THE SOIL FERTILITY PROBLEM OF INDIA.

By H. Martin-Leake.

(Communicated by Prof. N. R. Dhar, F.N.I.)

It is with some demur that I have acceded to a request that I contribute a paper to this Symposium, for it is long since I have been actively engaged on research, and I have, therefore, nothing new to offer. But there are two old sayings. One of these refers to the difficulty of seeing the wood for the trees; and it is true that one who is engaged on studying a specialized problem—and science now covers so vast a field that all active investigators are of necessity specialists—runs a risk of failing to see how his particular problem fits into the generalized pattern. The other is that it is the spectator who sees most of the game. It is these considerations which have led me to accept the invitation, and it is as a spectator only that I contribute the following views on the relative merits of organic and inorganic manures.

The use of inorganic, or artificial manures is a product of the West and followed from the work of Liebig. That development has divided the world into two. In one section the use of artificials has become standard practice, in some extreme cases to an extent that the use of organic manure is completely discarded; in the other artificials have not yet been introduced. Broadly speaking, these two sections may be defined as West and East, though the distinction is not so clear cut. In Africa, for instance, alongside the settled tracts where the latest cultural practices are adopted, are tracts with the most primitive agricultural system of all—shifting cultivation. Shifting cultivation side-tracks the question of manuring, for a new virgin tract is opened up as soon as the old one becomes exhausted. But in India and China, typical of the East, pressure of population has led to the development of a system of permanent cultivation of a very skilled type not based on artificials, a skill which is the outcome of the necessity for maintaining a permanent level of fertility. Climatic differences naturally dictate certain differences in the practice adopted, but the major human-controlled factor lies in the extent of the use made of organic residues, particularly human residues. It is the economic circumstances and not lack of skill which forms the limiting factor in India. The need for feeding his family and stock and for producing cash crops to buy the bare necessities which his holding cannot produce, has forced the Indian peasant to feed his straw to his cattle instead of growing a rotational fodder crop and to use their droppings as fuel. If his yields are relatively low, it is for this reason and not through any lack of skill, the measure of which is the nice adjustment between the amounts removed as crops with the maintenance of a certain standard of permanent fertility. With a lesser degree of skill, fertility would have been destroyed and a desert produced.

But India is now at the cross-roads. Her rapidly increasing population, combined with the absence of any extensive fresh areas available to be opened up for cultivation, since the major sources of irrigation are already developed, is creating a demand for food which can only be met by the rather precarious dependence on external sources of supply or by an increase in the average yield obtained from an acre, the latter objective only to be obtained by raising the level of fertility permanently. It is natural, seeing the apparent increase in production in the West through the use of artificials, that attention should be directed to this method as a solution of India's problem.

Before embarking on such an imitative course, however, it is very desirable that those responsible for taking the decisions involved should scrutinize carefully the evidence of the West. Though artificials have long been in use in the West, it is only in the last half century that their growing use has reached a degree likely to produce, in association with the decrease in the use of organic manures, an appreciable and measurable effect. Here there is at once met a difficulty; what can be accounted acceptable evidence? That artificials can, and do lead to large, sometimes very large increases in yield is undoubted; millions of experiments, conducted all over the globe and under very divergent conditions prove this, and in commercial practice their use has become general. But these facts hardly provide adequate, and certainly not conclusive evidence. The vast majority of these experiments measure only the short term effects; what is of concern here is the permanent level of fertility, and this is a long term effect. The very fact that so many experiments are devoted to determining the residual effect over a year or two is suggestive. Is it possible, then, to trace a trend in the general level of fertility under a continuous system using artificials? Where meteorological conditions vary so widely from year to year, with their direct effect on yield, the statistically conclusive evidence is naturally hard to come by. Nor is that the only obstacle. In recent years there has been an outpouring a varieties which, selected as these are for their capacity to give higher yields through better adaptation to local conditions, necessarily introduces a further complication in any statistical analysis. Furthermore, there is suggestive evidence that the continuous raising of seed under conditions which neglect the humus factor, leads to a progressive debility which finds expression is ill-health and it is neglect of this possibility that rules out that longest series of experimental trials, those at Rothamsted, as offering conclusive proof.

It is not here possible to review that growing mass of evidence indicating that humus is the most fundamental factor affecting healthy growth and, through it, yield. That mass of evidence, embracing the growing incidence of disease, the running out of varieties and so on, is amply recorded in the literature on the subject and is sufficiently weighty to carry conviction to most impartial minds even if each observation is not conclusive in itself and fails to provide the ultimate proof demanded by modern statistical analysis. Here I can only outline that evidence which most nearly fulfils the rigorous conditions of such analysis.

South Australia possesses a climate characterized by low rainfall; from 8" to 20 with only a fraction of the area here dealt with exceeding 16". The wheat belt here by 1886 contained nearly 2 million acres under that crop which, by 1930, reached a maximum of 4 million acres. A very detailed statistical analysis of 'The Yield Trends in the Wheat Belt of South Australia, 1896–1941' has been made by E. A. Cornish.[1] By the division of the area into units according to the length of the period under cultivation and by the elimination of such variable factors as rainfall and types of soil, he isolated a positive trend in yield due to the factors (*a*) maintenance of an adequate phosphorus and nitrogen supply, (*b*) the adoption of cultural practices suited to the various types of soil, (*c*) the use of improved varieties, and (*d*) the maintenance of the physical condition of the soil, and a negative trend due to a reduction in fertility consequent on agricultural exploitation of the soil. With regard to this reduction in fertility he comments 'this (the negative trend) has proceeded so far in some areas that it outweighs the beneficial effects of recent advances and results in a progressive decline', a decline which has gone so far that a Pastoral and Marginal Agricultural Inquiry Committee in 1948 recommended the abandonment of wheat growing as the major operation in these depleted tracts. In attempting to trace the cause of this loss of fertility, he is led to the conclusion that it is due to the depletion of the organic reserves of the soil, affecting both the nitrogen and water supply.

---

[1] *Australian J. Sci. Research,* **1949**, Series B, 2, pp. 83–137.

The second paper to which I would draw attention, comes from Hawaii. Hawaii has attained the proud position of producing more sugar per acre than any other country. It has done this by organizing within an industry run on a plantation basis a highly efficient technical service applying all the latest teachings of science. Yet, as L. D. Baver shows,[1] all is not well with the cane sugar industry of Hawaii. Among the factors accounting for this leadership is the varietal programme; yet none of the new varieties have fulfilled their promise when brought into commercial use. Under such conditions, the initial rise in yield is followed by a levelling off and, ultimately, a retrograde movement, and this in spite of the concurrent ameliorative conditions. Here is to be seen that process which has been so characteristic of the sugar industry of all countries, the running out of varieties with the consequent necessity for their replacement at ever shorter intervals. And this is not a phenomenon inherent in the new varieties; it was the running out of the centuries-old standard varieties that gave the urge to varietal breeding once it was recognized that the sugar-cane set seed.

But Baver carried his investigation to cover a wider field, giving the results of an analysis of crop yields in Ohio. He gives, in the form of a 'productivity index', a percentage loss or gain per annum for various crops. This, for crops like maize, grown in rows, is $-2{\cdot}0$. He further states that the cropped lands have lost about one-third of the original organic content and that a cubic foot contains about 22 per cent more soil than originally, with a consequent reduced aeration. He sums up his conclusions in words almost identical with those written by Cornish: 'The natural productive capacity of the soil has been deteriorating at a rate almost fast enough to offset all the improvements in soil and crop management.' Here, again, the cause of the deterioration is attributed to neglect of the organic factor. Though this case is not recorded with the same wealth of statistical proof, it has a technical value which is convincing. Under the very divergent conditions of South Australia, Hawaii and Ohio, the same conclusion is reached; it is the neglect of the humus factor which is the prime defect in the modern approach to cultural problems. Through this neglect, the farmer is advised to spend more and more on artificials merely to find that he has to face further expenditure for dusts and sprays to check the diseases attacking a debilitated crop.

What is the lesson to be drawn by India from the above? She differs from what has here been termed 'The West' in the fact that artificials have, as yet, not been incorporated in her agricultural practice. Her problem differs in consequence; in both cases, the need is for greater attention to the organic status of the soil, but the approach is different. In the West it is a retreat from an excess of artificiality in agricultural practice to a nearer approach to Nature; in India it is a restoration of those organic materials of which the soil has been deprived through the more pressing demands of a dense population. The average fertility of her soils is, in consequence, low and must be raised to a higher permanent level if the needs of her growing population are to be met. The temptation to take the easier apparent solution through resort to the wide use of artificials is great, though that raises economic and financial questions of no mean order, but she will do well to study closely the experience of the West before doing so. The mass of evidence now available justifies the belief that, with attention to the organic status of her soils, a soil fertility can be built up and maintained at a level which will give yields equal to those now obtained temporarily by the use of artificials. That is no dogmatic statement. It is reasonable to suppose that there are exceptions when certain deficiencies will limit yields, but the requirements of exceptional cases should not form the guide for general practice.

India will do well to press on with her well-founded plans for the return of all organic wastes and to mark time with her plans for the bulk production of artificials

[1] *Hawaiin Planters' Record*, 1949, 53, pp. 1–12.

through hydro-electric development—that power could be used to better purpose—and she will be well-advised to search out other sources of organic matter. And here it is possible to make a very tentative suggestion, the practicability of which is quite unknown to me but may be worthy of investigation. India has a wealth of coal, much of which is of low calorific value. May it not be possible to develop this wealth by a process of distillation to yield gas and volatile products sufficient to cover cost, leaving a residual fuel to be distributed at nominal cost? Thus might be overcome the present need for burning cattle droppings which would become available for composting with other residues of the peasant's holding. The higher fertility would release part of the holding for fodder crops, in turn releasing some of the straw for composting.

So far, I have considered the practical issues. There remains the more fundamental problem of the exact rôle played by organic matter in the development and maintenance of fertility. Much has to be learned before anything more than a broad answer can be given to this complex problem. As is so often the case in matters of this complexity, it is empiricism and analysis which relates cause to effect. That dictates practice, while science only later finds the explanation of that relationship. On this aspect I can touch only lightly.

The soil can be considered from three angles, chemical, physical and biological; and organic matter plays a rôle in each. But its especial rôle is biological, for it is organic matter that supplies the energy required by that teeming soil population which justifies for the soil the adjective 'living'. By a series of steps starting in the eighties of last century, a generally accepted interpretation has been arrived at which ascribes to the biological activities of the soil organisms the breaking down of nitrogenous organic matter and the fixation of free nitrogen. The nitrogen cycle, in the course of which nitrogen is rendered in a form available to the plant, is a biological phenomenon. But Nature works by devious routes, and N. R. Dhar and his associates at Allahabad, as the result of work covering a number of years, have obtained results strongly suggesting that, under the influence of light and especially light of an intensity found in the tropics, an a-biotic fixation of nitrogen takes place, and to an extent that would add materially to the supply of available nitrogen. That this work should have received so little attention is, perhaps, only in accord with expectation; a biological interpretation of the nitrogen cycle so long accepted as satisfying will not be discarded lightly. A-biotic fixation adds complexity to the nitrogen cycle; fixation, biotic and a-biotic, will take place concurrently in the soil and the problem arises of unravelling the two. Particularly, it may be asked, what is the relationship of each to the seasonal rise in nitrogen fixation during the hot weather and following the rains, hitherto considered adequately explained as biological phenomena? But if much remains to be discovered as to the exact rôle of a-biotic nitrogen fixation, one fact already stands out; the presence of adequate organic matter is as important in one case as in the other. The major practical problem remains the same; the organization of an adequate supply of organic matter for addition to the soil. A better understanding of the forces, both biotic and a-biotic, at work will form the basis for the determination of the optimum manner in which organic material may be used.

Let me conclude with a quotation from an unpublished record of the late G. Clarke, contained in some writings of his which have recently come into my possession. Though nearly twenty years have passed since he left India, his work on sugar-cane in the United Provinces has, perhaps, not been entirely forgotten. He wrote as follows:

The weather produces conditions which give rise to seasonal biological activity in the soil differing in some respects from that occurring in the temperate climate of Europe. The final result of biological change is the accumulation of nitrate which is the important factor determining yield. In England this takes place gradually during the spring and early summer under the influence of slowly rising temperature. In North India the accumulation of nitrate reaches a peak point twice during the year before the break of the monsoon and the sowing of the summer crop, in June, and again at the end of the rains, as the soil slowly dries and becomes aerated by the cultivation for the winter crop. In the hot weather the nitrate is produced very quickly in a few weeks, and in much larger quantity than in the cold season. Nearly all of it disappears from fallow land after a few heavy falls of rain, but it is not entirely leached out of the soil as one might at first sight suppose. Under the influence of high temperature and ample moisture, a subsidiary nitrogen cycle is set up. There is intense fungal growth in the soil and a large part of the nitrogen passes into fungal tissue. It is immobilized and packed away for future use. The rapidity with which the nitrogen cycle operates under tropical conditions constitutes the fundamental difference between tropical agriculture and that of colder climates.

I had often to reply to arguments which maintained that the productivity of the soil had decreased. The records of the United Provinces did not support this view and, indeed, it was not to be expected.

It is true that Indian soils contain a very small amount of humus and nitrogen compared with the soils of colder and moister climates. The oxidation processes are so intense that only resistant forms of nitrogen are left in the soil organic matter which have been put out of action, namely reduced to a state in which further change is extremely slow. The crops obtain very little from this resistant material and cultivation has not much effect on it. There is no accumulated fertility in India, but this does not mean that the land is incapable of producing crops or that the yield cannot be raised. The capacity of the soil to maintain the underground life necessary for healthy crops depends on a smaller quantity of humus and nitrogen (75 to 100 lbs. per acre) which is in constant circulation and constantly undergoing transformation. Some of it is removed every year by the crops. Twenty to thirty are washed out at the beginning of the rains. Much of it is immobilized and passes into fungal tissue to become available later when the fungi die and decay. The supply is replenished every year by non-symbiotic fixation, the energy necessary being provided by the freshly prepared humus produced annually by the decay of roots and weeds.

This small quantity of freshly made humus and the active nitrogen that it contains is the working capital of the Indian cultivator and the foundation of the ancient system of Indian agriculture, which has established a perfect balance between the removal of fertility by the standard yields and the recuperative processes of the soil. By this method of farming the productivity of the Gangetic plain is inexhaustible.

Agriculture in the United Provinces can be raised to a level three times higher than at present, as I showed in the most conclusive manner at Shahjahanpur. For over twenty years 100 mds. of sugar and 26 mds. of wheat per acre were obtained. The average yields in the United Provinces were 30 maunds of sugar and 10 maunds of wheat per acre. This result depended on raising to and maintaining at a high level the balance between soil aeration, organic matter, plant food and variety.

His comment on the danger attending the introduction of artificials into this delicately balanced system has been recorded by me before, but is worth repeating:—

> Short cuts to increased production such, for example, as the excessive use of artificial nitrogenous manures, under the conditions which prevail in the United Provinces are attended by the gravest risks.
>
> Irreparable damage can be done to the magnificent soil which for thousands of years has been the wealth of India. Its recuperative power, namely, its power to fix nitrogen by non-symbiotic processes, which is increased by rational methods of intensive cultivation, will be destroyed and more and more

artificials will have to be used. A state of affairs will inevitably arise in which the active soil organic matter will be used up during the attempts of the organisms to deal with the unnecessary nitrogen. Desert conditions will make their appearance, accompanied by alkalis which will put a stop to cultivation of any kind.

Issued January, 1953.