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SOIL IMPROVEMENT IN RELATION TO CROP PRODUCTION

BY

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I ask your permission to direct your attention to some aspects of soil improvement in relation to crop production. I propose to pass in brief review some of our problems and then to touch on the work to which my colleagues Khan Sahib Sheikh Mahomad Naib Husain, Rai Sahib S. C. Banerjee and myself have devoted a number of years at the Shahjahanpur Research Station. My subject is directly connected with the supply of the first necessity of life, namely, food. By what methods is the world going to continue to feed its growing population? It is increasing at the rate of nearly 20 millions a year, and it cannot be suddenly checked. Can food be found for all these extra mouths, or will the pressure on our land resources become unbearable, and end in disaster? That is the colossal problem facing the world in the next few generations. It must be met either by a continual expansion of cultivation, or an intensification of production on land already cultivated.

How do we stand in India in respect to these questions? I have proceeded in a somewhat empirical fashion to ascertain the relation between population and arable land. I have selected, in making my estimate, the figures used in international statistics, the total area sown and the current fallows. I have deducted the area required for the production of exported cotton, food grains, oilseeds, jute and tea which account for about 80 per cent of the value of our exports. This estimate is admittedly rough and must be regarded as suggestive rather than as an exact measure, but it is sufficiently near to illustrate my points.

I have taken the year 1922–23 following the census year 1921, and the year 1925–26. In 1922–23 the total area sown in that part of India for which agricultural returns are made was 327 million acres, 61 were fallow, making a total of 388 million acres. From this may be deducted as producing exported material for cotton 14, for foodgrains 9, for oilseeds 5, for jute 2, for tea 0·6 million acres, or 31 million acres in round numbers. So that 357 million acres are left to supply the requirements in home produced food and other essential commodities of the 297 million people who live in the territory covered by these figures, viz., 1·2 acres per unit of population.

A similar calculation for 1925–26 gives the same result. I have selected for a summary comparison the United States of America and France, two countries possessing points of resemblance to India. In both, as in India, agriculture is of predominant importance. In the United States 356 million acres are in cultivation. Sixty-five million producing exported material may be deducted from this, leaving 291 million acres of cultivated land devoted to supplying a population of approximately 112 million, or 2·6 acres per unit of population. The dominant characteristic of American economic life has hitherto been abundance of land resources. France, a country which is largely self-supporting, has 36·3 million hectares of cultivated land for a population of 39·3 million, approximately 2·3 acres for each head of the population.

In considering these figures we have to allow for the fact that the vegetarian diet adopted by our people is more economical of the resources of the soil than the diet of the people of the United States and France. Living is cheap in India, but when all has been said that can be said, we are left with the plain fact before us that we have one half the area of cultivated land for a unit of population.

The past experience of the world shows that as long as new land of the necessary quality is available, increased food will be obtained less by increased skill and expenditure on old land than by taking up new land. Our map has shown for several decades well over a hundred million acres in the British Provinces of India classified as culturable waste. Why is not new land coming into cultivation? I cannot give a complete answer. No such process can be observed in steady operation on a scale sufficient to raise the 'per capita' area of cultivation to a level which will meet our food requirements. Some recent settlements in this province show an increase in cultivation of only 1 to 3 per cent in 30 years, while in others the area is stationary. For a number of reasons the area of culturable waste gives an unreal conception of our resources. Much of the land thus classified includes areas physically capable of being employed for crops only when our need is so extreme that considerations of cost of utilization are relatively secondary. Fifty per cent we know is situated in Burma and Assam, out of the sphere of action of our chief agricultural races. A great deal is in Tarai tracts where health reasons prevent extensive settlement. Land is coming under the plough, to some extent, in the villages of the Sarda canal area in these provinces, and will do so elsewhere as irrigation schemes mature, but in India, as in other parts of the world, new land of the necessary quality for food crops is no longer easy to find.

This brings me to the first part of my argument—the necessity of increasing the acre yield of land now under the plough if an ample supply of food and the home grown necessaries of life is to be assured to the Indian worker, and his standard of living raised above subsistence level. It is a difficult problem but it is not insoluble.

When I considered this matter some months ago, I asked myself three questions:

(1) What factors are in our favour, and what are against us, when we begin to intensify our cultivation?

(2) Will the knowledge and experience of other countries help to accelerate our progress? What new knowledge do we need?

(3) What is the quantitative measure of the result we may expect?

I propose to give you the answers that suggested themselves to me, based on conditions in these provinces where my experience has been gained.

We have in our favour two things. In the first place soil that is easy to manage and quickly responds to treatment, and secondly agricultural workers attached to their calling and possessing a strongly developed land sense which, by some curious twist in our make up, can only be acquired in childhood. We shall not come up against a shortage of agricultural workers of the kind that is hindering development in Australia and Canada. In these countries a high degree of skill has to be directed to economy of labour by the use of machinery and labour saving devices. In India our efforts will have to be devoted to economising land. We are better placed than most countries as regards the primary essential for increasing production per unit of land, namely, man power. You may ask me, 'What is delaying our progress with two such assets?' This opens up a wide sociological study. I believe ignorance and a larger share of ill-health than should fall to the lot of an average being play a part. The stimulus required seems to be education of a rural type. I cannot, however, pursue this issue, and return to my agricultural text.

We have to contend against difficult weather conditions and short growing seasons requiring early maturing and specialised varieties of crops. The Howards, in the *Development of Indian Agriculture*, describe graphically the effect of the monsoon on the soil and on the people. It is indeed the dominant factor in rural India.

We shall always at intervals experience years of short rainfall and this gives additional force to my argument for increasing the acre yield in favourable seasons by improved soil management if we are to avoid starvation. Much has been done to intensify yields without any commensurate increase of labour on soil improvement by the introduction of more heavily cropping varieties. I need only quote as examples wheat and cotton in the Punjab and wheat and sugarcane in the United Provinces, which are adding crores to the cultivators' income. Indian conditions, however, test the skill of the plant breeder very severely and further steps in improvement in this direction are not going to be easily won.

I now pass on to that part of my subject which has greater interest for a scientific audience than some of the stubborn facts I have placed before you. I mean the consideration of some aspects of recent work on soil improvement and the lines on which enquiry may be directed in India.

Since Boussingault introduced the method of exact field experiment in 1834, research on the soil and the conditions of crop growth has been continuous in Europe and America. The methods of approach have become more exact with each advance in pure science. We, therefore, start our work on soil improvement in India with tools ready made. Investigations carried out in other countries have given us the principles involved and often the technique of methods of research. Our work for the moment is to apply them to conditions where soil processes differ widely both in intensity and time of occurrence, from those of temperate climates. I have been impressed by the desirability of applying to our problems a conception developed in recent years by the Cambridge and Rothamsted workers, which has given a new and wider significance to the field experiment. The final yield gives us no indication of what happens during the plant's life or how it responds to factors operating at successive stages of growth. The modern method makes quantitative observations of crops throughout the period of growth and examines the results by statistical methods. This is nothing more than reducing to exact measurement and scientific treatment the observations which every practical farmer makes but does not formulate. The advantage is obvious. Information covering a wider range than the old type of field experiment can be obtained in a few years, instead of taking generation. You will remember that Lawes and Gilbert waited twenty years before discussing the results of their experiments. The field experiment lasting twenty or more years no longer fulfils our requirements. We want results in a reasonable time, accompanied by proof of their reliability, which will tell us not only the final yield but how that yield is obtained.

This leads up to another conception, namely, the critical periods of crops which will repay closer quantitative study in a country characterised by singularly short growing periods and rapidly changing conditions. By critical period I mean the relatively short interval during which the plant reaches the maximum sensibility to a given factor and during which the intensity of that factor will have the greatest effect on yield. These periods seem to be associated with some phase of growth in which the plant is undergoing modifications demanding the rapid formation and movement of food material. Italian workers have found that the twenty days before the crop comes into ear constitute an important critical period for wheat in relation to humidity and soil moisture. If during this period these factors are in defect of the minimum needed for the normal development of the plant, the crop will be small even if there is abundance throughout the rest of the vegetative period.

Our observations at Shahjahanpur indicate that two periods in the growth of sugar-cane have special significance: (1) May and early June when the tillers and root system are developing and (2) August and September when the main storage of sugar takes place. A check received at either of these permanently reduces the yield. The acre yield of sugar is positively and closely correlated with the amount of nitrate nitrogen in the soil during the first period, and with soil moisture and humidity in the second period.

Food crops pre-eminently demand combined nitrogen. You will remember how Sir William Crookes startled the world 30 years ago by the statement that the wheat eating races were in deadly peril of starvation owing to the rapid exhaustion of soil nitrogen. The age in which he lived had become accustomed to abundant supplies of cheap food from the great plains of the American continent. Fertility accumulated since the glacial period of luxuriant plant growth and bacterial activity suddenly became available for exploitation, and was plundered at an appalling rate by rough and ready methods of cultivation. Nitrogen was disappearing from the soil out of all proportion to the amount recovered in the crop. The extraordinary fertility of some of these new regions is shown by the data recorded by Shutt, an acre of soil to a depth of one foot containing from 20,000 to 25,000 lb. of nitrogen. This figure may be compared with the amount of nitrogen in an acre foot of soil in these provinces, which lies between the limits of 1,000 to 3,000 lb. I shall refer to this again shortly.

Crookes was almost the first to realise that there was a limit to cheap production from new land, but his forecast was too gloomy. He visualised the exhaustion of the chief granary of the western world within a generation or two. In some important respects he misapprehended the problem. He did not know as we know that other agencies step in and stop the plunder of the soil before it has gone too far. It is only under improper methods of cropping and cultivation that permanent soil deterioration is a real and dangerous phenomenon. Land properly handled does not become exhausted. Much of the land of Europe has been cultivated since the days of the Romans or even earlier. It is, if anything, more fertile than ever. In India we have in existence a method of farming which has maintained for ten centuries at least a perfect balance between the nitrogen requirements of the crops we harvest and the processes which recuperate fertility.

When we examine the facts, we must put the Northern Indian cultivator down as the most economical farmer in the world as far as the utilization of the potent element of fertility—nitrogen—goes. In this respect he is more skilful than his Canadian brother. He cannot take a heavy overdraft of nitrogen from the soil. He has only the small current account provided by the few pounds annually added by nature, yet he raises a crop of wheat on irrigated land in the United Provinces that is not far removed from the Canadian average. He does more with a little nitrogen than any farmer I ever heard of. We need not concern ourselves with soil deterioration in these provinces. The present standard of fertility can be maintained indefinitely. This is not my text. Production must be raised if we are to live in reasonable security and comfort.

In one respect Crookes was right. He foresaw that the intensification of production required more combined nitrogen than the limited supplies furnished by the distillation of coal and the nitrate deposits, to counter-balance the colossal wastage which civilisation and urban life bring about. The fixation of atmospheric nitrogen was, as he put it, vital to the progress of civilised humanity. This problem has been solved in the last ten years and is one of the remarkable achievements of applied science. It could have been solved sooner if money had been forthcoming for long range research, but it took the war to bring us to our senses. Thirty years ago the fixation of 29·4 grams of a mixture of nitrogen and oxygen at the expenditure of one horse power was recorded as a scientific achievement. In 1928–29 the estimated production of nitrogen compounds by synthetic processes was equivalent to 1·3 million metric tons of pure nitrogen, or over 6 million long tons of Sulphate of Ammonia, which can be sold at prices low in comparison with the prices of agricultural produce. We are entering on an era of nitrogen plenty which is bound to react favourably on the world's food production. One of our problems is to find out how we can make use of this discovery in India. The probability is that the full benefit of fertilizers will be realised only on land reasonably supplied with organic matter.

I may be allowed here to sound a note of warning. Great as are the possibilities offered by synthetic nitrogen compounds there is danger in adjusting our standards of living to increased production based entirely on imported fertilizers. They may be cut off suddenly by international disturbances. The war is too near an experience and the promise of universal peace too uncertain to ignore this side of the question altogether. It will be but a wise precaution to establish their manufacture in India when the correct way of using them has been worked out, their value demonstrated and a demand created.

Our problem is more complex than the simple addition of nitrogen compounds to the soil. We have to face under peculiar conditions of climate the question of controlling moisture, organic matter and air supply in the soil, of regulating the supplies of nitrogen so that it may be available in the right form and quantity when the plant most needs it, so that none may be wasted, and to make use to the utmost of those processes by which nature supplies nitrogen free of charge. These problems centre round the changes which organic material undergoes in the soil and the nitrogen transformations which accompany them.

We have two methods of soil improvement possessing enormous potentialities for increasing crop production and so simple in operation that they can be used by everybody:

(i) the preparation of quick-acting manures from waste organic material

(ii) the use of green manure crops.

I do not propose to discuss recent work on the first method. The practical details have been worked out thoroughly by the Howards at Indore, and by Fowler, Richards and their co-workers at Cawnpore. A paper on this subject is going to be placed before you by Dr. Fowler. I will not anticipate what he is going to say beyond remarking that the results which he has allowed me to examine, place in your hands a method of the greatest value for increasing the outturn of rabi crops which require in this province a quicker acting manure than that provided by turning in a green crop.

We have been working for some years at Shahjahanpur on the utilization of green manure for sugarcane. We have ploughed in on an average of three years observations, 218 maunds per acre of sanai (*Crotolaria juncea*) which adds 50 maunds of dry organic material and 75 lb. of nitrogen to each acre. We have succeeded in raising crops of 850 maunds per acre without the addition of any fertilizing agent other than the sanai produced by the land itself.

Our method of soil treatment is to bring about the early stages of decomposition in the presence of ample moisture. The rainfall after the sanai is ploughed in is carefully watched. If it is less than 5 inches in the first fortnight of September the fields are irrigated. In this way we secure in most of our soils an abundant fungal growth as the land slowly dries. We prevent large accumulations of nitrates in the autumn, which may be lost before the sugar-cane is sown and concentrate the nitrogen in easily decomposable organic form in mycelial and microbial tissue, until it is wanted in mineral form in the spring.

Throughout the experiments we have made estimations of nitrate. The accumulation of nitrate reaches its maximum in May and June just before the first heavy rain. At this time the crop is about ⅓ grown. We have not observed any subsequent large formation of nitrate up to the completion of growth in October. The final yields are in proportion to the mineral nitrogen present in the first period and this suggests at once the importance of available nitrogen in the early stages of the growth of sugarcane. This view is by no means a new one. It has recently been developed by Gregory at South Kensington and Rothamsted, who found that barley absorbed 90 per cent of its total nitrogen when it had made about one-third of its growth. If it is substantiated by further work and found to apply to all crops it gives a clue to several improvements in soil management.

In our studies in connection with the intensification of sugar-cane cultivation we have been influenced by American investigations and methods, more specially those of the workers led by Waksman, who have studied the decomposition of cellulose and dead organic material in the soil. They have shown that the structure of the carbonaceous energy material in the soil largely determines the type of decomposition and the nitrogen trasformations. If moisture and temperature conditions are favourable, the decomposition of cellulosic energy material, the chief constituent of green manure, is mainly accomplished by fungus activity resulting in the formation of large quantities of mycelial tissue and the removal of nitrogen temporarily from the reach of higher plants. The synthesised material is later decomposed by other micro-organisms forming mineral nitrogen and humic material, and a definite period of time is required to complete these changes. A large volume of work has been published in the last five years. It explains much that was obscure regarding the utilization of green manure in India, particularly the time factor to which Howard drew attention many years ago.

I now approach the last and most difficult part of my task, to estimate the increased production we may look for by the application of scientific methods to our agricultue. What I am going to say will be more readily understood if I give the production of wheat in a few countries for the crop sown in 1926, which was, on the whole, a good year throughout the world. It is as follows:

United Provinces Irrigated	...	12·2	mds. per acre.
„ Unirrigated	...	8·2	„
Canada	...	13·2	„
U. S. A.	...	10·7	„
France	...	13·0	„
Germany	...	17·5	„
Great Britain	...	22·5	„
Belgium	...	26·3	„

A glance at these figures shows what an immense potential increase of production is open in many countries, especially in America and India. The physical possibility or perhaps even the limit of production in the United Provinces is shown by the yield obtained at the Shahjahanpur Research Station. In 1926 it was 28·8 maunds per acre. In the last 11 years, including two in which the wheat crop was a partial failure, 243 acres have yielded 5,945 maunds or 24·4 maunds per acre. Soil and climate do not impose a serious restriction on production. We cannot, however, take one striking instance of large yields achieved on a small acreage under favourable conditions as the basis of an estimate of the future production of the country as a whole. The actual level in any country is bound to be behind the ideal, no matter how well developed educational and propaganda machinery may be.

It is safer, if such a course be possible, to consider average results obtained in countries which have been compelled to employ intensive methods, but we have no adequate basis of comparison with our conditions. There is no example of a tropical or semi-tropical country in which scientific methods have been applied over a wide area by independant and unsupervised workers.

Sugar-cane cultivation in Java is often quoted as an example of what can be done. It illustrates the combined effect of strictly supervised labour and scientific methods on about one million acres of land, carried out with the object of gaining the highest possible interest on Dutch capital. It does not illustrate what we are aiming at in India—agricultural improvement initiated and carried through by the people themselves, as the result of education and uplift, on 300 million acres.

Let us examine the course of events in Europe and America and learn what we can from them.

In mediaeval England the yield of wheat was 7 maunds per acre. When the consolidation of holdings was completed by the enclosures in about the last quarter of the eighteenth century the yield rose to 14 maunds per acre. It remained at this level until 1,840 when a further advance was made possible by the use of better methods and the introduction of nitrogen fertilisers. By 1870 the yield had risen to 20 maunds per acre.

In America low yields and a growing industrial population are causing uneasiness. By studying agricultural conditions in other countries the conclusion has been reached that 47 per cent represents a possible all round increase of production on the present cropped area. Experts do not agree as to the probable increase in the next few decades. This is placed between the limits of 10 and 30 per cent. These figures are based on considerations of labour. This, as I have said, scarcely enters into our problems in India. We have more people employed in agriculture per unit of cultivated land than any other country, with the possible exception of China and Japan.

The improvement of sugar-cane cultivation extends over 260,000 acres in the United Provinces and gives some indication of the possible course of events. The yield of the unimproved crop in a year of average character is 350 maunds per acre. We pass through four definite stages of improvement:

(1) Better cultivation of the old varieties, yielding 450 maunds per acre.
(2) The introduction of heavier cropping varieties accompanied by a further improvement in cultivation, yielding 600 maunds per acre.
(3) The introduction of some fertilizing agent, such as green manure, yielding 800 maunds per acre.
(4) The intensive cultivation of heavy cropping varieties, yielding 1000 maunds per acre.

The increase over the normal production is 28, 71, 128 and 185 per cent. I believe if such simple modifications of practice as the use of green manure crops and composts made from waste material, were applied to all our arable land, production would be more than doubled; but this means that every cultivator would be conducting his operations in a scientific manner—a state of affairs not yet reached in any country. The point is that it is not to be expected. We must allow for the inertia which will retard the general adoption of improvements in so large a country as India. After giving due weight to this and taking into consideration the abundance of our labour resources and the extraordinary response of our soil to better treatment, it is reasonable to believe that within the next two or three decades we may increase the all round out-turn of our cropped land by 30 per cent in normal seasons. But I assume that much more money will be spent on scientific research and extension work in villages than is now spent.

I hope I have said enough to show that soil improvement in India is worth an effort. It requires generous expenditure from the national exchequer, and there is no better investment, for it gives, to use the words of Huxley, an immediate return of those things which the most sordidly practical man admits to have value. We are working in times well suited for agricultural development. Indifference is giving way. There is a stir throughout the countryside. We can call the movement what we like, but the plain fact is that men are no longer satisfied with a life which provides only hard work and barely enough to eat. Many things are being suggested, but they deal more often than not with preliminaries to social well being, and leave untouched the vital problem of producing more food. In the end the scientific worker will come to the rescue, and the solution will be reached through the experiment station.

NOTES ON SOME PAPERS PRESENTED BEFORE THE SCIENCE CONGRESS

Dr. Gilbert J. Fowler and his collaborators presented the results of their further experiments on the preparation of organic composts with special reference to the economic use of urine in the manufacture of composts and the part played by the 'activator' in the fixation of atmospheric nitrogen. The authors have found that while cow's urine is an important agent for facilitating fermentation, it appears to play no part in the fixation of nitrogen. On the other hand, there is evidence that the presence of 'activator' induces quick rotting and also fixation of nitrogen. Experiments at Coimbatore have also shown distinct evidences of fixation of atmospheric nitrogen during the fermentation of waste organic matter but the extent of fixation appears to depend on certain carbon-nitrogen ratio in the material.

In a paper dealing with studies on soil Actinomyces, Mr. P. K. De of Bangalore records his observations on the role played by Actinomyces in the decomposition of complex organic matter in the soil. Three strains, viz., *Actinomyces scabis, A. chromogens and A. albosporeous* were studied. Of these, the last one was found to be the most active using up the different carbohydrates, the intensity of attack being in the following order—starch, glucose, cane-sugar, arabinose and cellulose.

Messrs. L. S. Nigam and H. N. Batham of the United Provinces examine data obtained in different countries of the world on the seasonal variations in the nitrate content of the soil along with those of the authors. The conclusions drawn are:

(1) the greatest accumulation of nitrates takes place during summer months and the least during winter.

(2) there seems to exist a close relationship between the fluctuations of nitric nitrogen content of soils and different seasons of the year.

(3) the solar activity which appears on the earth in the form of different seasons of the year appears to be a most important factor in controlling the nitrifying bacterial activity in the soil.

The movement of water and soluble salts in the soils with repeated doses of irrigation water at the Agricultural Research Station at Sakrand formed the subject matter of a paper by Mr. V. A. Tamhane and his collaborators. Smaller doses of irrigation water given more frequently leached out soluble salts better than larger doses of irrigation water at longer intervals. For instance, two inches every ten days was more effective than three inches every fifteen days. In the presence of appreciable amount of calcium salts in these soils, sodium salts are leached to a greater degree than calcium salts;