SOILS AND MANURES.

THE SOIL IN RELATION TO CROP PRODUCTION.

FACTORS WHICH DETERMINE FERTILITY.

The fertility of a soil depends only partly on the amount of plant-food (potash, lime, phosphoric acid and nitrogen), and partly on the power the soil possesses of making use of these compounds. We have to take into account the other characteristics which induce to fertility, especially the power possessed by the soil of changing the condition of the plant-food.

The soil is not an inert mass of material, out of which the plant picks whatever material is present for its nourishment, and, having exhausted that, dies. When we talk of changes that take place in the soil, we must realise that the changes are constantly going on, that the material of which the soil is composed is continually changing, that the growth and decay of the plants, the movements of underground animals and of minute organisms, the fall of rain, the evaporation of moisture, alterations of temperature, of night and day, of summer and winter, even alterations of atmospheric pressure, the passing of clouds, and countless other phenomena of which we take no heed, or whose action we do not yet fully understand, all these agencies produce an incessant series of changes within the soil. When we add to these the changes produced by human agencies—by cultivation, by ploughing, liming, manuring, etc., etc.,—it will be seen at once that a mere statement of the amount of fertilising material in the soil, even if we could say how much was actually available for any particular crop, is not all that is wanted if we are to judge of the soil's fertility.

The fertility of a soil depends then, in the first place, upon the presence of a sufficiency of plant-food, and, secondly, upon certain physical characteristics, possessed more or less by all soils, which effect the splitting up of the mineral ingredients and nitrogenous matter in such a way as to render them available to plants, as well as regulating the supply of water, warmth, etc.

Of these physical characteristics the most important are:—

The texture or porosity of the soil. On this characteristic depends a large number of the properties conducive to fertility.

By the porosity of the soil is meant the fineness and the number of its pores. We must distinguish between this and permeability to water; a coarse sand, for example, is permeable to water, but possesses properties exactly opposed to those of a porous soil. Humus soils are especially porous. On the fineness of texture depend the following characteristics:—

The capillary power, by which is understood the power of imbibing water. This property maintains a continual circulation of water within the soil, and consequent aeration. It is, moreover, largely through the agency of this circulating water, which is charged with carbonic acid and different salts, that the mineral and, in a less degree, the organic matter of the soil is rendered available for plant-food, and presented in solution to the plant.

The capillary power of a soil depends very largely upon the fineness of its texture. The nearer the texture approaches that of a sponge the greater will be its capillarity.

Humus has a very high capillary power, which is not possessed to any extent by either coarse sand or clay.

The capacity of the soil for water is also of special interest, and depends partly upon its porosity and partly on its content of organic matter. Peaty and humus soils, other things being equal, have the highest capacity for water, followed in order by marls, clays, loams and sand.

The phygroscopic power—that is, the power of attracting water vapour—is of practical importance, in that it prevents undue evaporation, and prevents the soil from becoming parched up. It also serves as a guide to the absorptive power for other gases. This property, like capillarity, is due entirely to the fineness of texture, and the order is the same—humus, clay, loam, marl, sand and coarse sand.

The absorptive power of the soil for salts is another factor of very great importance in determining the fertility of a soil. This power which soils possess of removing saline matter from solution and retaining it within their pores is, due partly to the chemical nature of the soil, resulting in a chemical interchange of basic constituents, and partly to its mechanical structure, the fineness of its texture, substances such as humus and clay possessing the power in a remarkable degree.

NITRIFICATION.

We now come to the most important property possessed by soils as affecting their fertility and, at the same time, the most obscure, namely their power of nitrification. This property depends upon a number of points on some of which our information is not very clear.

From what we know of the process of nitrification, we can lay down with tolerable certainty the following conditions as being favourable to the process:—

We must have free access of air, and moisture, a certain degree of warmth, the presence of nitrogenous organic matter prone to oxidation (represented by humus). The presence of reducible mineral matter, such as sesquioxide of iron or metallic sulphates, is also favourable. A sufficiency of basic substances to combine with the nitric acid appears also to be advantageous to nitrification.

Putting on one side the bacteriological aspect of the phenomena involved, we shall find that the formation of nitrates within the soil is due primarily to oxidation, that within certain limits the power of oxidation which the soil possesses is also the measure of its nitrifying power.

We are, therefore, justified in assuming that a soil will be most favourable to the development of the nitric ferment which combines the following characteristics:—

1st.—A proportion of humus

2nd.—Warmth

3rd.—Provision for free access of air and of moisture (these depend upon its porosity, and are determined by its capillary power).

4th.—Good drainage, to prevent stagnant water accumulating.

5th.—A certain proportion of basic substances.

These conditions are more fully discussed elsewhere, but it will be seen that, beyond the presence of certain mineral and organic matter, the conditions favourable to nitrification are those whose presence otherwise indicates fertility—namely, fineness of texture and absence of excessive water. If the capillary power of a soil is low, it indicates an unfavourable condition of nitrification.

It has been stated that the presence of nitrates in the soil assist in rendering soluble the potash in such insoluble combination as felspar, which is an additional mode by which the nitric organism promotes fertility.

Provided, then, that the condition of the soil, as indicated by the physical properties above enumerated, is favourable to the metabolism of plant-food, its fertility will depend upon the amount of that plant-food, and it is immaterial whether that food be now in a soluble state or not. If the mineral and nitrogenous matter are present in sufficient quantity, and the soil possesses high absorptive capacity, high capillary power—in short, is of good texture, and possesses the conditions conducive to nitrification—it may be fairly expected to prove a fertile soil; and, in cases where one or more of the conditions conducive to fertility are absent, we may look to improved methods of cultivation to attain that fertility.

The above considerations lead us to attach special importance to two factors in particular besides the chemical nature of the soil. One factor is the texture of the soil, its porosity, and the second is the amount of humus or decaying organic matter it contains.

It may be worth to study these two points a little more in detail.

TEXTURE OF SOIL.

We have seen that the texture is of first importance in determining the fertility of the soil. We will now discuss some of the conditions which affect the texture and some of the means to be adopted to promote the desired porosity of texture.

RELATION OF TEXTURE TO MOISTURE.

The ideal condition of the soil as regards moisture is obtained when the soil contains about half the amount of water which it is capable of holding.

For example, a fairly heavy clay soil will have on the average a capacity for water of about 40 per cent.—that is to say, 100 lb. of such soil will contain, when fully saturated with moisture, about 40 lb. of water. It is generally agreed that the amount of moisture most favourable to plant growth is something under half this amount, namely, about 18 per cent. If a much larger proportion of water exists than this, the interstices of the soil are filled with water instead of air, conseqently there is a deficiency of oxygen, which we have seen is one of the prime agents in promoting chemical action within the soil. The soil becomes what is called water-logged, and the chemical action which we have recognised as essential to fertility is at a standstill. The roots of the plants, moreover, are immersed in water.

The condition of things in a soil containing the proper amount of water, and in good tilth, is pretty much as follows:—The minute grains of which the soil is composed do not form a compact mass, but the intervening spaces are so small that they act as capillary tubes, of the same nature as the pores of a sponge or the little tubes of an ordinary wick, and their effect upon the water present is exactly the same as the bundles of hollow tubes in the wick—that is to say, they draw the water up by the attraction of the sides of the tubes. Each grain of the soil will be then surrounded by a thin film of water, which in its turn encloses and surrounds small bubbles of air. (In the case of a water-logged soil, these bubbles are driven out, and there is little or no air in the soil). In and out amongst the grains of soil the plant pushes its roots and its root-hairs in search of food and moisture.

If the above rough description is at all clear it is obvious that the water in the soil is continuous—that is to say, a sufficiently minute organism could pass through the entire soil in the water, without ever having to touch a particle of soil, or pass through a bubble of air. The result of this is that, supposing a particle of water be removed at any point, either by evaporation at the surface or by absorption by means of the root-hairs, its place is at once taken by adjacent water, and the whole of the water in the soil is at once set in motion until equilibrium is again restored. It follows from this that a crop with well-developed roots is itself an important factor in retaining moisture within the soil, for, as the water is absorbed by the root-hairs at any point and circulates through the plant, its place is taken by adjacent particles of water, so that a steady flow of water is set up towards that point.

The evil effects of too much moisture, which cannot get away, have been already mentioned. In addition, it is to be noted that this is one of the most common causes of sourness in the soil. Sourness—that is, the formation of certain acids within the soil—is directly due to the absence of air and oxygen, and can be remedied by the free admission of air, as by turning over and exposing to the atmosphere.

To prevent this accumulation of water, the remedy is to drain. In many cases where it is due to the presence of a stiff clay subsoil, through which the water cannot penetrate, subsoiling is resorted to; but, it is also possible to have too little water in the soil, with the result that the crops wither and die, and this takes place when the evaporation equals or exceeds the absorption by the roots. Plants absorb water only through their roots and root-hairs.

EVAPORATION.

The soil-water evaporates in two ways. The water absorbed by the root diffuses throughout the cell-system of stems and leaves, and evaporates through the breathing-pores of the leaf. Water is also lost by evaporation from the surface of the soil.

Both kinds of evaporation are increased by high temperature, dryness of the atmosphere, or a high wind—that is to say, evaporation is most rapid in hot, dry weather and a windy day; it is slowest in cool, moist weather and calm air.

The advantage of shelter in the shape of trees is, therefore, quite obvious as a means of cooling and moistening the air and breaking its force and thus preventing too rapid evaporation. It is, unfortunately, universally ignored in South Africa, where every tree is religiously "cleared" and the crops protect themselves against drought as best they can.

I do not know of any other method for checking the evaporation from the leaves which has been successful, though one or two have been suggested.

With regard to the evaporation from the surface soil, the case is different. Evaporation from the surface can be checked by mulching. A covering of leaves or farmyard manure or any other form of mulch, protects the surface-soil from the heat and the dry winds which cause rapid evaporation, and prevent the too great loss of moisture; or the same result can be obtained by hoeing or stirring the surface-soil, which has the effect of breaking or widening the capillary tubes at the surface, and by this means preventing the upward motion of the water, for a time at least, and until the water has found out the new channels. Hoeing, therefore, which is generally practised for the removal of weeds, has another equally beneficial action, and it should be done, even where there are no weeds. The above remarks show how important a matter is the texture of a soil in its relation to moisture, the ideal soil being of a fine tilth, from which excessive moisture drains readily away, in which there is free movement of air and water, and in which too rapid evaporation is checked.

HUMUS.

Closely connected with the soil's texture and its consequent relation to moisture is its content of humus. Humus is the black or brownish matter in the soil produced by the slow decay of organic matter, whether of animal or vegetable origin. It is not a definite chemical compound, but a mixture of a number of different compounds, the nature of which varies, both with the original matter and with the age of the product.

Over that considerable portion of arable land on which the rainfall is limited or uneven, the need of retaining within the soil whatever moisture is received as rain is one of paramount importance in the treatment of the land. The maintenance of the soil's fertility in these areas becomes largely a question of conserving this sometimes scanty supply, and soil treatment having for its object suitable means of maintaining the most favourable conditions as to moisture will claim the most serious consideration of the farmer.

As the land taken into cultivation gradually extends so as to include more of the area within the belt of reduced rainfall and approaching to semi-arid conditions, this question of the conservation of soil moisture becomes of increasing importance.

It far exceeds in importance the question of manuring, and it is safe to say that unless the conditions as to moisture are satisfactory the application of manure is not likely to be of any benefit, and the money expended on their use is practically thrown away.

Apart from the question of cultivation and drainage, the maintenance of the best conditions as to water within the soil depends to a very large extent upon the presence of humus. Humus, which is derived from the gradual decay of animal or vegetable matter within the soil, is one of the most important of the soil's constituents, and any great variation in its amount affects profoundly the value of the soil for agricultural purposes.

FUNCTIONS OF HUMUS.

The presence of humus in the soil increases the fertility in the following ways:—

In the first place it absorbs and retains moisture in the soil, and prevents surface evaporation. A surface soil, fairly rich in humus exercises much the same influence on the underlying soil as does a mulch of dead leaves or other vegetable matter. During dry spells, and under the influence of the hot winds usually prevalent under such conditions, the loss of moisture from the soil by surface evaporation is enormous, and in soils destitute of humus this loss is so rapid as to result in the drying up of the soil and the wilting of the crops. The final result of such conditions is the formation of scalded spots and the complete removal of the fine surface soil in the form of dust.

The humus in the soil is the ingredient which is most subject to alteration and destruction, and under dry conditions it is more or less rapidly destroyed. As soon as it has lost its moisture and become dry it is rapidly burnt out by the combined action of sun and air. So that it is exactly in those circumstances where its presence is most essential that it is most liable to destruction, and the necessity for renewing it most urgent.

The presence of humus in the soil also tends to improve its texture, lightening and loosening it, and preventing compaction of the surface, so that it is of special value in the amelioration of stiff soils.

It is the principal source of nitrogen in the soil, and by its decay under the influence of soil organisms, ammonium salts and nitrates are produced, which are the forms in which this important element is assimilated by the plant. It is of interest to remember that the humus or arid or semi-arid regions is richer in nitrogen than that of the moister districts. This is a point of great importance with reference to the potential fertility of these soils. In point of fact from a variety of causes acting together, the soils of the dry climates are richer in plant-food of all kinds than are the soils in regions of greater rainfall, consequently nothing but the absence of water prevents these from being extremely reproductive. There is, therefore, no problem which exceeds in importance that of retaining in soil the little moisture that it receives, and any operation that succeeds in arresting even partially the unavoidable loss of that moisture deserves the highest consideration.

METHODS OF SUPPLYING HUMUS.

There are three ways of supplying humus to soils in need of this constituent, namely, by the application of generous additions of farmyard manure (in cases where this is available), by the application of compost manure, and by green-manuring, or the ploughing-under of a quickly-growing green crop (leguminous for choice).

(a) FARMYARD MANURE.

Except in the dairies or such farms on which the animals are stall-fed the material known as farmyard manure is nothing more than the solid excrements of animals, and does not contain either the urine or the vegetable matter used as bedding which is the characteristic of farmyard manure made and used in Europe and colder countries.

Owing to the absence of vegetable matter such manure has very little value in the formation of humus, and it is probably more economically used in the compost heap.

(b) THE COMPOST HEAP.

The compost heap is a most valuable adjunct to the farm, and it is a very great pity that it is not more frequently to be found.

A heap or pit can be made very economically, and is of special value in that it utilises all sorts of vegetable and animal refuse, which would otherwise be wasted, and converts it into a valuable manure, rich in organic matter, and eminently suited for soils low in humus or subject to droughty conditions.

The principle of the compost heap is the fermentation of easily-decomposed vegetable material in the presence of earth and lime. It is not only substances like peat and straw, which form the usual basis of compost heaps that are thus decomposable, but almost every kind of organic substance, both of vegetable and animal origin, can be thus composted. Dead leaves, bush scrapings, saw dust, weeds, tops and stalks of vegetables, as well as bone and animal refuse, can be treated in this manner. In the case of animal refuse the operation is much slower, and substances like bones should be first crushed. It is also important to be sure that animal refuse so treated is not derived from a diseased source.

The best way of making and maintaining the compost heap will depend largely upon local surroundings.

As a general method of procedure the following will be found satisfactory: Make a heap with alternate layers of earth, refuse and lime. Under the term refuse is included all the refuse material of animal or vegetable material mentioned above. Cover the whole with a layer of earth. When a sufficient quantity of refuse is again collected place it on top of the heap and cover with a layer of lime, and lastly of earth, until the heap is three or four feet high. The heap should be kept moist, and for this purpose all refuse water from the house, slops, urine, etc., should be added. The heap may be conveniently watered by making a hole into the interior and pouring the liquid in. The outer covering of earth has the object of absorbing any ammonia which is evolved in the process of fermentation and by the action of the lime.

When the heap has been prepared it must be left to itself to ferment for some time. Probably a few months will be sufficient unless very refractory substances, such as bone, etc., are present.

In a few months' time it should be well forked over and another layer of lime and finally of earth should be added. In the course of another month or two it should be ready for use and you will have provided yourself at a very slight cost with an excellent manure, rich in humus, and will have utilised for the purpose a great amount of refuse material which would otherwise be lost or burnt. When refuse material is burnt, the ashes, though still possessing manurial value on account of the lime and potash and phosphates they contain, are of incomparably less value than the original substances out of which they are derived, owing to the absence of humus material and of nitrogen, both of which have lost in the process of burning.

Instead of a heap the compost may be conveniently prepared in a pit. In either case the bottom should be cemented, or so drained that the liquid escaping from the mass can be collected and returned to the compost.

It will be found advantageous to prepare a second heap while the first one is ripening and being used. It will also be found that if it is desired to use more concentrated fertilisers, such as superphosphates, potash, and ammonium salts, these can be mixed with advantage with the compost manure before being applied to the land. Used in this way they will be in less danger of leaching away and will be of greater benefit than if applied directly to the land.

(c) GREEN-MANURING.

Amongst the most effective methods of supplying humus to the soil and increasing its fertility is the practice of green-manuring—that is, the ploughing-under of a green crop. The beneficial action of this operation is a two-fold one; it enriches the soil, in the first place, by supplying it with a considerable proportion of readily-available plant-food, and, in the second place, by adding humus, and thus, improving the soil's texture and its power of absorbing and retaining moisture. When such a crop is buried, the surface soil becomes enriched by the nourishing materials which the crop during the period of its growth has drawn from the air and from the lower portions of the subsoil, and this material is now placed within the reach of the succeeding crop.

During the growth of the plant the soil has, in addition, been stirred up and disintegrated by the development of the roots. When ploughed under, provided that sufficient moisture and warmth are present, the buried mass decomposes with more or less rapidity, and the succeeding crop gets the benefit of the fertilising ingredients contained in the decaying mass of vegetation in a readily-available form. The resulting humus is of the greatest value, not only as a source of plant-food, but in improving the soil's texture, in preventing too rapid evaporation, and in enabling the soil to absorb and retain water, thus rendering it less liable to suffer during dry spells.

A further important result is the formation of carbonic acid by the decomposition of the buried crop. Carbonic acid is given off abundantly in the fermentation of the mass and assists in the disintegration of the soil and in rendering available the plant-food contained in it.

Green-manuring is effective both in sandy and in heavy clay soils, and, indeed, on all soils deficient in humus. On sandy soils the effect of green-manuring is to consolidate the soil, the humus formed binding the particles together. On clay soils, the effect of the addition of humus and the other production of carbonic acid is to loosen and aerate them. When conditions as to warmth and moisture are favourable, and the crop decomposes fairly rapidly, the production of soluble plant-food proceeds with considerable rapidity. This is especially the case in respect of nitrogen, which is the principal manurial ingredient. Nitrification (that is, the conversion of the nitrogenous material of the plant into soluble nitrates) takes place quite rapidly. In sandy soils, green manures nitrify more rapidly than manures like dried blood, bone-dust, etc., and only less slowly than ammonium sulphate; while in stiff clay soils the green crop nitrifies very much more rapidly than either sulphate of ammonia or animal manures.

With regard to the kind of crop to be used for the purpose of green-manuring, a good deal of latitude is permissible. Any crop that is rapid and luxuriant in growth, and that can be readily turned under, is suitable for the purpose, and the selection will be guided by considerations such as the time of year at which it is to be grown, its suitability to soil and district, etc. Amongst the most effective class of crops for the purpose are leguminous plants, such as clover, cowpea, lupins, etc., since these are specially valuable on account of their power of obtaining their nitrogen from the air. They are, therefore, especially suitable for soils poor in nitrogen, and are of high value in enriching the soil with this ingredient. There are, however, many other crops which are suitable for the purpose, and frequently used, such as mustard, buckwheat, etc. These are all rapid growers, and can be grown as catch-crops—that is to say, after the main crop has been harvested and before the succeeding one is sown. The practice of growing a crop of tares or vetches after the wheat crop has been harvested is very common in Europe, and can be followed successfully in districts where the autumn rainfall is sufficient. Such a catch-crop occupies the ground only at a time when it would be otherwise unoccupied, and, during its growth, is collecting plant-food from air and soil, which is utilised for manuring the succeeding crop.

The practice of green-manuring is of special value in orchard work, where the green crop can be grown and ploughed under between the rows.

It must be borne in mind, in all cases, that green-manuring depends for its success upon conditions favourable to the decomposition of the buried green crop, namely, sufficient warmth and moisture. A crop ploughed under in the late Autumn or Winter will nitrify only slightly, and the same applies to ploughing-under a crop in a dry season. If the land is quite dry the crop will remain buried without decomposition for a considerable period, and its benefit is lost.—*The South African Sugar Journal*, Vol. X., No. 9.

MANURING OF VINES.

Speaking generally, it may be said that sickly vines produce poor-quality fruit and light crops, and in order to maintain quality and quantity, manuring is deserving of every consideration where vines exhibit any inclination to weakness and low yields. Diminished yields from debility represent a loss in value of the crop which would fertilise the vineyard for some years. It is easier to maintain vigour than to renew it once the vines have been appreciably weakened.

It is estimated that vines will remove annually per acre from the soil approximately 40 lb. of potash, 45 lb. nitrogen, and 10 lb. phosphoric acid, and it would appear only reasonable to replace at any rate a portion of this each season.—*Agricultural Gazette of N.S.W.*, Vol. XXXVII, Part 2.