

THE PART PLAYED BY ORGANIC MATTER IN SOILS*†

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The formation of residues of organic matter in the mineral fragments which are the products of the weathering of rocks is one of the landmarks in the production of a cultivable soil. It is in fact the most important landmark, for only when such organic matter is present can the products of weathering rightly be called soil. By this accumulation, agricultural soil is distinguished on the one hand from sand, and on the other from weathering products such as china clay. Thus it is that to a unique degree the acceptable properties of an agricultural soil are connected with the reserves of organic matter which it contains. The following is an attempt to condense into the space of a single lecture an account of the ways and means by which organic matter exerts this prepondering influence.

Soil organic matter results from the decomposition of living plants grown in or on the surface of weathering mineral. Starting with primitive forms, such as the green algae which can be seen for example as a thin film on rocky surfaces, plant pots and the like, a more and more complex vegetation is developed as time goes on, until in some such climax as forest with abundant leaf fall, a definite layer rich in organic matter is attained. All soils contain organic matter in varying stages of decomposition, but agriculturally, it is the partially decomposed mass which is important, particularly that portion forming a dark, amorphous substance, usually referred to under the loosely conceived name of humus. Humus is what is termed a colloid. The name is derived from the Greek word for glue, and was first used to describe this type of substance because the earlier discovered colloids had the property of stickiness quite well developed. As our knowledge of this type of substance has increased, more definite methods of diagnosis have become known, but for soil colloids at least this property of stickiness is still a general one. It is the proper-

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ties that humus has as a colloid which are responsible for one important aspect of humus as a beneficial substance in the soil. With this aspect, the effect of humus on the physical properties of the soil, I propose to deal first.

The importance of a good tilth in an agricultural soil is a point which there is no need to labour, although it is notoriously hard to define just what is meant by tilth. Soil in a good state of tilth works easily without being too open. It does not wash down and run in wet weather, nor bake and 'cap' in dry spells. It drains easily without parching; it does not become waterlogged. Now all these properties are affected to an enormous extent by the size of the particles of which the soil is made up and by the state of aggregation or packing in which they are found. This latter property is modified considerably by the presence of humus. In the first place, visualizing humus as a jelly like substance which coats the surfaces of mineral particles, it is obvious how it tends to bind loose and sandy soils. With stiff clay soils, soils that is with a considerable quantity of very fine particles, the effect is the opposite. The very intimate incorporation of humus with the mineral particles makes for the association of these particles in groups or crumbs which are less tenacious than an aggregate of clay alone would be.

A further beneficial effect is traceable to the colloidal property of imbibing considerable quantities of water. This action is accompanied by swelling, and the reverse action by shrinking. Such processes, alternating one with another, cause ruptures in the aggregates of soil particles, so that the conglomerations of soil crumbs are constantly altering, allowing of adequate aeration and the formation of minute drainage channels. The forces exerted in rupture and shrinkage are very great indeed. The actual rotting of a piece of plant material has a similar effect in that the volume of the humus-transformed substance is less than the original organic matter and leaves an air and drainage channel.

From what has been said it is evident that one cannot separate tilth effects from the question of the moisture holding capacity of the soil. A soil well supplied with organic matter can hold more water than a similar soil with-

out it. This refers to actual gross quantity, and in mineral soils such as have been considered, this is almost always an advantage. What is more it holds the water where it is wanted-in the upper layers of the soil. The idea of a mulch is a familiar one, and of the various forms of mulch, organic matter ranks high in efficiency. On stiff tenacious soils, where additional water might be regarded at first sight as a disadvantage, a very important effect occurs. Whilst increasing the water holding capacity, humus nevertheless raises the moisture content at which the soil becomes sticky. In other words mere increase in water holding capacity would be a disadvantage if the soil became sticky in so doing. But with an adequate supply of humus, the advent of this undesirable limit is postponed, and, coupled with a greater supply of available moisture, is the advantage of a more comprehensive range of moisture content under which the soil is workable. Two of the most striking examples of the effects we have so far been discussing are illustrated on the classical plots at Rothamsted.

Barnfield is the most tenacious field on the farm, and at mangold sowing in wet weather the soil runs and then cakes with consequent harmful effect on the young seedlings. The plot which has received F.Y.M. since 1856 is spared these disadvantages, so that even in the early stages of growth the plants come away more quickly, and have a healthier appearance.

The corresponding plot on the Broadbalk permanent wheat field shows in its 85 year records much less fluctuation in yield than any other owing to the stabilising effect of the organic matter on tilth condition and moisture content. Moreover the tile drain of this plot only flows after heavy rain. That drainage is adequate is shown by the state of the crop, but the organic matter in the soil can hold up the moisture without waterlogging, and a too rapid drainage is prevented.

A third aspect of the question is the effect of organic matter on the composition of the dilute solution in the soil from which the plant derives all its mineral food materials. There is an idea abroad that humus contributes largely and directly to the acidity of the soil, but this is a perversion of the actual case. Humus acts as a stabilizer in this case too, insomuch that it needs the release of a

much greater quantity of acidic substance or withdrawal of a much greater quantity of basic material in a humus soil to alter the degree of acidity than in a soil not so supplied. In the current phraseology of soil science a humus soil is a well 'buffered' soil.

Then with regard to the actual nutrient elements in the soil, and more especially those which are added as manures, a soil devoid of colloid material would be absolutely incapable of retaining them under the continued influence of drainage. Colloids have the power of absorbing such important elements of nutrition as ammonia and potash. The explanation of the manner in which this is done must be reserved for another time, but the mere statement of the fact shows how important humus is for a soil in this particular respect. Incidentally, it is due to this absorbing effect on soil bases that it is possible to counteract undue acidity by the addition of lime.

So far, consideration has been entirely confined to the humus content of the soil *ie.* organic matter which has reached a certain stage of decomposition. All the effects spoken of have been the result of those properties of humus which we have spoken of as colloidal. The actual processes of decomposition of raw organic matter are no less important for our consideration.

Whilst humus itself is not a nutritive substance as far as the higher plant is concerned, the products of the decomposition of organic matter represent the current account on which the plant draws for its supply of nitrogen. The action of bacteria and fungi in breaking down the complex substances of plant residues is a fact of everyday knowledge. The ammonia which is the final product of degradation is the starting point for other bacterial action whereby nitrates are formed from which the plant can benefit directly. The prime cause of this decomposition of organic matter by soil organisms is their search for energy producing substances. Just as our human stores of energy are replenished by our assimilation of certain food stuffs, the so-called carbohydrates, (sugar, starch), so the micro-organisms obtain their energy by breaking down the carbon-containing matter of the soil. At the same time as they obtain the necessary energy, they require nitrogenous food as we do, and so some of the nitrates which have been

formed as a by-product of other reactions are assimilated too, and revert in the bodies of the organisms to a form not immediately available to the plant.

There are, therefore, two opposing actions going on in the soil as a result of bacterial and fungal activity, one which breaks down to nitrate, and one which starting from nitrate builds up again. Eventually, the bacteria responsible for building up die and the breaking down starts again. The balance left by these processes is what goes to feed the crops and what is lost in drainage. If the building up process were absent, it is easy to see that in course of time all the nitrogen would become transformed into nitrates, and except for the crop's requirements, would be lost inevitably in drainage. Fortunately, as just indicated, a considerable portion of this is recapitalized.

The fact that when bacteria multiply as a result of an adequate supply of energy material, they lock up a definite quantity of nitrogen too, accounts for the fact that the ratio of the amount of carbon (energy material) to nitrogen in a soil is roughly constant, and has a value of about 10. This is an experimental fact of great importance, for, if a rich nitrogenous substance is added to a soil, what I have called the capital account is not benefitted unless a corresponding amount of carbon is added. On the other hand, if a rich carbonaceous substance is added, the bacteria will multiply and deplete the soil of nitrates in their attempt to provide adequate food for their multiplication. Such a thing occurs when unrotted straw is added to soils, a fact which was demonstrated many years ago at Rothamsted by the sudden decrease in crop when straw was ploughed in. Fortunately, this depletion of available nitrates is temporary, but is none the less serious.

The main point of the argument, however, is to show that whilst the continued supply of soluble artificials to a soil may at great expense supply enough nitrogen for immediate needs, the rest being lost in drainage, it does nothing to conserve nitrogen in the soil. Green manures on the other hand usually supply enough of both carbon and nitrogen to preserve the balance, and for that reason are of particular value. Experience in a variety of crops seems to show that a judicious use of soluble manures and organic matter does in fact give the best results. In this connec-

tion, manures like blood meal and castor cake must be ranked as relatively readily available for their carbon content is much too small to conserve the large quantities of nitrogen they contain.

To sum up, organic matter in the soil is an excellent stabilizer, preventing large crop fluctuation by ensuring good tilth, stable moisture relationships, retention of valuable nutritive elements, and a conservation of the capital supply of nitrogen, the most expensive and most easily lost of all crop requirements.