Composting in Tropical Agriculture
Review Paper Series No. 2

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FOREWORD

This manual has been written by Howard Dalzell of the Agricultural Centre, Medak, India, in conjunction with the Compost Studies Group at the University of Birmingham. During his 10 years experience of agricultural development in India, Dalzell has carried out the practice of composting, with support from the University team in England. This manual is the result of their joint experiences. It is hoped that it will be of value to other people involved with agricultural development under tropical conditions.

The Compost Studies Group at the University of Birmingham was formed in 1965 to study the composting of organic wastes from municipal, farm and garden sources. The writing of the present manual forms part of a research project on composting which is being financed by the Wolfson Foundation, whose support is gratefully acknowledged.

SUMMARY

Composting is the breakdown of organic wastes by simple plants and animals to produce humus. This manual describes the basic process and its dependence upon the proper provision of moisture, air supply and heat conservation. The different materials suitable for composting, and proven methods of heap construction, are discussed. An evaluation of farm composting, in terms of labour used and plants nutrients produced, is then given.

Farming systems intended to increase agricultural output in under-developed areas must take account of environmental, technological and socio-economic conditions. As the composting process described is simple in technique the authors consider it is applicable to many agricultural development situations. All stages of the processes can be carried out with manual labour. However, a high degree of mechanisation can be introduced where appropriate.

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1. INTRODUCTION

There are almost as many farming systems as there are farmers. In many ways each farm is a unique enterprise but the extremes can be taken as:

ADVANCED	SIMPLE
High cost	Low cost
High risk	Low risk
High output	Low output
High profit	Low profit
Advanced technology	Simple technology
Low labour usage	High labour usage

Advanced systems have developed in affluent countries mainly because of:

a) low labour availability due to the demand for manpower by competing industries;
b) a relative scarcity of land because of high population densities;
c) the ease of implementing technical advances within a well-developed infrastructure.

These developments have taken place over hundreds of years; hence social changes have not lagged behind technical advances, and in some cases have stimulated these advances.

It has been widely assumed that the advanced agricultural systems of developed countries would have far-reaching effects in developing areas. In many instances this has been so; however, there are more cases where farmers have not adopted these techniques, or have tried them and failed. The following are among the reasons for this situation:

a) **Cost.** An underdeveloped country is frequently lacking in capital. High cost systems are not likely to find widespread application in such countries especially among smaller farmers.
b) **Risk.** Advanced agricultural systems have tried to eliminate environmental risks, such as pests and diseases, by improving control and prevention methods. This may well increase cost but is acceptable if the measures succeed. A major environmental risk in many underdeveloped countries is rainfall, too much or too little. It is possible to improve irrigation facilities by building dams but these are expensive and may not be

useful if rainfall is much less tha ormal. More advanced farming may thus lead to an increased technical and capital liability without ensuring a reduction in risk.

c) **Output and profit.** There is a need for increased output to relieve the world food shortage. At the same time small farmers need increased profits to improve their standard of living. High cost farming systems may only achieve high output at increased food prices which may not be within the means of the local economy. If the economy cannot sustain such prices then the farmers' profit margin may not rise satisfactorily.

d) **Technology.** It is not the purpose of this manual to argue that technical advance is not useful or that it is needed only in Western countries or by rich farmers in developing countries. Experience has shown that advanced technology cannot be applied in a developing country unless the infrastructure of that country is adequate. Moreover, sufficient attention must be given to training and extension services and the local economy must be able to absorb the costs of the technical innovation. The more sophisticated the technology, the less likely it is that these conditions can be met.

e) **Labour usage.** The main asset of most developing countries is a large labour pool. This is often viewed as a problem in terms of food supply. Clearly, in many areas a farming sytem which minimises labour usage will not be readily acceptable or at all appropriate.

In view of the above considerations there is a need in developing countries for farming systems of an intermediate type such as:

Low cost
Low risk
Increased output
Increased profit
Modified and improved technology
High labour usage

Such systems will be of great relevance to the vast areas of un-irrigated agriculture in the tropics where cultivation is carried out by smallholders.

One of the most important considerations in increasing agricultural output is raising the level of soil fertility. An excellent method of improving the structure of tropical soils and of increasing the supply of plant nutrients is by the practice of composting — the conversion of organic waste materials to humus.

Composting has been practised in some areas of China for many centuries. In essentially small-scale batch operations, crop residues, animal and human wastes, plus silt from rivers and canals have been assembled into heaps. The resulting humus has then been returned to the agricultural holding, enabling the soil to be kept in good structure and fertility for long periods of time.

Interest in composting in the West probably stemmed from a visit to China in 1909 by Professor F. H. King of the U.S. Department of Agriculture. His observations on composting in China were read by Sir Albert Howard, a British Economic Botanist employed by the Indian Government. After several years of experimentation in the 1920s, Howard established a method of composting which gave satisfactory results in terms of the organic wastes, labour supply and climatic conditions in his district in India.

After several decades in which it was little practised, composting is now in vogue and likely to remain so. The present manual describes the process, proposes a simple approach to compost heap construction and examines the economics of compost production and use.

2. PRINCIPLES OF COMPOSTING

Composting is the breakdown of organic wastes by enormous numbers of micro-organisms and soil fauna, such as worms, in a moist, warm, aerated environment to give a humus end product. The micro-organisms are the very tiniest and simplest members of the plant and animal kingdoms.

An outline of the composting process is given in Fig. 2.1. The micro-organisms take in moisture, oxygen from the air and food from the organic wastes. They give off carbon dioxide, moisture and energy; they reproduce themselves and eventually die. Some of the energy is used for growth and movement; the rest is given off as heat which one tries to conserve in a compost heap. As a result the heap passes through warming-up, peak temperature, cooling down and maturing stages. The final compost product, humus, consists of the resistant parts of the organic wastes, some breakdown products, plus dead and living micro-organisms.

For the process to give a satisfactory compost product the organisms must be given optimum conditions of food, air, moisture and warmth.

2.1 Organisms

A list of the main classes of organisms involved in the composting process is given in Table 2.1 and the organisms are illustrated in Fig 2.2. Some of the very small micro-organisms can live under cold conditions below 15° C, others prefer normal temperatures 15-40° C, a few can exist in very hot conditions 40-75° C. Some of the macro-fauna, the small soil animals, aid the composting process by physical attack on the organic wastes, tearing them into small pieces which are more readily broken down by the micro-organisms.

Many of these organisms are present on the raw materials. However, there is evidence that the addition of some partly decomposed material from an existing compost heap to a new heap will accelerate the process by introducing acclimatized micro-organisms.

Table 2.1 Organisms in Composting

Microflora (very small plants)	Bacteria Actinomycetes Fungi, moulds, yeasts Algae Viruses
Microfauna (very small animals)	Protozoa
Macroflora (larger plants)	Fungi (mushrooms and toadstools)
Macrofauna (small soil animals)	Mites Ants, Termites Millipedes, Centipedes Spiders, Beetles Worms

2.2 Food

As can be seen from Fig. 2.1 the composting process is essentially a biological reorganisation of the carbon fraction of organic material. This fraction consists of very many different substances. Some, such as sugars, are simple in form and easily soluble in water; these can be readily taken in by the micro-organisms. Others, such as the polymers hemi-celluloses and cellulose, are more complicated and the micro-organisms must chop them up by enzymes (biological catalysts) first before they can be eaten. Some material, lignin, is highly resistant and woody and only breaks down in the soil after

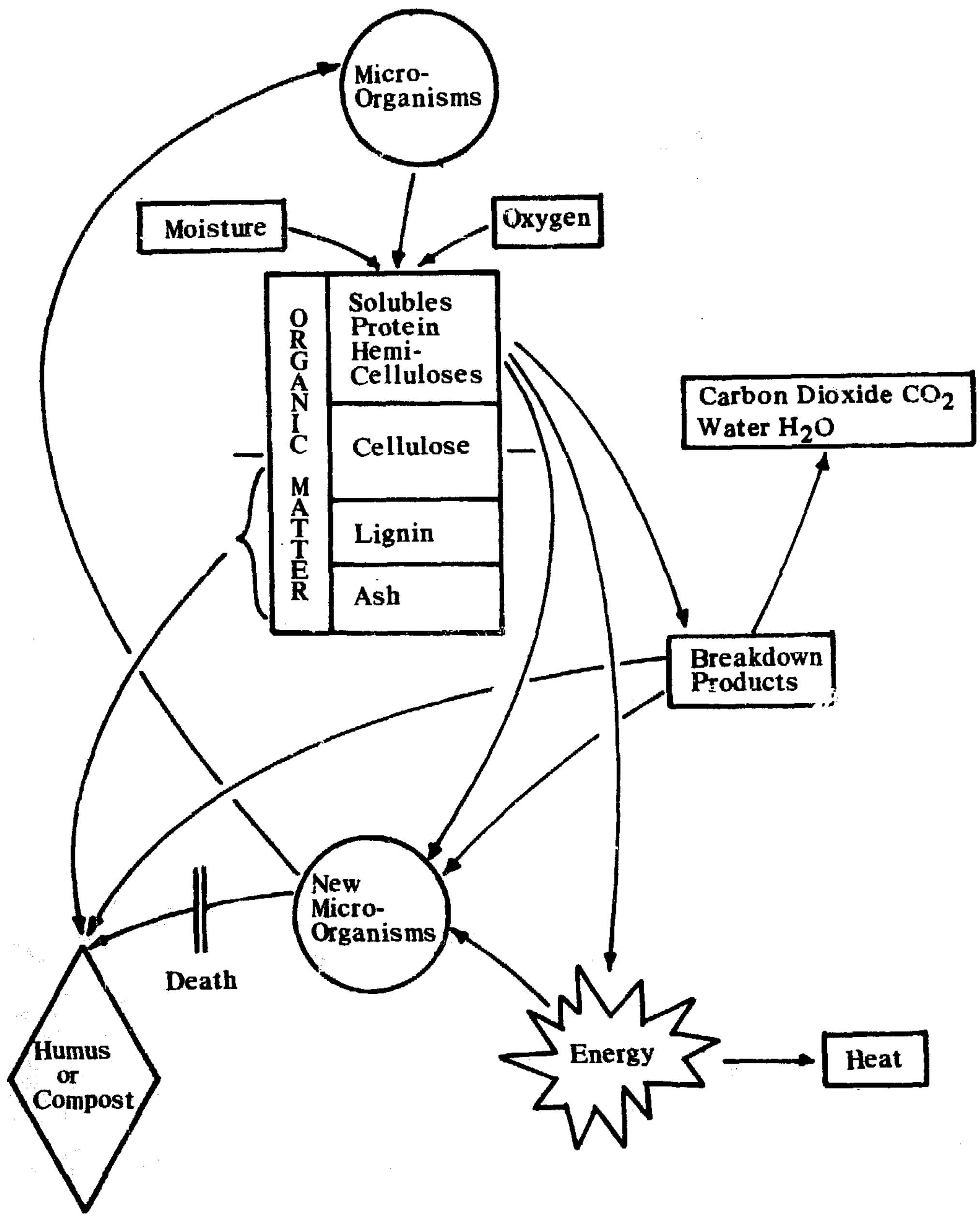


Fig. 2.1 The Composting Process

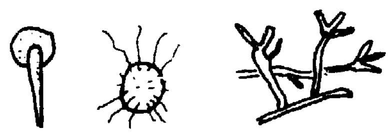
BACTERIA

Very tiny, enormous numbers. Many varieties - spheres, rods, filaments. Some form spores. Size range 1 - 8 µm.

ACTINOMYCETES

These have slender branched filaments. Flourish under hot, fairly dry conditions. Filaments 0.5 - 2 µm in diameter.

FUNGI

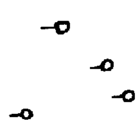


Larger organisms. Filaments and spores. Several varieties. The thermophilic ones very important. Size range 3 - 50 µm.

ALGAE

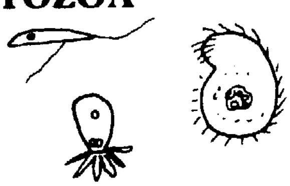
Prefer wet conditions. Size range 10 - 100 µm.

VIRUSES



Extremely small. Need a host organism, bacterium or actinomycete, to live on. Size: head 0.1 µm diameter, tail 0.2 µm long.

PROTOZOA



Move around with whips or hairs. Some prey on the bacteria. Size range 5 - 80 µm.

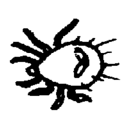
MACRO-FUNGI

or Higher Fungi. Grow up through the compost heap with fruiting body in the air above. Size of head about 25 mm diameter.

MILLIPEDES

Millipedes mainly vegetarian. Centipedes carnivorous. Sizes: millipedes 20 - 40 mm long, centipedes 30 mm long.

MITES



Wide range of sizes. Some are vegetarian, others carnivorous. Size range 0.1 - 2 mm.

WORMS

Eisenia foetida, or manure worm, very important in the manure heap. Size range 30 - 100 mm.

Sizes: 1 um = 10^{-6} m = 0.001 mm.

Fig. 2.2 Organisms in Compost Heaps.

many years. An outline of the reorganisation of the different fractions — solubles, polymers and resistibles — by the cells of the micro-organisms is shown in Fig. 2.3.

An important nutrient in this process is nitrogen and, in general, if sufficient nitrogen is available most other nutrients will also be available in adequate quantities. It is important that the ratio of carbon to nitrogen (C/N ratio) is about 35 in the initial mixture. If it is much higher, the process will take a long time before sufficient carbon is oxidised off; if it is lower, then nitrogen, which is an important fertiliser component of the final compost, will be volatilised off as ammonia.

Anything that has lived — plant or animal — can be composted, but crockery, glass, metal, plastics and man-made fibres should not be used. A list is given in Table 2.2. of some organic waste materials together with their nitrogen content and C/N ratios.

For various reasons better results are obtained when mixtures of different ingredients are composted; it is important to mix these constituents thoroughly.

In practice not all the materials in the table will be available for composting. In tropical situations fresh green material, such as weeds, is frequently used for forage while dung is sometimes burnt for fuel. As a result the available wastes tend to be those with rather high C/N ratios. It is important, therefore, to conserve liquid manure as this supplies nitrogen; moreover, it also contains potash and trace elments. In many cases facilities are not provided for the collection of liquid manure; in these situations the soil under the animals can be collected from time and time and used for composting.

Nitrogen may also be added in the form of organic manures such as bone meal, hoof and horn meal, oil cakes and dried blood. Inorganic nitrogenous fertilisers such as urea and ammonium nitrate may also be used. However, ammonium sulphate is not recommended as it appears to have an adverse effect on worms.

In order to maximise the nutrient content of the product compost, it is important to reduce serious leaching from the heap by protecting it against heavy rainfall and water-logging.

Table 2.2 Approximate composition of materials suitable for composting.

Material	Nitrogen % dry weight basis	C/N ratio
Urine	15 - 18	0.8
Dried Blood	10 - 14	3
Hoof and Horn Meal	12	?
Night Soil,Dung	5.5 - 6.5	8
Grass	4	20
Bone Meal	4	8
Brewers Wastes	3 - 5	15
Farm Yard Manure	2.2	14
Water Hyacinths	2.2	20
Pigeon Pea Stalks	0.7	70
Millet Stalks	0.7	70
Wheat Straw	0.6	80
Coconut Fibre Waste	0.5	300
Fallen Leaves	0.4	45
Rice Straw	0.4	100
Sugar Cane Trash	0.3	150
Rotted Sawdust	0.2	200
Fresh Sawdust	0.1	500
Paper	nil	infinity

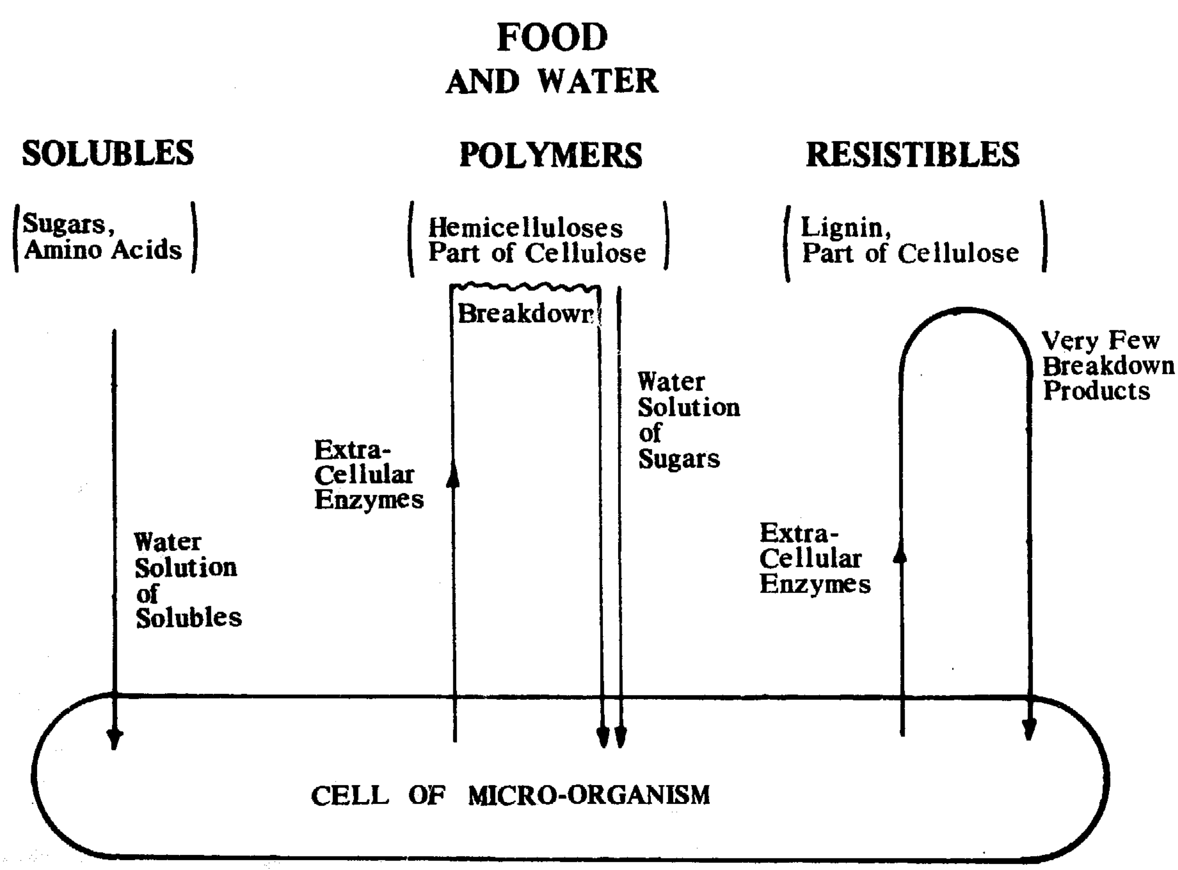


Fig. 2.3 Food Supply

2.3 Aeration

An adequate supply of air to all parts of the heap is essential in order to supply oxygen for the organisms and to flush out the carbon dioxide produced. Absence of air (anaerobic conditions) will lead to different types of micro-organisms developing, causing either preservation (similar to silage-making) or putrefaction of the heap.

If the particle size of the raw materials is too small then the spaces between them will also be small and aeration will be reduced. If the particle size is very large the surface area for attack by micro-organisms is much reduced; the reaction will then proceed slowly or may stop altogether. The ideal range of particle size is ½ - 2 inches (1-5 cms). It may be necessary to chop or crush bulky material to improve particle size. Careful blending of ingredients when building the heap, and turning the heap two or three times during the process, will help to ensure continuing adequate aeration.

No part of the composting mass should be more than 2½ feet (75 cms) from an unrestricted source of air. This can be achieved in practice by laying brushwood beneath the heap and incorporating vertical air-vents in the heap at the time of building and turning.

2.4 Moisture

All organisms require water for life. The optimum moisture content of ingredients for composting is 50 - 60%. The maximum practical moisture content depends on the structural wet strength of the materials. Weak materials, such as paper, collapse readily on composting, the pores fill with water and anaerobic conditions set in. Stiff materials, such as straw, retain their wet strength for a long time and can be composted at high moisture contents. For practical purposes the material should be as damp as a squeezed-out sponge.

In tropical conditions the materials will often be drier than in temperate climates and will also dry out more quickly during composting. Care must be taken therefore to ensure an adequate moisture content at all times. This can be achieved in practice by the following:

a) wetting the mixture initially and at each turning.

b) composting in pits during hot weather to reduce evaporation. The use of pits during the monsoon may lead to waterlogging; in this season the heap may be built above ground.

c) making heaps in the lee of buildings or trees, or the use of artificial wind-breaks.

d) shading of the heap from direct sunlight.

e) siting pits with their long sides at right angles to the direction of the prevailing wind.

In dry tropical conditions water may be a limiting factor to crop growth. In a marginal water situation one must question whether to use water for composting or irrigation. The preparation of one ton (1000kg) of finished compost may require up to 600 imperial gallons (2700 litres) of water. A dressing of 10 tons/acre (t/a) of compost would thus require 6,000 gallons (27,000 litres) which is equivalent to an irrigation of 0.3 inches per acre.

Many factors have to be considered in assessing whether such an irrigation would be of greater benefit than a dressing of 10 t/a (25 t/ha) of compost. Among these factors are the loss of water by seepage and evaporation before the irrigation reaches the plant, the moisture status of the soil at the time of irrigation, the effect of compost on the moisture characteristics of the soil, nutrients supplied by the compost, soil type and the soil and water management practised.

On balance, and taking a long term view of soil management rather than one crop only, it is considered that below a dressing of 10 t/a (25 t/ha), compost production will represent a better usage of water.

2.5 Temperature

The normal temperature-time curve of a compost heap is shown in Figure 2.4. This shows that the heap passes through stages of warming-up, peak temperature, cooling down and maturing. When warming up, all the very reactive compounds such as sugars, starches and fats, are broken down. At peak temperature the heap is losing as much heat as the micro-organisms produce. When cooling down, the straws and stalks are decomposed, mainly by the fungi. At the end of this period most of the available food supply has gone, in-fighting starts between the micro-organisms, antibiotics are released and the larger soil animals, especially worms, move in for a few weeks.

The time taken to maturity will depend on the nature of the ingredients, the conditions of aeration and moisture in the heap and on ambient conditions. The reaction proceeds quickly in the tropics and under optimum conditions will be completed in three months.

If the heap is turned there will be an increase in temperature resulting from increased microbial activity. A temper-

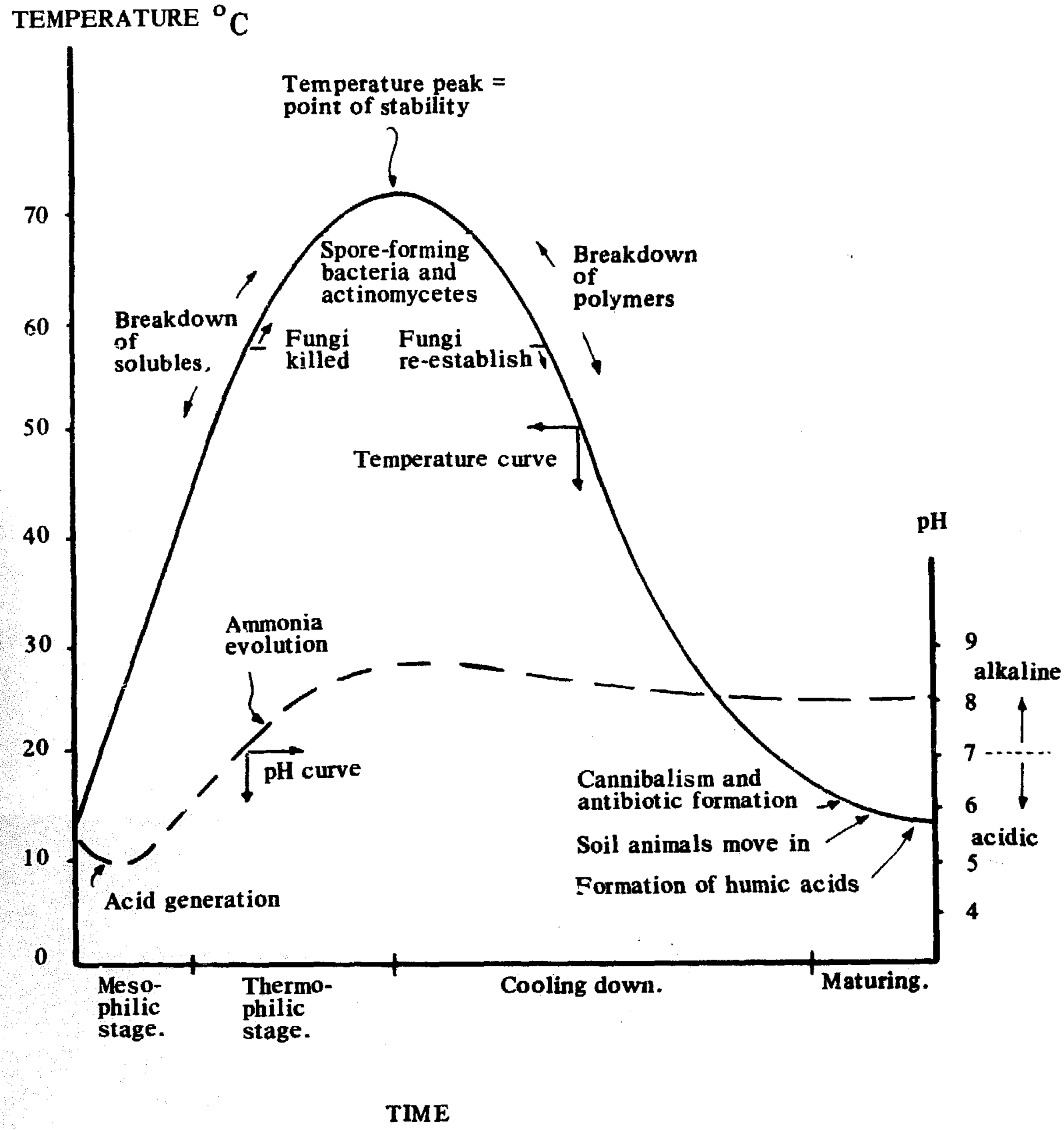


Fig. 2.4 Temperature and pH variations in a Compost Heap

ature of 55 - 60° C, held for at least a day, is essential to kill most weeds, seeds and disease-causing organisms (pathogens). With large heaps, in tropical conditions, provided that the heap is protected from the wind, there is little advantage in adding special insulation around the composting mass. It is important to restrict the size of heaps to a maximum of 8 feet (2.5 metres) wide and 5 feet (1.5 metres) high in order to prevent overheating in the centre and difficulty of aeration.

2.6 Heap acidity or pH

The usual pattern of acidity or pH in the composting process is illustrated in Fig. 2.4. This shows that the material becomes slightly acidic at the start of composting and then turns slightly alkaline after a few days.

Highly alkaline conditions will lead to excessive loss of nitrogen by volatilisation as ammonia; accordingly it is wise not to add lime to a heap. Highly acid initial conditions may lead to a failure of the heap to warm up. If careful attention is paid to the mixing of materials, moisture content and aeration, then there will be no necessity to try to influence the pH of the process.

Some ammonia is normally lost from a compost heap; the amount can be reduced by adding a little soil, about 1% of the weight of the heap, well mixed in with the other ingredients.

3. PRACTICE OF COMPOSTING

Given the same materials it is possible to make good or bad compost. Care and attention to detail at all stages will result in a good final product. If the heap is properly built then fly or odour problems will be minimised.

This chapter considers the layout of composting installations, equipment required, heap construction and turning, and the usage of the compost product.

3.1 Layout of composting areas.

The layout chosen will depend on the following factors:

Siting of animal houses
Source of water
Transport of raw materials
Transport of finished compost
Volume of production
Season of production.

Making the compost close to animal houses will minimise the transport of animal manure and will almost certainly mean easy access to water. It is unlikely to be economic to construct overhead tanks and piped water supply systems specifically for composting. Siting close to animal houses may have the disadvantages of long transport distances for crop wastes from the fields and for distribution of the finished product. If the critical factor in siting is access to water, then it may be appropriate to compost close to wells. From a transport point of view it may be better to have compost areas close to each of several wells than to have one centralised production unit.

Compost is produced in pits during the dry part of the year and in above-ground stacks, between the pits, in the monsoon season.

A heap (pit or stack) built to a height of 5 feet (1.5 metres) with a base area of about 400 sq. feet (37 sq. metres) will produce 6 - 8 tons of compost per batch. It will be possible to produce 2 to 3 batches from a pit each year and normally 1 batch from a stack.

A possible layout for a large centralised unit is shown in Fig. 3.1 and details of pits and stacks are given in Figs. 3.2 and 3.3.

Important points to remember are:

a) site with the long side of the pit or stack at right angles to the direction of the prevailing wind.

b) use existing wind breaks, such as buildings or trees, for shelter.

c) leave sufficient space, at least 12ft (3.66m), between pits to enable the building of a monsoon stack.

d) maximum depth of a pit should not exceed 2ft (0.6m).

e) maximum height of a stack should not exceed 5ft (1.5m).

f) if small amounts are being composted the heap dimensions can be scaled down. It is far better to build up a small heap rapidly than a large one slowly. The minimum size advisable is 3ft x 3ft x 3ft (1 metre cube).

g) roofing of heaps will improve the process by preventing moisture loss through sun and wind in the hot season and nutrient loss through leaching by rain in the monsoon. The roof construction should be light and simple. A frame of rough poles strong enough to withstand heavy rain should provide sufficient support. The roof should be sloped and have a minimum height above the heap of 2 inches (5 cms) to allow aeration. The covering can be made from local material

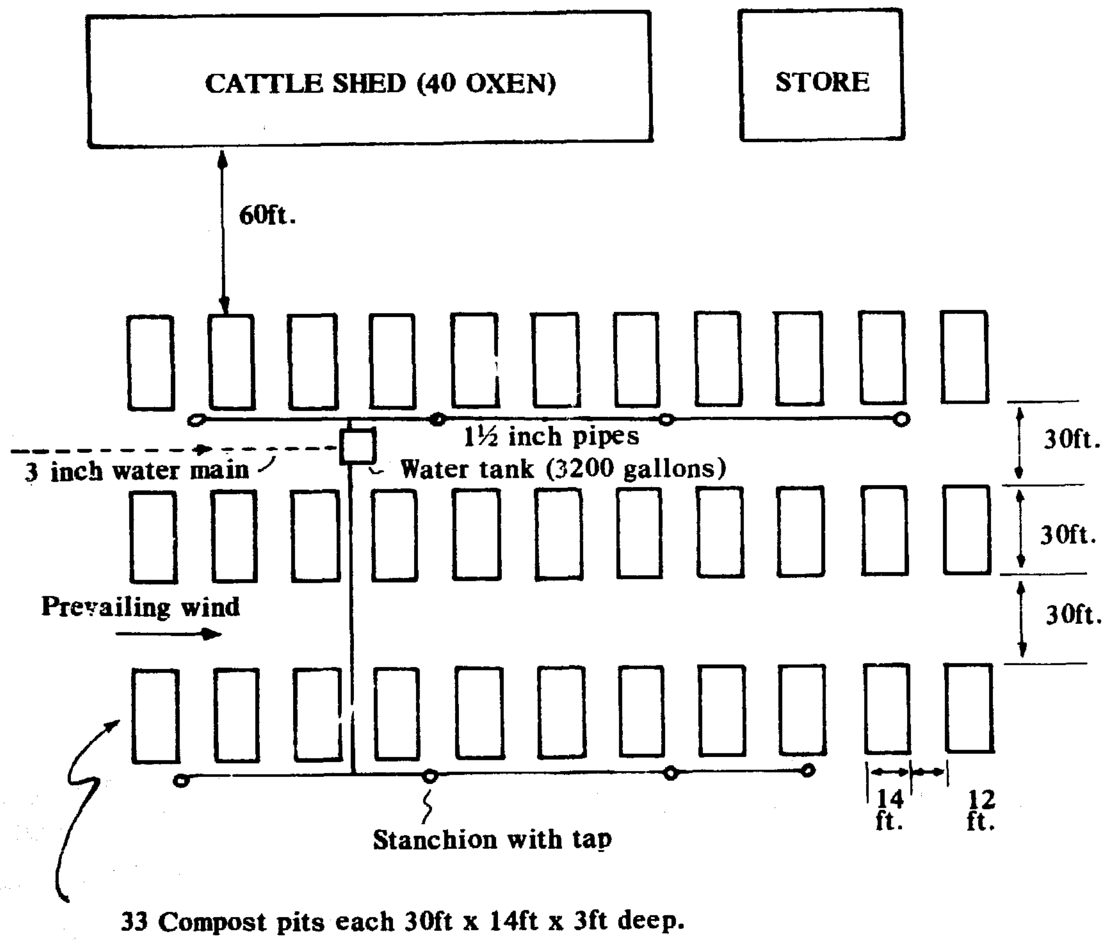
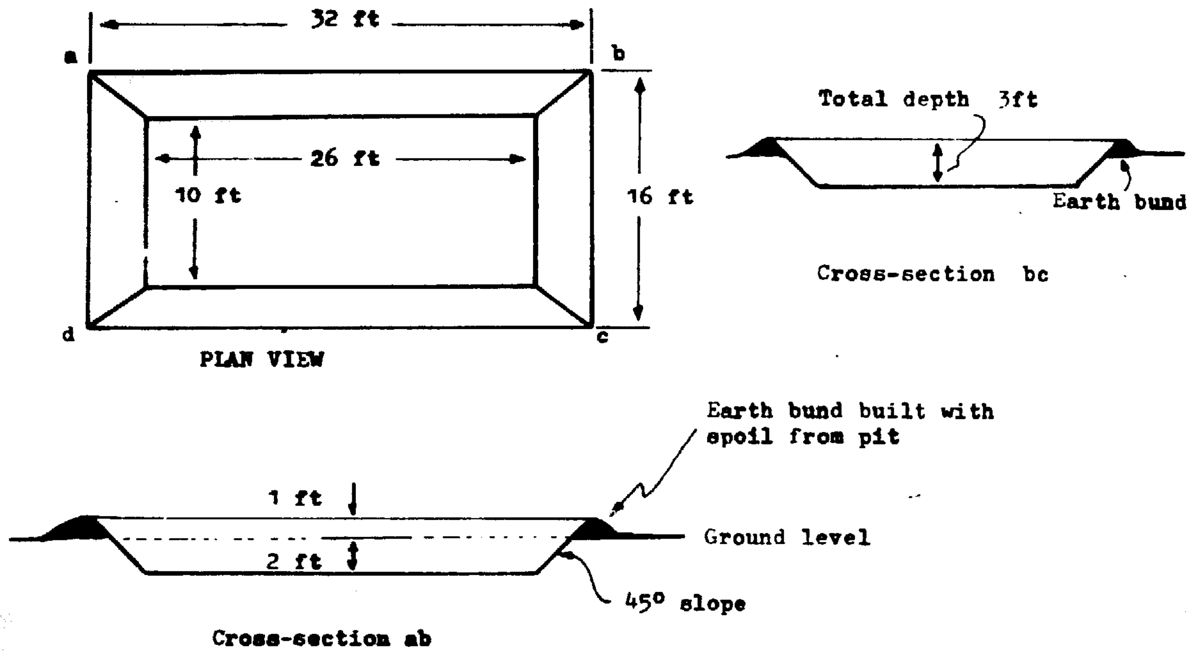


Fig. 3.1 Layout of compost unit at Indore, in India



		Length	Breadth
Dimensions:	At bottom of pit	26ft (7.9m)	10ft (3.1m)
	At ground level	30ft (9.2m)	14ft (4.3m)
	At top of bund	32ft (9.8m)	16ft (4.9m)

The depth should not exceed 2ft (0.6m) below ground or aeration will be adversely affected.

Fig. 3.2 Constructional details of a compost pit

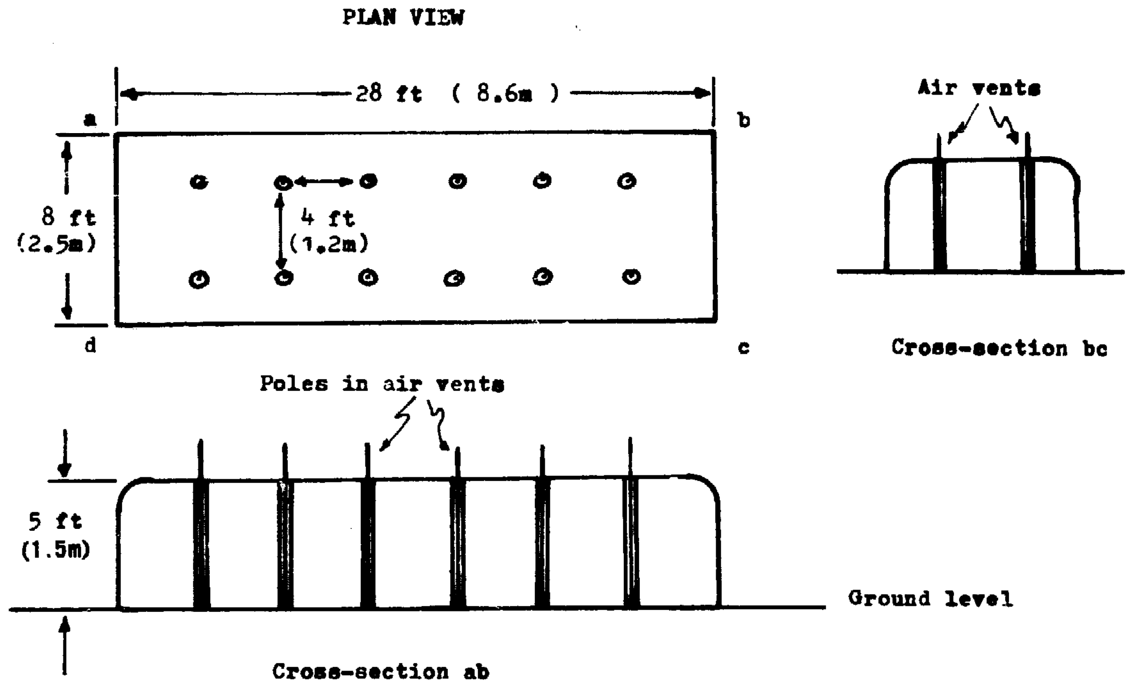


Fig. 3.3
Constructional details of a compost stack above ground

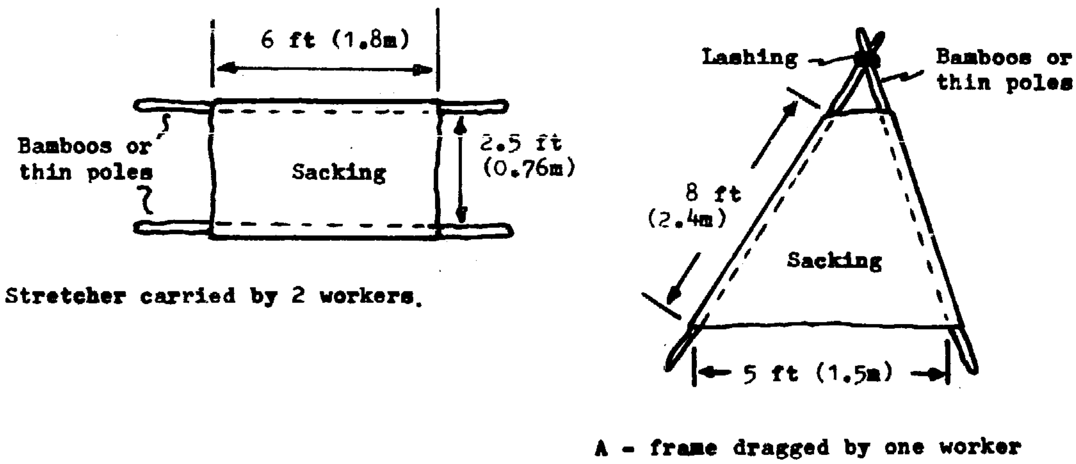


Fig. 3.4 Stretchers for carrying wastes

such as coconut matting, grass matting, old fertiliser bags or plastic sheeting. If a non-porous cover is used then it should be perforated with ½ inch diameter (1 cm) holes every 6 inches (15 cms).

3.2 Equipment required for composting

Heap construction can be done satisfactorily using rudimentary equipment which most farmers will already have or can make easily.

a) Collection and transport of wastes. The conventional transport system of the area will normally be adequate. Stretchers of the type shown in Fig. 3.4 are cheap and effective for collection of vegetable wastes and fallen leaves and loading them into carts for transport. The capacity of a bullock cart for carrying bulky materials can be increased by building a frame of light poles on it and covering the sides with any locally-available matting or sacking.

b) Making and turning heaps. Handling materials can be done with local baskets and rakes. Light poles, 6 - 8 feet (2 - 2.5 metres) long and up to 2 inches (5 cm) in diameter, will be useful in establishing air vents.

c) Watering. Locally-available tins or mud pots can be used but care must be taken to ensure even distribution of small volumes of water. A watering can is more effective; better still a hand sprayer, such as those used in crop spraying. Such sprayers should have no traces of pesticides in them when used in composting. Water from a piped supply must be in the form of a fine spray.

3.3 Preparation of materials

a) Fresh green materials such as weeds and vegetable trimmings. These can normally be used without pretreatment. In the monsoon season, however, they may have a very high moisture content and should be allowed to wither a little.

b) Coarse materials such as stalks of cotton, maize, millet and the pulses. These are best if broken before use. This can be done by chopping with sickles or in a chaff cutter. It can also be achieved by using the materials as bedding in an animal shed or laying them on a farm road where they will be broken up by normal farm transport. Although the ideal particle size for composting is below 2 inches (5 cms), even partial breakage by the methods described is worthwhile.

c) Vegetable wastes such as rice bran, dry tree leaves and various cereal straws. These can be used without pretreatment.
d) Woody materials such as sugar cane trash, treebark and sawdust. These should be steeped in water for several days, or pre-composted by dumping in a pit with moist earth for several weeks. When added to a compost heap they must be as damp as a squeezed-out sponge.

Where possible, materials should be passed through animal sheds as bedding; in this way they will soak up urine (a rich potassium source) and dung. Deep littering is more effective in this recycling than is daily cleaning, and provided sufficient bedding is used, deep littering of cattle and poultry in the tropics has no ill-effect on animal cleanliness or health, and does not create a fly problem. If all the material is required as bedding, composting will not be necessary as the resulting farmyard manure (F.Y.M.) can be used directly on the fields. If some of the available materials are unsuitable for bedding, or are in excess of that required, they can be composted with the F.Y.M.; if no F.Y.M. is available the materials can be included in a compost heap.

3.4 Building the heaps

Materials should be stored until sufficient are available to make one or more heaps. When building a heap, whether in a pit or a stack, it is a good idea to start by laying a lattice of old branches or brushwood at the bottom. This will help with aeration and prevent water-logging of the lower layers.

In building a heap it is important to mix ingredients thoroughly, trying to get a homogeneous mass. In practice it is difficult to achieve this until the heap has been turned for the first time.

Some materials such as urine-earth and wood ash may only be available in very small quantities. It is useful to mix these with each other outside the heap and to include in the mixture some compost from an earlier heap. The increased volume of the mix will make it easier to distribute the individual ingredients evenly through the new heap and the compost will introduce adapted micro-organisms.

The base area of the heap should be divided into six roughly equal transverse sections, five of which are filled and the sixth left vacant. Building is carried out one section at a time, beginning in the first section.

Each section is made up of seven layers approximately 9 ins (23 cms) deep. Within each layer quantities of the various compostable raw materials are incorporated, in proportion to the total amounts available for the complete operation. For instance, in a 9 inch (23 cms) layer one may have 4 inches (10 cms) of coarse dry wastes, 3 inches (7.5 cms) of green weeds and leaves, 2 inches (5 cms) of manure and a sprinkling of urine-earth/wood ash. In this way no ingredient will be exhausted before the heap is complete. Materials can be carried to the heap in baskets or stretchers, emptied on and raked level. Each layer is moistened with a fine spray of water until it is damp but not sodden.

Restricting the maximum depth of any plant ingredient to 4 inches (10 cms) and any manure to 2 inches (5 cms) will assist in aeration.

Materials with very poor aeration qualities, such as grass clippings and sawdust, should not be placed in layers but should be premixed outside the heap with a coarse ingredient. The layering process is illustrated in Fig. 3.5.

When two layers of a section have been completed, ventilation holes should be started. This is done by probing vertically through the wastes with a pole and gradually increasing the size of the hole to approximately 4 inches (10 cms) by waggling the pole. The pole will remain in position and ensure that the air vent continues to the top of the completed section. The first hole should be at a distance of not more than 2 ft (60 cms) from the edge of the heap and the maximum distance between the holes should be 4 ft (1.2 m).

Once the air vents have been established, the building of the section can continue as before until a height of 5 ft (1.5 m) has been reached. Building of the second section can then begin and so on until five sections have been completed. The sixth section is left empty, being used later when turning the heap. It is very important not to walk on the heap at any stage as this will compress it and decrease aeration.

The heap should be lightly watered on completion and again the next morning. A diagram of a freshly built heap is given in Fig. 3.6. This shows the ventilation poles, which are left in place, and the height of the heap above ground level.

3.5 Turning the heap

Within a week of completing the compost heap the centre should have warmed up to its maximum temperature; a little steam should be rising out of the vertical air vents. The com-

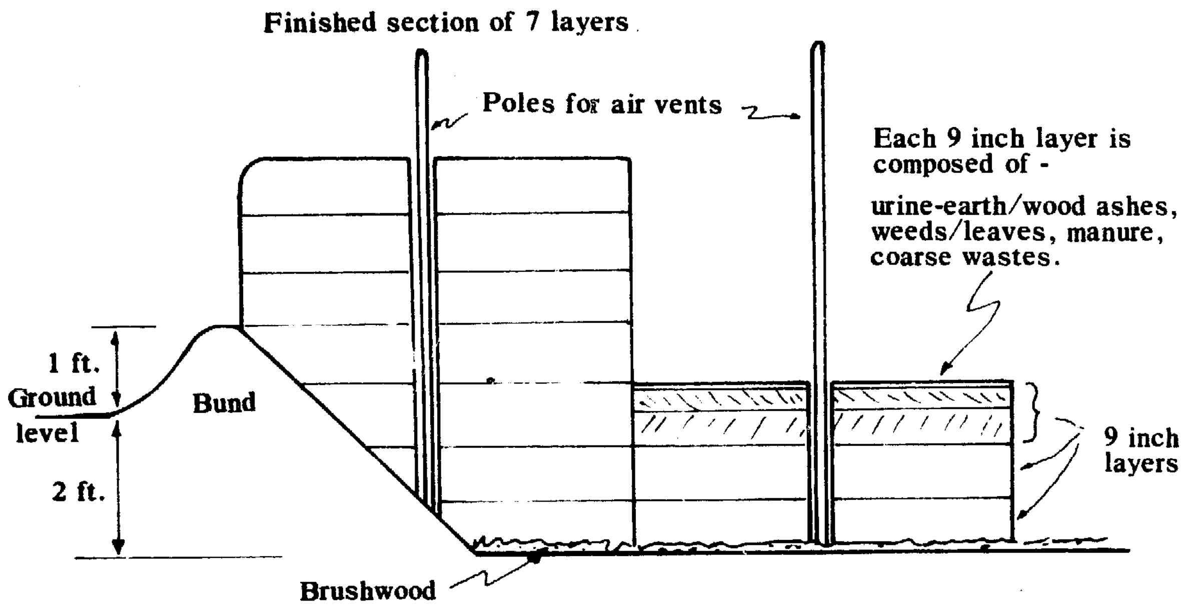


Fig. 3.5
Partly-built compost heap showing layers of ingredients

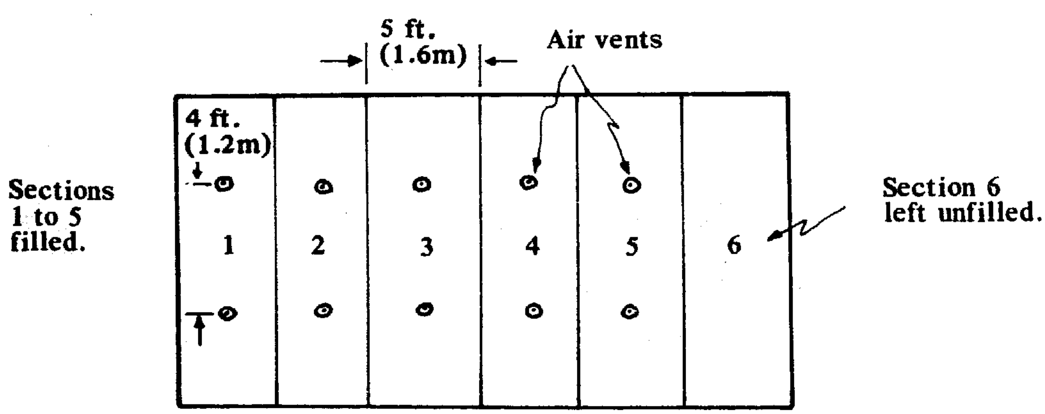


Fig. 3.6 Plan view showing completed compost heap

bined effect of heat, moisture and attack by the micro-organisms weakens the fibrous strength of the organic waste and the mass sinks to the level of the bund wall around the heap.

The heat extends through the heap to about 6 inches (15 cms) from the sides. The temperature falls rapidly in the outer zone reaching ambient level at the earth walls of the pit or the exposed edge of an unprotected heap. The material in this cooler region composts slowly and the weeds, seeds, and diseased material may not be completely destroyed. Fly larvae and pupae can develop in these cooler areas but will be destroyed by the higher temperatures in the centre of the heap. Hence it is most important to turn the heap so that the cooler top, bottom and sides are mixed back into the middle of the new heap once the central temperature has started to drop. Turning also helps the thorough mixing of the ingredients in the heap and enables the air and water situation to be checked.

Normally the first turn is carried out ten to fourteen days after building the heap. Up to this time the only attention necessary is the occasional shaking of the poles in the air vents. Turning is done by putting the top 9 inches (23 cms) from section five onto the floor of section six, mixing it in the process. Water is sprayed on as necessary. The next 9 inches (23 cms) is then put on top of this and watered. The air vents must be re-established. When section five has been completely turned into section six, section four can be turned into section five and so on until each section has been turned, leaving section one vacant. The first turn is now complete. The mass should warm up again and some steam be evolved. No further attention is required except for keeping the air vent holes open.

The second turn is carried out after a further three weeks, during week five after heap construction. If the heap has dried out, or the original materials are still recognisable after nine weeks, a third turn is warranted.

The final compost product should be mature about 12 weeks after starting, although it may take longer in the monsoon. The mass will have cooled down and shrunk to less than half its original volume. Apart from some small portions of twigs, none of the original components should be recognisable. Mature compost has a friable texture, an earthy smell and is dark brown or grey in colour.

3.6 Use of compost

The product compost can be used at once. If it has to be stored it should be protected from rain and sun either by the roof used during the process or by covering the heap with coarse uncomposted material.

If compost is spread on land and not ploughed in quickly there is a danger of loss of nutrients due to either rain or strong sunlight. It is recommended, therefore, that where possible it is applied to the land immediately before ploughing. It should be ploughed in to a depth of not more than 4 inches (10 cms); it will then be readily accessible to developing plant root systems. The compost breaks down slowly, releasing both the major plant nutrients, N P and K, plus minor and trace elements. It is attractive to earthworms and other soil fauna. The gummy constituents help to bind the soil particles into crumbs while its organic components increase the water holding capacity of the soil. It is improbable that a harmful level of compost could be applied and thus the general rule is to use as much as possible. In temperate climates organic matter applied to the soil is broken down over a period of years and hence is usually applied once every three or four years. In tropical conditions it is broken down much more quickly and hence a different pattern of dosage, as explained below, is appropriate.

Example: A cultivator with 5 acres (2 hectares) of land and 30 tons of compost available.

Temperate Zone	**Tropical Zone**
Apply on a rotational basis to one third of the acreage each year.	Apply to all land annually at 6 t/a (15 t/ha).

With quantities of less than 3 t/a (7.5 t/ha) available, it is difficult to get an even spread of material on the land; hence it is probably better to spread at this rate on smaller areas on a rotational basis.

If heavy dressings of compost are used, reductions should be made in the quantities of inorganic fertilisers applied. The appropriate reductions can be calculated using Tables 4.3 - 4.8. Through its ability to supply the minor and trace elements to the soil, and to improve soil structure and water-holding capacity, the use of compost with inorganic fertilisers may well increase the response to that fertiliser.

4. ECONOMIC ASPECTS OF COMPOSTING

Most farmers in the developed world can purchase whatever quantity of inorganic fertiliser they wish to use. Because of the high cost of labour and mechanisation they may not be able to handle large quantities of organic materials. These factors explain the decrease in the practice of farm-scale composting in the period from 1950 - 1970. However, there has recently been renewed interest in the West in composting, mainly for the following reasons:

a) the economic pressure of the oil crisis and diminishing sources of inorganic raw materials.

b) problems of pollution caused by the dumping of untreated wastes.

c) concern about deterioration of soil structure if levels of soil organic matter fall.

d) increasing interest in, and economic premiums on, organically grown health foods.

The economic situation differs greatly in the developing world, a major portion of which falls in the tropical belt. Labour costs are much lower. Labour is much more readily available and, in cases where composting would utilise family labour, no cash outlay would be required. Collecting, composting and spreading organic wastes would create work opportunities for under-employed labour. Raw materials for composting are not subject to artificial shortages due to local or international market fluctuations. Unlike oil or raw materials for inorganic fertilisers, they are locally renewable. It is true that increasing emphasis on composting might well lead to a shortage of some organic wastes, but this could be largely offset by:

a) modification of the farming system to produce organic materials in greater quantities. This can be done without reducing yields e.g. by planting leguminous trees and hedges, and by better control of grazing to reduce dependence of livestock on straw products.

b) use of organic wastes which are at present employed for other purposes e.g. cattle dung is often used for fuel sugar cane trash is normally burnt on the field.

c) use of organic wastes which are at present discarded e.g. human sewage (night soil), forest litter, paddy husk.

Farm transport is not only cheaper than in the West but, being mainly animal-drawn, relies less on oil. In many cases the transport of materials would add little to total farm transport costs as it could be done when existing vehicles are not required for other work.

The farmer may face a dilemma of not having sufficient inorganic fertiliser or sufficient irrigation for all his land. The likelihood is that all available inorganic fertiliser will be used on irrigated land and none on rainfed, un-irrigated land. He may also be tempted to use all his cash for inorganic fertiliser and ignore such possibilities as better seed, pesticides and improved equipment.

In dryland farming conditions in the semi-arid tropics, there are many tracts of soil which would support much larger yields of crops given better seed, small dosages of inorganic fertilisers and better soil and water management. There is evidence to show that on poorer soils if the level of production is increased, then the soil becomes depleted of trace elements; deficiencies appear which are not seen under the traditional farming pattern. Such deficiencies can be prevented by the use of organic manures and composts.

At this point it must be emphasised that composting is not being advocated as a panacea for all ills. There are situations where sufficient organic raw materials would not be available or when the making of large quantities of compost would not fit easily into the farming system. The advantage of composting is that in many situations it has definite social, economic and agricultural benefits. The decision on whether or not to make compost will depend on the cost and availability of labour, organic raw materials and inorganic fertiliser in that locality. These factors can vary from year to year. Although the decision is normally made on a nutrient supply basis, it is important to take account of the need for organic matter to maintain and improve the soil structure.

In making comparisons between composts and inorganic fertilisers on a nutrient basis several points must be borne in mind:

a) composts vary widely in composition depending on the raw materials used in their preparation. It is unlikely that the total amount of any nutrient will be greater than that present in the original raw material.

b) composts usually provide all the major plant nutrients, Nitrogen (N), Phosphorus (P), Potassium (K), and a wide range of micro-nutrients, whereas inorganic fertilisers do not.

c) nutrients are normally released more slowly from composts than from very soluble inorganic fertilisers. Consequently the effects of compost can last for more than one season; loss of nutrients from the soil by leaching during the growing season is reduced by the use of compost.

Details of the percentages of N, P and K in some of the more common inorganic fertilisers and in a number of composts are presented in Tables 4.1 and 4.2.

Table 4.1 Composition of inorganic fertilisers

Fertiliser	% N Nitrogen	% P Phosphorus	% K Potassium
Urea	46		
Ammonium Nitrate	34.5		
Ammonium Chloride	26		
Di-ammonium Phosphate	21	23.1	
Ammonium Sulphate	21		
Calcium Ammonium Nitrate	15-20		
Calcium Cyanamid	10-20		
Ammonium Phosphate	11	21.0	
Triple Super Phosphate		19.6-21.8	
Super Phosphate		6.5-8.6	
Basic Slag		3.5-9.5	
Muriate of Potash			39.0-51.5
Potassium Sulphate			35-39
Kainit			11.5-16.5

Notes:

a) Nutrients are expressed as P and not P_2O_5, and as K and not K_2O.

b) Several of the fertilisers vary in quality from batch to batch, depending on the source of raw materials. Ranges are quoted for such fertilisers but individual manufacturers may standardise their product. The specification on the bag should always be checked.

c) Proprietary compounds are increasingly produced. This may give rise to some confusion over names e.g. 'Ammophos' may be the proprietary name for a complex with different N and P values from the chemical compound ammonium phosphate. In the same way 'Nitro-chalk' differs from calcium ammonium nitrate.

Table 4.2 Composition of various composts and organic wastes (expressed as % of fresh weight)

Composts from:	%N	%P	%K
1. Cotton stalks and dung	0.40	0.13	1.4
2. Vegetable wastes	0.49	0.12	0.9
3. Vegetable wastes and dung	0.43	0.10	1.0
4. Mixed weeds and sann hemp	0.41	0.11	1.7
5. Mixed weeds	0.40	0.12	1.3
6. Poultry dung and straw	1.1	0.9	0.8
7. Garden compost	0.4-3.5	0.3-1.0	0.2-0.3
8. Straw & sewage sludge	0.5	0.15	0.12
9. Municipal compost	0.4-1.6	0.1-0.4	0.2-0.6
10. Poultry manure & sawdust	1.0	0.4	0.46
11. Pig slurry & straw	0.53	0.37	0.33

Notes:
Items 1 - 5 are for compost made in tropical conditions. The high values of Potassium (K) are due to careful conservation of animal urine.

In Tables 4.3 to 4.8 a comparison is made between the NPK nutrient supply from a typical compost and from various inorganic fertilisers. Tables 4.3 to 4.5 list the weight of Nitrogen, Phosphorus, and Potassium fertilisers supplying nutrients to the crop equivalent to those from 1 ton of the typical compost in the year of its application. Tables 4.6 to 4.8 show the tons of the compost needed to supply nutrients equivalent to 1 cwt (50 kgs) of N, P and K inorganic fertiliser; these also give the number of man days required to produce the compost.

In preparing the tables the following assumptions have been made:

a) a typical farm compost in tropical conditions will contain on a fresh weight basis:
0.5%N, 0.2%P and 0.3%K.
Such a compost will have a moisture content of about 50% and animal manures will have been included in its manufacture.
b) all the nutrients in inorganic fertilisers will be available to the crop in the year of application.
c) the following percentages of nutrients in the compost will become available to the crop in the year of application.
Nitrogen — 25%; Phosphorus — 100%; Potassium — 80%.

No account has been taken of the availability in succeeding years.
d) to prepare and spread one ton of compost will require 3 man days.

Table 4.3 Nutrient comparisons of compost with inorganic Nitrogen fertilisers

Fertiliser	Weight of fertiliser supplying Nitrogen to crops equivalent to 1 ton of compost in year of application. lbs	kgs
Urea	5.9	2.7
Ammonium Nitrate	7.9	3.6
28:28:0 Complex	9.9	4.5
Ammonium Chloride	10.6	4.8
Ammonium Sulphate	13.2	6.0
Di-ammonium Phosphate	13.2	6.0
Calcium Ammonium Nitrate	13.8-18.7	6.3-8.5
15:15:15 Complex	18.3	8.3
Ammonium Phosphate	25	11.4
Calcium Cyanamid	13.9-27.5	6.3-12.5

Table 4.4 Nutrient comparisons of compost with inorganic Phosphorus fertilisers

Fertiliser	Weight of fertiliser supplying Phosphorus to crops equivalent to 1 ton of compost in year of application lbs	kgs
28:28:0 Complex	15.4	7.0
Di-ammonium Phosphate	19.1	8.7
Ammonium Phosphate	20.9	9.5
Triple Super Phosphate	19.8-22.0	9.0-10.0
15:15:15 Complex	29.3	13.3
Super Phosphate	50.6-68.2	23-31
Basic Slag	46.2-125.4	21-57

Table 4.5 Nutrient comparisons of compost with inorganic Potassium fertilisers

Fertiliser	Weight of fertiliser supplying Potassium to crops equivalent to 1 ton of compost in year of application	
	lbs	kgs
Muriate of Potash	10.4-13.7	4.7-6.2
Potassium Sulphate	13.7-15.2	6.2-6.9
15:15:15: Complex	35.2	16.0
Kainit	31.9-46.0	14.5-20.9

Table 4.6 Nitrogen equivalent — tons of compost supplying equivalent amount of Nitrogen (N) to crops in year of application as 1 cwt (50 kg) of inorganic fertilisers

Fertiliser	Tons compost equivalent to 1 cwt (50 kg) fertiliser	Man days to produce compost
Urea	18.4	55
Ammonium Nitrate	13.8	41
28:28:0 Complex	11.2	34
Ammonium Chloride	10.4	31
Ammonium Sulphate	8.4	25
Di-ammonium Phosphate	8.4	25
Calcium Ammonium Nitrate	6.0-8.0	18-24
15:15:15 Complex	6.0	18
Ammonium Phosphate	4.4	13
Calcium Cyanamid	4.0-8.0	12-24

Table 4.7 Phosphorus equivalent — tons of compost supplying equivalent amount of Phosphorus (P) to crops in the year of application as 1 cwt (50 kg) of inorganic fertiliser

Fertiliser	Tons compost equivalent to 1 cwt (50 kg) fertiliser	Man days to produce compost
28:28:0 Complex	7.0	21
Di-ammonium Phosphate	5.8	17
Ammonium Phosphate	5.25	16
Triple Super Phosphate	4.9-5.5	15-17
15:15:15 Complex	3.75	11
Super Phosphate	1.6-2.2	5-7
Basic Slag	0.9-2.9	3-9

Table 4.8 Potassium equivalent — tons of compost supplying equivalent amount of Potassium (K) to crops in year of application as 1 cwt (50 kg) of inorganic fertiliser

Fertiliser	Tons compost equivalent to 1 cwt (50 kg) fertiliser	Man days to produce compost
Muriate of Potash	8.0-10.8	24-32
Potassium Sulphate	7.3-8.1	22-24
15:15:15 Complex	3.1	9
Kainit	2.4-3.4	7-10

The assumption of 3 man days for the production and spreading of 1 ton of compost is based on recent experience at the Medak Agricultural Centre, India, using the equipment outlined in this manual. It is similar to the figure achieved by Sir Albert Howard[1] at Indore in India in the 1920s but higher than the figure of 2 man days per ton reported from an estate at Chipoli in Rhodesia in the late 1930s. It should be noted that much of the work involved in composting can be carried out by female labour. Where wage rates are low Tables 4.6 to 4.8 indicate that compost can provide a cheap alternative source of nutrients to many of the less concentrated single nutrient fertilisers. When considering the supply of the three major nutrients, compost may compete economically on a nutrient basis with the more concentrated fertilisers.

For example:

Application	Nutrients supplied to crop in lbs. Nitrogen	Phosphorus	Potassium
1. Inorganic Fertilisers			
a) Urea, 60 lbs	27.6	-	-
b) Triple Super Phosphate, 220 lbs	-	45.1	-
c) Muriate of Potash, 101 lbs	-	-	52.0
Total, 381 lbs	27.6	45.1	52.0
2. 10 tons typical compost	27.5	44.0	52.8

The labour cost of 10 tons of compost is 30 man days. In many areas this will be less costly in cash terms than the combination of inorganic fertilisers shown as being equivalent in nutrients supplied.

The above considerations have been concerned solely with nutrient supply. They have taken no account of the beneficial effects of compost on the trace element supply, soil structure and water-holding capacity. Inorganic fertiliser has little direct effect upon these factors.

5. CONCLUSIONS

From the following points of view composting is relevant to intermediate agricultural systems and suitable to many tropical areas of developing countries:

a) Cost. The capital expenditure needed for a composting installation as described is low. The operating costs are moderate, being mainly for labour. As a result the cost of nutrients in compost compares favourably with the cost of purchasing them in the form of inorganic fertilisers.
b) Risk. If the simple principles explained in this booklet are followed then there is little risk of failure in the composting process. Well-made compost added to the soil on a regular basis will go a long way towards eliminating the risk of nutrient deficiency diseases which can easily occur with fast-growing crops on poor soils. By improving soil structure, compost will assist crops to withstand the effects of water scarcity; it will also improve drainage, thereby reducing the risk of water-logging.
c) Output and profit. There is no doubt that the use of compost increases crop output. Unless labour costs are very high this will normally result in higher profits for the farmer.
d) Technology. The technology of composting is simple. Many farmers in the tropics heap waste products unsystematically and little composting takes place. The knowledge required to correct this is easy to understand. No non-indigenous machinery is involved and the farmer will already have the necessary equipment.
e) Labour usage. Composting uses a lot of labour. In areas of high unemployment or under-employment this is a definite advantage. For a farmer with a lot of unpaid family labour, it provides an opportunity to turn effort into money.

Composting can be of value to the general economic life of rural areas by recycling wastes which are currently discarded or burnt, by providing opportunities for work, and by reducing heavy dependence on imported inorganic fertilisers. If compost is made properly, in a heap that heats up adequately, then weeds, pests and diseases in the raw materials are controlled and the product can be used safely in agriculture.

Composting can compete economically with inorganic fertilisers in many areas on a nutrient basis when fertiliser costs are high, labour costs are low, organic raw materials are readily available and where cash for fertiliser purchase is borrowed at high interest rates.

Composting can be carried out at any time and hence can be fitted into any slack period in the farming year. Compost can be used in conjunction with inorganic fertilisers; an improved response is normally obtained.

Use as much compost as possible, as often as possible. Apply it immediately before ploughing time; do not plough it in deeper than 4 inches (10 cm).

To prepare good compost attention must be paid to the choice of raw materials and to the moisture, temperature and aeration of the heap. In making compost the following points must be remembered:

DO	DON'T
Use organic materials only (except for approved additives).	Compress the heap by walking on it.
Mix ingredients thoroughly.	Restrict the flow of air into the heap.
Water carefully to the damp sponge condition.	Use thick layers of one material.
Turn the heap thoroughly at the right times.	Overwater.
Cover the heap when necessary.	

The importance of recyling organic wastes is being increasingly recognised. At present many of the wastes available in tropical situations are poorly used. Composting is an excellent method of converting them to a form which provides significant agricultural benefits.

APPENDIX A Glossary of terms and abbreviations

Composting	is the process of breakdown of organic wastes by enormous numbers of micro-organisms and small animals in a warm, moist, airy situation. The end product of composting is compost or humus which helps to keep soils in good structure and provides nutrients for plants.
Heap	is the term used for a mass of composting organic matter. The heap may be built on the ground when it is referred to as a STACK or may be built below ground in a PIT.
Aerobic	means in the presence of oxygen/air.
Anaerobic	means in the absence of oxygen/air.
Muriate of Potash	is the term for fertiliser grades of potassium chloride.
Kainit	is an impure form of potassium chloride, usually containing sodium salts and/or magnesium salts. The percentage of potassium in kainit may vary greatly from sample to sample.
Calcium Ammonium Nitrate	is also known as C.A.N. or 'Nitrochalk'. It is prepared by mixing ammonium nitrate with calcium carbonate; the nitrogen content of the product depends on the proportion of ingredients used.
hundredweight (112 lbs)	cwt
tons per acre	t/a
tonnes per hectare	t/ha
centimetres	cm
metres	m
inches	in
feet	ft

APPENDIX B Conversion factors

British Units		Metric Units
1 inch	=	2.54 centimetres
1 acre	=	0.405 hectares
1 gallon	=	4.55 litres

Metric Units		British Units
1 centimetre	=	0.39 inches
1 hectare	=	2.47 acres
1 litre	=	0.22 gallons

For field scale practice:

To convert	*Multiply by*
tons/acre to tonnes/hectare	2.5
pounds/acre to kilograms/hectare	1.12
gallons/acre to litres/hectare	11.2
hundredweights to kilogrammes	50
P_2O_5 to P	0.44
K_2O to K	0.83

APPENDIX C Basis of calculations to compare nutrients supplied by compost and inorganic fertilisers

Let

N_C be the percentage of a nutrient in the compost.

N_F be the percentage of that nutrient in the fertiliser.

A be the percentage of that nutrient available to the crop from the compost in the year of application.

Then

1. a. $N_C \times 10$ = weight of nutrient in kg in 1 tonne of compost.

b. $\frac{N_C x 10 x A}{100} = \frac{N_C A}{10}$ = weight of nutrient in kgs in 1 tonne of compost available to the crop in the year of appli-ation.

c. $\frac{N_C A}{10} \times \frac{100}{N_F} = \frac{10 N_C A}{N_F}$ = weight in kg of inorganic fertiliser to supply an equivalent weight of nutrient to the crop as one tonne of compost in the year of application.

2. a. $\frac{N_F}{2}$ = weight in kg of nutrient in 50 kg of inorganic fertiliser.

b. $\frac{N_F/2}{\frac{N_C A}{10}} = \frac{5 N_F}{N_C A}$ = number of tonnes of compost providing an equivalent weight of nutrient to the crop in the year of application as 50 kgs of inorganic fertiliser.

Example 1

Find the weight of urea supplying the same weight of nitrogen to a crop as 1 tonne of compost in the year of application.

Concentration N_F = 46%
Concentration N_C = 0.5%
Availability A = 25%

From 1.c.

$$\frac{10N_CA}{N_F} = \frac{10x0.5x25}{46} = \frac{125}{46} = 2.717\text{kg}$$

Example 2
Find the weight in tonnes of compost supplying an equivalent weight of potassium in the year of application to a 50 kg dressing of Muriate of Potash.

Concentration N_F = 51.5%
Concentration N_C = 0.3%
Availability A = 80%

From 2. b.

$$\frac{N_F/2}{\frac{N_CA}{10}} = \frac{5N_F}{N_CA} = \frac{5x51.5}{0.3x80} = \frac{257.5}{24} = 10.729 \text{ tonnes}$$

APPENDIX D References for further reading

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The International Institute of Biological Husbandry Ltd. (I.I.B.H.)

The Institute is an organisation which was founded in 1975 for the purpose of promoting the scientific development of biological/organic agriculture as a viable alternative to modern orthodox agriculture.

Orthodox agriculture is a system almost totally reliant upon fertilizers and other resource- and energy-intensive chemicals to achieve its high levels of productivity. However, the use of these chemicals can be considered in many ways to be both biologically and environmentally unsound. Biological husbandry, on the other hand, is a system of agriculture which relies mainly on natural, biological processes for the maintenance of soil fertility and for the control of pests and diseases. Based upon traditional farming methods and developed in recent years mainly by practical farmers, biological husbandry has reached a position where it can compete with orthodox agriculture. Its further progress, however, requires the development of a foundation of scientific theory and research in order to raise the level of credibility of biological agriculture to that of orthodox agriculture.

The Institute particularly wishes to attract into membership concerned scientists and agriculturalists from all over the world, but membership is open to all who are in sympathy with its aims. In brief, these are: the development of the science of biological husbandry and its promotion in all countries of the world so that all peoples may be able to feed themselves by means of a stable, self-perpetuating and self-contained agriculture suited to their particular conditions. Further details concerning membership and the activities of the Institute may be obtained from: The Secretary, The International Institute of Biological Husbandry, 9 Station Approach, Needham Market, Ipswich, Suffolk, IP6 8AT.

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