SOIL FERTILITY, NUTRITION AND HEALTH.*

(By Sir Albert Howard, C.I.E., M.A., formerly Director of the Institute of Plant Industry, Indore, Central India, and Agricultural Adviser to States in Central India and Rajputana. Reprinted from "Chemistry and Industry," by kind permission of the Society of Chemical Industry.)

In order fully to apprehend our subject, it is necessary to look back nearly 100 years and pass briefly in review the great industrial era of the nineteenth century, making the development of agricultural science and practice during that period of remarkable material prosperity and suggesting wherein it has proved inadequate to ride the storm in which those years culminated—a storm as unforeseen as it has proved disastrous to agriculture.

In the year 1840 Liebig published his celebrated essay entitled "Chemistry in its Applications to Agriculture and Physiology," embodying his well-known mineral theory on the substances found in the ashes of crops. Up to this time, the fertility of the soil had been maintained by means of some form of organic matter, such as farmyard manure, supplemented by suitable crop rotations, including fallows; the accepted view that soil required humus was unchallenged. From 1843 onwards experimental theory centred in the new thought advanced by Liebig; the idea that stimulation must of necessity mean progress gained credence in an age when progress was the watchword; soil chemistry, as we know it to-day, was born. With the further development of the Liebig tradition at Rothamsted and elsewhere, came steady progress in the manufacture and use of artificial manures. After the Great War, when the factories engaged in the fixation of atmospheric nitrogen for the manufacture of explosives had to find other markets, the use of nitrogenous fertilizers in agriculture increased, until to-day the majority of farmers and market gardeners in this country base their manurial programme wholly on the cheapest forms of nitrogen, phosphates, and potash on the market. What may be conveniently described as the NPK mentality dominates farming practice alike in the experimental station and the countryside. Vested interests entrenched in time of national emergency have gained a stranglehold.

What has been happening to the land during these 100 years? For a time all seemed to be well and agriculture shared in the general prosperity. Just as soon, however, as the original store of humus, which is found in all fertile soils, began to diminish a number of subtle changes made their appearance. Insect and fungous diseases increased and it became necessary to combat these with poison sprays; animal diseases are now rife. Deeper and more extensive cultivation became a necessity and increase in production was the only goal. Old-time tests such as taste and quality in produce were abandoned, and at a moment when, had they been applied, they would have shown clearly in what direction chemical manures were leading us. For artificial manuring leads tortuously to artificial demand, and it has not been enough that we should regulate production to demand. Agricultural policy must achieve a definite goal, and that goal is neither the economic necessity of the hour nor yet the building up of emergency reserves—it is the health of the nation.

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The species of account that Mother Earth is likely, sooner or later, to present to those who misuse her resources may be examined in the United States of America. There the vast heritage of reserve fertility created in the past by the forest and the prairie has been used up to produce the large and ever-increasing quantities of food and raw materials needed by the urban populations engaged in commerce. The early settlers proceeded to cash in their humus mine and had no thought but to get rich quickly. The whole subject of soil fertility remained unexplored; such questions as the correct balance between animals and crops did not arise. Large crops were obtained without manure of any kind and while the original store of organic matter lasted all appeared to go well. To-day the bill is in the hands of the American people and their Government. In 1935, an eminent American engineer uttered a solemn warning that if the soil were to be continuously squandered, as then, the country might expect "less than a hundred years of virile national existence".

Over vast areas of the country the loss of organic matter has been followed by the destruction of the crumb structure; the compound soil particle has lost an essential constituent—the cement provided by humus. In the drier wheat areas, like Dakota, farms are blowing away; the deserts are on the march. In the tract drained by the Mississippi River the destruction of the crumb structure has been followed by loss of soil permeability to such an extent that the land is unable to drink in the rainfall and extensive erosion has been the inevitable result. It has been stated that the denuded areas approach in size all cultivated Germany. Over-stocking, over-cropping, over-stimulation, the wholesale destruction of timber—these are the malpractices which destroy fertility.

The lessons taught by the middle west and by the prairie provinces of Canada, where agriculture has collapsed with such dramatic suddenness, are being repeated in certain areas of this country which have been regularly manured with artificials only. Both the North American and the British methods of crop production have shown themselves to be lacking in the one thing that matters in agriculture—permanency.

Let us examine a system that will pass the test of permanency; let us turn to China, where the system of agriculture is at least 4,000 years old, and note the major respect in which it differs from our own. In China the processes of decay invariably receive as much attention as the processes of growth. Every possible kind of waste—vegetable, animal, and human—is carefully collected and put back into the soil. Animal residues, and more especially urine, are utilized to the full. This has been done for 40 centuries, and Chinese agriculture presents the one unanswerable argument in its favour—success. The soil has continued to maintain a dense population without the importation of food from other countries; the good earth is handed on as a great possession from one generation to another. We have here a remarkable example of practice anticipating theory.

The striking contrast between the failure of western science to maintain soil fertility and the success of the methods followed by the peasants of China was one of the factors which gave rise to the Indore process for the conversion of vegetable and animal wastes into humus. The immediate consideration, however, was the need for increasing the fertility of the soil of India in order that improved varieties of crops might come into their own. The introduction of improved varieties by themselves yielded only a small increment; the combination of improved varieties plus improved soil conditions doubled the crop and left the land in good condition.

The Indore process is simple. A layer about 6 inches deep of mixed vegetable wastes is lightly covered with about 2 inches of farmyard manure followed by a good sprinkling of earth. If any wood ashes are available these are added with the soil. The proportion of mixed wastes to farmyard manure must not exceed 3:1 by volume. The sandwich process is repeated until the material in the heap or pit is after fermentation 3 feet thick. The layers must be kept moist, but not wet, lest the air supply be interrupted. The moistened heap should resemble, as far as possible, a pressed-out sponge. The temperature rapidly rises to about 150 degrees Fahrenheit and the whole mass becomes covered with greyish-white mycelium. After two or three weeks the heaps or pits are turned and watered if necessary. A second turn and watering follows at the end of six weeks from the start, by which time the mass has crumbled and turned black. In three months from the beginning the carbon: nitrogen ratio falls from 33:1 in the original mixture to about 12:1, when the humus, which resembles old leaf mould, is ready for the land.

Over-acidity, faulty aeration, too much moisture, or an unsuitable site—any of these may present a passing problem in this country. Such problems must be tackled bearing in mind the special circumstances giving rise to them. In no case yet have they proved insoluble.

The process is a partial reversal of the work of the green leaf. In the cells of the leaf simple substances obtained from the soil and the atmosphere are synthesized by means of the energy of sunlight into carbohydrates and proteids. The fungi and bacteria in the compost heap practically undo this synthesis until a comparatively stable condition of organic matter is reached in the shape of humus. This is the real food of the soil and of the crop. The second stage in breaking down the materials made by the leaf is only reached when the soil organisms oxidize humus into simple substances once more which can be absorbed by the roots of plants. The wheel of life has then completed a single revolution.

It is not difficult to understand that the use of artificials in feeding the crop direct side-tracks a portion of Nature's essential round; artificial stimulus applied year after year, and at the same time, must inevitably breed evils, the full extent of which are as yet dimly seen. The relation between quality and yield, for example, does not lend itself to scientific formulae. The time may come when yield will depend entirely upon quality, but quality can never under any circumstances depend upon yield. Factory-made manure is the weak link in the chain of agricultural economics.

In devising the Indore process the various methods of dealing with soil fertility all over the world were naturally studied, as well as the work of the experimental stations in manuring, from the time of Liebig onwards. The result was illuminating. The practice of the peasants in China—the Farmers of Forty Centuries—suggested the desirability of making the fullest use of every form of vegetable and animal waste. Most of the research work underlying the Indore process was found scattered through the literature, very much as materials lie about in a builder's yard before the building is erected. Everywhere fragments of a larger question were to be found. The nearest approach to the Indore process was made by Rothamsted, where, however, the investigators made two fatal mistakes: (1) the use of chemicals instead of urine as an activator in breaking down vegetable wastes, and (2) the patenting of the ADCO process. Urine consists of the drainage of every cell and every gland of the animal body and contains not only everything needed by the fungi and bacteria which makes humus, but all the accessory growth substances as well. ADCO merely supplies nitrogen and minerals as well as lime—a far inferior base to the wood ashes and soil used in the Indore process. It focuses attention on yield rather than on quality. Further, the patenting of a process always places an investigator in bondage; he becomes a slave to his own scheme. Progress then becomes difficult, or even impossible.

The adoption of the Indore process all over the world has been very rapid. Thanks to the help of Major Grogan, D.S.O., and Sir Milsom Rees, G.C.V.O., practically every coffee estate in Kenya and Tanganyika had adopted the method by the end of 1933. Tea, sugar, sisal, cotton, coco-nuts, maize, and other large-scale industries soon followed. In 1935, a beginning was made in Great Britain, where now a number of estates, farms, and market gardens are busy converting all their wastes into humus. Some of the experimental stations in this country have followed the lead of the live wires in the farming community.

The Indore process has already outgrown its early beginnings. The underlying principles have enabled the problem of green-manuring to be solved; an uncertain method of enriching the soil has been converted into something which can be relied upon. This development was worked out during the last two years on the potato areas of South Lincolnshire which have begun to suffer from a shortage of humus. After the pea crop—grown for canning—has been harvested, the land is immediately drilled with beans. The sown area is then covered with a layer of crushed straw from the shelling machines followed by a thin layer of farmyard manure. The Indore process then sets in on the surface of the soil. The beans grow through the fermenting mass and at the end of September are ploughed in with the layer of finished compost. Decay is rapid and by the time the fields are planted in potatoes the following spring the resulting humus has been incorporated in the soil and is ready for nitrification. This modification is known as sheet composting—the making of humus in a thin layer all over the surface. Catch crops of beans or mustard or a crop of weeds can also be manured with humus, or a farmyard manure, before plough-in in the autumn, when sheet composting again takes place. The turf of old pastures or old leys can be converted into humus in a similar fashion. The Indore process has in this way been applied with success to no less than three important practical problems—green-manuring, the effective utilization of weeds and stubble, and the better utilization of the old turf of grassland.

Another important development has also taken place. In India, Ceylon, and Africa, town waste and night soil are now being converted into humus by the Indore process. In some cases, as in Nairobi, the production of humus from town wastes is being carried out on a commercial scale and Humetco—the trade name for the compost—has been on the market for some time. In Great Britain developments are taking place in the same direction. Dust-bin refuse is being used on a large scale as a constituent in the compost heaps for such crops as fruit and hops, and also in ordinary farming practice.

The adoption of the Indore process is not confined to the British Empire. Some of the papers describing the method have already been translated into German and Spanish, and I believe a Danish version is in process of preparation.

The most important development of the Indore process in Great Britain concerns the proper use of dustbin refuse, of seaweed, and of the vast stores of organic matter in the old turf of grassland. As is well known, the contents of the dustbin in this country are either buried or burned. Very little finds its way back to the land. Yet this material is exactly what is wanted in the compost heap in a country like Great Britain, where so much green waste (which is liable to pack in the heaps) is available, and where the total volume of plant residues is not so great as in the tropics. Town wastes perform two useful functions: (1) they help to aerate the heaps and to absorb the surplus rainfall, and (2) they increase the volume of the resulting humus.

The harvest of the sea is now only imperfectly reaped in the form of fish. Much of this harvest—the seaweed thrown up on the shore—is still largely wasted, although it is perhaps the most effective constituent of a compost heap that occurs in this country. A few examples are needed in which the seaweed brought in by the tide is composted with the municipal wastes of seaside towns, the resulting humus being used for intensive vegetable growing. A suitable beginning might be made at Worthing, in Sussex, where large quantities of seaweed are thrown up on the beach and where no agricultural use is made of the wastes of the town.

The proper utilization of the organic matter in the turf of pastures and leys is now one of the chief items on the programme of the Welsh Plant Breeding Station at Aberystwyth. Professor Stapledon is constantly urging the ploughing up and re-seeding of grassland, which, of course, involves the manufacture of humus in the surface soil. Another similar application of the Indore process is the system of milking-bails devised by Mr. Hosier on the chalk downs of Wiltshire.

It is a fact that British agriculture does not supply one-half the total food consumed. Common sense, therefore, dictates that those articles of diet in which supreme freshness is (or should be) the sole criterion of their true nutritive value should be home-grown. This means intensive cultivation (and incidentally a high rate of employment); it means also improvement and indeed curtailment of those 16,000,000 acres of permanent pastures in England and Wales, which Professor Stapledon once confessed in public made him "see red"; it means increasing livestock; and it means all this in the national interest. Now the conversion of agricultural and municipal wastes into humus for increasing the fertility of the soil has a direct bearing on health. It will in all probability be the means by which a new forward move in preventive medicine can be initiated. There exists to-day a considerable body of evidence which supports the view that the fertility which follows the regular application of humus is the surest foundation upon which to build the health of a nation. There is undeniably a close connexion between quality and health, but it defies analysis. The word "bloom" subtly suggests both. Quality in produce, although difficult to define, is saleable.

In the case of the wheat crop raised on Viscount Lymington's estates in Hampshire, careful records have been kept of the life of wheat straw when used for thatching. Wheat straw from fields manured with organic matter, partly of animal origin, lasts ten years as thatch; straw from similar land manured with artificials last five years. What the difference in quality is between the two sets of grain has not yet been determined. In Worcestershire experienced merchants are convinced that the highest quality crops are always produced with farmyard manure.

In vegetable growing the effect of organic manuring quality can be seen on a large scale on Mr. Secrett's farm on Walton-on-Thames. Mr. Secrett uses practically no artificials and raises his produce on fermented stable manure. He stands at the head of his profession as regards quality.

At the Iceni Nurseries at Surfleet, Captain Wilson has been converting all waste products into humus by the Indore process since November, 1935. The result has been amazing as regards the improvement in quality. Further, in a memorandum to members of the British Association visiting his estate on 4th September, 1937, Captain Wilson states—

"The method of humus-making which has been employed is known as "The Indore Process" and it has proved remarkably successful. The output in 1936 amounted to approximately 700 tons and in the current year will probably be about 1,000 tons.

"As a result of this utilization of humus the land under intensive cultivation, has already reached a state of independence, and for the last two years no chemicals have been used in the gardens at all either as fertilizers or as sprays for disease and pest control. The only wash which has been used on the fruit trees is one application each winter of lime sulphur, and it is hoped to eliminate this before long."

In Madras, McCarrison found that grain produced with farmyard manure contained more vitamins than that grown with minerals. In a recent lecture at the Royal Institution, this investigator summed up his long experience on nutrition as follows:—

"What I want you to learn from this lecture is that it is the foodstuffs themselves that matter to you, rather than any chemical ingredient of them. These when properly combined in the diet, supply all the food essentials, known and unknown, discovered or undiscovered, needed for normal nutrition, provided they are produced on soils which are not impoverished. For if they be produced on impoverished soils their quality will be poor and the health of those who eat them—man and his domestic animals—will suffer accordingly. Man is literally created out of the earth, since it is the earth that supplies, through the agency of plants, materials out of which he is made. If, therefore, he is to derive all the benefits which the earth is so ready to yield to him he must employ his intelligence, his knowledge, and his labour in rendering it fit to yield them to him. In this country impoverishment of the soil goes on apace because we take out of it in the form of crops more than we put into it in the form of animal and other organic manures. This impoverishment leads to infertility of the soil and this, in its turn, to a whole train of evils; pasture of poor quality; poor quality of the stock raised upon it; poor quality of the foods this stock provides for man—meat, eggs, milk; poor quality of the vegetable foods he raises for himself; and faulty nutrition with resultant disease in plants, beasts and man. Out of the earth are we and the plants and animals that feed us created and made, and to the earth we must return the things whereof we are made, if it is to yield again foods of a quality suited to our needs."

The evidence in favour of the view that disease resistance in plants and animals depends on soil fertility is also considerable.

My own experience in India from 1905 to 1931, is summed up in a paper on the "Role of Insects and Fungi in Agriculture," published in *The Empire Cotton Growing Review*, XIII, July, 1936, p. 191. I have had no reason to alter this opinion; rather my conviction as to its truth has strengthened. I said then—

"Insects and fungi are not the real cause of plant diseases, and only attack unsuitable varieties or crops improperly grown. Their true role in agriculture is that of censors for pointing out the crops which are imperfectly nourished. Disease resistance seems to be the natural reward of healthy and well-nourished protoplasm. The first step is to make the soil live by seeing that the supply of humus is maintained."

The most striking confirmation of my views has been supplied by commercial vegetable growers all over the country who use humus only for growing their products.

In regard to animal diseases, my experience in India was very similar. From 1910 onwards, I was allowed to have my own oxen at Pusa, Quetta, and Indore, and I made full use of these animals for the study of disease. The greatest care was taken in the selection of the breed and of the type of animal; the feeding, hygiene, and management was as near perfection as I could make them. For twenty-one years—1910 to 1931—I was able to study the reaction of well-fed animals to the epidemic diseases such as rinderpest, foot and mouth disease, septicaemia, and so forth, which frequently devastated the countryside. None of my animals were segregated; none were inoculated; they frequently came in contact with diseased stock. No case of infectious disease occurred. The reward of well-nourished protoplasm was a very high degree of disease resistance, which might even be described as immunity.

A simple explanation of the results described in the last portion of this article is that a fertile soil enables the green leaf to carry out the synthesis of carbohydrates and proteids in an effective manner. Two important results then follow:—(1) insects and fungi find such crops unpalatable, and (2) the organisms which are associated with the diseases of animals fail to flourish. The energy of sunlight through the agency of a fertile soil can therefore be effectively transmitted, first to the plant and then to the animal. It follows from these results that there must be a common baseline—soil fertility—in all future work connected with nutrition. If this is not ensured confusion and uncertainty will result. The research structure must above all things, have a firm foundation; the results obtained in the various countries and at the various centres must be comparable. It will not be sufficient in the future to work on material of varying nutritive value. In the past investigators have used such produce as existed; they have rarely grown their experimentl material on really fertile soil and based their experiments on the very best produce Nature can provide; the agricultural basis of much of the reasearch structure is therefore faulty.

Research upon the lines I suggest pre-supposes, of course, a conscious and deliberate forward policy in agriculture, based upon land in good heart and vigorously pursued in perhaps the greatest of all national interests—health.