STUDIES OF COMPOSTING UNDER TROPICAL CONDITIONS

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It has been recognised since earliest times that crops cannot be grown continuously on one area of land without either, resting the land, or, carrying out some form of manuring, to maintain the fertility of the soil.

The types of manure used in Modern Agriculture fall into two classes. The inorganic fertilisers and the organic manures. The former has only been introduced into agriculture in comparatively modern times. Organic manures on the other hand, have been used since man first started systems of permanent arable cultivation as distinct from primitive shifting cultivation and nomadic stock keeping. In modern agriculture the extent of organic manuring depends largely upon economic and environmental factors and, in the tropics especially, upon the cost and availability of artificial fertilisers.

This paper is concerned with the production of organic manure by making compost. No paper on this subject, however, can be complete without considering the relationship of organic manures to the soil and, the various forms of manuring. Part one is therefore devoted to this. Part two deals with the principles, and part three with the methods, of composting. In all these sections reference has been made to the literature on the subject. Part four describes the trials carried out this year on methods of making compost. The object of the trials was to find methods that would be simple, and which, at the same time, would produce good manure at low cost. The latter is of great importance at the present time. A section has therefore been included dealing with the cost of production of compost.
PART I. ORGANIC MANURES IN RELATION TO THE SOIL,

A. Value of Organic Matter in the soil.

A considerable amount of literature has been devoted to the subject of organic manuring. Much of this has led to controversy as to the comparative value of organic and inorganic manures.

Some workers such as Sir Albert Howard (11, 12, 13) seem to consider that organic manuring is the "be all, end all" in this respect. The view taken by Howard is that artificials ruin the soil, induce pests and diseases, and therefore, should not be used at all in agricultural practice. He advocates mixed farming with livestock and seems much against any system of monoculture. There is no doubt that where possible the use of dung and urine on the soil will enhance its fertility. In some areas, however, livestock cannot be kept, either due to disease, economic, or environmental factors. Also certain crops, such as tea and orchard crops, have to be grown under a system of monoculture.

Instances are quoted by Howard in which large increases in yields were obtained by organic manuring alone over those previously obtained using only artificials. These in the main seem to be isolated cases. It is doubtful if every farm could economically produce enough organic manure for complete manuring without the use of some artificials. In any case the examples mentioned indicate not that the use of artificials ruins the soil and lowers crop yields, but that the system of husbandry was at fault, judicious use not having been made of these compounds in conjunction with organic manures. The lowering of the yields was probably due to poor physical standard of the soil. Most workers take a wider view than Howard and consider organic and inorganic manures to be complimentary rather than supplementary. From the considerable evidence available this view would seem to be the correct one.

It is however, in a subject such as this, impossible to be dogmatic. The types of manure and the methods employed to make and incorporate them in the soil must, of necessity, vary according to the different soil types, crops, climatic, environmental and economic factors. No "rule of thumb" methods can be laid down, even for the making of dung or compost. Some attempts have been made to do this, especially at Indore, where Howard (11) has laid down a rigid time-table for the production of
compost under the "Indore" system. Experiments and trials at various other places have shown that these methods often had to be modified to suit local conditions. Beckley (2) working in Kenya found that the Indore process as set down by Howard worked well but was not economic under Kenya conditions. Thus, although broad general principles of manuring can be laid down as a guide, the details will have to be varied for each set of conditions.

In order to decide on the manurial programme for any particular set of conditions, it is essential to know what the manures consist of, and the effect that they have on the soil. For consideration of this question it is convenient to divide manures into the two classes already mentioned, i.e. Artificial fertilizers and Organic manures.

Artificial fertilizers are inorganic chemical compounds, each of which supplies to the soil one or more of the elements necessary for plant growth. (It should be noted that the term inorganic is applied in the biological not the chemical sense). Artificialis have no effect on the physical state of the soil and their action is temporary.

Organic manures on the other hand have a rather wider application. The elements necessary to plant growth are supplied to a certain extent. They also have an important effect upon the physical condition of the soil due to the production of Humus.

Manurial Value of Humus

In the process of decomposition of organic material a chemical biological complex known as humus is formed. It is a transitional stage in the rotting down of complex organic compounds into simple inorganic ones. It is neither stable, nor of constant composition. It consists of an unstable mixture of organic compounds in various stages of complexity, inorganic compounds, and a large number of dead and living micro-organisms. The latter are engaged in breaking down and building up the various compounds of the complex.

Much of this humic material is in a colloidal state, thus, having similar properties to the clay in the soil. Due to this physical state, under certain conditions, humus can materially increase the water holding capacity of the soil. This fact is of considerable importance in areas that are subject to prolonged dry seasons. At the same time, by virtue of its being in the colloidal state, humus holds basic ions in the soil.
by surface absorption and thus tends to prevent this being leached out by rain water. Also a group of compounds in the humus known as humic acids form loose combinations with basic ions, these compounds being known as humates. This action is especially important in the case of iron which tends to become oxidised to an insoluble and unavailable form. The humic acids, however, form loose combinations with it, holding the iron in a form available to plants. Thus, in an iron rich soil lacking humus, plants may suffer from iron chlorosis. The addition of humus to the soil will often rectify this. The humates are relatively unstable, and plant roots can readily obtain the nutrient ions from them. In addition, the decomposition and oxidation of the organic matter, releases a steady flow of available plant nutrients which can be utilised by the crop. The products of oxidation include carbon dioxide from the respiration of the micro-organisms. This is, in the main dissolved in the soil water to form the weak carbonic acid. The latter acts upon the soil particles dissolving unavailable nutrients. From this solution the plants' root hairs can absorb these nutrients.

The actual nitrogen-phosphate-potash content of humus itself varies considerably, depending upon the constituent materials and its method of production. The manurial value of humus, however, as pointed out lies not only in its nutrient content, but also in the plant nutrients made available indirectly from other sources, and those which it holds in the soil. Waksman (23) quotes figures for the base exchange capacity of humus and the clay fraction of the soil. The figure given for humus is about seven times that of clay.

Humus = 151 m.e. per 100 gms.
Clay = 24 m.e. per 100 gms.

These figures apply to one case only and will vary widely under different conditions. For instance the clay figure will depend on the amount of Kaolin clay present. Kaolin clay has a lower base exchange capacity than Montmorillonite clay. Waksman also quotes a case where it was found that, humus and clay were not additive in their ability to absorb bases. The explanation given was that humus and clay form a weak chemical combination. The result is that probably some of the bonds used for base absorption when the components are separate, are satisfied when the two are in combination.
From the facts stated in this section it can be seen how the crops can benefit from the use of organic manures in conjunction with artificials, the humus from the former fixing the nutrients from the latter, until they are required by the plant.

A subject that has caused a considerable amount of controversy of recent years is that of growth promoting substances in humus, other than the normal inorganic elements. These substances have been called auxins, auximones, and phytamins by different workers. These compounds are supposed to be plant hormones or precursors, and they have been compared with hormones and vitamins in animals. These compounds are supposed to be present in humus, especially that prepared from fresh dung. According to some workers they are derived from animal hormones that are excreted from the body, mainly in the dung and urine. These are supposed to be more prevalent in the excreta of the females. Experiments with female sex hormones have shown that they stimulate the growth of tomatoes. Waksman has made an extensive review of the work done on this subject. He quotes a suggestion that a definite relationship exists between phytamins, vitamins, and hormones. It has also been suggested that some microbes can change compounds in animal excreta into others (phytamins), that can be absorbed by plant roots. Claims have been put forward that better seed is obtained from plants manured with dung, and that stock 'do' better on hay from plots so manured. Howard supports these theories, and also claims that most plant diseases would be eliminated by continued organic manuring. This last claim is without doubt very much exaggerated, and has no evidence in support of it. All advocates of this theory, however, agree that these compounds are organic ones and that they promote growth and increase disease resistance. There is no doubt, however, that plants can grow without their presence. Howard also emphasises the importance of the mycorrhizal relationships between plant roots and fungal hyphae. Although known to exist in what appears to be a symbiotic relationship with the roots of some plants, including tea, very little is known or understood of the value of this to either the plant or the fungus.

It is not proposed to go into this matter any further in this paper, as there seems to be no conclusive evidence in support of either of these theories, although further investigations might be worthwhile on the evidence available.
Water Holding Capacity

The value of humus in increasing the water holding capacity of light soils is mainly due to its colloidal nature. Owing to this property the size of pore spaces in the soil become smaller. The result is that more of the soil water becomes capillary water. Capillary water can be defined as that water, which cannot be drawn through the soil by gravity alone, the capillary force holding it being too great. Waksman gives an example where 100 parts of humus in the soil was capable of absorbing 400 - 600 parts of water. A soil containing plenty of humus, therefore, becomes resistant to drying out and enables crops to grow even in times of drought. In the case of light sandy soils this is very important especially in tropical areas, where there is a well defined dry season. In these cases humus not only prevents excessive drainage but also excessive evaporation. Waksman also points out that the water holding capacity of humus is considerably greater than that of clay.

In the case of heavy clays that already contain a large amount of colloidal material, and have a large water holding capacity, the effect of humus is rather different. The water holding capacity is not increased, in fact the opposite may be the case. The soil after an application of organic matter becomes more full draining. This is due to the effect humus has upon the structure of clay soils and is discussed in the next section.

Physical Condition of the Soil

All soils from clays to sands have their physical condition improved by the presence of humus. In the case of heavy clay soils the small colloidal particles of clay become aggregated together, or flocculated, by the humic material. This is largely brought about by a loose chemical combination of the clay and humus. According to Ehrenburg, quoted by Waksman, the humus dispurses the clay particles and forms a film of humate around them. This is then flocculated by CaCO₃ in the soil forming a crumb structure. When a crumb structure is formed in a clay aeration and drainage is improved. Humus has a similar effect upon ferric hydroxide and thus helping to prevent a pan being formed. At the same time the action of the humus tends to make the iron available to plant roots, as mentioned in a previous section.
The formation of this permanent crumb enables a good tilth to be produced that is less likely to be beaten by heavy rain into an impervious surface layer. The rain water is able to penetrate into the soils and the excess can drain through it and not over it. In this way "run off" water is reduced to a minimum and the danger of soil erosion correspondingly lessened.

In the case of light sandy soils the humus forms a layer round the mineral particles. Drainage tends to be reduced and mineral elements in the soil are made available to the crop. The binding action of the humus also causes a crumb structure to be formed. In sands, the humus acts as a cement. In the tropics and in sandy soils humus is rapidly oxidised and lost, and it is necessary to keep putting on heavy dressings of organic matter if the improvement in soil structure is to be maintained. One of the factors causing the considerable and serious soil erosion in the wet tropics and sub-tropics is the loss of soil organic matter, and the failure to replace it.

B. METHODS OF ORGANIC MANURING

1. Farm Yard Manure

The earliest form of organic manure used in the west was Farm Yard or Pen Manure. This consisted of the dung and urine of stock mixed with waste organic materials of the farm. The latter was made up largely of cereal straw, and was used as bedding in the stock pens. The general system followed was to put a layer of straw in the pen. When this was soiled, more straw was put on top. This method continued until the mixture of straw and excreta was several feet thick. The pen was then cleared and the manure either built into a heap to rot down further, or else carted straight to the field. Manure produced in this way is of high quality, although there is a tendency for ammonia gas to be lost if the heap is allowed to become too dry.

Up to 1914 large numbers of steers were fattened in pens in the arable districts of England primarily for the manure that they produced. By this means all the waste products of the farm were returned to the soil.

Since 1920 the production of pen manure by this method has fallen off considerably owing to the fall in prices, especially those of arable crops.
In the tropics not so much pen manure is produced and much of this is either wasted, or else applied only to the fields near the pen. This is due largely to the lack of transport facilities. The Chinese however, always make considerable use of pen manure and also of night soil. Also in many tropical countries there is legislation to prevent the bedding being left in the pen for more than 2 - 3 weeks owing to the danger of fly breeding. Thus the pen has to be more frequently cleared out than in the English system. There is some doubt however, as to the necessity for this frequent cleaning out of the pen provided that a thick layer of clean litter is always kept on the top. However, despite the advantages of this system from the manurial point of view, the rising labour costs have tended to make its production uneconomical in most areas.

To replace this system in some temperate countries, stock are grazed on grass and clover leys, these being ploughed in after a few years. The animal excreta is thus dropped on the soil by the stock, and 'nitrogen starvation' in the following arable crops is less likely to occur than in other forms of organic manuring such as Green Manuring.

2. Green Manuring

Green Manuring entails the sowing of a crop specifically for ploughing in and incorporating into the soil. Very frequently green manure crops are grown as catch crops between the main cash crops. They often take the place of a fallow. Pieters and McKee (25) who have given a review of the work carried out on this subject states that it is rarely that a full growing season can be profitably given over to a green manure crop. They also point out that Green Manures are mainly of value in keeping up the organic matter content of the soil, rather than increasing it. From this it can be realised that a successful green manure crop must be one that gives the maximum bulk in the shortest possible time. Also the plant must be capable of doing this in the non-cash crop season.

In order to enable the green manure crop to have a long enough growing season it is the practice in some places to under sow it in the cash crop. This is mainly done where the cash crop is a cereal.

Green Manure plants can be divided into two main types:

1. The Leguminosae.
2. The non-Leguminosae.
The main difference between these two types from the green manurial point of view, is the fact that the legumes increase the nitrogen content of the soil. This is due to the nitrogen fixing activities of the root nodule organisms and the fact that there is more nitrogen in leguminous protein. In the case of non-leguminous plants none of the elements required for plant nutrition are actually added to the soil. The green manure plants nevertheless, by absorbing the nutrients from the soil, prevent their loss by leaching and at the same time, produce humus when ploughed in and acted upon by the soil microflora.

It is often found that the yield of the crop following the ploughing in of a non-leguminous green manure, is depressed. This is because the soil micro-organisms, in order to obtain nitrogen for their own metabolism, take it from the soil, there not being enough in the organic matter. The result is that the crop suffers temporarily from nitrogen starvation. Temporary nitrogen starvation is more likely to follow the ploughing in of mature, than young and immature plant material. This is because the young plant is richer in protein and other nitrogenous substances than the old one. For the same reason nitrogen deficiency is likely to occur after the ploughing in of stubble and other trash after harvest. This deficiency is not so likely to occur after the ploughing in of a leguminous green manure, owing to the higher nitrogen content of both the plant and the soil, after growing this type of crop. It can, however, occur, depending on the stage of maturity and the legumes grown.

The method normally employed to eliminate this factor, is to give the soil a dressing of some nitrogenous fertiliser such as Sulphate of Ammonia, at or just after ploughing. Howard suggests that an application of urine would be the more beneficial than a nitrogenous salt. This method no doubt has many advantages but would, in the majority of cases, be impracticable. Most farms do not produce sufficient urine for this purpose, and in any case, the cost of collecting, carting, and spraying the urine on the ground is prohibitive in most cases.

Although the use of leguminous plants as green manures would make the application of nitrogen either unnecessary or satisfactory at a reduced rate, non-legumes often give a greater bulk of organic matter. As the primary object of green manuring is to supply humus to the soil, the latter
is in more common use especially in the tropics. The cost of dressing the
soil with an inorganic nitrogenous manure is comparatively low. With the
result that even using a non-legume, green manuring is probably the cheapest
form of organic manuring, provided that a cash crop does not have to be
sacrificed. Experimental evidence however, as to its comparative value
with pen manure and compost is rather conflicting. Some results indicate that
it is not so effective as the other two. Further investigation could
profitably be carried out on this subject, especially as, in times of low
prices, this form of manuring might be economic whereas the other two would
not be.

3. Mulching

This consists simply of laying trash on the ground and allowing it
to rot in situ. This system is often followed in orchard and other permanent
crops. This method has the great advantage of cheapness, and some experiments
indicate that mulching may be more effective than ploughing the material in.
It has been claimed that, on sugar estates in Trinidad, using pen manure as
a mulch has a better effect than ploughing or digging in, despite the loss
of nitrogen that must result.

In any case, in wet tropical areas, mulches rot down rapidly forming
a surface humic layer. Further investigation, however, is needed.

4. Artificial Farm Yard Manure or Compost

The making of artificial farm yard manure or compost is a very
ancient practice amongst the Far Eastern peoples, especially the peasant
farmers of China and Japan. The methods employed by them has been described
by King in "Farmers of Forty Centuries". Briefly it consists of mixing
all the organic waste of the farm with dung, urine, and night soil. This is
allowed to ferment and is then applied to the soil. Although this method
of making organic manure has been known for so long in the East, it is only
in comparatively modern times that it has spread to the western world.

In 1920 the researches of Hutchinson and Richards at Rothamsted (14)
resulted in the patenting of the "Adco" chemical process. The proprietary
compound "Adco" is now wellknown, and is used to accelerate the composting
process. Since then other research workers have devised various systems of
making compost. This work has been carried out in both the East and the
West. Unfortunately, comparatively little account seems to have been taken
of the economics of the process in these investigations. This is one of
the main factors preventing the greater spread of composting.

Many of the factors that place a limit on the production of farm yard manure also apply to the composting process. The main one of these is the labour cost, which is high in both cases. Water also is essential for both these processes, in the former case mainly for the stock, and in the latter it is required to keep the compost heaps moist. As water is essential for composting whether heaps or pits are used, these must be near a good supply unless the rainfall is sufficiently heavy. During the rainy season in wet tropical areas the latter is often the case. Under these circumstances the compost heaps can be built near to where the final product is to be used. In any case the material to be composted will, in nearly every instance, have to be carted at least once and probably twice, before it is finally applied to the soil.

Animal excreta is not essential for producing compost although it is valuable. Compost can therefore be made even if no stock is kept.

Composts are better than Green Manures, and the ploughing in of other undecomposed material, in that, it is already well rotted, before being incorporated in the soil. Therefore no depression in crop yields is likely to follow its application. Also none of the detrimental effects of opening up the soil causing excessive drying and aeration normally follow the use of compost. In the case of the other materials mentioned this may happen under some conditions.

Unlike a non-leguminous green manure, compost actually adds plant nutrients to the soil. On the other hand if the soil is left in fallow before applying the manure there is a risk of loss of nutrients by leaching in the wet weather, and during the dry season loss of ammonia gas may occur. These risks will be reduced by either growing a green manure or a cash crop.

Normally no special crop is grown for composting, all waste organic material being used for this purpose. For this reason compost is economical on land and will thus often allow a higher proportion of cash or food crops to be grown on the holding. This process is eminently suited to many tropical regions where livestock are few and dung scarce. Composting is probably more suited to a small holding than an estate. The cost of obtaining sufficient material to manure an estate in addition to the cost of production usually make it uneconomic. Estates are more likely to have a programme of green manuring and mulching. A quantity of pen manure and compost is often made
in addition however.

It is important, therefore, that a method of composting be evolved that can be carried out by uneducated peasants. The methods must be simple, involve a minimum of labour, and the materials and any artificial accelerators must be cheap. It should also be noted here that such a system is also required by larger farms employing labour. A minimum of supervision of labour would be required and casual labour could be employed for this purpose.

Part II. PRINCIPLES OF COMPOSTING

The decomposition of organic matter is now known to be due to the activities of fungi, bacteria, and actinomycetes. This can take place in the soil, cattle pen, or the compost heap. In this section the factors affecting the activities of the various microorganisms in the compost heap will be dealt with.

1. Parent Material

The importance of parent material lies partly in its chemical, and partly in its physical, makeup. These factors cannot be dealt with separately as they are interdependent. In considering the decomposition of plant material its constituent compounds can be conveniently divided into the following groups.

1. Non-nitrogenous water soluble compounds and lower insoluble carbohydrates.
2. Celluloses and hemi-celluloses.
3. Fats and Waxes.
4. Lignins and Ligno-celluloses.
5. Nitrogenous organic compounds including proteins and aminoacids.

These compounds are broken down easily by micro-organisms. They are also utilised by the nitrogen-fixing bacteria both for energy, and to build up into their own protoplasm, the nitrogen being obtained from the air. The other microbes engaged in decomposition attack these compounds first, obtaining the requisite quantity of nitrogen either from the nitrogenous material in the plant tissue or, when all this has been utilised, from an external source. In most materials used for composting, nitrogen is present only in small quantities. Rege (22) states that Pentosans are the main source of quickly available food for the decomposition fungi. He qualifies this,
however, by stating that the lower carbohydrates are quite as good, but rarely present in quantity in compost material. Pentosans do not form a very high percentage of the parent material. Unlike Rege, Waksman (24) does not attach much importance to pentosans for the reason given above.

(ii) In celluloses and hemi-celluloses form the greatest part of the material normally used for composting. Usually from 50-80% of the dry matter. These compounds are not so easily broken down by fungi and bacteria as group (i). According to Rege they are attacked mainly after the pentosans have been utilised. The celluloses are mainly attacked by the non-nitrogen-fixing microbes and therefore, nitrogen in some form will have to be supplied except in cases of young succulent material and legumes. In the two cases mentioned enough nitrogen may be present for maximum microbial activity. With all other material decomposition will proceed very slowly unless nitrogen is supplied. Phosphate is also required by bacteria and fungi but the quantity needed is small, sufficient being normally present.

(iii) Fats and Waxes are compounds that are decomposed only very slowly. On the other hand they are only likely to be present in small amounts in any material used for compost. They tend to form a physical barrier to micro-organisms and if in quantity, slow down the rate of decomposition.

(iv) The lignins and ligno celluloses are found in large quantities in the older plant tissue, especially in woody stems and roots. These compounds are only slowly decomposed and form much of the bulk of humus. Young non-lignified tissue decomposes rapidly leaving no humus. If in large quantities, however, lignins slow down the rate of decay. Thus, Rege noted that decomposition was negligible in pine needles during a laboratory experiment. In old woody tissue these compounds often form a physical barrier for celluloses against microbial attack.

Rege calls lignins the inhibitory factor, and pentosans the energy factor, in the process of decay. He states that if the ratio of pentosans to lignins is greater than 1, decay is rapid and if less than .5, it is very slow. Later workers including Waksman, while agreeing that fungi attack the pentosans fraction before the celluloses, consider that, as there is a far greater quantity of the latter in composted material, it has greater importance as microbial food. Tambe and Wad (10) state that, with suitable handling, lignified material is good for humus production. Howard and Wad (11) found that crushing the woody stems under carts, and soaking in water, did
much to overcome the physical impedence of lignin to microbial attack.

(v) Proteins and other nitrogenous compounds are readily decomposed by the microflora in a compost heap. The nitrogen is used for building up microbial protoplasm.

2. Micro-organisms involved in decomposition

The process of decomposition of plant tissue is essentially one of fermentation and oxidation due to the action of micro-organisms.

The microbes involved can be divided into three main groups.

(i) Fungi
(ii) Actinomycetes
(iii) Bacteria

According to Rege (22), fungi play the main part in the decomposition especially at the start. He qualifies this, however, by pointing out that probably the fungi are later decomposed by bacteria. It is now considered that, although fungi are probably the main agents of decay at the start, bacteria and to a much lesser degree actinomycetes play some part especially in the later stages. Nikiforoff (21) states that more of the decomposition of organic material is by fungi in forest soils, and by bacteria in grassland soils. Even taking this view there is undoubtedly some modification in arable lands, and in compost heaps. It seems likely, therefore, that both bacteria and fungi play an important part in the compost heap, the one being complimentary to the other. Undoubtedly bacteria are the main class of organisms decomposing fungal and bacterial remains, thus, freeing plant nutrients locked up in the protoplasm. In this way N.P.K. and minor elements are returned, through the soil, to higher plants. The other products are mainly CO₂ and H₂O.

Nitrogen fixing bacteria are present in comparatively small numbers in a compost heap. Hutchinson and Richards, and later Hardy, estimate the amount of nitrogen fixed as only about 1% of the original dry weight of the material. Their action is thus of relatively small importance. Howard however, has found that the growing of Sunn hemp on compost heaps beneficial, due to the increase of nitrogen. The nitrogen fixing, in this case is, of course, due to the symbiotic bacteria in the roots.

The activities of aerobic and anaerobic organisms is discussed in the action dealing with aeration.
3. Nitrogen

The investigations of Hutchinson and Richards showed that nitrogen is an essential factor in the process of decomposition. In order to build up the protein of their own bodies, micro-organisms must have a readily available supply of nitrogen. Most of the material used in composting consists of non-nitrogenous organic compounds. Unless nitrogen is added to this material in some available form, decay will almost cease, once the small quantity of nitrogen present has been utilised. Hutchinson and Richards report a rise in temperature of 15 - 20°F after the addition of nitrogen to some rotting material. This indicates renewed activity of the microbes. There is however an optimum ratio of nitrogen to carbonaceous material. Any excess of nitrogen is not only a waste, but also retards the rate of decomposition. In the case of an excess, the nitrogen tends to be leached out of the heap or lost as NH₃ gas. The above mentioned workers' results, prove that the nitrogen percentage of the final compost is fairly constant for similar materials under similar conditions, although the original nitrogen percentages may be very different. This shows that any excess present at the start of the process has been lost before the final compost is produced. These workers found that the optimum amount of nitrogen was 75 parts to 100 parts dry straw by weight. These results have been confirmed by others including Halversen and Torgersen, and Brown and Smith. Waksman considers that the C/N ratio assimilated by microbes to be about 33 to 1. This would be for complete decomposition. As that is not desirable considering the physical properties of organic matter, he recommends a C/N ration of 140/1. This would mean having 7 parts of N to every 100 parts dry straw, thus substantiating the results previously quoted. These figures all apply to cereal straw, and are mainly obtained from laboratory experiments. On a field scale 1% by weight of nitrogen is generally considered sufficient for most materials likely to be used. Many nitrogenous substances can be used. Brown and Smith in comparative experiments using inorganic sources of nitrogen put them in the following order.

(i) Sulphate of Ammonia
(ii) Nitrate of Soda and Urea
(iii) Calcium Nitrate
(iv) Calcium Cyanamide
From the practical aspect, the main considerations are cost and availability. Sulphate of Ammonia is normally the cheapest, and easiest to obtain, and is therefore most commonly used.

The proprietary compound "Adco" is known to contain nitrogen in the form of calcium cyanamide. It has been successfully used in both temperate and tropical regions, but its more widespread application is prevented by the high cost.

Organic nitrogen is added in a number of materials, the main ones being dung, urine and night soil. Urine is usually diluted before being applied as, in the undiluted state, the concentration of nitrogen is high and loss of ammonia gas often results. Owing to the great variability in composition of these materials, it is impossible to give quantitative figures for their use. These materials have been used to a very large extent by workers in India. There is no doubt, however, that part of the success that has resulted from the use of this type of material, is due to its value as an inoculum.

4. Carbon: Nitrogen Ratio

Howard considers that the C/N ratio of the final product of composting should be as near as possible to 10. This he states is the C/N ratio of most soils. Beckley, however, refutes this by stating that the C/N ratio of tropical soils vary from 23 - 5.3. There seems to be no doubt that compost can be beneficially applied to the soil even if the C/N ratio is greater than 10.

5. Air and Moisture

One of the most important factors affecting the composting process is the air : moisture balance of the heap. Too much aeration results in excessive drying out of the material, resulting in the cessation of the activities of the micro-organisms. On the other hand, material that is too closely packed or that is water-logged produces anaerobic conditions. Under these circumstances anaerobic organisms become predominant. These are not only slower in their action than aerobic ones but, owing to the production of acids, activity soon ceases. The result is a silage-like material. From this it can be seen that sufficient air must be allowed into the heap to keep aerobic conditions and at the same time drying out be prevented.
Some materials such as cereal straws do not absorb water easily. Once they are well soaked, however, they tend to pack down to the exclusion of air. Such materials are usually well soaked and then mixed with some more open material such as maize straw or Sunn hemp. Long stalks are often chaffed, or broken by the treading of stock. Thus, by suitable treatment, and mixing of the material available, the correct air:moisture balance can be obtained.

Compost can be made in heaps or pits. Which is used depends largely on the climatic conditions. Pits tend to reduce aeration and conserve water, while heaps do the reverse. Howard advises the use of pits in the dry, and heaps during the wet season. This is probably the best method to follow.

The height of heaps or pits will affect aeration. If they are built very high, the material at the bottom will tend to become compacted due to the weight above, and anaerobic conditions will result. Howard and Wad advise a maximum height of 2'. Some American workers have made good compost in heaps up to 6' high. The optimum for most conditions would seem to be about 4 feet.

During decomposition heaps and pits tend to settle due to their own weight, and aeration becomes limited. In order to overcome this it is the normal practice to turn the heaps at least once during the process. Howard and Wad at Indore turned the heaps three times. Most other workers find that one or two turns are sufficient.

Compost heaps must never be allowed to dry out. If the rainfall is not sufficient, water must be applied. The amount depends upon local conditions. It may be noted, however, that the inclusion of dung in a heap will increase its water holding capacity.

6. Reaction

Aerobic micro-organisms engaged in decomposition require a neutral or slightly alkaline reaction. Under anaerobic conditions the compost tends to become acid, due to the production of fatty acids. Under aerated conditions this is not likely to occur. Waksman, Tenney and Dickm (1) state that time has no effect on decomposition unless inorganic nitrogen is added. Howard and Wad added wood ashes to check acidity when using
organic sources of nitrogen. In most cases, however, this would appear to be unnecessary.

7. Temperature

The building of a compost heap is normally followed by a rapid rise in temperature that may reach over 70°C. This is followed by a gradual decline, the final product being at about 30°C. Turning of a heap is usually followed by a rise in temperature. The temperature is considered by Howard to be an index of microbial activity. While to an extent this is true, the initial rise is above the death point of all but the thermophylic bacteria. The death point of fungi is below 60°C and they only become active again when the temperature has fallen below this point. Howard and Wad state that the high temperature has the beneficial effect of killing weed seeds and pests.

8. Inoculation

This involves the addition of some substance containing the decay organisms to the compost heap, in order to hasten the process. Halversen and Torgersen found that no advantage was derived from using an inoculum on cereal straw. "Adco" powder has also been found quite efficient without using any inoculum. Fowler (6) found dung and well rotted compost beneficial. Howard and Wad (11) made use of a system whereby, at each turning, an inoculation was made from a heap at a stage later in decomposition. They hoped to ensure by this method, that the correct organisms were present at each stage.

9. Measurement of the efficiency of Decomposition

Masefield (19) working at the College attempted to find a standard method by which to judge the final compost. He used various criteria including temperature, Nitrogen percentage, and Degree of Humification, and "Judgement by hand and eye". The last two were found to give the best agreement. Other workers have also tried to find some system of assessing the value of the final products. There seems, however, to be little agreement between various systems used on the material. Masefield concludes that "judgement by hand and eye" is the best criterion, as it is the only method that can take into account all parts of the heap at the same time. This method also is the only one available to the farmer.
In the trails described in this report this method was used. Chemical analyses were however made and temperature readings noted.

PART III. METHODS OF MAKING COMPOST

This section deals with the main systems of composting that have been advocated by various workers. Most of the world’s compost is made by methods that are based on these. Modifications have been introduced in different places but as these are in the main of only local interest it is not proposed to describe them.

1. Chinese and Japanese Methods

King (18) describes methods of composting that have been carried out by the peasants of China and Japan for centuries. All the waste organic matter from the fields and houses is mixed with night soil, dung, and urine from the stock. Wood ashes are also added to check acidity. This is composted in pits or compost houses. The compost may be turned during the process, and water is added if the heaps or pits show any signs of drying out. According to King excellent compost is made in this way.

2. Indore System

Howard and Wad (11) evolved a system of composting that is similar to the traditional one of the Chinese. The aim was to turn all the waste products of Agriculture into humus, by a system that would be continuous throughout the year. In this system compost is made in pits during the dry season to avoid excessive evaporation. In the wet season heaps are built to prevent water logging. The maximum depth of both pits and heaps is two feet. The method employed is as follows:

Earth is dug out of the floors of the cattle pen to a depth of 6 inches. This urine earth is then ground up and incorporated with the compost mixture. Earth is then replaced in the pen. The soil of Indore is very calcareous and this no doubt neutralises any acidity that develops. Wood ashes and half rotted compost are also added, the latter as an inoculum. The heaps or pits are turned according to a time table. At each turn the material is given a further inoculation from a heap a stage further on in the process, to ensure a sufficiency of the necessary organisms at each stage.

Howard (12, 13) and Beckley (2) state that this method gives compost of high quality. The latter, however, qualifies this statement by pointing out that it is expensive to make, especially in labour. Thus it is only
suitable where labour is cheap and plentiful. Also as the process is somewhat complex it is not suitable for use where casual labour is employed, unless careful supervision is given. Its high cost tends to make it unsuitable for estate practice. On the other hand peasants are deterred by its complexity.

Brown (3) at the College in 1939 found that the cost of compost per ton by the Indore method was cheaper than most other methods. It must be remembered, however, that the cost of labour then was \( \frac{1}{3} \) of the cost in 1947.

3. Modified Indore System

This system is similar to the Indore method but rain water only is used. It was evolved by Jackson and Wad to overcome the prejudice of the Indian peasants against the complexity of the Indore process. It is not necessary to put the litter under livestock.

Brown (3) found that the system worked well if the rainfall was heavy. It was found to take slightly longer than the other methods but was the cheapest.

4. Fowler's Activated Compost Method

Fowler (6) advocated a method of using activated compost and sewerage sludge as inoculum. The system was tried by Wood (7) at the College. He found that the method gave good results but was not economic.

5. Mauritian Pen Methods

Hardy (8) has described a method used by the Mauritian cane planters to compost cane trash. The cane trash and other waste materials are spread on the floor of the cattle pens. After two weeks the pen is cleaned out and more trash is put in. The litter cleaned out of the pen is built into heaps.

It is claimed that more waste material can be made into manure by this process per head of cattle than by the making of ordinary farm yard manure. Hardy quotes a case in Trinidad where 100 tons of manure could be made annually per head of cattle by this method, but only 20 tons of Farm Yard Manure.

This system is dependent upon the number of stock kept. For this reason its application is somewhat limited.
6. Chemical Methods

The chemical methods of making compost emanate from the discoveries of Hutchinson and Richards at Rothamstead. As a result of their investigations the Adco Company was formed to produce the patent Adco mixture. Amongst other chemicals Adco was known to contain calcium cyanamide. Adco simply supplies the necessary microbial nutrients, of which the main one is nitrogen. No inoculation has been found necessary. Hardy (9) found Adco inferior to urine earth and cow dung. The investigations of Brown at the College indicate that its cost makes it uneconomic.

The primary object of the use of chemicals in compost making is to raise the nitrogen status as stated above. The pH at the same time must be kept around 7. The addition of phosphate has also been advocated by some workers. Its use, however, does not appear to be necessary in most cases. Usually 1/4 - 1 cwt. of Ammonium sulphate is used with 1 cwt. of ground limestone per ton of trash. This will raise the nitrogen to about 1% in most materials used, which, as stated previously, is the amount of nitrogen found to be necessary for decomposition.

7. Use of an Artificial Inoculum

An artificial inoculum going under the name of Fertosan has been produced by Fertosan Ltd. The Company claims that it contains dormant bacteria, nutrient material, and also, a secret material for the elimination of disease. In appearance it is a mixture of a grey powder and a yellow substance that rather resembles ground up gelatine.

The mixture is dissolved in warm water and then diluted. Part of the mixture will not dissolve. The Proprietors suggest that the heaps be made in the following way:

1. 6 - 12 inches of trash
2. Light sprinkling of lime
3. 6 - 12 inches of trash
4. Sprinkle with fertosan solution
5. 1 inch of soil

This is then repeated until the heap is about 4 feet high. The compost is stated to be ready in 6 weeks. Straw, trash and garden waste can be used. It is claimed that three tons of compost can be produced from 1 ton of straw by this method. There do not appear, however, to have been any unbiased trials carried out with this product.
PART IV. COMPOSTING TRIALS

The objects of the composting trials carried out at the College this year were:

1. To find a system that is efficient in composting farm wastes under Trinidad conditions, and, which is at the same time cheap. The latter is very important, and for this reason, the costs for all operations have been computed for each method employed.

As the trials this year had to be started during December and January, the materials available for composting were limited. The materials used were old and rather woody sunn hemp, Rice straw and mature Elephant Grass.

Four methods were compared:

1. Using an activator of old compost and dung and urine.
2. Mauritian Pan system
3. Using the proprietary Fertosan mixture
4. A chemical method.

The weather conditions were very dry over most of the composting period, although two heaps had a spell of wet weather during December and the beginning of January. In order to minimise evaporation during the dry weather, four heaps were built in a composting shed on the College farm. The two heaps built in December were in the open and, for the first five weeks, could be considered to be under typical wet season conditions. After this the rainfall dropped off and the latter half of the composting period was during an unusually severe drought.

The rainfall figures were:

- **December**: 10.24 inches
- **January**: 2.59 "
- **February**: .29 "
- **March**: .13 "
- **April**: .05 "

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>December</td>
<td>10.24 inches</td>
</tr>
<tr>
<td>January</td>
<td>2.59 &quot;</td>
</tr>
<tr>
<td>February</td>
<td>.29 &quot;</td>
</tr>
<tr>
<td>March</td>
<td>.13 &quot;</td>
</tr>
<tr>
<td>April</td>
<td>.05 &quot;</td>
</tr>
</tbody>
</table>

Temperature readings were noted for each heap, every day at the start, but at longer intervals afterwards. Previous workers appear to have found difficulty in obtaining accurate temperature readings. Webster used bamboo tubes which were inserted into the heap. The thermometer was lowered down these tubes. This method has the disadvantage that the tubes cause local increased aeration and the thread of the thermometer drops rapidly on withdrawal making accurate readings difficult to obtain.
Also the thermometer is not in close contact with the heap. Soil probe thermometers and automatic recording thermometers have also been used.

This year an ordinary thermometer was used, enclosed in a metal case. This method has the advantage that the thread drops slowly on withdrawal. The thermometer is well protected, and there are no permanent tubes to cause localised aeration.

The final compost was judged by hand and eye and by chemical analysis.

**Heap I**

812 lbs. of Rice straw and 542 lbs. of Sunn Hemp stems (Crotalaria spp.) were used for this heap. The Sunn hemp stems were green but hard and there was a fair proportion of green leaf. This material was not chaffed. The Rice straw was clean and dry. 516 lbs. of well rotted dung and compost was used as an inoculum. This material had the additional value of increasing the water holding capacity of the heap, which was rather open in texture. The heap was built in layers, 21 gals. of urine and 8 gals. of water being added during building.

During the first week there was little rain, and the heap tended to become rather dry. It was noticeable that during this time the temperature rose very slowly (Fig.1). When, however, the rainfall increased there was a sharp rise to 47°C. After the middle of January the dry season set in and water had to be applied to the heap.

When the heap was turned, 37 days after building, considerable decomposition had taken place, although, this was mainly confined to the rice straw. The Crotalaria stems were hard and unaltered. The bottom of the heap was rather dry. It seemed that the layers of rice straw and compost had absorbed most of the water, preventing it from penetrating to the bottom. The material was, therefore, well mixed before remaking. There was no rise in temperature after this turn.

Samples of this heap were analysed after 57 days. It was noted that the reaction was alkaline although no lime was added at any time.

A further turn was given after 84 days. The material was dark brown in colour and was well rotted although some hard woody stems remained. Final samples were taken after 96 days. The stems although retaining their form could easily be crushed. The material appeared to have made good compost. This was confirmed by the chemical analysis. The C/N ratio was 12.3, and the Degree of Humification was 74.
Heap II.

The materials used were similar to those of Heap I. In this case, however, the Sunn Hemp was trampled in a pen for 4 days, to break up the stems.

The quantities used were:
- Rice straw 941 lbs.
- Sunn Hemp 608 lbs.
- Old Compost 226 lbs.

The heap was built in layers as for Heap I, 6 gallons of urine being poured on the material. The temperature rose to 47°C in 4 days, the rain being fairly heavy at this time.

The heap was turned after 27 days. The Sunn hemp stems were rotting down better than in Heap I, although the rice straw showed signs of waterlogging. The limited aeration due to the shorter stems probably caused this.

The aeration as in Heap I remained alkaline. A further turning was given after 75 days. Final samples were taken 86 days after the start of the trial. The compost did not appear to be satisfactory as Heap I, and the Degree of Humification was lower, being 64. Throughout the limiting factor in this heap appeared to be lack of aeration. Nevertheless, a reasonable compost was obtained in 86 days.

Heaps III and VI.

These two heaps were made using the proprietary mixture Fertosan. The material used was Elephant Grass, chaffed in the case of Heap III, and long in Heap VI. These heaps were built in a composting shed to conserve moisture, under the dry season conditions then prevailing. Both heaps consisted of 15 cwt of Elephant Grass, with ½ cwt of lime and 7 gallons of Fertosan solution.

The latter was made up as follows:
- 1 packet of the mixture was dissolved in 5 oz. of warm water.
This was then diluted to 7 gallons with water for use on the heap.

The heaps were built as follows:
- 6 inches of Elephant Grass
- Layer of Lime
- 6 inches of Elephant Grass
- 1 gallon of Fertosan solution
- Thin layer of soil
This was continued until the heap was complete. The Elephant grass was soaked in a pool of water before the building of Heap III commenced.

The temperature in the case of Heap III (Chaffed Elephant grass) rose rapidly to 70°C. This heap was turned after 36 days. At this time the heap was well rotted at the top, but the bottom resembled silage. This latter indicated lack of aeration and excessive compaction. The original heap was five feet high, and the weight of the upper layers was undoubtedly a contributory factor. As with the previous heaps there was an alkaline reaction although, in this case, lime had been added. Final samples were taken after 81 days. The C/N ratio was 14 and a very good compost was produced. Unfortunately, owing to the shortage of H₂O₂ the Chemistry Department was unable to carry out the Degree of Humification determination on this heap, or on the other two analysed.

The treatment of Heap VI was similar, except that long Elephant grass was used. Owing to the length of the stems, however, the heap was of a very open texture despite attempts to reduce aeration by putting soil on the top. Excessive drying out took place, and the trial had to be abandoned. No chemical analysis was done.

Heap IV.

Sulphate of Ammonia and Lime were used in this trial to promote decomposition. The heap was intended for comparison with the fertosan method.

The materials used were:
- 15 cwts. chopped Elephant grass
- 56 lbs. ground limestone
- 45 lbs. Sulphate of Ammonia

The chopped grass was soaked in a pool of water made by blocking the irrigation trench, as with Heap III. A rapid rise in temperature followed the building of the heap. When the heap was turned, the material seemed to be decomposing satisfactorily throughout. This turn was carried out 5 weeks after building the heap. Final samples were taken 80 days after the start of the trial. In this case, although the final analysis indicated a better compost than Heap III, its appearance indicated that decomposition had not been so satisfactory. A good compost was nevertheless obtained.

Heap V.

This trial was carried out following the "Mauritian Pen" system.
2861 lbs. of material (mainly Elephant grass) was taken from the Oxen pen, and built into a heap. Included in this weight of material, was the dung and urine from the oxen. The temperature curve was similar to that of the other heaps, except that no rise was observed after turning. The decomposition seemed to be more rapid than in the other heaps. The compost could have been used before the final samples were taken 77 days after building. The compost judged both on appearance and on analysis was the best produced in these trials.

Cost of Production of Compost

Before any system of compost making can be considered to be of practical value, the cost of production has to be examined. In the trials this year, therefore, records were kept, and the cost per ton of final compost computed. The actual costs apply only to Trinidad conditions owing to the different labour costs in other places. The cost can, however, be corrected by substituting the applicable labour costs.

The original material was considered to have no value in these calculations. The cost of labour is taken on the basis of 1 man hour costing 18 cents.

Owing to the scattering of Heaps I and II by the wind and poultry no final weights could be taken. For the purposes of these calculations it was considered that 9 cwts of final compost was produced.

Heap I

Cutting 5 cwts. Sunn Hemp 14¢
Carting 12 cwts. Sunn hemp and rice
Man 40¢
Cart and Ox 40¢

Building Heap 2 man hours 36¢
Watering (94 gals.) 1 man for 1 hr. 34 mins. 27¢
Turning twice 2 man hours 36¢
Cost of approximately 9 cwts. of compost $1.94
Cost per ton of compost $4.31

Heap II

Cutting Sunn Hemp
Carting Rice and Sunn Hemp
### Heap II

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost per Ton of Compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting Sunn Hemp</td>
<td>15¢</td>
</tr>
<tr>
<td>Carting Rice and Sunn hemp</td>
<td>47¢</td>
</tr>
<tr>
<td>Building the heap</td>
<td>1.10</td>
</tr>
<tr>
<td>Watering (83 gals.)</td>
<td>27</td>
</tr>
<tr>
<td>Turning twice</td>
<td>36</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$4.65</strong></td>
</tr>
</tbody>
</table>

### Heap III

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost per Ton of Compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting 15 cwts. Elephant grass</td>
<td>41¢</td>
</tr>
<tr>
<td>Carting</td>
<td>1.01</td>
</tr>
<tr>
<td>Chaffing</td>
<td>74</td>
</tr>
<tr>
<td>Building the heap</td>
<td>54</td>
</tr>
<tr>
<td>1 packet of Fertosan</td>
<td>36</td>
</tr>
<tr>
<td>Lime (56 lbs.)</td>
<td>15</td>
</tr>
<tr>
<td>Watering (60 gals)</td>
<td>27</td>
</tr>
<tr>
<td>Turning once</td>
<td>27</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$9.68</strong></td>
</tr>
</tbody>
</table>

### Heap IV

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost per Ton of Compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting 15 cwts. of Elephant grass</td>
<td>41¢</td>
</tr>
<tr>
<td>Carting</td>
<td>1.01</td>
</tr>
<tr>
<td>Chaffing</td>
<td>74</td>
</tr>
<tr>
<td>Building the heap</td>
<td>36</td>
</tr>
<tr>
<td>Lime (56 lbs.)</td>
<td>15</td>
</tr>
<tr>
<td>Sulphate of Ammonia (45 lbs.)</td>
<td>1.96</td>
</tr>
<tr>
<td>Watering (63 gals)</td>
<td>27</td>
</tr>
<tr>
<td>Turning once</td>
<td>27</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$10.34</strong></td>
</tr>
</tbody>
</table>
In this case the 25 cwts. of grass mixed with dung and urine from the pen was considered to contain 1 ton of grass. The calculations have been computed on this basis.

Cutting 1 ton of Elephant grass 54¢
Carting " " " " 1.35¢
Carting from the pen and building the heap 2 man hours = 35¢
1 ox and cart for 1 hour 18¢ 54
Watering (49 gals.) 1 1/2 man hours 22¢
1 Turn 1 man hour 18¢
Cost of 1 1/2 cwts. of compost $ 2.83
Cost per ton of compost $ 4.92

Summary of costs

Heap I $ 4.31
Heap II $ 4.65
Heap III $ 9.68
Heap IV $10.34
Heap V $ 4.92

The extra cost of heaps III and IV is partly due to the chaffing artificials, and fertosan, and partly due to the great loss in weight of the material during composting. These figures are all undoubtedly higher than would be the case had much larger quantities been used. The methods used in Heaps I, II and IV would probably be quite satisfactory for small holders although in each case and especially in the case of V the quantity of compost that can be made will depend on the number of stock kept.

Conclusions

The trials described in this paper indicate that good compost can be made under the "dry season" conditions in Trinidad, using a minimum of water after the preliminary wetting. It would seem that provided suitable material is used, 100 gals of water added is the maximum necessary. Heap VI using fertosan and long Elephant grass was a failure due to the open texture of the material. It would seem best to use a mixture of material in the compost heap. Adjustment can then be made to obtain the most efficient decomposition. Fertosan used on chaffed elephant grass was found to be efficient but expensive. The cheapest methods were found to be those using dung or old compost as activators. The methods also gave a higher proportion of plant nutrients.
### Summary of Composting Trials and Analyses

<table>
<thead>
<tr>
<th>HEAP</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time Table</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heap built</td>
<td>2.12.46</td>
<td>12.12.46</td>
<td>20.1.47</td>
<td>21.1.47</td>
<td>24/1.47</td>
<td>27.1.47</td>
</tr>
<tr>
<td>1st Turn</td>
<td>8. 1.47</td>
<td>8. 1.47</td>
<td>25.2.47</td>
<td>25.2.47</td>
<td>25.2.47</td>
<td>14.3.47</td>
</tr>
<tr>
<td>2nd Turn</td>
<td>24. 2.47</td>
<td>24. 2.47</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Final sample</td>
<td>8. 3.47</td>
<td>8. 3.47</td>
<td>10.4.47</td>
<td>10.4.47</td>
<td>10.4.47</td>
<td>-</td>
</tr>
<tr>
<td>Period in days</td>
<td>96</td>
<td>86</td>
<td>81</td>
<td>80</td>
<td>77</td>
<td>-</td>
</tr>
</tbody>
</table>

| Original Material | 16. 3.5. | 15.3.21 | 15.0.0 | 15.0.0 | 25.2.5 | 15.0.0 |
| Lime             | -        | -        | 0.2.0  | 0.2.0  | -      | 0.2.0  |
| Sulphate of Ammonia | -    | -        | -      | 0.1.17 | -      | -      |
| Final weight of Compost | * 9.0.0 | *9.0.0  | 7.2.21 | 10.0.11 | 11.0.26 | -      |

* Estimated weights.

| Water added during the process (gals.) | 94 | 83 | 60 | 63 | 49 | 108 |

#### Chemical Analyses

##### (1) Percent Fresh Material

| Moisture | 59.1 | 64.8 | 69.9 | 75.6 | 68.8 | -   |
| Ash      | 21.5 | 17.3 | 18.0 | 10.3 | 18.3 | -   |
| Total organic matter | 19.4 | 17.9 | 12.1 | 14.1 | 14.9 | -   |
| N        | 0.87 | 0.81 | 0.48 | 0.63 | 0.65 | -   |
| P2O5     | 0.44 | 0.39 | 0.49 | 0.36 | 0.71 | -   |
| K2O      | 0.67 | 0.73 | 0.43 | 0.33 | 1.06 | -   |
| pH       | 8.3  | 8.4  | 8.4  | 5.2  | 8.4  | -   |

##### (ii) Percent Oven-dry Material

| Ash      | 52.6 | 50.1 | 59.8 | 42.2 | 52.2 | -   |
| Total organic matter | 47.4 | 49.9 | 40.2 | 57.8 | 47.8 | -   |
| N        | 2.20 | 2.34 | 1.58 | 2.58 | 2.07 | -   |
| P2O5     | 1.12 | 1.14 | 1.62 | 1.48 | 2.26 | -   |
| K2O      | 1.69 | 2.12 | 1.80 | 1.54 | 3.41 | -   |
| C/N ratio | 12.3 | 10.8 | 14   | 10.8 | 11.5 | -   |
| Apparent degree of Humification | 74.0 | 64.0 | *   | *   | *   | -   |

* No estimation due to shortage of hydrogen peroxide.

The 'Fertosan' mixture was examined by the Mycology Department. It appears to contain large and small bacteria, and nutrient media. The species of bacteria could not be determined.
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