. Ammonium fertilizers are also prevented from leaching because humus holds ammonium in an exchangeable and available form.
13. It acts as a buffering agent. Buffering checks rapid chemical changes in pH and in soil reaction.

Role of Organic Matter in Retention, Movement and Availability of Soil Water :

Retention of soil water :

Water-holding capacity is increased by organic matter. Organic matter increase the amount of available water in sandy and loamy soils. Water is held in the capillary pores or micro pores. Organic matter helps to increase the capillary pores in a soil. Organic matter itself has a great capillary capacity. Undecomposed organic matter is generally porous having a large surface area which helps to hold more capillary water. The humus that is formed decomposition has a great capacity for absorbing and holding water. Hence, the presence of organic matter in the soil controls the amount of capillary water.

Movement of soil water :

In saturated flow or gravitational flow, water percolates down (vertically) into the lower layers. Organic matter helps to maintain a high proportion f macro pores, larger the pore space, grater the flow. In capillary movement or unsaturated movement water moves from lower level (thick moisture level) to upward level (thin moisture level). Upward rise of water is higher in micro pores or capillary pores. The humus helps to increase the capillary pores.

Availability of soil water :

Organic matter binds soil particles into structural units called **aggregates**. These aggregates help to maintain loose, open, granular condition. Water infiltrates and percolates more readily. Thus, organic matter refuces surface run off and makes soil water more available to plants.

Disadvantages of Organic Manure :

1. Nutrients are so low that huge quantity of manure has to be added for the desired dose of nutrients.
2. Transport of the huge quantity of manure to the site application is difficult.
3. It increases the cost also.
4. The rate of mineralization and the rate of release of nutrients, particularly of the nitrogen, is slow.

....

Chapter 6

Concentrated Organic Manures

Concentrated organic manures are those that are organic in nature and contain higher percentages of major plant nutrients like nitrogen, phosphorus and potash, compared to bulky organic manures like F.Y.M. and compost. These concentrated manures are made from raw materials of animal or plant orgin. The common concentrated organic manures are oil cakes, blood-meal, fish manures, meat-meal and wool waste.

Oil cakes

A large variety of oil cakes are produced in the country. Oil cakes can be grouped into two classes, namely **(i) Edible oil cakes** - suitable for feeding to cattle and **(ii) non-edible oil cakes** - not suitable for feeding to cattle. Normally, edible oil cakes, should be fed to cattle as concentrates. But cultivators in India apply some of the edible oil cakes to the soil. Thus both the types of oil cakes are utilized as concentrated organic manures.

Roughly, two million tons of oil cakes are produced annually in India. Oil cakes contain not only nitrogen, but also some phosphorus and potash, along with a large percentage of organic matter. The chemical composition of the principal oil cakes available in India is given in table given ahead.

Oil cakes are the quick-acting organic manures. Though insoluble in water, their nitrogen becomes quickly available to the plants in about a week or ten days after application. The *mahua* cake, however is an exception, as it nitrogen does not become available till about two months after application. As such *mauha* cake should be applied about two months before sowing, provided the soil is moist. This cake is suitable for application to orchard and long duration crops like sugarcane and tapioca.

Oil cakes should be well-powdered before application, so that they can be spread evenly and are easily decomposed by microorganisms. They can be applied a few days prior to sowing or at sowing time. Oil cakes, especially groundnut cake, are also applied extensively in the from of a top-dressing to sugarcane. Depending on crop, oil cakes are applied broadcast, drilled or placed while earthing up near root zone.

Average Nutrient content of Principal Oil cakes

Oil cake	Percentage composition		
	N	P_2O_5	K_2O
Non-edible oil cakes			
Castor cake	4.3	1.8	1.3
Cotton seed cake undrcorticated	3.9	1.8	1.6
Karanj or honge cake	3.9	0.9	1.2
Mahua or ippi cake	2.5	0.8	1.8
Neem cake	5.2	1.0	1.4
Safflower cake, undecorticated	4.9	1.4	1.2
Edible oil cakes			
Coconut cake	3.0	1.9	1.8
Cotton seed 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
Rape seed cake	5.2	1.8	1.2
Safflower cake, decorticated	7.9	2.2	1.9
Sesame or til cake	6.2	2.0	1.2

Country ghani or Ghana oil cakes usually contain a little more oil than the hydraulic or expeller-pressed oil cakes. Owing to the higher percentage of oil, country ghani oil cakes are somewhat slow-acting, as oil prevents rapid conversion of organic organic nitrogen into an available form. Deoiled neem cake is a by-product of the oil production and can be used as a manure. There are different ways of using neem cake as a manure, such as (i) an organic manure (ii) blended with a nitrogenous fertilizer, specially urea, to inhabit nitrification and improve fertilizer efficiency, or (iii) by first extracting neem cake with ethanol or acetone and /or mixing the cake as a N fertilizer.

Blood-meal:

Dried blood or blood-meal contains 10 to 12 per cent of nitrogen and one to two percent of phosphoric acid. An adult cattle gives about 13.6 kg of blood, and a goat or sheep about 1.36 kg. at present, slaughter houses do not take proper care in collection of the blood. They should be provided with pucca of concrete floor with a central drain leading into a blood storage tank.

The blood clot is first treated with commercial copper sulphate at 125gm per 100 kg of clot. It is then evaporated to dryness on a sand bath. Next, it is spread on a concrete floor covered over by a net, and allowed to dry in sun. When completely dried, it is powerded, bagged and sold as blood-meal.

precautions for pathogens and responses to earthworms are necessary. Specially if horse dung is used, we have to be extremely, cautions of Tetanus virus that is common in horse dung and is lethal to human beings. In sheep dung immediate growth is poor.

2) Agricultural waste :

These comprise all items discarded after harvesting and threshing of the produce, like stem, leaves, husk (excepting paddy husk) peels, vegetable waste, orchard leaf litter, processed food wastes, sugarcane trash and baggage; and processing wastes.

3) Biogas slurry :

After recovery of biogas, if not required for agricultural use, viz, in conventional composting can be used for vermin composting.

4) City leaf litter :

As yet no data is available on tonnage of leaf litter from avenue or residential areas that is burnt. All this can be converted into vermicompost. This would keep cities clean and would provide useful product- the vermicompost on success of vermiculture on different types of leaf litter, some information is available. These are mango, guava, grasses and certain weeds. However, researches are wanting for generating more information.

5) City refuge :

City refuge or garbage on daily production basis comprise important items of city pollution. Its management (collection and disposal) costs lot due to various factors. Composition of city refuge widely varies. Considerable portion of city refuge can be got sorted and recycled or composted. For composting however, it is essential that toxicants should not be mixed with the material. Most of household as kitchen waste can be vermin composted. This concept if well practiced and managed would manifold reduce over all generation of city refuge.

6) Forestry wastes :

These also comprise various types of plant products like wood shavings, peels, saw dust and pulp. All these besides various types of forest leaf litter can be used.

7) Industrial wastes :

Some types of Industrial wastes, viz. waste from food processing, distillery, etc. can also be used in vermin culture with some manipulations in regard to vermicompost able conditions.

8) Waste paper and cotton cloth etc:

These are decomposable organic waste. These if are not being recycled for other useful products, can be recycled with vermicomposting.

More specifically following combinations can be used as feed for earthworms for vermin culture and vermicomposting. However, exact proportions may have to be adjusted with little pre-testing.

1. Biogas slurry with some leaf litter and some soil sprinkled over.
2. cow dung + Sheep droppings + horse dung mixed in equal quantities.
3. Cow dung or mixed dung + agricultural waste in ratio of 10:3
4. Old cow dung (minimum 7 days).
5. Only agricultural waste or sewage sludge or kitchen waste or leaf litter or their mixture.

Note : In place of agricultural waste the substances like gram bran, kitchen waste, rice polish, sewage and sludge, vegetable waste, and wheat bran can also be used.

Standard diet given by Prof. R.D. Kale comprises cow dung or mixed dung + Gram bran + Wheat bran + Vegetable wastes in ratios of 10:1:1:1 + Some powdered egg shell.

Material combinations thoroughly mixed with upturning with a spade to mix. Heaps are watered and kept in shade for partial digestion for 2 to 3 weeks. Then it is beaten to break lumps, i.e. make it some-what powdery and used as feed for earthworms.

In addition to above numerous other combinations have been tried and or can be tried with care. For example de-oiled Neem kernel cake can also be used after it has been partially matured or decomposed. Fresh de-oiled Neem cake has been reported to reduce reproduction and so does sheep dung. Vermistabilization is also delayed in some combinations. For all such problems, best is to subject it to initial pre testing.

Some mushroom cultivators are vermicomposting "spent" or used substrates after mushroom harvest for vermicomposting. Treatments of this material too is same and is to be mixed with any of the feed materials.

Types of Vermicomposting :

Small scale or Indoor Vermicomposting :

This is conducted in covered areas (with a shade). It is preferred and recommended for areas where protection from climatic adversaries like high rains, prolonged spells of high or low temperatures (from less than 10^0 F to more than 45^0 F) and predators like ants, rodents and large insectivorous birds are abundant.

Indoor culture and composting can be practiced in abandoned cattle sheds, poultry sheds back yards or underneath temporary thatched sheds. Thatching material should be locally available material as drawn from agricultural wastes or material of non-marketable grade from Social Forestry programmed, viz. stem straws from subabool plants and straw of harvested crop plants.

Large scale or Outdoor Vermicomposting :

Large scale vermicomposting is of two types (1) simple promotion of vemic activity in fallow fields after harvesting corps. And (2) large scale commericialised vermicomposting in open heaps.

Other types of Vermicomposting :

There can be several names designated to vermicomposting. Basically all are same but vary only with extent of waste mass to be vermicompostd and composting container(s). Some even tag with names of mechanical structures used as composting containers, viz. vermiexcelerator etc. This is common with some commercial establishments in USA and Europe.

In process of simple promotion of vermin activity, in fallow fields ridges are to be raised by 8-10" and whole area is divided into smaller plots in accordance with existing ground level. Partly digested (= decomposed) wastes, largely-comprising agricultural wastes are somewhat uniformly spread over plots. It is watered to keep moist and covered with other decomposable organic wastes like weeds and leaf litter etc. this helps conservation of moisture and promotes vermin activity, i.e. soil humification. Over this leaf litter dwelling species of earthworms are introduced along with a thin layer of somewhat mature cow dung manure. The process is allowed to continue for 3-4 or more months, but periodic light irrigation or moistening is continued.

Prolonged **vermic activity** on fallow fields resulted in conditioning the soil. It helps in formation of humus, improves soil aeration, percolation infiltration and nutrient content, etc. All these eventually promotes soil health management and yields of plants. Thus the process is important integral of organic farming. In fact process is important for soil reclamation etc. viz. under *jhum* or shifting cultivation.

In some parts of America, such natural vermicomposting is practiced. In India, with average small land holdings, this may not be possible, but at community level, viz. for Panchyati Ends (like Pastures), this is certainly possible. Likewise for Forestry plantation, it is suitable.

Requipments for Vermicomposting :

There are no special material requirement(s) for vermiculture and vermicomposting. Still for planning any programming certain scientific points are required to be kept in mind for optimal result (composting). These have been termed here as **'requirements for vermicomposting'.**

1) Bedding Material :

This is the lower most layer of earthworm feed substrate that is required to be vermicomposted. For this any biodegradable matter is used like banana stem peels, coir pith, coconut leaves, sugarcane trash, stems of crops, grasses or husk. Waste or discarded cattle feed can also be used for bedding.

2)Container :

Vermi-composting container can be of any shape or size and requirement depends upon quantity of waste to be composted and number of live earthworms we want to culture. On average, 2000 adult earthworms can be maintained in containers of 1 m^2 dimension. These with appropriate conditioning of composting material would convert approximately 200 kg wastes every month. Interestingly, roughly in a container of 2.23 x 2.23 meter it is possible to maintain 10 kg of earthworms to have an expected conversion rate of approximately 1 ton per month. However, to have optimal conversion normally, only upper 9-12 inches layer is composted. This should be softly scrapped off.

3) Cover of feed substrates :

This is required for reducing moisture loss and also save worms from extra movements (out side substrate) or from predators like ants. Moist gunny bag covers also help in conservation of moisture.

4) Moisture content :

Moisture content during vermicomposting should be maintained between 30-40 per cent. If moisture is high, dry cow dung manure or leaf litter should be mixed with substrate.

5) pH :

pH of substrate should be between 6.8 to 7.5. For non-scientists; measurement of pH can be done with use of pH paper strips available from chemists. These pH indicator strips are dipped in soil solution (soil and distilled water), colour changes and which is matched with color chart on cover of strip booklet. 7.0 pH indicates its neutral condition, less than 7 indicates its acidic nature and greater than 7 indicates alkaline condition of soil.

6) Selection of right type of worm species :

This is important to have optimal results. In general, species to be used for vermicomposting should be high in terms of growth rate of earthworms (protein conversion), high temperature tolerance, and pressure, as well have high reproduction rate. Two groups of earthworms are found :

(i) Surface earthworms :

They are short in length (3-4 inch) and eat more organic matter (90 per cent) as compare soil (10 per cent). Surface earthworms include **Epiges** and **Endoges** types of worms and also known as **r-selected** species. They are characterized to have more metabolic rate (high conversion rate) and high production rate and are more useful for vermicompost.

After collection of compost from top layers, feed material is again replenished and composting process is rescheduled. After 2-3 months checking is made to see the condition of bedding material and growth rate of earth worms. Normally reproduction of earth worms goes on, bit goes down after 9 months. Then mature or old worms should be removed.

Vertmicomposting efficiency :

In general a bed of 1 m x 1m x 0.5 m requires 30 to 40 kg of beeding and feed material. This can support 1000 to 1500 earthworms which would multiply and compost the matter from upper layers. So upper layers of organic matter should be periodically replenished. Many experts suggested that from top layer, accumulating casts should be periodically removed as it reduces vermic activity or reproduction. Whole organic matter gradually gets decomposed with exhilarations by vermic activities and matter is converted into vermicompost. Vermicompost is reported to contain 5 times more nitrogen, seven times more phosphorus, 11 times more potassium, 2 times more magnesium and calcium. These are in a from that is readily assimiable to plants.

The decomposition of organic waste depends upon several factors. Earthworm activities like burrowing, feeding and defecating exhilarate process of decomposition. So large the no. of earthworms present in an appropriate medium and conditions, faster would be vermicomposting. Thus initially, i.e. immediately after intorudction of worms, first lot of vermicompost is ready within 60-70 days. Gradually with bacterial decomposition leading to breaking of larger masses and increase in numbers of worms, vermicompost is ready in 30-40 days only. According to available extrapolative estimates, 1 kg of earthworms (i.e. nearly 1000 adult *Eugenia* species worms) would produce 10 kg in 60-70 days.

Transportation of live worms :

With gradual development and functioning of vermicomposting beds, or tanks; a stage is attained when surplus numbers of earthworms are produced. These can be sold to other vermiculturists and various other usages like areas ranging from export potentials to local demands. In such situations, needs of transporting live earthworms arises.

Transportation of live earthworms is very simple and easy. Cocoons are to be hand picked with brush and collected in some container having same feed material with some moisture. Feed material should be approximately ½ gm per cocoon for every 24 hours of transportation journey period. Cocoons can be gently packed in any clean perforated container viz. Soft;ly put in muslin bag and which is put in any other plastic jar having perforated lid for aeration. Final postal packing or air freight packing should also be perforated.

Application of Vermicompost :

Broadly vermicompost application is to be done in same manner as conventional farm yard Manure is applied. For various usages, vermicompost application can be done in under mentioned manner.

Flower or Garden pots

Make a 2-3" pit around plant ensuring that roots are not cut and fill vermicompost around it. Cover compost with ranked over soil and water. For preparation of garden pot soil, basic preparation are same. Only 10-40 parts vermicompost can be mixed in soil before filling pots for transplanting seedlings. Succeeding application would be same as conventionally done. Some experts even opine that 20-30% recommended dose of chemical fertilizers be substituted with vermicompost. Seed bed preparations can also be done with simple addition of vermicompost in conventional manner.

In Horticulture :

In horticulture plants, vermicompost application is preferred and is applied by mixing equal quantity of cow dung manure. Application quantity (in general, 5 kg per plant) depends upon age and size of plant. Method involves preparation of a ring around plant base of ½ to 1 feet depth and 1 to 2 feet wide. In this ring, mixture of vermicompost and farm yard or cow dung manure is filled. Over this a thin layer of soil is put and finally covered with organic matter comprising dry leaves, weeds (minus seeds), husk, coir, or even old hesian. This process completes important step of 'mulching' and then watering should be done. Generally application can be repeated every month or at conventional periodicity.

Above methods can be tried by hobbyists for kitchen or in 'Terrace' Gardens for vermicompost application around flower, fruit and vegetable plants in homes.

In agriculture :

Utilization of vermicompost in agriculture has so far bee limited due to low level of production of vermicompost. However, first application at seedling stage, mixed with FYM in equal proportion may be useful. Estimate dosage is around 5 tons/ha. Second application may be repeated after one month. Though some experimental data of small plots has been reported, yet large scale trials are wanting.

....

Chapter 8

Fertilizers

Fertilizers are inorganic substances that contain one or more ingredients of plant food, in large proportions. Some organic synthetic substances like urea have also been included in this category. They may be natural substances or artificial products. Fertilizers which contain only one plant nutrient are termed as **'Straight fertilizers'** which may be distinguished from **'Compound fertilizers'** which have two or more fertilizers.

Straight Fertilizers :

When a fertilizer contains a single primary nutrient, it is called straight fertilizer. Such fertilizer is called nitrogenous or phosphatic or potassic. For example, urea.

Complex or Compound Fertilizers :

Two or more nutrients in one compound is known as complex or compound fertilizers. Complex fertilizers are granular and easy to apply. Examples are :

Fertilizer	N	P_2O_5	K_2O
Diammonium phosphate	18	46	-
Ammonium phosphate sulphate	20	20	-

In the example, 100 kg of Diammonium phosphate contains 18 kg of N and 46 kg of P_2O_5, the remaining 36 kg is inert material.

Beside the reaction of the fertilizer there are other more potent factors which modify their action. In light-textured soil where irrigation facilities exist or there is adequate rainfall the use of sodium nitrate may not produce alkalinity. But sodium will accumulate rapidly in the soil if the soil is heavy and the rate of infiltration is low.

Some fertilizers, such as ammonium nitrate, are very hygroscopic in nature and rapidly absorb moisture, particularly during the monsoon season.

Nitrogenous Fertilizers :

The deficiency of nitrogen in the soil is foremost and crops respond to nitrogen better than to other manurial ingredients.

Classification : The nitrogenous fertilizers are broadly classified into 4 groups (given in following table :

Classification of Nitrogenous fertilizers

Source of nitrate	Name of fertilizer	% of nitrogen	% P	Reaction (acidity / basicity)
Nitrate	Sodium nitrate ($NaNO_3$)	16.0		Basic
	Calcium nitrate $Ca(NO_3)_2$	15.0		-do-
	Potassium nitrate (KNO_3)	13.0		-do-
Ammonium	Ammonium sulphate $(NH_4)_2SO_4$	20.6		Acidic
	Ammonium chloride (NH_4Cl)	25.0		-do-
	Diammonium phosphate $(NH_4)_2\ HPO_4$	21.0	53	-do-
Nitrate and ammonium	Ammonium nitrate (NH_4NO_3)	33.5		-do-
	Ammonium sulphate nitrate $(NH4)_2SO_4.NH_4NO_3$	26.0		-do-
	Calcium ammonium nitrate	20.5		Neutral
Amide	Urea $CO(NH_2)_2$	46.0		Acidic
	Calcium cynamide ($CaCN_2$)	22.0		Basic

Characteristics of nitrogenous fertilizers :

I) Nitrate Fertilizers : Of the nitrate fertilizers the most common in use is sodium nitrate or calcium nitrate.

a) Nitrate group of fertilizers are soluble in water and hygroscopic (absorbs moisture from the atmosphere to become sticky).

b) They are alkaline in nature. Especially the constant use of sodium nitrate, creates deflocculating of clay particles and poor drainage.

c) Contains less percentage of nitrogen than other groups so that its use is diminishing at a fast rate.

d) They are completely soluble in water and readily available for the use of plants as such, without any chemical change in the soil.

e) The nitrate is not retained (adsorbed) by the soil and is liable to fast leaching.

f) These are applied in small doses and repeated at intervals on standing corps (top dressing).

g) If so use is not suitable for rice crop in early stage of growth. Because rice plants take nitrogen in ammonical form.

II) Ammonium Fertilizers : This group of fertilizers are in wide use particularly ammonium sulphate.

a) Ammonium fertilizers are soluble in water but not hygroscopic.

b) They are acidic in nature.

Chapter 9

Phosphatic Fertilizers

Classification and Characteristics: Phosphorus fertilizers are classified into : (A) Water-soluble, (B) Citrate-soluble, and (C) Insoluble.

(A) Fertilizers Containing water-soluble phosphorus

Sr.No.	Name of the fertilizer	Chemical composition	Percentage composition		Acidity or alkalinity
			P_2O_5	N	
1	Superphosphate (ordinary) (single superphosphate)	$Ca(H_2PO_4)_2$	16-20	-	Natural
2	Superphosphate (concentrated) (triple super phosphate)	$3Ca(H_2PO_4)_2$	40-48	-	Natural or acidic
3	Diammonium phosphate	$(NH_4)_2HPO_4$	54	21	Acidic

Characteristics :

1. Phosphate is water-soluble and quick acting (available).
2. Very less leaching loss in this group of fertilizers.
3. Should be applied in neutral and alkaline soils.
4. **Superphosphate and soil reaction.** When superphosphate is applied to neutral or alkaline, the soluble monocalcic phosphate combines with lime in the soil and dicalcic and tricalcic phosphates are produced. The phosphates are then said to be reverted. Since the reverted phosphates are chemical precipitates, they are in a fine state of division and offer a large surface for the soil solution to act. As a result, even tricalcic phosphate is rendered soluble slowly and gradually, and made available for plants.

When the soil is acidic an the pH is 5.5 or lower, the iron and aluminum in the soil become soluble and combine with the soluble phosphates in superphosphate. Iron and aluminium phosphates that are formed, as a result, are very insoluble and do not become available for the use of plants ordinarily. The phosphates are then said to be fixed or tied up in the soil.

When the pH of the soil ranges from 5.5 to 6.5 the light acidity of the soil assists greatly in dissolving the tricalcic phosphate present in the soil and making it available for crops.

The organic matter in the soil effectively prevents applied phosphates from being tied up (fixed) in the soil in insoluble forms and even releases phosphates that had already been fixed, is likely to influence phosphate application practice in the future.

Super phosphate :

The phosphorus in bones and rock phosphates is in the form of tricalcium phosphate (insoluble) and therefore, does not become readily available to plants. The insoluble phosphate in rock phosphate is converted into a soluble form by treating with sulphuric acid and the resulting product is called superphosphate (ordinary). When phosphoric acid instead of sulphuric acid is used (for treating rock phosphate) in preparation of super phosphate, a high grade material containing 40-48 percent phosphoric acid is obtained. This is called **concentrated** or **triple super phosphate.**

(B) Fertilizers containing citrate-soluble phosphorus

Sr. No.	Name of fertilizer	Chemical composition	Percentage composition	Acidity or alkalinity
			P_2O_5	
1	Basic slag (Indian)	$(CaO)_3.P_2O_5.SiO2$	3-5	Alkalinity
2	Dicalcic phosphate	$CaHPO_4$	35-40	Acidic

Characteristics :

1) Insoluble in water but soluble in citric acid, so that does not become readily available to plants.
2) No leaching loss.
3) These are slow acting fertilizers therefore, applied in the soil 15-30 days before sowing.
4) These type of fertilizers should be used in natural and acidic soils.

Basic Slag :

It is more effective in soils with high rainfall and that are neutral to acidic in soil reaction. It is advisable to apply it in heavy applications and about a month before sowing the crop to compensate for its slow action. It is alkaline in reaction.

Dicalcic Phospahte :

It has high amount of citrate-soluble phosphate and has an excellent physical condition. Due to its phosphate in dicalcic form, it is cheaper and there are less chances for fixation. It is effective on soils of acidic, neutral and alkaline reaction.

c) Fertilizers containing insoluble phosphorus

S.N.	Name of the fertilizer	Chemical composition	Percentage composition		Acidity or alkalinity
			P_2O_5	N	
1	Rock phosphate	$Ca_3(PO_4)_2$	20-30	-	
2	Bone meal		18-20	3	Alkaline

Characteristics :

(1) Because of their insolubility and very slow availability, fertilizers of this group should be applied in the soil about 2 months before sowing. Phosphorus is available in the form of tricalcium phosphate.

(2) Generally, deep placement is done in highly acidic soils.

Rock Phosphate :

For effective results, it should be used in heavy application, particularly with organic matter. Its availability is increased by the presence decaying organic matter. Rock phosphate must be finely ground before application in acid soil.

Bone-meal :

Bone meal is very safe and slowly available in the soil. Bone meal can be applied in acidic soil with light, medium and heavy texture. Its efficiency increases when organic matter is present in adequate quantities.

....

Chapter 10

Potassic Fertilizers

Classification :

	Fertilizer	Chemical form	Percentage composition (K_2O)	Reaction
1	Potassium chloride (muriate of potash)	KCL	60	Neutral
2	Potassium sulphate	K_2SO_4	50	Neutral

Characteristics :

1) Potassium fertilizers are water-soluble but not hygroscopic in nature.
2) They are readily available to plants.
3) There is no leaching loss.
4) As they are neutral in reaction so have little or no effect on the soil pH.

Potassium Chloride :

Its use is found effective in acidic and heavy soils. Based upon the chemistry of chloride ion in the soil it is inferred that under acidic soil conditions it replaces OH ions associated with the free iron oxides and therefore, in such soils muriate of potash (potassium chloride) is likely to give more response than sulphate of potash. Besides, chlorine ions are less strongly retained on soil colloids than sulphate ions. It can be more safely used on heavy soils where chlorine ions will not accumulate very much.

Potassuim Sulphate :

This fertilizer is more effective on light and medium soils with high pH (alkaline and calcareous soils). Under wet conditions it is preferable to apply potassium sulphate than potassium chloride. The SO_4 (sulphate) ions are retained by soils more strongly than Cl (chlorine) ions in the heavy soils. Excess of sulphate ion in the heavy soil develops toxicity. Further in heavy (compact) sols uptake of potassium from potassium sulphate is restricted due to limited oxygen supply.

....

Chapter 11

Fertilizer Mixtures

In fertilizer mixtures 2 or 3 straight (single) fertilizers are mixed thoroughly. For example, Hara bahar (18N:18P:6K) and Sufla (20N+20P+0K)

Advantages of Mixed fertilizers :

The advantages of fertilizers mixtures are summarized as follows :

1) The farmer is supplied a balanced fertilizer mixture that is adopted for each soil and each crop.
2) Time and labour costs are saved since all of the fertilizer materials are applied at one time.
3) Fertilizer mixtures can be prepared in a manner to correct residual acidity of certain nitrogen fertilizers.
4) Fertilizer mixtures in balanced form help in maintaining good physical condition of soil.
5) One nutrient increases the availability of other nutrient.
6) Balanced fertilizer mixture provides tolerance against drought, cold, pests and diseases.

Disadvantages of mixed fertilizers :

The arguments against using fertilizer mixtures that are usually put forward are :

1) The unit cost of plant nutrients in mixtures is higher than that of purchasing the same materials separately.
2) The improper mixtures may not be suitable for all soils.
3) The purchase and use of correct formulation of fertilizer mixture requires relatively greater knowledge. Lack of proper knowledge about the proper mixture for a specific soil type and a particular crop may result in improper use.
4) When mixed fertilizers are used, single nutrient fertilizer may still be necessary at a specific plant growth stage. For example, nitrogen in split application (top dressing), i.e. at 2 or 3 stages of plant growth. Therefore, farmers have to purchase nitrogenous fertilizers for split application (top dressing), apart from mixed fertilizers.

Principles of Mixing Fertilizers :

The compatibility of various fertilizers for mixing depends upon the various reactions that take place. Most fertilizers could be mixed together without any adverse effects, while some fertilizers react with one another. Some of the changes brought about by injudicious mixing (incompatibility) of fertilizers are indicated below:

(1) **Loss of nitrogen from injudicious fertilizer mixtures :** Basic compounds liberate ammonia gas from ammonium salts and organic nitrogenous manures, and lead

to loss of nitrogen. Quick lime, slaked lime, potassium carbonate, basic slag and cynamide, which are basic in nature, should not therefore, be mixed with ammonical fertilizers and organic manures.

(2) **Lumps formation in incompatible mixture :** Superphospahte is likely to form lumps when mixed with other fertilizers and kept over for some time. It reacts with nitrate and librates nitric acid and makes the mixture sticky and inconvenient for handling.

(3) **Unavailability of phosphate in wrong mixtures :** Substances like slaked lime react with superphosphate on mixing and soluble monocalcic phosphate is reverted to dicalcic and tricalcic forms (which are insoluble and unavailable to plants.)

Materials used in fertilizer mixtures : The following types of materials used in making the mixture :

(1) **Nutrients :** Supplier of plant nutrients (fertilizers).

(2) **Conditioner :** They help maintaining a good physical condition of the mixture. They can be powdered tobacco stalks, paddy husk powder, etc.

(3) **Neutralizer :** They are used to neutralize the residual acidity of certain fertilizers in mixture e.g. ammonium sulphate. Mostly dolomite, limestone are used for this purpose.

(4) **Filler :** they are sand, soil, powdered coal, ash etc.

Types of Fertilizer Mixtures :

(i) **Open chain fertilizer mixture :** the producers write the percentage of available nutrients from those mixtures, thus, it facilitates the farmers to select the right type of grade for his crop and soil.

(ii) **Closed chain formula fertilizers mixtures :** these mixtures do not indicate their grade (% of available nutrients) and type of fertilizers mixed together. Thus, the farmers cannot choose a correct mixture for their use in production of crops.

Fertilizer Mixtures available in the market :

1.	Sufla (15:15:15)	2.	Sufla (20:20:0)
3.	Lakshmi (12:12:12)	4.	Lakshmi (8:8:8)
5.	IFFCCO –1 (10:26:26)	6.	IFCCO-2 (12:32:16)

Grade :

Grade of mixed fertilizers is 5-5-10 (fertilizer ratio of 1:1:2), means that 100 kg of the mixed fertilizer of this grade will contain 5 kg of N, 5 kg of P_2O_5 and 10 kg of K_2O. The source of N, P and K are urea (46 of N), single superphosphate (16% P_2O_5), muriate of potash (60% K_2O), respectively. For this grade, 10.9 kg urea, 31.3 kg superphosphate and 16.7 kg muriate of potash will be used. The total weight fertilizer ingredients will be 58.9 kg. to this fertilizer mixture, 41.1 kg of inter material will have to be added to make up 100 kg bag of mixed fertilizer. The inert material is usually soil, coal, ash, sand etc. known as filler. A filler is weight make up material added to fertilizer ingredients to produce a mixture of desired grade.

Balanced Fertilization :

Plants contain 90 or more elements, only 16 of which are currently known to be essential. The elements essential for plant growth are carbon, hydrogen, oxygen, phosphours, potassium, nitrogen, sulphur, calcium, iron, magnesium, boron, managanese, copper, zinc, molybdenum and chlorine. On practical point of view, generally application of nitrogen phosphatic and potassic fertilizers are considered as balanced fertilization.

Unbalanced fertilization has led to decrease in the yield of crops and also deteriorate the physical condition of the soil. The growing of crops by using only nitrogen fertilizer have depleted the reserve of available phosphoric acid, postash, and other nutrients in the soil. The result is that subsequent additions of nitrogen fertilizer do not result in increased yields because some other essential elements such as phosphorus and potash are now a limiting factor.

Balanced application of fertilizers enhances the efficiency of nutrients. For example, the efficiency of a nutrient like nitrogen is greatly enhanced when it is used in conjunction with phosphorus. For instance, when a dose of 30 kg of nitrogen was applied in the field, only 14 to 30% of nitrogen is utilized by the crops. On the other hand, when 30 kg of nitrogen was applied along with 30 kg of phosphoric acid, the recovery of added nitrogen varied from 23 to 50%. This clearly shows that phosphoric acid contributed to the better utilization of the nitrogen. Just as phosphoric acid helps in the better utilization of nitrogen, potash also helps in the better assimilation of nitrogen and phosphoric acid.

Balanced fertilizer application, particularly, phosphorus and potash makes plants more drought resistant and winter hardy. Balanced fertilization imparts plant vigour and resistance to certain diseases.

A certain balance among the various nutrients is essential if the greatest efficiency in the use of fertilizer is to be obtained.

....

Chapter 12

Methods of Fertilizer application

Various methods are used for fertilizer application. The methods are classified as follows :

Methods of Fertilizer application
↓

↓ Application in solid form
- ↓ Broadcasting
  1. Basal application
  2. Top dressing
- ↓ Placement
  1. Plough sole
  2. Deep
  3. Sub-soil
- ↓ Localized placement
  1. Drill
  2. Band
  3. Side dressing
  4. Spot placement
  5. Ring placement

↓ Application in liquid form
1. foliar application
2. application in irrigation water

A) Application of Fertilizers in Solid form :

I) Broadcasting : Evenly spreading the dry fertilizer over the entire field and incorporating by cultivation is termed as broadcasting.

i) Basal application : Evenly spreading of solid fertilizers over the entire field before or at sowing or planting is called basal dressing.

ii) Top dressing : The broadcasting of the fertilizer on closely sown standing crops is called top dressing. Generally, nitrogenous fertilizers are used for top dressing. N-fertilizer should not apply on wet leaves.

II) Placement :

(i) Plough sole placement : Fertilizer is placed in a continuous band on the bottom of the furrow during the process of ploughing.

(ii) Deep placement : Usually nitrogenous fertilizer (urea) is placed in reduction zone (deep in the soil), where it remains in ammonical form and is available to the crop slowly.

(iii) Sub-soil placement : Fertilizers like phosphate and postash are placed in sub-soil. This method is recommended in humid and semi-humid regions where many sub-soils are strongely acidic.

III) Localized Placement : Fertilizers are applied close to the seed or plant.

(i) Drill placement or contact placement : Fertilizers are drilled along with the seed, using suitable equipment (e.g. fertilizer drill or seed-cum-fertilizer drill.)
(ii) Band Placement : This is a system of localized placement of fertilizer in the hill or along the row of crops.
iii) Side Dressing : The fertilizer applied after the crop has been seeded in spaced rows. This may be done either as a continuous band near the crop row or dibbled in between the plants. Side dressing is a very common practice in long duration crops such as sugarcane.
iv) Spot placement : Sometimes the fertilizer is placed in between the plants in pinches at the base of each pair of plants.
v) Ring placement : In this method, fertilizers are applied around the plants in ring (basin).

(B) Application of fertilizers in Liquid form :
1.Foliar Application :

Some fertilizers in liquid form can be applied spraying directly on the leaves of crop plants. Several nutrient elements are readily absorbed by leaves. Urea (N-fertilizer) and micronutrients like zinc sulphate, magnesium sulphate etc. are most common. Since urea is an organic form of nitrogen, it causes the least injury. It can be sprayed at the rate of 2-4 per cent. Three kilograms of urea in 500 liters of water has been reported safe.

Advantages :

(1) This method may be suitable where soil application of fertilizers are not possible. For example, hills, sandy soil etc.

(2) Micro-nutrients are required in small quantities and there solution are not strong. Their application by foliar spray has given better results compared to soil application.

Disadvantages :

(1) Plant nutrients are absorbed through the leaves only limited quantities,

(2) In several cases of plant nutrient deficiencies, it will generally, take more than one spray application to correct the deficiency.

(3) Strong solution may cause leaf injury.

(4) It is costly method.

Principles involved in selecting the correct method of Fertilizer Application :

1. Nitrogen fertilizer is easily soluble in water and moves rapidly in all directions from place of application. Nitrogen applied in soil surface reach the plant root easily and rapidly. As such, these fertilizers are broadcast on the soil surface just before sowing.
2. Leaching and volatilization loss is very high in nitrogenous fertilizers. So that N-fertilizers are suitable for top dressing and side dressing.
3. To reduce the fixation of phosphate, phospatic fertilizers should be so placed that they come into minimum contact with the soil particles and are close to the plant

roots. In other words, localized placement of phosphatic fertilizers near the seed or seedling roots should be practiced.

4. Phosphatic fertilizers are not much suitable for top dressing.

Time of application of fertilizer : Princliples governing selection of proper time for application of fertilizers are :

1. Nitrogen is required throughout the crop growth. Nitrogen is taken up by the plant slowly in the beginning, rapidly during the grand growth period, and again slowly as it nears maturity.
2. Nitrogen is lost easily through leaching. Therefore, it is better not to apply too much nitrogen fertilizer at one time, but to apply in spilt doses throughout the growth period.
3. Phosphorus is required during the early root development and early plant growth. As such, crop plants utilize $2/3^{rd}$ of the total requirement of phosphorus when the plants accumulate $1/3^{rd}$ of their dry weight.
4. All phosphatic fertilizers release phosphorus for plant growth slowly. As such, it is always recommended that the entire quantity phosphatic fertilizers should be applied before sowing or planting.
5. Potash behaves partly like nitrogen and partly like phosphorus. From the point of view of the rate of absorption, it is like nitrogen, being absorbed, upto the harvesting stage. But potash fertilizer like phosphate become available slowly. As such, it is always advisable to apply the entire quantity of potash at sowing time. Leaching of potash is greater in sandy soils. This means split application of potash is desirable I sandy soils.

Factors affecting optimum fertilizer dose : The factors which affect the optimum fertilizer dose are :

1. Initial Soil Fertility :

Plants growing on soils high in available plant nutrients responds little to application of fertilizers. This soil requires little dose of fertilizers.

2. Soil pH :

In neutral soil (pH 7.0) response of fertilizers is maximum. In acidic, saline and alkaline soils availability of fertilizers is reduced, thus, higher application is needed.

3. Soil Texture :

Sandy soil requires greater amount of fertilizer in comparison to a clayey soil.

4. Soil Erosion :

Eroded soil requires heavier fertilizer dose.

5. Rainfall :

There is high requirement of fertilizer in the areas of high rainfall.

6. Previous Crop Raised :

If an exhaustive crop like maize is taken during the *kharif* season, the wheat crop to be sown during *rabi* season requires a higher dose of nitrogen.

7. Intensity of Cropping :

Higher the cropping intensity, higher removal of nutrients.

8. Sowing Period :

If the crop is sown late, dose should be increased.

9. Irrigated Area :

Fertilizer dose should be more in comparison to un irrigated areas.

Difference between Organic manure and Inorganic manure

	Organic manure or green manure	Chemical fertilizer or Inorganic manure
A	Organic manures are poor in plant food. They supply almost all the ingredients of plant food.	They are rich in plant food and supply individually one or two elements of plant food only.
B	**Physical properties**	
1	**Soil structure** : Organic manure improves the soil structure (granular)	No such effect on structure.
2	**Water-holding capacity** : they improve water holding capacity.	There is no effect on water holding capacity.
3	**Permeability** : by the use of organic manure, the soil becomes more permeable.	No effect of fertilizer on permeability.
4	**Drainage** : it improves drainage in the soil.	No effect.
5	**Soil erosion** : it checks the soil erosion.	No effect on erosion.
6	**Evaporation** : it decreases evaporation loss from soil.	No effect.
C	**Chemical properties.**	
1	Nutrients are slowly become available.	Quickly available, specially nitrogen-fertilizer.
2	It decreases leaching of nutrients form soil.	No such effect.
3	It increases buffering capacity in the soil.	Fertilizer has no such effect on soil.
4	It supplies some micro-nutrients.	Not supply mocronutirents.
5	Organic matter does not produce acidity or alkalinity in the soil.	Some fertilizer like dodium nitrate produces salinity and alkalinity in the soil.
6	Organic manure upon decomposition produces organic acids which help to dissolve minerals such as potassium and make them more available to growing plants.	No such effect.
D	**Biological properties**	
1	It increases the growth of microorganism.	It slightly increases the growth of microorganism.
2	Macroorganisms like earthworms gets their food from organic manure.	Microorganism do not utilize fertilizer for food.
E	**Use**	
1	Organic manures are applied 15 to 30 days before the crop is sown.	Nitrogen fertilizer is applied immediately before sowing. Phosphatic fertilizers are applied some days before sowing.
2	It may not be used on standing crop.	Used on standing crop.
3	Not used in liquid form	Used in liquid form as foliar application
4	Used in huge quantity	Used in small quantity.
5	Organic manures are incorporated in soil.	It is also incorporated in the soil but may be used as top dressing

Chapter 13

Materials supplying Secondary nutrients

Calcium, magnesium and sulphur- these three essential elements, are called secondary nutrients because to the manufactures of commercial fertilizers, these nutrients are of secondary importance in the process of manufacture. However, these secondary nutrients are as essential as major nutrients. The secondary nutrients are added to the soil through some of the commercial fertilizers. Among the major plant nutrients, research work on calcium and magnesium has been limited in India. However, the field management of calcium and magnesium as essential plant nutrients is of considerable importance in view of the large area under acid soils where inadequate availability of a Ca and Mg can be limiting factor in balanced fertilization programme.

There are seven macronutrients : iron, manganese, zinc, copper, boron, molybdenum and chlorine. Among them, chlorine has been very recently added to the list by California workers. Though micronutrients are required in small amounts, they are as essential as major nutrients like nitrogen.

Secondary Nutrients :

(i) Calcium : Calcium occurs in nature in carbonate, sulphate and hayroxide forms, complex calcium silicates, and organic matter. It occurs as exchangeable cation in the vast majority of approximately neutral or slightly saline soils. Such soils are located in the Decccan tract of India mainly as deep black and medium black soils and in Northern India as alluvial soil. The acid soils of India are low in calcium. Thus the low pH of acid soils is indicative of calcium deficiency. Correcting soil acidity through liming has been dealt with in detail in chapter 10. since the neutral and slightly alkaline soils of India are rich in calcium, there is no special need to supply calcium to these soils. Calcium is indirectly added to the soil through fertilizer and soil amendments. Approximate percentage of calcium in commonly used fertilizers is given in given table.

Approximate Calcium content of some fertilizers and soil amendments

Fertilizer / soil amendment	% of calcium content
Nitrogenous fertilizers	
Calcium nitrate	19.5
Calcium ammonium nitrate	8.1
Calcium cyanamide	39.1
Phosphatic fertilizers	
Superphosphate (single)	19.5
Superphosphate (triple)	14.3
Bone-meal	23.0
Dicalcium phosphate	22.9
Basic slag	33.9
Soil amendments	
Limestone	32.3
Gypsum	29.2

Among the various fertilizers and soil amendments containing calcium, superphsopate is consumed on a large scale in India. Similarly, calcium ammonium nitrate, manufactured on large scale at Nangal (Punjab), supplies calcium to the soil in addition to nitrogen.

About one-third of Indian soils are acidic. By virtue of having low base saturation, particularly in high rainfall areas, many acid soils may be deficient in Ca. However, Ca is perhaps the least researched nutrient in India. Soils containing less than 25% of their cation exchange capacity (CEC) or less than 1.5 me exchangeable Ca/100 gm soil have usually been considered as Ca-deficient.

Response to Ca application as a nutrient are often masked under the overall effect of liming on crop yields. It is not possible to separate the specific response to Ca from the multiple changes brought about in the soil by liming. Legumes are generally more responsive to Ca than cereals.

(2) Magnesium :

This essential plant nutrient has not been observed to be deficient on a wide scale in any part of India. However, usually soils containing less than 1 me exchangeable Mg/100 gm soil or less than 4-15% of CEC occupied by Mg are considered deficient. Like Ca, deficiency of Mg can be a problem in leached, acid soils under high rainfall. Magnesium can be leached out more easily as compared to Ca thus making cid, sandy soil particularly vulnerable to Mg deficiency. It can be a problem in the acid laterite soils of Kerala, Maland are of Karnataka, Nilgiris in Tamil Nadu, certain areas of Andhra Pradesh under cotton, citrus, and banana, in Goa, parts of H.P. and in the north-eastern region. Several horticultural corps in different parts of India are found to suffer from Mg deficiently and benefit from Mg application.

Some experiment work with magnesium application in small doses (5.6 to 56 kg per hectare) through soil or spray, indicated significant responses with paddy at Warangal, with potato at Bangalore and with wheat and sorghum at the Indian Agricultural Research Institute, New Delhi. However, more experimental work needs to be carried out to determine if it is necessary to supply the element through fertilizers to improve crop yields. As such no special material containing magnesium has been recommended by the State Department of Agriculture.

Magenusium is, however, indirectly applied to the soil through commercial fertilizers and soils amendments, as some of these materials contain magnesium, as seen in table given below :

Approximate percentage of Magnesium in some fertilizers and soil amendments

Fertilizer / Soil amendment	% of Magnesium content
Nitrogenous fertilizers	
Calcium ammonium nitrate	4.5
Calcium nitrate	1.5
Phosphatic fertilizers	
Superphosphate (single)	0.3
Basic slag	3.4
Potassic fertilizrs	
Sulphate of potash	0.6
Soil amendment	
Dolomite limestone	4.6 to 10.6

In general, magnesium content of fertilizers and soil amendments are low, compared to calcium and sulphur contents of these materials. Calcium ammonium nitrate, basic slag and dolomite limestone supply nearly four kg of magnesium with the application of 100 kg of these materials.

(3) Sulphur :

Sulphur is considered as the fourth major nutrient for plant growth. Crops generally absorb S in amount comparable to P, which is another major nutrient. A recent reports places the number of districts suffering from varying of degrees of S deficiency at around 1.30. S deficiency in Indian soils and crops is widespread and still increasing. Close to 25% of the total cultivated area is estimated to be suffering from S deficiency. If this problem is neglected, the unavoidable consequences will be drops in yield, lower production costs. Currently, the annual S fertilizer deficient in India is estimated at 885,000 tones. This will increase to 1.5 million tones by 2010 unless corrective measures are taken. .

Sulphur and crop quality

Sulphur plays an important role in improving the quality and marketability of the produce. As reported sulphur can improve crop quality in the following ways :

1. Increasing the oil content of seeds.
2. Synthesis of S-containing amino acids and protein percentage.
3. improving nutrional quality of forages.
4. Improving starch content of tubers.
5. improving baking quality of wheat.
6. raising sugar recovery in sugarcane.
7. enhancing marketability of copra.

Source of Sulphur :

Over 60 fertilizers containing S are known to agriculture, but main fertilizers and soil amendments as source of S in India are given in table below.

The fertilizers and soil amendments, mentioned above indirectly add every year a substantial amount of sulphur to the Indian soils. Based on FAI Fertilizer Statistic, total fertilizers added to Indian soils during 1992-93 was 516,000 tones.

Approximate sulphur content of common fertilizers and soil amendments consumed in India

Fertilizer / Soil amendment	Sulphur percentage
Ammonium sulphate	24
Ammonium sulphate-nitrate	15
Single superphosphate	12
Ammonium phosphate sulphate	15
Potassium sulphate	18
Gypsum	13-18
Pyrite	22
Zinc sulphate	11-18

Besides addition of S through fertilizers containing sulphur, it is also advisable to apply 20-50 kg S/ha as Elemental S (Sulphur Powder) mainly to oilseed crops. This dose should be applied 3-4 weeks before planting in moist and aerated soils.

....

Chapter 14

Bio fertilizers

The term Biofertilizer has been coined to embody all such microorganisms which add, conserve and mobilize the plant nutrients in the soil. Such microorganisms have somehow come to be called as biofertilizers, a term which is a misnomer, compared to commercial fertilizers manufactured on a large scale by factories. In other words, biofertilizers are based on renewable energy sources and are ecofriendly compared to commercial fertilizers.

Biofertilizers play a very significant role in improving soil fertility by fixing atmospheric nitrogen, both, in association with plant roots and without it, solubilise insoluble soil phosphates and produce plant growth substances in the soil.

Classification :

Depending upon the nutrient provided, Verma and Bhattacharyya (1994) have broadly classified biofertilizers as follows :

Biofertilizers (BF)

- Nitrogen fixing biofertilizers (NBF)
  - NBF for legumes: *Rhizobium*
  - NBF for cereals: *Azospirillum*, *Azotobacter*, *Azolla*, BGA
- Phosphate Mobilising biofertilizers (PBBF)
  - Phosphate solubiliser: *Bacillus*, *Pseudomonas*, Aspergillus
  - Phosphate absorber: *Va-mycorrhiza* (VAM)like Glomus

Brief characteristics of various biofertilizers listed above, are :

1. ***Rhizobium*** : belongs to family Rhizobiaceae, symbiotic in nature, fix nitrogen 50-100 kg N per hectare with legumes only. It is useful for pulse legumes like chickpea, red-gram, pea, lentil, black gram, etc., oil seed legumes like soyabean and groundnut and forage legumes like berseem and Lucerne.

2. ***Azospirillum*** : belongs to family Spirlaceae, chemoheterotropic and associative in nature, by producing growth regulating substances, fixes 20-40 kg N/ha. Application of this biofertilizer results in increased mineral and waste uptake, root development,

vegetative growth and 15 to 30 % increase in crop yield. It is recommended for rice, millets, maize, wheat, sorghum, sugarcane and co-inoculant for legumes.

3. *Azotobacter* : belongs to family azotobacteriaceae, chemoheterotropic in nature, free living. It is non symbiotic in nature and fixes nearly 20 to 40 kg N/ha. It produces growth promoting substances like vitamins of B group. Indole acetic acid and Gibberellic acid. This biofertilizer is recommended for rice, wheat, millets, other cereals, cotton, vegetable, sunflower, mustard and flowers.

4. *Azolla* : belongs to family Azollaceae, symbiotic in nature, suitable for only flooded rice and fixes upto 40-80 kg N per hectare, symbiotically with Anabaena azollae, depending on soil temperature and availability of phosphorus since its survival is difficult at high temperature and in soils with low phosphorus content. It is recommended as green manure because of its large biomass and high N content for submerged rice fields, within maximum temperature of 38 °C. The yield increases is 15 to 20 per cent.

5. BGA : (Blue Green algae) or Cyanobacteria : These belongs to eight different families Phototropic in nature and produce Auxin. Indole Acetic Acid and Gibberellic acid, fix 20-30 kg nitrogen per hectare in submerged rice fields. Application of BGA increases paddy yield by 15-20 per cent, under submerged condition.

6. Phosphorus : Solublising Biofertilizers or microorganisms (PMBF). These microorganisms are mainly bacteria and fungus. The important genes and species, in this category, listed by Motsara *et al.* (1995) are :

Micro-organism	Important genus	Important species
Bacteria	*Bacillus* Family : Bacilliaceae	*B. megaterium var. phosphaticum.* *B. citculans* *B. subtillis* *B. polymyxa*
	Pseudomonus *Family : Pseudomonadales*	*P. striata* *P. liquifaciens*
Fungi	*Family : Monilaceae*	*A. awamori* *A. furnigalus* *A. flavus*
	Penicillum *Family : Monilaceae*	*P. digitatum* *P. liiacinum*

These microorganisms posses the ability to bring insoluble soils phosphate into soluble forms by secreting several organic acids. Under favourable conditions, they can solubulise 20 to 30 per cent of insoluble phosphate and crop yield may increase by 10-20 per cent. It is recommended for all crops.

7. Mycorrhiza or VA-mycorrhiza (VAM) : These are obligate symbiont with five genera recognized on the basis of spore morphology. These enhance uptake of P, Zn, S and water, leading to uniform crop growth and increased yield. Also enhance resistance to root disease and improve hardiness of transplant stock. Recommended for forest trees, forage, grasses, maize, millets, sorghum, barley and leguminous crops.

....

Teaching Schedule

Course Title : **Manures, Fertilizers and Agro-chemicals**
Course No. : **SSAC – 243** (New Course) Semester : IV
Course : **B.Sc. (Agri.)** **Credits : 3(2+1)**

Lecture No.	Topic	Weightage
1-3	Introduction : Raw materials for organic recycling, sources of organic matter and their composition C:N ratio (Plant and animal refuges).	5
4 and 5	Bulky and concentrated organic manures, composition, decomposition and nutrient availability	5
6 and 7	Preparation of FYM, composts, different methods of composting	5
8 and 9	Mechanical compost plants, Vermicomposting	5
10 and 11	Green manuring ; Types of crops, advantages, disadvantages , Oil cakes : their composition and nutrient availability	3
12	Sewage and sludge, Biogas plant slurryl	5
13 and 14	Fertilizers : Classification of NPK fertilizers, manufacturing process and properties of major nitrogenous fertilizer (ammonium sulphate, urea, calcium ammonium nitrate, ammonium nitrate, ammonium sulphate nitrate) their fate and reaction in soils	6
15 and 16	Manufacturing process and properties of phosphatic fertilizers. Single super phosphate, enriched super phosphate, ammonium phosphate, ammonium polyphosphate), Potassic and complex fertilizers their fate and reactions in the soil.	5
17	Secondary and micronutrient fertilizer their types, composition, reaction in soil and effect on crop growth	5
18	MID TERM EXAMINATION	
19 and 20	Fertilizer control order, handling and storage of fertilizers	4
21 and 22	Biofertilizer and their role in the crop production	5
23 and 24	Organic chemistry as prelude to agrochemicals, diverse type of agrochemicals	4

25 and 26	Botanical insecticides (Neem) purethrum, synthetic pyrethroids	4
27 and 28	Synthetic organic insecticides, major classes	4
29 and 30	Properties and use of some important insecticides under each class	5
31 and 32	Herbicides – major classes – properties and uses of 2-4 D, atrazine, glyphosate, butachlor, benthiocarb	5
33 and 34	Fungicides – major classes, properties and uses of carbendazim, carboxim, captain, tridemorph and copper oxychloride	2
35 and 36	Insecticides Act, plant growth regulators	3

Reference books :

1. Soil fertility, Theory and Practice : J.S. Kanwar
2. Soil fertility and fertilizers ; Tisdale S.L., W.L. Nelson and J.D. Beaten
3. Chemistry of manures and fertilizers : A Moria Kulandi and T.S. Mani Kam.
4. Manure and Fertilizers : Yawaalkar K.S., J.P. Agrawal and S. Bande.
5. Hand book of fertilizer use : 1980 FAI publication.
6. Biofertilizers in Agriculture 91986) Subbarao N.S. Oxford and IBH Publication, New Delhi.
7. Role of earth worm in Agriculture (1959) ICAR, New Delhi.
8. Organic manures (1984) : Guar *et. al.*
9. Hand book of manures and fertilizers (1971), ICAR, New Delhi
10. The Nature and Properties of Soils, Nyle C. Brady.

....