Original Articles.

The Soil.

Some Present Day Conceptions.

F. A. STOCKDALE, C.B.E., M.A., F.L.S.,

Director of Agriculture, Ceylon.

MOST agriculturists in Ceylon, when one talks about soils, refer to general terms to a classification which includes cabooky soil, clay soil, gravelly soil or sandy soil. An examination of soils as one passes through the country indicates clearly the above-mentioned classes into which the soils can be readily grouped and there are considerable stretches of the different types. A further examination of the various quarries worked by the Public Works Department shows, in some measure, how some of these soils have been formed. They are, generally speaking, the products of the decomposition *in situ* of the gneiss and quartz schists. From solid grey-blue gneissic rock one passes, if one proceeds upwards, into layers—often distinctly defined—where the rock shows signs of decay and of changed colour. Higher, the rock is further decayed and disintegrated and shows some fissures which are filled with earth and stones. Higher still, the disintegrated rock is in a state of decomposition and has crumbled; a greater admixture of earth and stones has taken place and above this we come to what is known as the sub-soil represented generally in Ceylon by a sticky reddish clay containing stones or portions of decomposing rock in greater or lesser quantities. Above this sub-soil is the soil proper—distinguished by its darker colour as the result of admixture with decaying vegetable matter from the plants which are or have been growing upon the surface.

The formation of such soils can readily be studied in quarries and in some road cuttings. In certain places the unchanged rock

comes close to the surface whilst in others it is frequently at considerable depths. Varying degrees of decomposition and disintegration can be found and several different types of rocks can be distinguished.

Under tropical conditions the formation of such sedentary soils is brought about mainly by two agencies. The chief of these is water, which dissolves some of the carbon dioxide from the upper layers of soil, and becomes an effective solvent of the complex minerals which make up the rock. The roots of plants which penetrate into cracks and fissures in the rock in the pursuit of water, as they grow exert a pressure which widens the cracks and later when they die leave behind them a channel for percolation, constitute the second agency of disintegration.

All soils are not however sedentary. They are often moved by water and often deposits of gravel, sand and silt are caused as the result of this transportation. Examples of such soils caused by transportation by water are seen in Ceylon. Similarly sandy soils are liable to be blown by the wind and give rise to drifts. Examples of such sandy drifts can be seen in the Jaffna peninsula and in certain other areas in the dry zone.

The above brief outline has been given in order to indicate the origin of the mineral portion of our soils. It is not proposed at this stage to deal with the chemical composition of such mineral portions but it is necessary to indicate that such portions of soils consist of particles of various shapes and sizes and that they are classified by mechanical analysis into gravel, coarse and fine sand, silt, fine silt and clay. These exist in varying proportions in different soils and in accordance with the variations in these proportions are soils classified.

The Organic Matter.

From the agriculturists' point of view however the most important constituent of the soil is its organic matter, and the loss of organic matter in soils under tropical conditions is rapid and is that part of a soil to which agriculturists in the tropics should pay special attention. In the writer's view, the success and permanency of permanent crops in the tropics are bound up with the maintenance of the organic matter in the soil. This organic matter arises from the decomposition of plant tissues derived in the main from previous generations of plants. Under forest

conditions, falling leaves, and decaying logs of previous generations of plants provide a steady accumulation of organic matter. These fallen leaves and the short-lived plants or grasses which have died are attacked by numerous micro-organisms in the soil and considerable quantities of plant food are set free. Part of these plant residues are changed into a blackish substance known as humus which assists the mineral particles of the soil to stick together and has the power of helping the soil to hold water and valuable manurial substances.

Moisture.

Soils always contain a certain quantity of water. The percentage varies with the climatic conditions. According to views held until recently this water was supposed to be surrounding the mineral grains in the form of thin films. This view no longer holds and is being discarded. Soil grains, which are of varying sizes, are coated with a colloidal jelly which is made up of silica, oxides of iron, aluminium, calcium, magnesium, etc. The composition of this jelly is complex. It contains organic substances as well as mineral. It has the power of binding the soil particles together and of holding water. In the absence of sufficient colloid, the soil is unable to retain enough water for the crop or to adhere together sufficiently to prevent being blown by the wind, but if the colloid is in excess the soils become sticky, liable to water logging and unsuitable for root development.

Micro-Organisms of the Soil.

The soil however is not a dead mass, but is literally full of life. The biological population of the soil consists of bacteria, fungi, algae and protozoa. The bacteria are the smallest and most numerous and from counts made at the Rothamsted Experiment Station number approximately 67,500,000 per gram of soil. These bacteria together with the fungi, decompose the residues of dead plants changing them into water, carbonic acid and plant food. The fibrous parts of the plants are also decomposed and give rise to humus. The role of the algae in the soil is not yet known, but they compete with the plant for food whilst certain protozoa feed upon the bacteria and keep down their numbers.

The latest views in regard to the role of the micro-organisms in the soil are given by Russel * as follows:—

" Two views have been held of the general nature of the soil population. It was at first thought that the population is formed of specialised groups of organisms, each engaged in carrying out a certain part of the decomposition of plant residues or the manufacture of plant food. As in a well-managed factory there was assumed to be division of labour, each organism carrying out its allotted task. The groups were known as "Ammonifying Organisms," "Denitrifying Organisms," "Nitrifying Organisms," etc. Methods were developed by which they could be picked out of the soil and studied, and these methods gave some remarkable good results and revealed much about the changes going on in the soil.

"The second and later idea is that organisms carry out the various decompositions for the purpose of obtaining food and energy for themselves: a few are restricted to one process only, and a few can bring about changes that most others cannot perform, but the greater number of the organisms can decompose many substances and effect sometimes one change and sometimes another, according as they can best obtain the energy and nutrients they need. This new conception has made the study of the soil organisms much more definite and interesting.

"The application of modern methods to the study of the soil organisms has led to several conclusions of great interest.

"First of all, the composition of the soil population differs remarkably little in the different parts of the world. The characteristic groups of algae, bacteria and especially protozoa are the same in the Arctic as in temperate and tropical climates; there is nothing to correspond with the geographical distribution of plant and animal groups. The explanation lies partly in the nature of the organisms themselves, partly in the soil as an abode for them. Micro-organisms are probably less sensitive to environmental conditions than plants or animals. Vital conditions at a depth from two to seven or eight inches below the soil surface vary less than on the surface itself; the temperature is more even and the atmosphere is almost always saturated or nearly so with water vapour; there are no marked differences in degree of humidity such as influence the distribution of animals and plants.

" So far as present knowledge goes, the soil organisms are living right up to their income in the way of food and energy supply. Any increase in available organic matter capable of supplying energy leads at once to a corresponding increase in activity of the whole population and also in numbers of the individual groups of organisms; this is accompanied by an absorption of ammonia and nitrate from the soil to supply them with nitrogen. Of two plots, one supplied with farmyard manure and the other not, the unmanured

* Sir E. J. Russel in "Soils and Manures" in a special report to the Royal Agricultural Society of England, 1926.

plot always contains fewer organisms, not only a smaller total population, but fewer of every kind yet enumerated.

" The nature of the organic matter added to the soil greatly affects the amount of ammonia and nitrate present. If the organisms in obtaining their energy consumes more ammonia and nitrate than they produce, the balance obviously has to come from the soil, which thus becomes impoverished. On the other hand, if the material attacked is sufficiently nitrogenous, they produce more ammonia than they need. In general, the line seems to be drawn at about 2 per cent. of nitrogen. If organic matter containing less than this is added, it stimulates the soil population to multiply, but does not give them sufficient ammonia for their requirements, and so they take ammonia and nitrates from the soil. A manure of this kind, therefore, does the plant no good, although it is organic. But if more nitrogen is present the organisms produce ammonia in excess of their requirements; this accumulation of ammonia and nitrates in the soil steadily increases with the percentage of nitrogen in the material decomposed. This explains the well-known fact that organic manures poor in nitrogen are of little use.

" The organisms in the soil do not appear to work independently of each other. They interact in two opposite ways. Competition is severe, but joint action and symbiosis are common. Winogradsky and Beyerinck have both discovered instances of an aerobic and an anaerobic organism living together to the mutual advantage of both. The bacilli that fix gaseous nitrogen from the air—one of the most important changes in the soil—work better when in company with other organisms than by themselves. Joint action—perhaps one should more strictly say consecutive action—is the normal occurrence in the soil. The by-products or metabolic products of one organism, if they are anything more complex than carbonic acid and water, are the starting-point for activity of other organisms; and this activity is continued by one or other of the population so long as there is any potential energy of oxidation in the products. There is no evidence whatsoever of the slowing down of micro-organic activity in the soil by accumulation of products corresponding to the slowing down in cultures; no " bacteriotoxins " can be detected and nothing to show that the " autointoxication " of the pure culture ever occurs in the soil. The products that might have these effects are quickly attacked by other organisms; the final products are carbon dioxide and nitrates, and both these are easily washed out from soil."

The most important bacteria from Ceylon's point of view are the organisms which occupy the nodules of leguminous plants and the Azotobacter which fixes gaseous nitrogen from the air. Recent laboratory experiments made by the Chemical Division of the Department of Agriculture indicates that markedly appreciable amounts of nitrates are formed under Ceylon conditions and the advantages of soil cultivation are made clearly evident.

Aeration.

The maintenance of satisfactory chemical changes and normal bacterial changes in a soil is dependent upon its proper aeration and the full significance of soil-ventilation as it might be called is now being recognised. The pore spaces in the soil between the different particles require to be replenished from time to time with supplies of oxygen and the excess carbon dioxide must make its escape. Unless this is provided for, biological activity necessary for breaking down the organic matter is retarded and valuable nitrogen may be set free as gas and lost to the soil. The effects of the very heavy rains of the monsoon are frequently observed on the plants themselves, and not uncommonly leaf shedding is seen. These effects are due to the cutting off of the air supply to the soil and in all badly aerated soils root development is poor and often shallow. The fixation of nitrogen by Azotobacter requires constant aeration and it is certain that an important need for the satisfactory growth of young clearings is adequate soil-ventilation. This is provided by cultivation and by proper attention to drainage. It is essential for successful crop production.

Erosion.

Sufficient has been said above about the formation of soils to indicate the importance of maintaining the fertile surface soil. This represents the main capital asset of the plantation and must be protected. A great impetus has been given to this question of the prevention of the loss of this surface soil in the past few years and most estates are giving careful thought to their several problems. The provision of silt-pits in surface drains is becoming more and more general and for new clearings systems of terracing are being evolved. There is no doubt that this question is still the most important one for Ceylon's agriculture and every effort should be concentrated on all sloping lands to checking the run-off of the rainfall, to assisting absorption and to preventing or, at least, decreasing erosion. There is little doubt that if attention had been given to this problem years ago the expensive manurial programmes now essential for maintenance of maximum growth and vigour would not have been necessary and there would have been less loss to crops from insect pests and fungus diseases.

(*To be continued*)