ORGANIC MANURES*
WITH SPECIAL REFERENCE TO COMPOSTS

INTRODUCTION

OF the many soil constituents the one that most affects the agriculturalist in the tropics is, perhaps, that mixed collection of organic matter, spoken of as humus. It is usual to refer to tropical soils, especially those of volcanic origin, as having a very high inherent fertility. In reality the contrary is the case. What one sees under tropical forest is not the utilization of immense supplies of plant nutrients but the rapid turnover of a mediocre supply. When such virgin soil is brought under cultivation, the accumulated supply of nutrients, present largely in the humus, is exploited. During the first few years bumper crops are obtained but, sooner or later, the humus content drops to a low level and so do the crop yields. The physical nature of the soil too changes; it becomes less easily worked, its water-absorbing capacity is decreased and its liability to erosion increased.

True, a great deal of the nutrient requirements of crops can be met by means of mineral fertilizers but the physical character of the soil cannot be so improved. It is essential to increase the humus content of the soil by judicious organic manuring. Not only does humus improve the texture of the soil by cementing the ultimate soil particles together into complex crumbs, thus making it easier to work, improving its water-absorbing capacity and decreasing its liability to erosion, but experience has shown us that the utilization of mineral fertilisers is enhanced. In short the use of organic humus-producing manures prevents soil deterioration with the concomitant decrease in crop yield.

The utilization of organic manures, in the soil, depends upon the activities of the soil population. Everyone has heard that, but for earthworms, many temperate soils would be sterile and many must have seen them dragging leaves into the soil. The activities of termites in Africa cannot be overlooked, they are well-nigh ubiquitous. But, besides these comparatively large animals, there is an immense micro-fauna and flora whose activities are of much more importance. It is they who are responsible for the decomposition of plant and animal residues and the conversion of complex bodies into simple compounds suitable for absorption by plants.

The micro-population of the soil is extraordinarily rich. A pound of ordinary rich soil will contain from fifty thousand million to five hundred thousand million bacteria and about five hundred million other microbes.

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This enormous population requires food, which may consist of the complex compounds that are found in plant and animal residues, or of simple substances such as carbon dioxide and mineral salts. All, however, contain a high percentage of nitrogen; bacteria, for example, contain, on the average 10 per cent. Each group has its definite function and increases in numbers as supplies of suitable food become available. Perhaps the best way of obtaining a picture of their activities and how they affect organic manuring would be first to consider the simple courses of the nitrogen and carbon changes in the soil and then the changes that occur when organic matter is concerned.

In both plant and animal remains practically all of the nitrogen is present in the form of the complex protein compounds. These are acted upon by certain microbes, part being used to build up their own body proteins and part converted into ammonia. The ammonia may be used by higher plants but most is used by two groups of bacteria with the production of nitrates, part again being retained in their bodies. In the form of nitrates the nitrogen may be used by the higher plants or by other bacteria or it may be leached down into the depths of the soil. In water-logged soils or soils with very bad aeration, nitrates often are reduced by certain groups of anaerobic bacteria to free nitrogen—denitrification. Counter-balancing the effects of these are the efforts of several groups of nitrogen-fixing bacteria, which have the power of converting the free gaseous nitrogen of the air into compounds directly or indirectly assimilable by the higher plants. Some of these nitrogen fixers live free in the soil, others live in symbiosis with a number of the higher plants, notably the legumes.

The carbon cycle is much simpler. The compounds of this element serve as the sources of energy of the microbes. Some is locked up in the bodies of the microbes but the greater part is respired as carbon dioxide which mainly returns to the atmosphere to be absorbed again by the higher plants. A small part remains in the soil with some of the nitrogen in the resistant humus constituents.

When plant or animal residues enter the soil the matter is not so simple. The normal residues are always complicated mixtures of carbohydrates, modified carbohydrates, such as the lignified or woody tissues, fats and waxes, proteins and other nitrogen-containing compounds.

Another complicating factor is the varied solubilities of the innumerable compounds present. Microbes have no mouths and can only use materials in solution which can diffuse into their bodies. Many of the insoluble materials such as starch and some proteins, are readily dissolved by means of digestive ferments excreted by the microbes. Other compounds, *e.g*,, the woody fibres, are more resistant and are only slowly attacked by ferments. The soluble substances are first utilised, then the less and less soluble materials. The skeletonisation of a leaf lying on the ground under a tree gives a very fine picture of the successive attacks.

The soil microbes are very largely built up of protein, thus very large quantities of nitrogen are tied up in the their bodies. Carbonaceous material, speaking generally, is used mainly as a source of energy.

It has been found that for every one part of nitrogen used by the soil flora some 25-50 parts of carbonaceous material is used. In other words, unless the material contains about 2-4 per cent. of its dry weight of nitrogen its decomposition will require some other source of nitrogen, the available nitrogen of the soil.

Table I, adapted from Lyon, Bizzell and Wilson, shows the effect of adding to soil varying amounts of organic matter, supplying the same quantities of nitrogen, upon the nitrate content of the soil.

TABLE I

Treatment		Nitrogen Content	Nitrate Nitrogen
		Per cent.	mgm.
Soil alone	...	—	950
Soil + Oat Roots	...	0·45	207
Soil + Maize Roots	...	0·79	511
Soil + Clover Roots	...	1·71	924
Soil + Dried Blood	...	10·7	1,751

Although in each case was the same amount of nitrogen added, only where a material rich in nitrogen was applied, has there been an increase in available nitrogen, in all other cases the amount of available nitrogen has been reduced. This reduction in available nitrogen persists until the ratio between the carbonaceous material and nitrogen has been reduced by decomposition and utilization by the microbes, as a source of energy, to about 30 : 1, at which limit any nitrogenous compound, such as ammonia, will be utilized by the nitrifying bacteria.

During the decomposition of the carbonaceous material, carbohydrates, etc., a series of compounds, difficult to estimate, are produced, so, in investigation, carbon is used as the criterion and, instead of speaking of the ratio between carbonaceous material and nitrogen, the simple ratio between carbon (C) and nitrogen (N) is used, usually termed the C : N ratio.

It must not be thought that, because nitrogen has been used up to produce microbial tissue, it is permanently locked up. The life of a microbe depends on the food supply. As long as this is ample they increase in numbers, but as soon as it becomes restricted, many of them die and their bodies, with the nitrogen, are used by others. Thus, although plant residues may contain only a little nitrogen, this nitrogen may be used over and over again.

Certain portions of the residues, notably the lignins, constituting an important part of the woody tissues, are with difficulty attacked by microbes. These undecomposed parts, together with certain decomposition products, go to form humus, which itself is only slowly decomposed.

The bodies of microbes are not simply nitrogen and carbon compounds, they contain many other elements, important among which is phosphorus. This in our soils is liable to be deficient and, if conditions are favourable to rapid microbial development, there may be a temporary shortage of available phosphate in the soil. Here, too, phosphorus is not permanently locked up but is liberated on the death of the microbes and the decomposition of their bodies in a form readily available to plants. It is often observed in these laboratories, that a soil rich in humus, may on testing show but little phosphate but on destroying the organic matter large quantities are found. This phosphate has been held in organic combination and only becomes available to plants on decomposition of the compound.