SOIL ORGANIC MATTER AND CROP ROTATION *

THE obvious importance of local factors — weeds, pests, diseases, labour costs and crop values — always tends to mask the more fundamental question of crop nutrition. Problems of soil fertility and crop rotations are inevitably complex, but it is suggested that in the tropics, and especially for cotton, they are not merely more directly important than in Western Europe, but also more amenable to experimental study.

The cotton crop provides abundant opportunity for loss of nutrient, for it needs cultivation at temperatures and moisture conditions under which soil organic matter is rapidly oxidised away. It provides no fodder or litter for stock and thus leads to unbalanced farming and soil exhaustion. In some of the older cotton areas the inevitable drain on the soil is met by heavy manuring by fertilisers, as in the Eastern cotton States of U.S.A., or through the residues of large cultivated crops, such as Egyptian berseem. Neither of these methods is practicable at present in most of the newer areas and some substitute must be found if stable systems of husbandry are to be attained. The soils start with very little organic matter, the oxidation processes in the soil are extremely rapid and the alternative rotation crops are so few that the agricultural problems can be clearly defined.

ASH CONSTITUENTS OF PLANTS

Cotton is grown successfully on such a variety of soils that it is unlikely that shortage of phosphate or potash will often prove to be a limiting factor, except in those areas, *e.g.*, South Africa, where almost all crops need phosphatic fertilisers. Attention may, however, be directed to one possible effect of rotation crops, especially leguminous ones, which is sometimes overlooked. In poor, light soils in countries of high rainfall, calcium and other bases are particularly liable to loss by leaching. It happens that in many soils of East and West Africa the surface soil is less acid, *i.e.*, richer in bases, than the deep sub-soil. Presumably the vegetation extracts basic material from the rapidly weathering rock and restores it to the surface during the decay of roots, fallen leaves and branches. Deeply rooting cultivated crops, especially leguminous ones, may be expected to have similar effects, for they are often rich in lime and phosphoric acid. Further, some leguminous crops, (*e.g.*, lupins) can utilise insoluble compounds, such as apatites of mineral phosphates, which are almost useless to cereals and many other plants.

One soil scientist — Professor Williams of Moscow — has even gone so far as to consider the most important contribution of the leguminous plants of leys and grasslands to the maintenance of fertility to be the

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restoration of calcium to the surface horizon of the soil. This may be an exaggeration, but it would be unwise to neglect the mineral elements in considering the effects of crop residues.

SOIL ORGANIC MATTER

All soils contain organic matter in all stages of decomposition from living plant and microbial tissues to amorphous colloidal humic materials. Unfortunately there are no satisfactory methods for fractionating or analysing this complex mixture of materials. Even the determination of the total amount of organic matter presents difficulties, for its carbon and nitrogen contents are not constant. In general, the ratio of carbon to nitrogen in the soil organic matter tends to fluctuate around 10:1. Some soils contain notable amounts of such inert materials as charcoal and coal. The total amounts of carbon and nitrogen tend to increase in grassland and forest soils, even in the absence of leguminous plants. Under cultivation they fall at rates which depend on moisture, temperature, and aeration. One-third of the total carbon and nitrogen of the soil was lost in fifty years of continuous cropping with wheat or barley on the light sandy loam of the Woburn Experiment Station. In the tropics the losses are naturally much more rapid. Except where the total amounts of organic matter are small and rates of change extremely rapid, it is almost impossible to follow by chemical analyses the annual changes in the total carbon or nitrogen of field soils. It must, however, be remembered that such processes as nitrogen fixation, denitrification and losses of nitrogen by leaching or as gas cannot be demonstrated in field soils without these difficult analyses. The presence of micro-organisms capable of affecting any of these changes is no evidence that they are in fact playing any considerable part in the production or loss of potential plant food; most of them may be found in any reasonably fertile soil.

It is now well known that green leaves, roots and other materials which are relatively rich in protein, decompose in the soil extremely rapidly with the liberation of much ammonia or nitrate. Such materials supply available nitrogen almost as rapidly as the usual nitrogenous fertilisers and should be treated with similar caution in soils liable to extensive leaching. We have argued that the failure of vetches as a preparation for winter wheat at Woburn is to be explained in part by rapid nitrification and loss during the lengthy periods when the soil is bare or carrying only a small crop. It may be that the apparent unimportance of the organic matter in the tops of leguminous plants in some of the Nigerian experiments results from similarly rapid losses when the tops are buried in the soil.

Cellulosic materials decompose very rapidly provided that sufficient nitrogen is forthcoming from other sources to meet the needs of the micro-organisms concerned. Straw and woody materials decompose more slowly and continue for considerable periods to use up the available nitrogen of the soil.

The effects of crop residues on the production of available nitrogen in the soil may generally be interpreted in terms of the composition of the materials added, the weather conditions, and the aptitude of the soil to store water and soluble nutrients. The most vital factor of all is the timing of the operations and this can be studied satisfactorily only in specific field experiments. It must never be forgotten that, in soil capable of rapid oxidation and liable to leaching, all cultivations in preparation for a new crop or in burying the residues of an old one greatly accelerate the decomposition and the risk of loss. Poor green manure crops can rarely be useful, for the inevitable losses may easily exceed any benefit from the material added.

AVAILABLE NITROGEN

Although nitrates occupy a unique position in the nitrogen economy of the soil, it would appear that undue attention is often given to the nitrate content of the surface soil. There are many reasons why the amount of surface nitrate cannot be regarded as a good measure of available nitrogen. Nitrate owes its unique position to the fact that it is the only stable compound of nitrogen which is not absorbed by the colloids. It is free to move up and down with the soil water and it is readily leached out. When rapid evaporation follows heavy rainfall or irrigation, the capillary rise of water from the saturated sub-soil carries nitrate to the rapidly drying surface where it may remain out of the root range of the crop. Thus, the ridges of the Sudan Gezira cotton soils often have high nitrate contents when the crop is obviously suffering from nitrogen shortage. In Queensland it has been found that in six to eight years cotton soils lose much organic matter and become markedly less permeable to water; the nitrate contents of the surface soil are actually higher than in the more fertile new soils. Here also, it appears possible that the surface soil remains sufficiently wet after heavy rains to allow capillary rise of soil water and surface concentration of nitrate.

In open soils nitrates are obviously liable to be leached away beyond the range of plant roots and it is generally recognized that fallowing or frequent cultivations may be very wasteful. In heavier soils with good soil structure, *i.e.*, with abundance of drainage channels and cracks, the gentle seepage of soil water allows nitrate and other soluble materials to diffuse into the lumps of sub-soil. Heavy rains drain away chiefly through the main channels and extract the accumulated salts only slowly.

Even without leaching or surface concentration the amount of nitrate in a soil is merely a balance between production and removal by plants and micro-organisms. Soils with large reserves of plant residues may contain little more nitrate than less rich soils, but they will continue to produce ammonia or nitrate for much longer periods.

SOIL WATER AND SOIL STRUCTURE

Under almost all conditions of soil and climate it has been observed that soils with large amounts of plant roots, organic manure, or humus absorb and retain water better than those which have lost much of their organic matter by frequent cultivation. The opposite extreme of impermeable and eroding soils is only too well known in many parts of the tropics where clean weeding has been practised. From experience and current teachings in countries with temperate climates, some tropical workers are inclined to assign the beneficial effects of cover crops, root residues and manures to the humus they provide. But most cultivated tropical soils contain so little humus and need such frequent additions of fresh organic matter to maintain this modest amount, that it seems more profitable to neglect the hypothetical effects of the humic material and to focus attention on the growing plants, the added materials, and their immediate decomposition products, when considering the physical effects as well as the more purely chemical ones.

It seems important to ascertain whether added organic manures are as effective as the roots of growing plants in draining and aerating the soil and opening up the sub-soil.

SOIL PROFILES AND SOIL CHARACTERISATION

In attempting to apply the results of experiments to other soils, either in the same district or more generally, it is essential to obtain some specification of the soil conditions. Too often it is assumed that this must require elaborate physical and chemical analyses. It may encourage agronomists and other cotton workers, who are unable to obtain the collaboration of a soil chemist, to know that the experience of soil surveyors and pedologists in all parts of the world has shown that the first and essential step in soil characterisation is to secure accurate description of the visible characters of soil profile down to and somewhat beyond the root range. Many cotton workers have occasion to explore the roots of plants or have the facilities of cheap labour for digging special pits. They should never miss suitable opportunities for describing, in great detail, the colour, texture, structure and thickness or depth of the successive horizons of the soil profile, as seen in a section. They need not worry about trying to fit their observations into any of the current schemes of soil classification, for all of these are purely tentative and deal with soils of temperate climates, where little cotton is grown. The descriptive soil data obtained in the cotton areas will be useful in extending methods of classifying tropical soils, but they will be even more immediately useful in interpreting the results of rotation experiments in terms of the nature of the soil and sub-soil, the depth of root range, and the water penetration and retention.