

**THE WASTE PRODUCTS  
OF AGRICULTURE**

# THE WASTE PRODUCTS OF AGRICULTURE

*Their Utilization as Humus*

BY

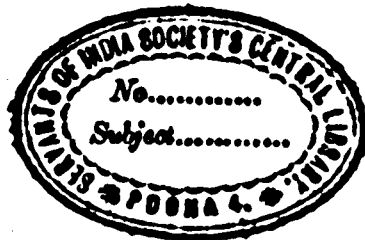
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HUMPHREY MILFORD  
OXFORD UNIVERSITY PRESS  
LONDON NEW YORK TORONTO MELBOURNE  
BOMBAY CALCUTTA MADRAS

1931

J:22

G1  
10912

PRINTED IN GREAT BRITAIN BY HEADLEY BROTHERS,  
109 KINGSWAY, LONDON, W.C.2; AND ASHFORD KENT.

*To*

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## PREFACE

ONE of the main features of crop production at the present day is waste. Except in the Far East, where the large indigenous population has to be fed from the produce of the country-side, little is being done to utilize completely the by-products of the farm in maintaining the fertility of the soil. The ever-growing supplies of agricultural produce, needed by industry and trade, have been provided either by taking up new land or by the purchase of artificial manures. Both these methods are uneconomic. The exploitation of virgin soil is a form of plunder. Any expenditure on fertilizers which can be avoided raises the cost of production, and therefore reduces the margin of profit. It needs no argument to urge that, in maintaining the fertility of the soil, the most careful attention should be paid to the utilization of the waste products of agriculture itself before any demands are made on capital—natural or acquired.

For the last twenty-six years, the senior author has been engaged in the study of crop production in India and in devising means by which the produce of the soil could be increased by methods within the resources of the small holder. These investigations fell into two divisions: (1) the improvement of the variety; and (2) the intensive cultivation of the new types. In the work of replacing the indigenous crops of India by higher yielding varieties, it was soon realized that the full possibilities in plant breeding could only be

achieved when the soil in which the improved types are grown is provided with an adequate supply of organic matter in the right condition. Improved varieties by themselves could be relied on to give an increased yield in the neighbourhood of ten per cent. Improved varieties plus better soil conditions were found to produce an increment up to a hundred per cent or even more.

Steps were therefore taken : (1) to study the conversion of all forms of vegetable and animal wastes into organic matter (humus) suitable for the needs of the growing crop ; and (2) to work out a simple process by which the Indian cultivator could prepare an adequate supply of this material from the by-products of his holding. In other words he has been shown how to become a chemical manufacturer. This task involved a careful study of the various systems of agriculture which so far have been evolved and particularly of the methods by which they replenish the soil organic matter. The line of advance in raising crop production in India to a much higher level then became clear. Very marked progress could be made by welding the various fragments of this subject—the care of the manure heap, green-manuring and the preparation of artificial farmyard manure—into a single process, which could be worked continuously throughout the year and which could be relied upon to yield a supply of humus, uniform in chemical composition and ready for incorporation into the soil. This has been accomplished at the Institute of Plant Industry at Indore. The work is now being taken up in Sind and at various centres in Central India and Rajputana.

The Indore process for the manufacture of humus is described in detail in the following pages. It can be adopted as it stands throughout the tropics and sub-tropics, and also on the small holdings and allotments of the temperate zone. How rapidly the method can be incorporated into the large-scale agriculture of the west is a question which experience alone can answer. It will in all probability depend on how far the process can be mechanized.

In the field of rural hygiene there is great scope for the new method. It can be applied to the utilization of all human, animal and vegetable wastes in such a manner that the breeding of flies is prevented, the water and the food-supply of the people safeguarded and the general health of the locality improved. Cleaner and healthier villages will then go hand in hand with heavier crops.

A.H.

Y.D.W.

Indore

6 April, 1931

*Of composts shall the Muse disdain to sing?  
Nor soil her heavenly plumes? The sacred Muse  
Nought sordid deems, but what is base; nought fair,  
Unless true Virtue stamp it with her seal.  
Then, planter, wouldst thou double thine estate,  
Never, ah! never, be asham'd to tread  
Thy dung-heaps. (From Grainger's *The Sugar Cane*.)*



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## I

### INTRODUCTION

**T**HE maintenance of the fertility of the soil is the first condition of any permanent system of agriculture. In the ordinary processes of crop production, fertility is steadily lost ; its continuous restoration by means of manuring and soil management is therefore imperative.

In considering how the ideal method of manuring and of soil management can be devised, the first step is to bring under review the various systems of agriculture which so far have been evolved. These fall for the most part into two main groups: (1) the methods of the Occident to which a large amount of scientific attention has been devoted during the last fifty years; and (2) the practices of the Orient which have been almost unaffected by western science.<sup>1</sup> The systems of agriculture of the Occident and of the Orient will now be briefly considered with a view of extracting from each ideas and results which can be utilized in the evolution of the ideal method of maintaining and increasing the fertility of the soil.

<sup>1</sup> In the general organization of agriculture, Europe stands mid-way between the east and the west and provides, as it were, the connecting link between these two methods of farming.

THE AGRICULTURAL SYSTEMS OF THE OCCIDENT

The most striking characteristic of the agriculture of the west is the comparatively large size of the holding. Large farms are the rule; small holdings are the exception.<sup>1</sup>

The large farms of the west are for the most part engaged in the production of food and a few raw materials like wool for the urban populations of the world, which are mainly concerned with manufacture and trade. To produce these vast supplies, and at the same time to place them on the markets at low rates, practically all the unoccupied temperate regions of the world, which are suitable for the white races, have already been utilized. The best areas of North America, of the Argentine, of South Africa and large tracts of Australia and practically the whole of New Zealand have during the last hundred years been exploited to produce the endless procession of cargoes of food and raw materials required by the great markets of the world.

The weakness of this system of agriculture lies in the fact that it is new and has not yet received the support which centuries of successful experience alone can provide. At first it was based on the exploitation of the stores of organic matter accumulated by virgin land, which at the best could not last for more than a limited number of years. Even now there is practically no attempt to utilize the large quantities of wheat straw and other vegetable wastes for keeping

<sup>1</sup> The growth of allotments for the production of vegetables in the neighbourhood of urban areas is a comparatively recent phenomenon and only affects a small area.

up the store of organic matter in the soil. The new areas of North America for example soon showed signs of exhaustion. Manuring has become necessary as in the case of the older fields of Europe. To supply the large quantities of combined nitrogen needed, all possible sources except the right one—the systematic conversion of the waste products of agriculture into humus—have one after the other been utilized: guano from the islands off the Peruvian coast, nitrate of soda from Chile, sulphate of ammonia from coal and more recently synthetic nitrogen compounds obtained from the atmosphere. These substances are supplemented by another class of nitrogenous organic manures such as artificial guanos, dried blood and slaughter-house residues, oil cakes and wool waste—the by-products of agriculture—and by another group of artificials—the various phosphatic and potassic fertilizers. These supplies of concentrated manures have enabled agricultural production to be kept at a high level. The fact of their existence for a time tended to distract attention from the fullest utilization of the by-products of the farm. Recently, however, a change has taken place and a large amount of scientific effort has been devoted to the problems which centre round the waste products, both animal and vegetable, of agriculture itself. The need of keeping up the supply of organic matter in the soil is now widely recognized.

After the large size of the holding and the necessity of manuring, the high cost of labour is another leading characteristic of western

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farming. The number of men per square mile of agricultural land who actually work is low.<sup>1</sup> This state of things has arisen from the dearness and scarcity of labour, which has naturally led to the study of labour-saving devices including the use of machinery. Whenever a machine can be invented which saves human labour its spread is rapid. Engines of various kinds are the rule everywhere. The inevitable march of the combine-harvester, in all the wheat-producing areas of the world, is the latest example of the mechanization of the agriculture of the west.

Another feature of this extensive system of large-scale agriculture is the development of food preservation processes, of transport and of marketing, by which the products of agriculture are cheaply and rapidly moved from the field to the centres of distribution and consumption. There is no great dearth of capital at any stage. Money can always be found for any new machine and for any new development which is likely to return a dividend. Land and capital are abundant; efficient transport and good markets

<sup>1</sup> The comparative figures of crop production per worker for the five-year period preceding the War, prepared by the United States Department of Agriculture, are instructive. The number of workers employed per 1,000 acres of crop land was approximately 235 in Italy, 160 in Germany, 120 in France, 105 in England and Wales, 60 in Scotland but only 41 in the United States. In Canada, according to Riddell, the 1911 figures show that every 1,000 acres called for only 26 workers. This observer states that in the three prairie provinces (Alberta, Manitoba, Saskatchewan) the figures are even more striking: the area under field crops was 17,677,091 acres, and the numbers engaged in agriculture was 283,472, so that each person so employed was responsible for 62 acres. Every 1,000 acres required only 16 workers. Since these data were published, further statements have appeared from which it would seem that the size of the working population in agriculture in North America has shrunk still further.



abound. The comparatively small supply of suitable labour and its high cost provide the chief agricultural problems of the west.

This system of agriculture is essentially modern and has developed largely as one of the consequences of the discovery of the steam engine and the rapid exploitation of the supplies of coal, oil and water-power. It has only been made possible by the existence of vast areas of virgin land in parts of the earth's surface on which the white races can live and work. As already mentioned the weak point in this method of crop production is that it is new and lacks the backing which only a long period of practical experience can supply. Mother Earth is provided with an abundant store of reserve fertility which can always be exploited for a time. Every really successful system of agriculture however must be based on the long view, otherwise the day of reckoning is certain.

Side by side with this method of utilizing the land there has been a great development of science. Efforts have been made to enlist the help of a number of separate sciences in studying the problems of agriculture and in increasing the production of the soil. This has entailed the foundation of numerous experiment stations, which every year pour out a large volume of printed results and advice to the farmer. At first the scientific workers naturally devoted themselves to solving local problems and to furnishing scientific explanations of various agricultural practices. This phase is now passing. A new note is beginning to appear in the publications

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of the experiment stations, namely that of direction and advice which can only be advanced by men whose education and training combine the ideas of science with the aims of the statesman. The feeling is not only growing but is being expressed that it is no longer the business of science merely to solve the problems of the moment. Something more is needed. The chief function of science in the agriculture of the future is to provide intelligent direction in general policy and to point the way.

### THE AGRICULTURAL SYSTEMS OF THE ORIENT

#### *Peasant Holdings*

The chief feature of the agricultural systems of the east is the small size of the holding. The relation between man-power and cultivated area in India is given in Table I.<sup>1</sup> In this table, based on the *Census Report* of 1921, the number of workers and the acreage cultivated have been calculated for the chief provinces of British India. Incidentally these figures illustrate how intense is the struggle for existence in this portion of the tropics.

These minute holdings are frequently cultivated by extensive methods (those suitable for large areas) which neither utilize the full energies of man and beast nor the potential fertility of the soil. Such a system of agriculture can only

<sup>1</sup> See opposite page.

result in poverty. The obvious line of advance is the gradual introduction of more intensive methods, for which the supply of suitable manure, within the means of the average cultivator, is bound to prove an important factor.

If we turn to the Far East, to China and Japan, a similar system of small holdings is accompanied by an even more intense pressure of population both human and bovine. In the introduction to *Farmers of Forty Centuries*, King states that the three main islands of Japan had in 1907 a population of 46,977,003, maintained on 20,000 square miles of cultivated fields. This is at the rate of 2,349 to the square mile or more than three people to each acre.<sup>1</sup> In addition Japan fed

TABLE I.—THE RELATION BETWEEN MAN-POWER AND CULTIVATED AREA IN INDIA

Provinces	Number of acres cultivated per 100 ordinary cultivators
Bombay .. .. .	1,215
North-West Frontier Province..	1,122
Punjab .. .. .	918
Central Provinces .. .. .	848
Burma .. .. .	565
Madras .. .. .	491
Bengal .. .. .	312
Bihar and Orissa .. .. .	309
Assam .. .. .	296
United Provinces .. .. .	251

<sup>1</sup> These figures agree very closely with those quoted in the *Japan Year Book* of 1931 in which the number of persons per square kilometre is given as 969 : equivalent to 2,423 to the square mile.

on each square mile of cultivation a very large animal population—69 horses and 56 cattle, nearly all employed in labour; 825 poultry; 13 swine, goats and sheep. Although no accurate statistics are available in China, the examples quoted by King reveal a condition of affairs not unlike Japan. In the Shantung Province, a farmer with a family of twelve kept one donkey, one cow and two pigs on 2.5 acres of cultivated land—a density of population at the rate of 3,072 people, 256 donkeys, 256 cattle and 512 pigs per square mile. The average of seven Chinese holdings visited gave a maintenance capacity of 1,783 people, 212 cattle or donkeys and 399 pigs—nearly 2,000 consumers and 400 rough food transformers per square mile of farm land. In comparison with these remarkable figures, the corresponding statistics for 1900 in the case of the United States per square mile were: population 61, horses and mules 30.

The problems of tropical agriculture for the most part relate to small holdings. The main purpose of this peasant agriculture is crop production; animal husbandry is much less important. In India the crops grown fall into two ✓ classes—(1) food and fodder crops and (2) money crops. The former includes, in order of area: rice, millets, wheat, pulses and fodder crops, barley and maize and sugar-cane. The money crops are more varied; cotton and oil seeds are the most important, followed by jute and other fibres, tobacco, tea, opium, indigo and coffee. It will be seen that food and fodder crops comprise ✓ 82 per cent of the total area under crops and that

money crops, as far as extent is concerned, are relatively unimportant.'

The primary function of Indian agriculture is to supply the cultivator and his cattle with food. Compared with this duty all other matters are subsidiary. The houses are built of mud, thatched

TABLE II.—AGRICULTURAL STATISTICS OF BRITISH INDIA, 1926-27

Area, in acres, under food and fodder crops	
Rice .. .. .	78,502,000
Millets .. .. .	38,776,000
Wheat .. .. .	24,181,000
Gram .. .. .	14,664,000
Pulses and other good grains .. .. .	29,154,000
Fodder crops .. .. .	8,940,000
Condiments, spices, fruits, vegetables and miscellaneous food crops .. .. .	7,537,000
Barley .. .. .	6,387,000
Maize .. .. .	5,555,000
Sugar .. .. .	3,041,000
<b>Total, food and fodder crops .. .. .</b>	<b>216,737,000</b>
Area, in acres, under money crops	
Cotton .. .. .	15,687,000
Oil seeds, chiefly rape and mustard, sesamum, groundnuts and linseed .. .. .	14,999,000
Jute and other fibres .. .. .	4,411,000
Dyes, tanning materials, drugs, narcotics and miscellaneous money crops .. .. .	1,729,000
Tobacco .. .. .	1,055,000
Tea .. .. .	738,000
Opium .. .. .	59,000
Indigo .. .. .	104,000
Coffee .. .. .	91,000
<b>Total, money crops .. .. .</b>	<b>38,873,000</b>

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with grass and are almost devoid of furniture. Expenditure on clothing and warmth is, on account of the customs of the country and the nature of the climate, much smaller than in European countries. Nevertheless, the cultivators require a little money with which to pay the land revenue and to purchase a few necessaries in the village markets. Hence the growth of money crops to the extent of about one-fifth the total cultivated area.<sup>1</sup> The produce, after conversion into cash,

TABLE III.—YIELD OF THE MORE IMPORTANT CROPS OF INDIA, 1926-27

Food crops			
Rice .. .. .	..	..	29,636,000 tons
Wheat .. .. .	..	..	8,941,000 "
Millets .. .. .	..	..	7,806,000 "
Gram .. .. .	..	..	3,979,000 "
Barley .. .. .	..	..	2,550,000 "
Sugar .. .. .	..	..	3,234,000 "
Maize .. .. .	..	..	1,919,000 "
Money crops			
Jute .. .. .	..	..	12,132,000 bales (each 400 lb.)
Cotton .. .. .	..	..	4,960,000 " "
Groundnuts .. .. .	..	..	2,035,000 tons.
Rape and mustard .. .. .	..	..	986,000 "
Linseed .. .. .	..	..	407,000 "
Sesamum .. .. .	..	..	411,000 "
Castor seed .. .. .	..	..	128,000 "
Tea .. .. .	..	..	392,917,800 lb.
Coffee .. .. .	..	..	34,286,806 "
Rubber .. .. .	..	..	23,002,700 "
Indigo .. .. .	..	..	18,100 cwt.

is afterwards either worked up in the local mills or exported. To some extent food crops are also money crops. The population of the towns and cities is largely fed from the produce of the soil, while in addition a small percentage of the total food grains produced is exported to foreign countries. In some crops like sugar-cane, the total out-turn is insufficient for the towns and large quantities of sugar are imported from Java, Mauritius and the continent of Europe.

When we come to the details of soil management, a further striking difference between the methods in vogue in the west and on the peasant holdings of the east is at once manifest. In China, fertility has for centuries been maintained at a high level without the importation of artificial manures. Although it was not till 1888, after a protracted controversy lasting thirty years, that western science finally accepted as proved the important part played by pulse crops in enriching the soil, nevertheless centuries of experience had taught the peasants of the east the same lesson. The leguminous crop in the rotation is everywhere one of their old fixed practices. Moreover, on the alluvium of the Indo-Gangetic Plain, the deep, spreading root-system of the pigeon pea (*Cajanus indicus* Spreng.) is utilized by the peasantry as an efficient substitute for the periodical subsoil ploughing which these closely-packed, silt-like soils require. In the case of the best cultivators, the general soil management and particularly the conservation and utilization of combined nitrogen has already reached a high level. This has been described, in the case of the United

Provinces of India, by Clarke in a recent paper which has been reproduced as Appendix B (p. 137). In China and Japan not only the method of soil management but also the great attention that is paid to the systematic preparation, outside the field, of food materials for the crop from all kinds of vegetable and animal wastes compelled the admiration of one of the most brilliant of the agricultural investigators of the last generation. The results are set out by King in his unfinished work—*Farmers of Forty Centuries*—which should be prescribed as a textbook in every agricultural school and college in the world.

Another feature of this agriculture is the cultivation of rice wherever the soil and water-supply permit. In the scientific consideration of the methods of soil management under which the rice crop of the Orient is produced, practical experience at first seems to contradict one of the great principles of the agricultural science of the Occident, namely the dependence of cereals on nitrogenous manures. Large crops of rice are produced in many parts of India on the same land year after year without the addition of any manure whatever. The rice fields of the country export paddy in large quantities to the centres of population or abroad, but there is no corresponding import of combined nitrogen.<sup>1</sup>

<sup>1</sup> Taking Burma as an example of an area exporting rice beyond seas, during the twenty years ending 1924, about 25,000,000 tons of paddy have been exported from a tract roughly 10,000,000 acres in area. As unhusked rice contains about 1.2 per cent of nitrogen the amount of this element, shipped overseas during twenty years or destroyed in the burning of the husk, is in the neighbourhood of 300,000 tons. As this constant drain of nitrogen is not made up for by the import of manure, we should expect to find a gradual loss of fertility. Nevertheless this does not take place either in Burma



Another important difference between the east and the west concerns the supply of labour. In the Orient it is everywhere adequate, as would naturally follow from the great density of the rural population. Indeed in India it is so abundant that if the time wasted by the cultivators and their cattle for a single year could be calculated as money, at the local rates of labour, a perfectly colossal figure would be obtained. One of the problems underlying the development of agriculture in India is the discovery of the best means of utilizing this constant drain, in the shape of wasted hours, for increasing crop production. There is therefore no lack of human labour in developing the agriculture of the east. Another favourable factor is the existence of excellent breeds of work-cattle and of the buffalo.<sup>1</sup>

The last characteristic of this ancient system of agriculture is lack of money. Again there is a great contrast between the east and the west. There is little or no spare capital for the improvement of the holding. Over large tracts of India at any rate, the cultivators are in the hands of the moneylender and indebtedness is the rule. For many years one of the pre-occupations of Government has been the discovery of safeguards

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or in Bengal, where rice has been grown on the same land year after year for centuries. Clearly the soil must obtain fresh supplies of nitrogen from somewhere, otherwise the crop would cease to grow. The only likely source is fixation from the atmosphere, probably in the submerged algal film on the surface of the mud. This is one of the problems of tropical agriculture which calls for early investigation.

<sup>1</sup> The buffalo is the milch cow of the Orient and is capable not only of useful labour in the cultivation of rice, but also of living and producing large quantities of rich milk on a diet on which the best dairy cows of Europe and America would starve. The digestive processes of the buffalo is a subject which appears to have escaped the attention of the investigators of animal nutrition.

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by which the cultivator can be saved from the worst consequences of his own folly—reckless borrowing for unproductive purposes—and maintained on the land. The recent development of co-operation and the rapid increase in the number of primary credit societies has only been possible because of this volume of indebtedness.

#### *Plantations*

While small holdings, accompanied by a dense population, are an important feature of eastern agriculture, nevertheless there are exceptions. Throughout this portion of the tropics European enterprise has removed the original forest and established in its place extensive plantations of such crops as sugar-cane, tea, rubber and coffee. The labour for these estates is obtained from indigenous sources; the capital and management are contributed by Europeans. Plantations of this kind are common all over the east and are an important feature of the agriculture of Java, Ceylon, the Federated Malay States, Assam and the uplands of Southern India. One of the features of this agriculture is the attention paid to manurial problems. Comparatively large sums of money are expended every year in the purchase of artificial manures, mainly for keeping up the supply of combined nitrogen. During a tour in Ceylon in 1908, when visits were paid by the senior author to a number of tea estates, the managers invariably produced their manurial programme on which suggestions were always invited. Ceylon at that time offered a tragic example of the damage which results from uncontrolled tropical rainfall

on sloping land, from which the forest canopy had been removed without providing a proper system of terracing combined with surface-drainage. Over large areas of hilly country, formerly forest and now exclusively under tea, practically the whole of the valuable surface soil rich in humus had been lost by denudation. The tea plant was producing crops from the relatively poor subsoil, supplemented by the constant application of expensive manures.<sup>1</sup>

### *Undeveloped Areas*

Very large stretches of the Orient are still under forest and at present carry a very small population, supported by hunting, fishing and by the small cultivated areas surrounding the villages.

<sup>1</sup> In a recent review of this question in *Crop Production in India*, published in 1924, the damage which has resulted from erosion on the plantations of the Orient was referred to (pp. 14-5) as follows:—

'It is in the planting areas of the east, however, that the most striking examples of soil denudation are to be found. Instances of damage to the natural capital of the country are to be seen on the tea estates near Darjeeling, on the hill-sides in Sikkim, on the upper terraces in the vale of Kashmir, in the Kumaon Hills, on the tea estates in Ceylon and Assam, and in the planting districts of Southern India and the Federated Malay States. In most of these areas forest land was so abundant that the need for the preservation of the soil was not at first recognized. Thanks to the efforts of Hope, a former scientific officer employed by the tea industry in Assam, the control of the drainage and the checking of erosion are now widely recognized and are being dealt with by the planters in many parts of India. A great impetus to this work was given by the publication in India of a detailed account of the methods in use by the Dutch planters in Java, where the terracing and drainage of sloping land, under tea and other crops has been carried to a high stage of perfection. In this island the area of land available for planting is strictly limited, while the feeding of the large indigenous population is always a serious problem. As a consequence the development of the island is very strictly controlled by the Government, and one of the conditions of planting new forest lands is the provision of a suitable system of terraces, combined with surface-drainage. The advantage is not all on the side of the State. The manuring of tea soils in Java is far less necessary than in Ceylon and India, while one important consequence of the retention of the valuable soil made by the forest is healthy growth, which suffers remarkably little damage from insect and fungoid pests.'

These undeveloped forest areas occur everywhere, particularly in the Malay Archipelago, the Federated Malay States, Burma and the low country of Ceylon. In the search for the ideal method of manuring in the tropics, the greatest care will have to be taken to preserve the valuable surface soil whenever the forest canopy has to be removed for the creation of new cultivated land. Some at any rate of these potentially rich tracts are almost certain to be taken up during the present century. They will therefore provide ample opportunities of applying any lessons in soil management, which science can extract from experiment and from experience. The serious mistakes of the past must not be repeated when the time comes for developing the vast areas of tropical forest still untouched.

It will be evident that the systems of agriculture of the west and of the east are very different and that the two have little or nothing in common. In a sense these two methods of managing land remind one of the two sides of a coin. The one supplements the other: each can be regarded as a part of one great whole. Clearly when attempting to evolve the ideal system of manuring and soil management of the future, both of these widely different methods of agriculture must be studied. This has been done by the senior author for the last twenty-six years in various parts of India—on the alluvium of the Indo-Gangetic plain at Pusa in Bihar, on the loess soils of the Quetta Valley on the Western Frontier and on the black cotton soils

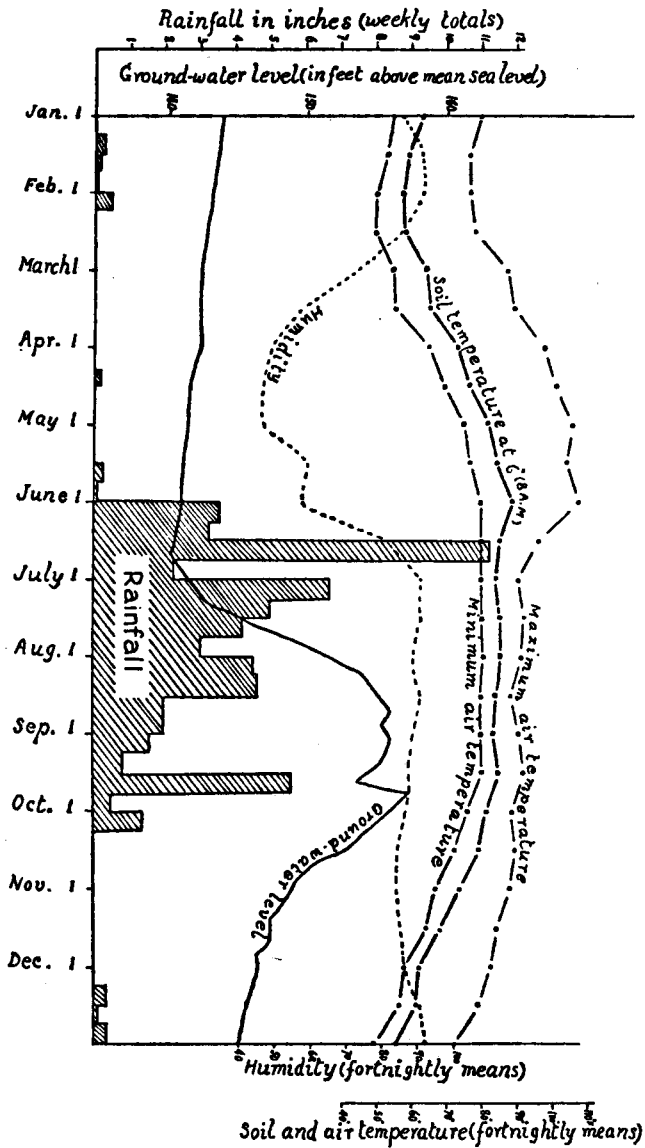


PLATE I. RAINFALL, TEMPERATURE, HUMIDITY AND DRAINAGE, PUSA, 1922

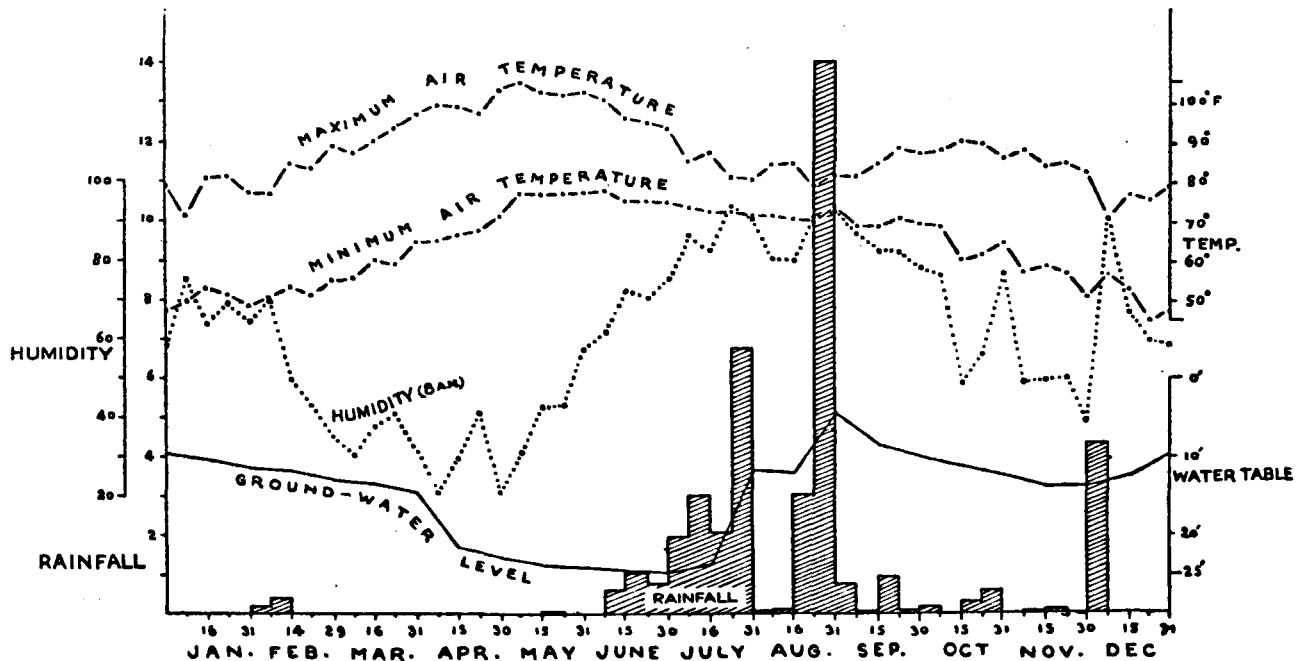


PLATE II. RAINFALL, GROUND-WATER LEVEL, TEMPERATURE AND HUMIDITY, INDORE, CENTRAL INDIA, 1928

of peninsular India at Indore. The chief climatic factors at Pusa and Indore are represented in Plates I and II. The climate of Quetta resembles generally that of Persia, where the rainfall is received mainly during the winter months, often in the form of snow. At these three centres a method of utilizing all the vegetable and animal wastes of the holding has gradually been evolved. The latest scientific work of the Occident and particularly that recently accomplished at the experiment station of New Jersey, together with the practices in vogue in India and the Far East, have been welded together and synthesized into a system for the continuous manufacture of manure throughout the year so that it forms an integral part of the industry of agriculture.<sup>1</sup> No extra labour is required in our manure factory. No imported chemicals such as Adco are needed in this process. No capital is required at any stage of the manufacture. The methods now in use at Indore form the main subject of this book, which also attempts to deal with a number of related matters such as—the role of organic matter in the soil, the methods of replenishing the supply of organic matter now in use and the recent investigations

<sup>1</sup> In considering all this information—the various agricultural systems in use at the present time, as well as the large volume of scientific papers dealing with manurial questions, which have been poured out by the experiment stations during the last fifty years, we have been impressed by the evils inseparable from the present fragmentation of any large agricultural problem and its attack by way of the separate science. All this seems to follow from the excessive specialization which is now taking place, both in the teaching and in the application of science. In the training given to the students and in much of the published work, the tendency of knowing more and more about less and less is every year becoming more marked. For this reason any review of the problem of increasing soil fertility is rendered peculiarly difficult, not only by the vast mass of published papers but also by their fragmentary and piecemeal nature.

which have been carried out on the conditions necessary for converting raw organic residues into humus which can be immediately nitrified in the soil and so made use of by the plant. The Indore process can easily be carried out, not only in the tropics but also on the small holdings of the temperate regions and on the allotments (provided space is made available) in the neighbourhood of urban areas, where it is now the practice to burn most of the vegetable waste. How rapidly the system can be introduced into the farming systems of the Occident is a question to which no answer can be given until the ideas in this book have been fully tried out in western agriculture. It is not impossible that they may founder for a time on the present high cost of labour. The method however is in full accord with the well-marked tendency in western agriculture towards a more intensive production. The inevitable change over from extensive to intensive methods has already begun. For production to be more economical, the acre yield must be increased. Already in the United States the suggestion has been made that the line of advance in crop production lies in restricting the area cultivated. A portion of the impoverished prairie lands should go back to grass. The crops needed should be raised from a smaller area. These ideas will become practicable the moment the farmer learns how to utilize the waste products of his fields in increasing the fertility of the soil. This is the greatest need of agriculture at the present day.



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## APPENDIX A

### THE MANURIAL PROBLEM IN INDIA<sup>1</sup>

THE manurial problems of India were considered in detail by the recent Royal Commission on Agriculture in India which, after an extensive study of the subject lasting more than two years, reported in 1928. That section of the report which deals with fertilizers is reprinted in full below. A study of this account will bring home to the investigator and to the general reader the evils which invariably result from the fragmentation of any large agricultural problem.

#### FERTILIZERS

80. Of the principal plant-food materials in which the soils of India are deficient by far the most important (except in parts of the crystalline tracts where the deficiency of phosphates may be more serious) is nitrogen, and the manurial problem in India is, in the main, one of nitrogen deficiency. India, as is well known, depends almost exclusively on the recuperative effects of natural processes in the soil to restore the combined nitrogen annually removed in the crops, for but little of this is returned to the soil in any other way. Much of the farmyard manure available is burnt as fuel whilst a large quantity of combined nitrogen is exported in the form of oil seeds, food and other grains, and animal products such as hides and bones. This loss is in no way compensated by the importation of nitrogenous fertilizers, for 1925-26 was the first year which the imports of sulphate of ammonia into this country, which amounted only to 4,724 tons, exceeded the exports and was also the first year in which the greater part of the production of this fertilizer by the Tata Iron and Steel Company at Jamshedpur and in the coalfields of Bengal and Bihar and Orissa was consumed in India. In these circumstances, it is fortunate that the

<sup>1</sup> Extract from the *Report of the Royal Commission on Agriculture in India*, Bombay, 1928, pp. 80-93.

recuperative processes in the soil are more pronounced in tropical and sub-tropical than in temperate regions. Although it has been stated in evidence before us that it has not been established that improved and higher yielding varieties of crops, more especially of wheat and sugar-cane, take more from the soil than the varieties they replace, and that their cultivation on present lines will not, therefore, be followed by any loss of permanent fertility, we are of opinion that there is justification for the view that improved crops generally require, for their fullest development, more liberal manurial treatment than those ordinarily grown. The subject is one which requires careful study by the agricultural departments in India and should form an essential part of the investigations discussed in the following paragraph.

#### MANURIAL EXPERIMENTS

81. An acceleration of the recuperative processes in the soil can be effected by improved agricultural methods, by adequate soil aeration, judicious rotations and the cultivation of green-manure crops. The loss of combined nitrogen can also be partially made up by the application of natural and artificial manures. With certain definite exceptions, however, such as, for instance, sugar-cane and the more valuable garden crops, it has yet to be determined for what conditions and for what crops artificial manures can be profitably used to stimulate crop production in India. In this connexion, we have been impressed by the importance of research into the fundamental problems connected with losses in nitrogen and with nitrogen recuperation. We saw something of the work in this field which was being carried on at Pusa by Dr. Harrison and at Nagpur by Dr. Annett. Although, ever since the reorganization of the agricultural departments in 1905, manurial experiments have engaged a large part of their time and energies and have been carried out on every agricultural station in India, it cannot be said that the agricultural experts are even yet in a position to give satisfactory advice to the cultivator in regard to the use of manures. A large amount of data has been collected but it has not been studied systematically or reduced to a form which would enable clear and definite conclusions to be drawn. The problem requires to

be studied in three aspects : in relation, in the first instance, to the crops which are dependent solely on rainfall, in the second, to crops which are grown on irrigated land, and lastly, to the planters' crops and intensive cultivation such as that of sugar-cane and garden crops. It is hardly necessary to point out that the use of nitrogenous or other artificial fertilizers is not profitable in all conditions. Where crop production is limited by a small rainfall, the annual additions of combined nitrogen to the soil as the result of natural processes may be sufficient to meet the needs of a crop the out-turn of which is limited by the moisture available. It has, for example, been found in the Central Provinces that the application of fertilizers benefits dry crops, including unirrigated cotton, only in years when the rainfall is adequate and that, in particular, it does not benefit wheat which, in that province, is grown on rainfall only. The planting community, which has its own specialist officers, needs no advice from the agricultural departments in regard to the economic use of manures. We would, however, take this opportunity of stressing the value of close touch between the community and the departments in regard to this and other agricultural matters. It is essential that the departments should be in a position to give the ordinary cultivator, both of irrigated and unirrigated crops, definite guidance on the point. The first step is the careful study of the existing material and the correlation of the results hitherto obtained. The second step is the formulation of a programme of experiment with the object of ascertaining, with all possible accuracy, the extent to which fertilizers can be used with profit. This programme should include the laying out of a short series of permanent manurial plots, on lines appropriate to conditions in India, on provincial experimental farms. Only by conducting manurial experiments over a number of years will it be possible to compile such records as would make a substantial contribution to the knowledge of the problems of manures and manuring under tropical and sub-tropical conditions about which little is yet known. The scientific value of continuous experiments depends on accurate methods of collection of all relevant data with a view to their subsequent correlation. All such schemes for manurial trials would

ordinarily be drawn up by the Director of Agriculture in close consultation with the agricultural chemist and the deputy directors of agriculture under whose immediate supervision the experiments would be conducted. We wish especially to emphasize the importance of manurial experiments on unirrigated land as the cultivator of such land, who runs, with his very limited financial resources, the risk of losing his crop in an unfavourable season, stands most in need of guidance in this matter. The study of the available data and the formulation of an ordered programme to replace the present somewhat haphazard methods of dealing with the problem would, we think, provide sufficient work to justify an officer of the Agricultural Department being placed on special duty for a limited period, but we prefer to make no definite recommendations on this point and to leave it to the consideration of the local governments. Local conditions vary so greatly between province and province, especially in regard to unirrigated land, that it does not appear necessary to attach an officer to Pusa specially to assist the provinces in this investigation. The Council of Agricultural Research should be in a position to advise as to the manner in which the experiments can best be conducted so as to secure uniformity of method as far as possible and to render the results obtained in one province of some value to other provinces.

#### INTERNAL SOURCES OF SUPPLY AND THEIR DEVELOPMENT

##### (a) FARMYARD MANURE

82. The first question which arises, in considering the internal supplies of nitrogen available in India and the methods by which these can best be developed, is that of the use of farmyard manure as fuel. The view is generally held that it is the absence of a sufficient supply of firewood which, over large parts of India, compels the burning of cow-dung as fuel. But it must be recognized that there is often a definite preference for this form of fuel, as its slow burning character is regarded as making it specially suitable to the needs of the Indian housewife. Thus we are informed that, in Burma, immigrant labourers from India persist in using cow-dung as fuel although an abundant supply of firewood is readily

available. Our evidence does not suggest any alternative fuel for domestic purposes in districts where wood and coal are dear. In some tracts, cotton-stalks, the dry stubble and stalks of *tur* (*Cajanus indicus*), the pith of jute and sann hemp and the megass of sugar-cane, where the use of the McGlashan furnace leaves a surplus which is not required for boiling the juice, could be utilized for fuel to a far greater extent than they are at present. Fuel plantations, more especially irrigated plantations, the formation of which we discuss in Chapters VIII and X, can assist only in a very limited area. In our view, the agricultural departments have a difficult task to perform in attempting to promote the utilization of farmyard manure for its proper purpose. Propaganda in this direction can only prove effective if an alternative fuel is suggested and if the cultivator can be sufficiently imbued with a sense of thrift to induce him to burn that which will probably seem to him a less satisfactory substance. There has been little advance in regard to the preservation of manure since Dr. Voelcker wrote his report on Indian agriculture in 1893. The practice of providing litter for cattle is rarely, if ever, adopted except on government farms. No efforts are made by the cultivator to preserve cattle urine. Manure pits are still seldom found in Indian villages. Where they do exist, no attempts are made to preserve the manurial value of the contents or to safeguard the public health by covering the material with earth.

(b) COMPOSTS

83. While the task is difficult, there is no doubt that something can be done to promote the better preservation of such farmyard manure as is not diverted to consumption as fuel, by using it as a compost with village sweepings, leaves, and other decomposed vegetable matter. In this connexion, we are impressed by the results achieved in the Gurgaon district of the Punjab, where many villages have, as a direct consequence of propaganda, adopted the practice of depositing in pits all village sweepings and refuse, along with a proportion of cow dung. The effects on crops to which such manure has been applied, and on the sanitation and general amenities of the villages, were most marked. There is no reason why

efforts on similar lines should not be made in other parts of the country. The Indian cultivator has much to learn from the Chinese and the Japanese cultivator in regard to the manufacture of composts. Artificial fertilizers are used as little in China as they are in India ; but there is no organic refuse of any kind in that country which does not find its way back to the fields as a fertilizer. Not only is all human waste carefully collected and utilized, but enormous quantities of compost are manufactured from the waste of cattle, horses, swine and poultry, combined with herbage straw, and other similar waste. Garbage and sewage are both used as manure. The agricultural departments in India are fully alive to the necessity for instructing the cultivator in the better preservation of manure and the use of composts, but there is great scope for an extension of their activities in this respect. For example, the possibilities of manufacturing synthetic farm-yard manure from waste organic material on the lines worked out at Rothamsted deserve to be fully investigated. At Rothamsted, research was at first directed towards discovering artificial means whereby the decomposition of straw might be effected. Straw contains three essentials to plant growth, viz. nitrogen, phosphate and potash. The work proved successful and a method was devised for treating large quantities of straw for the preparation of manure. Reagents were subsequently discovered which were capable of bringing about the rapid rotting, not only of straw but also of other plant residues, and thus of producing a valuable organic manure at a moderate cost. Synthetic farmyard manure is being prepared by the departments of agriculture in Madras and the Central Provinces. The agricultural department in Bengal, following the valuable lead given by Rothamsted, has attempted the manufacture of artificial farmyard manure on a considerable scale. Cattle urine and washings from cattle-sheds, mixed with bone meal, have been used with immediate success. Weeds, various grasses, sugar-cane trash, refuse, straw, prickly-pear, etc., have all proved capable of breaking down into excellent material approximating more or less closely in appearance and in composition to that of cow-dung. Experiments have also been made in Burma but have not so far proved successful. Valuable work on the

preparation of composts from night soil and refuse and from cattle urine, weeds, etc., is being done by Dr. Fowler at Cawnpore. In Europe, work of this character has now emerged from the experimental stage and processes devised for dealing with various classes of materials are already on the market. In India, however, the departments concerned have still to devise and introduce a practical method which can be used with profit by the ordinary cultivator on his own land.

The manurial value of earth obtained from the sites of abandoned villages is recognized in many parts of India. The quantities available are, however, negligible in relation to the manurial requirements of the country.

(c) NIGHT SOIL

84. Prejudice against the use of night soil has deterred the cultivator in India from utilizing to the best advantage a valuable source of combined nitrogen. There is, however, evidence that this prejudice is weakening and that, where night soil is available in the form of poudrette, it is tending to disappear. From the point of view of public health, the use of poudrette is preferable to that of crude night soil and, given co-operation between agricultural departments and municipal authorities, there is hope that the manufacture of poudrette should prove profitable to municipalities and beneficial to the cultivators in their neighbourhood. The methods of converting night soil into poudrette adopted at Nasik and elsewhere in the Bombay Presidency have been highly successful and appear well worth study by other municipalities. The advantages of this system of dealing with night soil appear to us to justify a recommendation that the departments of local self-government in all provinces should bring them to the notice of all municipal authorities and should also take steps to establish a centre at which members of the municipal sanitary staffs can receive a suitable training in this method of disposing of night soil. The agricultural departments should keep a watchful eye on all experiments in the conversion of night soil into manure and should themselves conduct such experiments. Where municipal authorities in any part of the country are in a position to



supply it, the agricultural departments should assist them to find a market by arranging demonstrations of the value of night soil as manure on plots in the neighbourhood of the towns.

Another way in which night soil can be converted into a form in which its use is less obnoxious to the cultivator is by the adoption of the activated sludge process. This process reduces sewage, by the passage of air through it, to a product which can either be used as required in the form of effluent from the sewage tanks or dried and sent where there is a demand for it. The activated sludge process is suitable only for towns which have a sewage system. It is much more expensive than conversion into poudrette but has the advantage of conserving a larger percentage of nitrogen. Up to the present, this system has been adopted in India on any considerable scale only at Tatanagar. The possibility of selling the product at a price that would yield a fair return on the cost of manufacture must depend upon a careful survey of all the relevant factors, including the local market for the product. In estimating the cost of the necessary plant, due regard should be paid to the cost which would be involved in installing any alternative method of sewage disposal, and, if it should prove possible to place a valuable fertilizer at the disposal of the cultivators at a price they can afford to pay, without risk of imposing any additional net charge upon the local ratepayers, we think that it is in the public interest that such schemes should be adopted.

#### (d) LEGUMINOUS CROPS

85. Another indigenous source of combined nitrogen to which increasing attention is now being paid by the agricultural departments in India, is leguminous crops and green-manures. The value of leguminous crops in his rotation has always been recognized by the cultivator and the work before the agricultural departments in regard to these crops lies not so much in popularizing the principle of their cultivation as in discovering the varieties of leguminous crops best suited to increase the soil fertility and in recommending such varieties to the cultivators. Recent research has drawn attention to the fact that such crops vary greatly in their power of fixing

nitrogen in the soil and should not be regarded as of equal value. Moreover, it is only when the leguminous crop is grown for green-manure that, in all cases, the soil gains in nitrogen. Mr. Howard instances gram as a crop which improves the soil and Java indigo as a crop which seriously depletes the supply of combined nitrogen.

(e) GREEN-MANURES

86. The agricultural departments in India have devoted much time and attention to work on green-manure crops with a view to discovering the crops which can best be used for green-manure, the time at which they should be grown and the manner in which they should be applied. Their work has shown that sann hemp on the whole gives the best result and it would doubtless be more often grown for use as green-manure were it not that it may exhaust so much of the moisture in the soil that, when it is ploughed in, there is not sufficient left both to decompose it and to enable a second crop to grow. Much experimental work is still, therefore, required to discover the green-manure crops which can best be included in the cultivators' rotations. The economics of green-manure crops from the point of view of the small cultivator also require to be worked out. The small cultivator is naturally hesitant about growing a crop which only indirectly brings him any financial advantage. With his slender resources, it is indeed not unreasonable for him to take the view that he cannot afford to sacrifice even a catch crop in this way and it is therefore not until the agricultural departments are in a position to demonstrate to him beyond a shadow of doubt the paying nature of green-manure crops on small holdings that these departments will be justified in persuading the small cultivator to adopt them or that their advocacy of them will stand any chance of success. In the present state of knowledge, such crops would appear an expedient to be adopted by the larger landholder and, for the small cultivator, a leguminous crop in his rotation would seem to hold out better prospects of benefit.

The possibility of growing such crops as *dhaincha* and ground-nut, the leaves of which can be used as green-manure without interfering with the commercial value of the crop, is

worth consideration. The use of ground-nut in this way for green-manure would furnish an additional reason for extending the area of this valuable crop. In the case of crops of a woody nature such as sann hemp, it must, however, be remembered that their utility as green-manure for the succeeding *rabi* crops depends to a large extent on the presence of sufficient moisture in the soil to rot the dry stems and roots.

In Madras, the Punjab and the Central Provinces, the experiment has been made of encouraging the cultivation of green-manure crops under irrigation by the remission of the charge for water from government sources or irrigation. The fact that the results have so far been disappointing may be due to a failure to accompany the remission with sufficient propaganda as to the advantages to be derived from the growing of these crops. We think that the continuance of the concession and its extension to other areas should be conditional on its being accompanied by an active campaign of propaganda, directed particularly to the larger landholder rather than the small cultivator. All areas where the concession is made should be kept under regular examination. If, after a period of five to ten years, it should appear that the concession given in regard to water charges has failed to achieve its main purpose, it should be rescinded.

(f) OIL CAKES

87. The loss to India of a valuable source of combined nitrogen as the result of the export of so large a proportion of its production of oil seeds was emphasized by many witnesses before us. The yield and exports of oil seeds during the last fifteen years are shown in the following table [see opposite page]:—

These figures indicate that, of the out-turn of the seed of cotton, ground-nut, rape and mustard, linseed and sesamum, the exports amount to an average of eighteen per cent and they suggest the loss which the soil of India suffers by the export of a valuable by-product on the assumption that the whole of the nitrogen contained might be returned to the soil. Under existing practice, indeed, much of this material would probably be fed to cattle and subsequently dissipated as fuel. But it is not surprising that the view that an export

TOTALS BY FIVE YEAR PERIODS

	Cotton Seed	Ground- nut	Rape and Mustard	Linseed	Sesa- mum	Total of Columns 2-6 7	Total of all Oil Seeds 8
1	2	3	4	5	6	7	8
<b>1910-11 to 1914-15</b>							
Yield ('000 tons) .. .. .	8,419	3,475	6,129	2,541	2,354	22,918	
Exports ('000 tons) .. .. .	1,125	1,035	1,149	1,983	494	5,786	6,832
Percentage of Exports to yield .. .. .	13	30	19	78	21	25	—
<b>1915-16 to 1919-20.</b>							
Yield ('000 tons) .. .. .	8,545	4,758	5,362	2,171	2,104	22,940	—
Exports ('000 tons) .. .. .	387	567	495	1,283	166	2,898	3,408
Percentage of Exports to yield .. .. .	4½	12	9	59	8	12½	—
<b>1920-21 to 1924-25.</b>							
Yield ('000 tons) .. .. .	10,733	5,786	5,602	2,203	2,336	26,660	—
Exports ('000 tons) .. .. .	686	1,240	1,181	1,376	119	4,602	5,116
Percentage of exports to yield .. .. .	6½	21	21	62	5	17	—
<b>Total of 15 years 1910-11 to 1924-25</b>							
Total Yield ('000 tons) .. .. .	27,697	14,019	17,093	6,915	6,794	72,518	—
Total Exports ('000 tons) .. .. .	2,198	2,842	2,825	4,642	779	13,286	15,356
Percentage of exports to yield .. .. .	8	20	16½	67	11½	18	—

tax on oil seeds and oil cakes within the purchasing power of the cultivator has found much favour and even received the support of the Board of Agriculture in 1919 and of the majority of the Indian Taxation Enquiry Committee, but not that of the Indian Fiscal Commission. Some witnesses before us went further and urged the total prohibition of export. Whilst we fully recognize the advantages to Indian agriculture which would follow from a greatly extended use of certain oil cakes as a manure for the more valuable crops such as sugar-cane, tobacco, cotton and tea, we cannot but feel that those who suggest the attainment of this object by the restriction or prohibition of exports have failed to realize the economic implications of their proposal. In the first place, it must be remembered that India has no monopoly of the world's supplies of oil-seeds and is not even the chief supplier of those seeds. The world's linseed market is controlled by the Argentine crop and the sesamum market by the Chinese crop. The competition of West Africa in the supply of edible oils is becoming increasingly serious. In these circumstances, it is an economic axiom that an export duty will be borne by the producer and that the cultivator will, therefore, receive a lower price for the oil seeds exported. The acreage under oil seeds in British India is still considerably below the pre-war level and the tendency to replace oil seeds by other crops which may be inferred from this would undoubtedly be greatly accentuated if any effective restrictions on export were imposed. The immediate fall in price, which would result from such restrictions, would tend to a reduction of area and consequently of out-turn. Even if such a fall in prices were obtained by the method advocated, the gain to the cultivator *qua* consumer would be far more than counterbalanced by the disadvantage to the cultivator *qua* grower by the loss of the income he at present derives from his export market. In the second place, it may be argued that if the Indian oil-crushing industry were fully developed to deal with the present out-turn of oil seeds, then the area might remain at its present level and there would grow up a considerable export of oil, while the cake would remain to be used as a feeding stuff or manure. The market for oil in this country is, however, a very limited one and will remain

so until India has reached a more advanced stage of industrial development. The oil-crushing industry would, therefore, have to depend mainly on the export market for the sale of its main product. The problem of cheap and efficient transport to the great industrial centres of the west presents almost insurmountable difficulties. Oil-crushers in India would find themselves in competition with a well-established and highly efficient industry and there is little reason to believe that their costs of production or the quality of their product would enable them to compete successfully with that industry. In the third place, even if restriction on exports succeeded in reducing the price of oil cakes, this would mean that a section of the agricultural community would be penalized for the benefit of another and much smaller section, for the growers of oil seeds would probably not be those who would make the most use of the oil cakes.

A similar line of reasoning applies to oil cakes, the average exports of which from India for the five years ending 1925-26 were 165,600 tons, against a negligible import. The oil cakes exported from India are a far less important factor in the world's supply than are the oil seeds and, in these circumstances, the burden of the duty would be entirely borne by the producer, in this case the crushing industry. There can, in our view, be little doubt that the effect of a duty on oil cakes, with or without a duty on oil seeds, would be the curtailment of oil-crushing activities and a diminution in the available supply of oil cakes, in other words, it would have effects entirely different from those desired by its advocates. It is not, therefore, by any restriction on trade that Indian agriculture is likely to reap greater advantages from the supply of combined nitrogen available in the large crops of oil seeds she produces. The only methods by which these advantages can be secured are by the natural development of the oil-crushing industry coupled with great changes in cattle management and in the use of fuel. The question how far the development of the industry can be promoted by Government assistance in the matter of overcoming difficulties of transport and in the form of technological advice in regard to improved methods of manufacture and standardization is one for the departments of industries rather than the departments of agriculture. An

extension of the oil-crushing industry would undoubtedly tend to promote the welfare of Indian agriculture and we would commend the investigation of its possibilities to the earnest consideration of all local governments.

(g) SULPHATE OF AMMONIA

88. The important potential sources of supply of combined nitrogen discussed in the preceding paragraphs are supplemented to a small though increasing extent by the sulphate of ammonia recovered as a by-product from coal at the Tata Iron and Steel Company's works at Jamshedpur and on the coal-fields of Bengal and Bihar and Orissa. There has been a very marked increase both in the consumption and production of this fertilizer in India in recent years. Of the 4,436 tons produced in 1919, all but 472 tons were exported and there were no imports. In 1925, of the estimated production of 14,771 tons, 6,395 tons were retained in India. With three exceptions, all the producers of sulphate of ammonia in India have joined the British Sulphate of Ammonia Federation which, through its Indian agents, is conducting active propaganda to promote the use of artificial fertilizers and has established a number of local agencies in agricultural areas in several provinces. The manner in which this source of supply is being developed is very satisfactory and it is still more satisfactory that a market for increasing quantities of the sulphate of ammonia produced in India is being found in the country. The importance of the price factor need hardly be stressed, for though the present average price of Rs. 140 per ton free on rail at Calcutta is much lower than that which prevailed immediately after the War, it is sufficiently high to preclude the application of sulphate of ammonia to any except the most valuable of the cultivators' crops, such as sugar-cane or garden crops.

(h) ARTIFICIAL NITROGENOUS FERTILIZERS

89. A method of increasing the internal supplies of combined nitrogen in India, the adoption of which has received powerful support, is the establishment of synthetic processes for obtaining combined nitrogen from the air in forms suitable for use as fertilizers. The Indian Sugar

Committee was of opinion that, from the point of view of the development of the sugar industry alone, the successful introduction of synthetic processes in India was a matter of the first importance. That Committee recommended that the possibilities of utilizing the hydro-electric schemes, which were at that time under investigation in the Punjab and the United Provinces, for the fixation of nitrogen should be thoroughly examined and that, if it were found that electric energy could be obtained at a rate approximating to Rs. 60 per kilowatt year, a unit plant of sufficient size to afford trustworthy information should be installed. Of the three processes in use for the fixation of atmospheric nitrogen, the arc process, the cyanamide process and the manufacture of ammonia by direct synthesis, the Committee considered the cyanamide process as the one which offered the best prospects of success in India but drew attention to the possibilities of the Haber process for obtaining synthetic sulphate of ammonia.

The position has changed greatly since the report of the Sugar Committee was written. The full effects of the diversion of the capital, enterprise and, above all, the research devoted to the manufacture of munitions to the production of peace time requirements, had not been felt in 1920. Since then, it has resulted in a fall in the world's price of nitrogen by fifty per cent, and there are prospects of still lower prices in the near future. We see no reason to question the view which was placed before us in the course of the evidence we took in London that, in present circumstances, only very large units with a minimum capacity of about 150,000 tons of pure nitrogen per annum can be expected to pay even under the most favourable conditions in Great Britain and on the Continent of Europe and that conditions in India make it much less likely that even a unit of that capacity would prove a paying proposition. The possibilities of manufacturing nitrogen from the air in India have already been exhaustively examined by a leading firm of chemical manufacturers in England, which has decided against proceeding with the project. It is probable that no factory on a scale which could be contemplated by any local government, or even by the Imperial Government, would be in a position to produce synthetic nitrogenous fertilizers at a price less than that at



which they can be imported. The whole object of establishing such a factory, that of producing fertilizers at a price which would place them within the reach of a far greater proportion of the agricultural community than is at present in a position to use them, would be defeated if a protective duty were imposed to enable its out-turn to compete against imported supplies. It is also to be hoped that, should the demand for artificial fertilizers in India make it worth while, private enterprise will come forward to erect synthetic nitrogen works in this country. While the economics of the industry remain as they stand to-day, we are unable to recommend any further investigation into the subject under government auspices.

#### CENTRAL ORGANIZATION FOR RESEARCH ON FERTILIZERS

90. The discussion of the question of nitrogenous fertilizers would not be complete without mention of the proposal placed before us by the British Sulphate of Ammonia Federation, Ltd., and Nitram, Ltd., for the establishment by the Government of India of a central fertilizer organization on which the Imperial and provincial agricultural departments as well as the important fertilizer interests would be represented. The two companies, which are already spending £23,000 annually on research and propaganda in India, expressed their willingness to increase this amount to £50,000, the additional amount to be handed over to a central organization constituted in the manner they suggest, provided that an equal sum is contributed by Government. The companies have made it clear that the research and propaganda they contemplate would be on the use of fertilizers generally and would not in any way be confined to that of the products they manufacture or sell. This offer, though not disinterested, is undoubtedly generous and we have given it our most careful consideration. We regret, however, that we are unable to see our way to recommend its acceptance. We cannot but feel that, whatever safeguards were imposed, the work of, and the advice given by, an organization, at least half the cost of which was borne by firms closely interested in the subject-matter of the investigation, would be suspect and would thus be deprived of much of its usefulness, especially since, as we

have pointed out, the agricultural departments in India are not yet in a position to pronounce authoritatively on the relative advantages of natural and artificial fertilizers. We, therefore, consider it preferable that the agricultural departments should remain entirely independent in this matter but we need hardly say that we would welcome the establishment by the two firms mentioned, or by any other fertilizer firms, of their own research stations in India working in the fullest co-operation with the agricultural departments, the Indian Tea Association, the Indian Central Cotton Committee and any other bodies interested in the fertilizer question. So much work remains to be done on the manurial problems of India that it is desirable that every possible agency should be employed on it. To the supply by the fertilizer interests of free samples for trial by the agricultural departments there can, of course, be no objection, but we do not consider that any financial assistance beyond what is involved in this should be accepted. In coming to this conclusion, we have not overlooked the fact that the Rothamsted Experimental Station accepts grants from fertilizer interests to meet the cost of experiments with their products. Rothamsted is not, however, a government institution and, further, the experiments it carries out are only undertaken on the clear understanding that the information obtained is not to be used for purposes of propaganda. The conditions at Rothamsted are thus entirely different from those under which it is proposed that the central fertilizer organization in India should function.

#### BONES AND BONE MEAL

91. Nitrogen deficiency can be remedied to some extent by the application of bones and bone meal. This form of fertilizer is, however, of greater value as a means of rectifying the deficiency of phosphates which, as we have pointed out, is more prominent in peninsular India and Lower Burma than that of nitrogen. As with other forms of combined nitrogen, an important quantity of this fertilizer is lost to India by a failure to apply it to the soil and by export. Except in the War period, the total export of bones from India has shown little variation in the last twenty years. The average exports for the five years ending 1914-15 were 90,452 tons, valued at

Rs. 64.20 lakhs. For the five years ending 1924-25 they were 87,881 tons, valued at Rs. 95.94 lakhs. In 1925-26 they were 84,297 tons valued at Rs. 89.16 lakhs and in 1926-27 100,005 tons valued at Rs. 97.76 lakhs. The imports of bone manures are negligible. Practically the whole of the exports are in the form of the manufactured product, that is in the form of crushed bones or of bone meal, the highest figure for the export of uncrushed bones in recent years being 545 tons in 1924-25. Only a very small proportion of the bone manure manufactured in India is consumed in the country. During the War period, when prices were low, freight space difficult to obtain and export demand weak, it was estimated that not more than ten per cent of the total production was consumed in India, and this at a time when the prices of all Indian agricultural produce were exceptionally high. Enquiries we have made show that there is no reason to believe that the percentage retained for internal consumption has increased since the close of the War. Many witnesses before us advocated that the heavy drain of phosphates involved in the large export of bones from this country should be ended by the total prohibition of exports and this proposal received the support of the Board of Agriculture in 1919, whilst the majority of the Indian Taxation Enquiry Committee recommended the imposition of an export duty. For much the same reasons as those for which we have rejected the proposal for an export duty on oil seeds and oil cakes, we are unable to support this recommendation. As was pointed out by the Board of Agriculture in 1922, local consumption, even in the most favourable conditions in recent years, has accounted for such a small fraction of the total production that the industry could not continue to exist on that fraction, and the imposition of an export duty would involve a serious danger of its extinction through the closing down of its markets. Further, any restrictions on export would deprive one of the poorest sections of the population of a source of income of which it stands badly in need.

For slow growing crops such as fruit trees the rough crushing of bones is sufficient, but for other crops fine grinding is required. The crushing mills are at present located almost entirely at the ports and, in order to get bone manures to the

cultivator, the establishment of small bone-crushing factories at up-country centres where sufficient supplies of bones are available has been advocated. A far more thorough investigation of the economics of the bone-crushing industry than has yet been carried out is, we consider, required before the establishment of such mills can safely be undertaken by private enterprise. The first essential is to obtain definite data in regard to the price at which, and the crops for which, the use of bone meal is advantageous to the cultivator. We suggest that the agricultural departments should take early steps to collect these data. The department of Government responsible should also investigate the cost of processing bones with special reference to those districts in which the development of hydro-electric schemes gives promise of a supply of cheap power. It should then be a comparatively easy matter to determine whether the level of prices is such as to justify any attempts on the part of Government to interest private, or preferably co-operative, enterprise in the establishment of bone-crushing mills in suitable centres. In determining the level of prices, allowance should be made for the advantage which local mills will enjoy in competition for local custom with the large units at the ports through the saving to the local concerns of the two-way transportation charges borne by the product of the port mills.

#### FISH MANURES

92. Little need be said about fish manures which are another source of supply of both phosphates and nitrogen. The export of these from India for the five years ending 1925-26 averaged 16,774 tons valued at Rs. 19.94 lakhs. In 1926-27 only 7,404 tons were exported valued at Rs. 9.21 lakhs. Except for a negligible export from Bombay and Sind, the exports of fish manures are confined to the west coast of Madras and parts of Burma.

The arguments against the prohibition of the export of bones or for the imposition of an export duty apply equally to fish manures. Any restriction of export would involve most serious hardship on the small and impoverished fishing communities of the two provinces, and cannot, therefore, be justified. The only measures which can be undertaken to

lessen the export of fish manures, without damage to the fish-oil industry or the curtailment of the amount of fish caught, are measures to establish that such manures can be profitably used for Indian agriculture at the price obtained for them in the export market.

#### NATURAL PHOSPHATES

93. Reference should be made here to the extensive deposits of natural phosphates which are to be found in the Trichinopoly district of Madras and in South Bihar. In neither tract do these phosphates exist in a form in which they can be utilized economically for the manufacture of superphosphate; and their employment in agriculture has been limited to applications of the crude material in pulverized form. This source of supply does not offer any important possibilities.'

## APPENDIX B

### SOME ASPECTS OF SOIL IMPROVEMENT IN RELATION TO CROP PRODUCTION<sup>1</sup>

By G. CLARKE, C.I.E., F.I.C., M.L.C.

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 Mohammad 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 twenty 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, oil seeds, jute, and tea, which account for about eighty 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 point.

<sup>1</sup> *Proceedings of the Seventeenth Indian Science Congress*, Asiatic Society of Bengal, Calcutta, 1930, p. 23.

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 under fallow, making a total of 388 million acres. From this may be deducted as producing exported material for cotton 14, for food grains 9, for oil seeds 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 292 million people who live in the territory covered by these figures, viz. 1.2 acres per unit 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: 65 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 one to three per cent in thirty 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 necessities 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 economizing 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 specialized 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 fact 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 sugar-cane 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 generations. 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 characterized 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 constitutes 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 periods 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 thirty 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 by 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 in an acre foot of soil in these provinces, which lies between the limits of 1,000 and 3,000 lb. I shall refer to this again shortly.

Crookes was almost the first to realize that there was a limit to cheap production from new land, but his forecast was too gloomy. He visualized 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 now 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 counterbalance the colossal wastage which civilization and urban life bring about. The fixation of atmospheric nitrogen was, as he put it, vital to the progress of civilized 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 realized 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 around 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:—

- (1) the preparation of quick-acting manures from waste organic material ;
- (2) 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

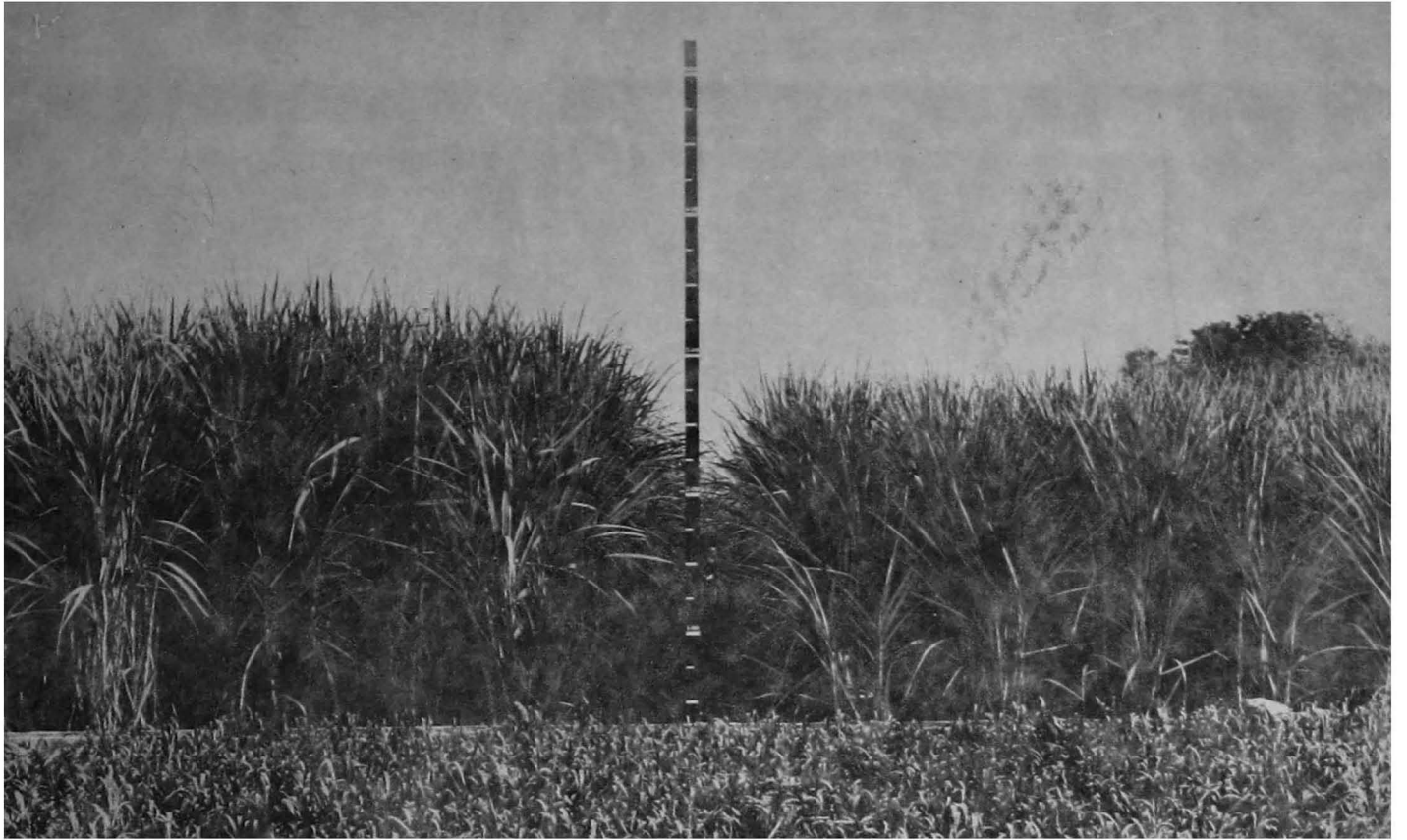


PLATE XII. GREEN-MANURE EXPERIMENT, SHAHJAHANPUR, 1928-29

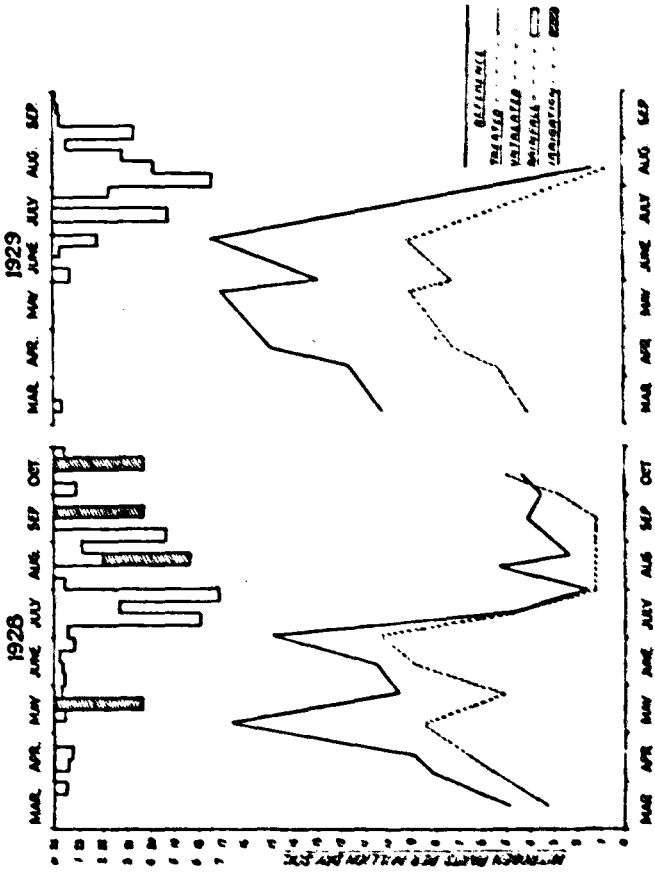


PLATE XIII. NITRATE ACCUMULATION, GREEN-MANURE EXPERIMENT, SHANJANAPUR

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 our hands a method of the greatest value for increasing the out-turn 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 sugar-cane. We have ploughed in on an average of three years' observations, 218 maunds per acre of *sanai* (*Crotalaria juncea*) which adds 50 maunds of dry organic material and 75 lb. of nitrogen to each acre. We have succeeded in raising crops to 850 maunds per acre without the addition of any fertilizing agent other than the *sanai* produced by the land itself.

I give below the results of twenty-seven randomized plots in the treated and untreated fields in 1928.

	Sugar-cane maunds (82 2/7 lb.) per acre	Raw Sugar maunds per acre	Dry Matter maunds per acre
Green-manure	847 ± 32	87.0 ± 3.6	246.1 ± 8.0
Control	649 ± 22	67.2 ± 2.6	200.1 ± 6.6

The illustration shows the crop in the field Plate (XII.). The practical result is worth Rs. 90 per acre. Our problem is to find out the conditions of cultivation necessary to decompose *sanai* in such a way that: (1) well aerated soil containing sufficient organic matter to prevent rapid drying out is ready for the crop in March; and (2) the nitrogen exchanges are such that this element is protected from loss until it is wanted, and is then present in a form which can be rapidly mineralized for the use of the young crop.

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 five inches in the first fortnight of September



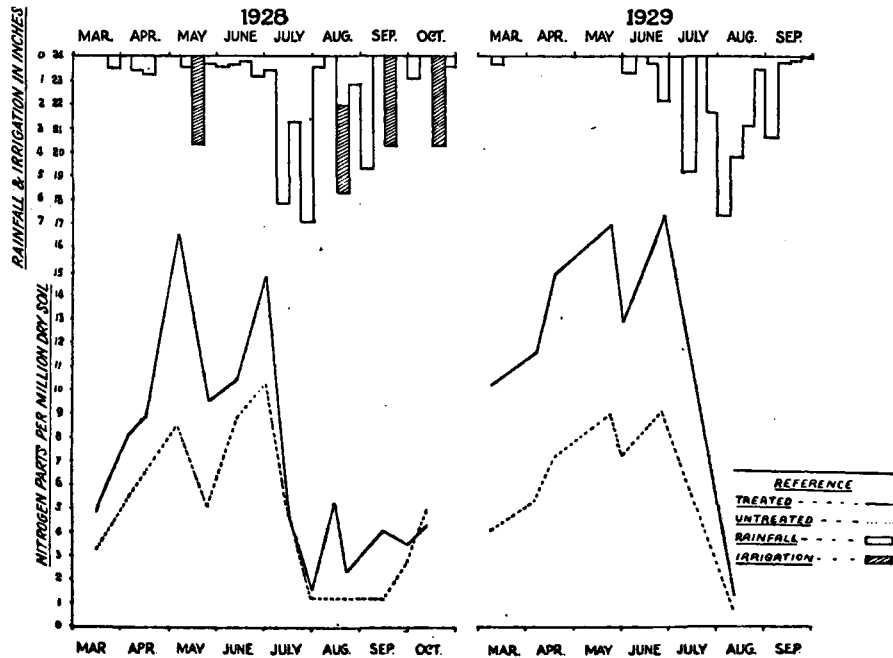


PLATE XIII. NITRATE ACCUMULATION, GREEN-MANURE EXPERIMENT, SHANJAHANPUR

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 our hands a method of the greatest value for increasing the out-turn 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 sugar-cane. We have ploughed in on an average of three years' observations, 218 maunds per acre of *sanai* (*Crotalaria juncea*) which adds 50 maunds of dry organic material and 75 lb. of nitrogen to each acre. We have succeeded in raising crops to 850 maunds per acre without the addition of any fertilizing agent other than the *sanai* produced by the land itself.

I give below the results of twenty-seven randomized plots in the treated and untreated fields in 1928.

	Sugar-cane maunds (82 2/7 lb.) per acre	Raw Sugar maunds per acre	Dry Matter maunds per acre
Green-manure	847 ± 32	87.0 ± 3.6	246.1 ± 8.0
Control	649 ± 22	67.2 ± 2.6	200.1 ± 6.6

The illustration shows the crop in the field Plate (XII.). The practical result is worth Rs. 90 per acre. Our problem is to find out the conditions of cultivation necessary to decompose *sanai* in such a way that: (1) well aerated soil containing sufficient organic matter to prevent rapid drying out is ready for the crop in March; and (2) the nitrogen exchanges are such that this element is protected from loss until it is wanted, and is then present in a form which can be rapidly mineralized for the use of the young crop.

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 five 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 estimates of nitrate. The curves show the accumulation of nitrogen in the first foot of fallow plots in the treated and control fields in 1928 and 1929 (Plate XIII.).

The accumulation of nitrate reaches its maximum in May and June just before the first heavy rain. At this time the crop is about one-third 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 sugar-cane. 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 connexion 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 transformations. If moisture and temperature conditions are favourable, the decomposition of cellulosic energy material, the chief constituent of green-manure, is mainly accomplished by fungous activity resulting in the formation of large quantities of mycelial tissue and the removal of nitrogen temporarily from the reach of higher plants. The synthesized 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 agriculture. 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 eleven 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 independent 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 mediæval England the yield of wheat was seven 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 fourteen maunds per acre. It remained at this level until 1840 when a further advance was made possible by the use of better methods and the introduction of nitrogen fertilizers. By 1870 the yield had risen to twenty 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 forty-seven 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 ten and thirty per cent. These figures are based on considerations of labour. This, as I have said, scarcely enters into our problem 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 2,81,000 acres in eighteen districts 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 1,000 maunds per acre.

The increase over the normal production is 28,71,128 and 185 per cent. The analysis of the returns is helpful in connexion with our problem. In the more important sugar producing districts seventy per cent of the sugar-cane area is planted with heavier yielding varieties. In some thirty per cent, and in a few only two per cent.

2,81,000 acres is almost exactly 33 per cent of the total sugar-cane area in the 18 districts for which special returns are made; on this area the yield has been slightly more than doubled so that there is an all-round increase in production of 33 per cent. This has taken 17 years to accomplish and brings the cultivator in 311 lakhs of rupees extra a year. 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 agricultural 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.

## APPENDIX C

### NITROGEN TRANSFORMATION IN THE DECOMPOSITION OF NATURAL ORGANIC MATERIALS AT DIFFERENT STAGES OF GROWTH<sup>1</sup>

S. A. WAKSMAN and F. G. TENNEY,  
New Jersey Agricultural Experiment Station, U.S.A.

To be able to understand the reasons for the rapidity of liberation of nitrogen from the decomposition of plants at different stages of growth, we must know the composition of the plant at these various stages and the nature of decomposition of the various plant constituents. Although the plant continues to assimilate nutrients, including nitrogen, until maturity, the percentage of nitrogen in the plant reaches a maximum at an early stage, then gradually diminishes, reaching a minimum at maturity or a little before maturity. This is true not only of nitrogen but also of certain other elements.

Plant materials decompose more rapidly and the nitrogen is liberated more readily (in the form of ammonia) at an early stage of growth and less so when the plant is matured. Two causes are to be considered here: (1) the rapidity of decomposition of the various plant constituents; (2) the relation of the nitrogen to the carbon content of the plant tissues.

At an early stage of growth, the plant is rich in water-soluble constituents, in protein and is low in lignins. When the plant approaches maturity, the amount of the first diminishes and of the second increases. The water-soluble constituents, the proteins and even the pentosans and celluloses decompose very rapidly provided sufficient nitrogen and minerals are available for the micro-organisms. The lignins do not decompose at all in a brief period of time of one or two months. More so, their presence has even an injurious effect upon the decomposition of the celluloses with which they are

<sup>1</sup> *Proceedings and Papers of the first International Congress of Soil Science*, Washington, D.C., 1927, p. 209.



combined chemically or physically. The larger the lignin content of the plant the slower does the plant decompose even when there is present sufficient nitrogen and minerals.

It has been shown repeatedly that the organisms (fungi and bacteria) decomposing the celluloses and pentosans require a very definite amount of nitrogen for the synthesis of their protoplasm. Since the cell substance of living and dead protoplasm always contain a definite, although varying, amount of nitrogen and since there is a more or less definite ratio between the amount of cellulose decomposed and cell substance synthesized, depending of course upon the nature of the organisms and environmental conditions, the ratio between the cellulose decomposed and nitrogen required by the organisms is also definite. This nitrogen is transformed from an inorganic into an organic form. Of course in normal soil, in the presence of the complex cell population, the cell substance soon decomposes, a part of the nitrogen is again liberated as ammonia and a part remains in the soil and is resistant to rapid decomposition. The amount of nitrogen which becomes available in the soil is a balance between the nitrogen liberated from the decomposition of the plant materials and that absorbed by the micro-organisms which decompose the non-nitrogenous and nitrogenous constituents. The younger the plant, the higher is its nitrogen content and the more rapidly does it decompose, therefore the greater is the amount of nitrogen that becomes available. The lower the nitrogen content of the plant the less of it is liberated and the more of it is assimilated by micro-organisms.

These phenomena can be brought out most clearly when the same plant is examined at different stages of growth. The rye plant was selected for this purpose. The seeds were planted in the fall. The samples taken on April 28th (I), May 17th (II), June 2nd (III), and June 30th (IV). In the third sampling the plants were divided into (a) heads, (b) stems and leaves. The fourth sample was divided into (a) heads, (b) stems and leaves, (c) roots. The plants were analysed and the rapidity of their decomposition determined, using sand or soil as a medium and 2 g. of the organic matter. In the case of sand some inorganic nitrogen and minerals were added and a soil suspension used for inoculation. The

TABLE I  
COMPOSITION OF RYE STRAW AT DIFFERENT STAGES OF  
GROWTH ON DRY BASIS

No. of sample	Moisture content at time of harvesting	Ash	Nitrogen	Cold water soluble fraction	Pentosans	Cellulose	Lignin
I	% 80.0	% 7.3	% 2.39	% 32.6	% 15.9	% 17.2	% 9.9
II	78.8	5.7	1.76	22.0	20.5	26.1	13.5
IIIa	57.4	4.9	1.01	18.2	22.7	30.6	19.0
IIIb	60.2	5.9	2.20	20.3	22.7	20.1	16.0
IVa	15.0	3.2	1.22	4.7	11.9	4.6	13.4
IVb	15.0	3.7	0.22	9.5	21.7	34.6	18.8
IVc	?	?	0.55	4.7	26.6	37.7	21.0

TABLE 2  
DECOMPOSITION OF RYE AT DIFFERENT STAGES OF GROWTH  
(2 g. of dry material added to 100 g. of sand or soil medium)

Date of sampling	No. of sample	Nitrogen content of material	CO <sub>2</sub> given off in 27 days		Available Nitrogen (NH <sub>4</sub> -N-NO <sub>3</sub> -N) absorbed (+) or liberated (-)	
			Sand medium	Soil medium	Sand medium	Soil medium
		%	mg.C.	mg.C.	mg. N.	mg. N.
April 28	I	2.39	337.7	286.8	+10.1	+22.2
May 17	II	1.76	280.5	280.4	+ 0.8	+ 3.0
June 3	IIIa	1.01	215.7	199.5	-12.1	- 7.5
.. 3	IIIb	2.20	261.9	244.8	+ 5.7	+ 7.5
June 30	IVa	1.22	269.9	273.7	- 4.4	- 2.1
.. 30	IVb	0.22	221.4	187.9	-16.0	- 8.9
.. 30	IVc <sup>1</sup>	0.55	187.0	158.4	- 8.1	- 9.4

<sup>1</sup> Root material used in the decomposition was equivalent to 1.67 g. of moisture free and ash-free organic matter.

evolution of carbon dioxide and accumulation of ammonia and nitrate nitrogen was used as an index of decomposition. Tables I and II show the composition of the plant and the amount of nitrogen made available after 26 days of decomposition.

When a plant material contains about 1.7 per cent nitrogen, as in the rye of the second sampling, there seems to be sufficient nitrogen for the growth of micro-organisms which decompose this material more or less completely. When the plant material contains less than 1.7 per cent of nitrogen, as in the case of the stems and leaves of the third preparation, additional nitrogen will be required, before the organic matter is completely decomposed (speaking, of course, relatively, since if a long enough period of time is allowed for the decomposition, less additional nitrogen will be needed). If the organic material contains more than 1.7 per cent nitrogen, as in the case of the plants in the first planting and the heads of the third sampling, a part of the nitrogen will be liberated as ammonia, in the decomposition processes. The difference between the nitrogen content of the heads and this hypothetical figure = 0.5 (2.2—1.7) per cent. or 10 mg. nitrogen for the 2 g. of organic matter; actually 5.7 mg. and 7.5 mg. of nitrogen were liberated as ammonia in the sand and soil media respectively. The difference between the hypothetical figure and the nitrogen content of the stems and leaves was 0.69 (1.7—1.01) per cent or 13.8 mg. nitrogen for the 2 g. of plant material used. Actually 12.1 and 7.5 mg. of nitrogen were consumed in the sand and soil media. Had the decomposition been allowed to proceed further, the results would have approached from both directions the hypothetical figure and, with prolonged decomposition (of synthesized substances), would have exceeded it.

The decomposition of 10 g. dry portions of the second sampling and 20 g. dry portions of the stems and leaves of the fourth sampling was studied separately in a sand medium containing available nitrogen and minerals. Only the data for the organic matter portion, insoluble in ether and water, are reported. The results show that the pentosans and celluloses are rapidly decomposed, while the lignins are affected only to a very inconsiderable extent. The nitrogen

figures are of direct interest here. Just about as much insoluble protein was left in the first as in the second experiment: in the first the protein is considerably reduced, in the second increased. This tends to explain the activities of the micro-organisms in the soil.

TABLE 3  
COMPOSITION OF ORGANIC MATTER AT BEGINNING  
AND END OF DECOMPOSITION

*Sample II*

Organic matter (free from ether and water-soluble substances and ash)	At beginning of experiment	At end of experiment
	mg.	mg.
Pentosan .. .. .	7,465	2,015
Cellulose (calculated) .. ..	2,050	380
Lignin .. .. .	2,610	610
Protein (insoluble in water) ..	1,180	750
Unaccounted for .. .. .	816	253
	8.6%	1%

TABLE 4  
COMPOSITION OF ORGANIC MATTER AT BEGINNING  
AND END OF DECOMPOSITION

*Sample IV—Stems and Leaves*

Organic matter present (free from ether and water-soluble substances and Ash)	At beginning of experiment	At end of experiment
	mg.	mg.
Pentosan .. .. .	15,114	8,770
Cellulose .. .. .	3,928	1,553
Lignin .. .. .	6,262	2,766
Protein .. .. .	3,403	3,019
Unaccounted for .. .. .	181	519
	10.25%	10.41%

The results show that since there is a very definite ratio between the energy and nitrogen consumption of the microorganisms decomposing the organic matter, it is easy to calculate, given a certain amount of plant material and knowing its nitrogen content, whether nitrogen will be liberated in an available form or additional nitrogen will be required within a given period of time. Calculations can also be made as to how much of this nitrogen is required for the decomposition of the plant material and how long it may take before the nitrogen is again made available.

## APPENDIX D

### AN EXPERIMENT IN THE MANAGEMENT OF INDIAN LABOUR<sup>1</sup>

By ALBERT HOWARD, C.I.E.

*One of the outstanding problems of the present phase of colonial development in Asia and Africa is that of the best and most scientific methods for the organization of work in large-scale agricultural undertakings. The author of this short article, who is a well-known authority on tropical agriculture and has for thirty years contributed to the scientific improvement of agriculture in the East as Imperial Economic Botanist at the Government of India Research Station at Pusa, at Quetta, and latterly in the State of Indore, describes a small-scale experiment from which many lessons may perhaps be drawn. The experiment has been tried in the State of Indore under the stimulus of having to obtain an adequate labour force to carry on the work of an agricultural experimental station in competition with the rival attractions exercised by work in neighbouring factories. No doubt the conditions are not entirely on all fours with those of plantations carried on under competitive conditions, but they are sufficiently similar to give the experiment a living and practical interest. As the author points out, the financial basis is provided mainly by the cotton industry in India and by the Indian States members of the Institute of Plant Industry, without any call for assistance by the Government of India or by Provincial Governments. As the article shows, the best results have been obtained under a scheme which provides for a six to seven and a half hour working day, paid leave, medical attendance, good housing, and opportunity for promotion for the labour employed. [Ed. International Labour Review]*

<sup>1</sup> *International Labour Review*, Geneva, 18, 1931, p. 636.

The foundation of the new Institute of Plant Industry at Indore in Central India in October 1924, provided the opportunity of breaking new ground in at least four directions, namely :—

- (1) The best method of applying science to crop production.<sup>1</sup>
- (2) The general organization and finance (including audit) of an agricultural experiment station.
- (3) The most effective way of getting the results taken up by the people; and
- (4) The management of the labour force employed.

The present article deals with the last of these items : with the methods by which a contented and efficient body of labour can be maintained for the day to day work of an agricultural experiment station, largely devoted to the production of raw cotton.

#### THE INSTITUTE AND ITS ORGANIZATION

The Institute of Plant Industry at Indore is supported by an annual grant of Rs. 1,15,000 from the Indian Central Cotton Committee and by subscriptions, amounting at the moment to Rs. 47,550 a year, from twenty of the States of Central India and Rajputana.<sup>2</sup> During the financial year 1929-1930, the income from all sources was Rs. 1,79,080, the expenditure was Rs. 1,75,041. The management of the Institute is vested in a Board of Governors, seven in number, elected by the subscribers, the Director of the Institute being Secretary of the Board. It will be seen that the main source of the funds available for the payment of labour is derived from the Indian Central Cotton Committee (a statutory body representing the growers, the cotton trade and the officers engaged in research on cotton) created for implementing the Indian Cotton Cess Act of 1923 : an Act which provides for the creation of a fund

<sup>1</sup> This aspect has been dealt with in *The Application of Science to Crop Production, an Experiment carried out at the Institute of Plant Industry, Indore*, Oxford University Press, 1929.

<sup>2</sup> In addition to these sources, the Institute makes use of the produce of the experimental area of 300 acres, of the royalties on its publications and of a number of miscellaneous items of income, including the fees earned for advice to individuals and bodies outside the Society.

for the improvement and development of the growing, marketing and manufacture of raw cotton in India. This cess is now levied at the rate of two annas per standard bale of 400 lb. on all cotton used in the Indian mills or exported from the country. The money available for the payment of labour at the Indore Institute is thus largely drawn from the cotton industry itself. At no period in the history of the institution has any financial assistance of any kind been asked for or obtained from the Government of India or from any of the Provincial Governments.

At the beginning, great difficulties were experienced in obtaining an efficient labour force. The Institute lies alongside the city of Indore, an important manufacturing and distributing centre with a population of 127,000. Nine large cotton mills (with 177,430 spindles, 5,224 looms, an invested capital of Rs. 1,67,97,106, and utilizing 68,000 bales of cotton a year) find work for 12,000 workers. In addition there are a number of ginning factories and cotton presses. The Institute therefore had to meet a good deal of local competition in building up its labour force. It was clearly useless attempting to recruit workers at rates below those readily obtained at the mills or in the city. Further, it soon became apparent that if the Institute was to succeed the Director would have to pay attention to the labour problem and devise means by which an efficient and contented body of men, women and children could be attracted and retained for reasonable periods.

Consideration of this problem led the Director to the conclusion that it could be solved by providing for the regular and effective payment of wages, for good housing, reasonable hours of work, with regular and sufficient periods of rest, and for suitable medical attention.

The application of these principles soon met with success. An adequate labour force has been built up; partly from men recruited locally and from the Rajputana States and partly from the wives and children of the sepoys of the Malwa Bhil Corps, the lines of which adjoin the Institute. A permanent labour force of about 118 is now employed throughout the year. In addition, a certain amount of temporary labour is employed for seasonal work.



The precise manner in which the principles above mentioned have been carried out in practice may now be described.

#### CONDITIONS OF LABOUR AT THE INSTITUTE

##### *Payment of Labour*

Wage rates for men on the permanent staff range from about Rs. 12 to Rs. 20 a month, while men on the temporary staff are paid 7 annas a day, women 5 annas, boys 3 to 6 annas, and girls 3 to 5 annas. After the rate of wages has been settled in each case, care is taken that : (1) the payment of wages is made at *regular intervals* ; and (2) the wages are paid into the hands of the workers themselves and there are no illicit deductions on the part of the men who disburse the money.

Regularity of payment is a matter of very great importance in dealing with Indian labour. At Indore, workers on daily rates receive their wages twice a month—on the 18th and the 3rd, in each case at 2.30 p.m. The permanent labour is paid monthly on the third working day of the following month. To ensure that all payments are actually made according to the attendance registers all disbursements are made in the presence of two responsible members of the staff. Both of these men have to sign a statutory declaration that the payments have actually been made. The signed statements come regularly before the Director for signature, and are in due course placed before the auditors. In making payments the envelope system is used, the payee making a thumb impression in ink in the register or signing his or her name. These arrangements have been found to prevent any illicit deductions on the part of the staff. The payments are made in public ; the rate of everybody's pay is known ; the signing of a proper declaration in the register makes it possible to institute criminal proceedings at once for any irregularity , the Director is always available for inquiring into any complaints. That none have ever been made proves that the labourers actually receive their pay in full at regular intervals. Payment is made in coin ; no attempt at payment in kind has ever been made ; no shops for the sale of food exist on the estate and nothing whatever is done to influence the workers as to how they should spend their wages.

*Hours of Labour*

After the regular payment of wages, the hours of labour come next in importance. Indeed in India rest and wages are to a certain extent interchangeable as the workers regard any extra rest as equivalent to an increase in pay. At first, the Institute observed the ten hours' day so common in India, but this was soon given up. It was found during the hot months of April, May and June that both the labour and the cattle required more protection from the hot sun. An experiment was therefore made to reduce the hours of labour during the hot months to six daily, beginning work at sunrise and ending the day at sunset. The actual working hours of the three hot months were arranged in two shifts—four hours in the morning and two in the afternoon with a six hours' rest during the heat of the day, i.e. from 10 a.m. to 4 p.m. At the same time the work was speeded up and both labour and supervising staff were given to understand that the six hours' day in the hot months could only be enjoyed if everybody worked continuously and conscientiously.

The first result observed was a marked improvement in the health and well-being of the men and animals, probably due to the operation of two factors: the health-giving properties of the early morning air and avoidance of excessive sunlight. With the improvement in general health there was a corresponding reduction in cases requiring medical assistance. To everyone's surprise, it was found possible to speed up the work very considerably. The experiment of shortening the hours of labour was then extended to the rest of the year; working hours were reduced from ten to seven and a half.

These working periods, six hours in the hot weather and seven and a half during the rest of the year, refer to the time actually at work; an extra half hour daily is spent in travelling to and from the place of work. In no case does the working period exceed seven and a half hours except for about a week at the sowing time of the monsoon crops. During this period, both man and beast do not obtain much more than two hours off duty for food during the hours of daylight. A full ten hours' day at high pressure is then the rule, as all realize that the sowing of cotton and other crops is a race against time. As soon, however, as sowing is over, the

workers enjoy an extra day's rest on full pay. The sowing of the monsoon crops is the only agricultural operation in Central India for which anything more than a seven and a half hours' day is necessary.

For three years the agricultural operations of the Institute have been conducted on the short hours system. The result has been successful beyond all expectation. The miracle of speeding up Indian labour has been achieved and shorter working hours have led not only to contentment but also to an increased output of work. This result has only been achieved, however, by careful and detailed planning of the work to be done each day. The daily work programme is drawn up by the Assistant in charge of the farm during the previous afternoon and submitted to the Director as a matter of routine, so that at daybreak each day the Assistant knows at once what has to be done and no time is lost in deciding what tasks have to be performed. The taking of the attendance and the allocation of labour to the various tasks occupies less than five minutes. In less than ten minutes after assembly, the various gangs are at work in the fields. A great point is made of getting down to the job at once. Punctuality is now the rule, and it is becoming rare to have to deal with late arrivals.

While it is important to start work with the sun, it is equally important to allow the labourers to reach their homes by sundown, particularly during the rains when snakes abound. Indian workers like to reach home in daylight—a point of great importance in obtaining their willing co-operation. Finally, it is very interesting to note that the policy of the square deal on the part of the Institute towards its labourers as regards hours is now being answered by a natural desire on the part of the workers to give the Institute a square deal. Less supervision is becoming necessary; everybody realizes that a reduction in hours is only possible if real work is done.

#### *Leave and Holidays*

The Institute is closed, except for work of extreme urgency, on Sundays and on twelve important festivals during the year. In addition to these sixty-four days, the permanent labourers are allowed one day's casual leave and one day's sick leave

every month provided they work twenty-five full days during the month. In cases of injury while on duty, they are allowed full pay up to a maximum of seven days. In the case of temporary labour, all holidays and leave, except the extra day allowed after the sowing of the monsoon crops, are given without pay.

#### *Housing*

As regards living accommodation, the demands of Indian labour are very modest. A roof which does not leak during the rains, a dry earthen floor, a room which can be locked up, a partially closed-in verandah which serves both as a kitchen and a store house for firewood, are all that is expected. At Indore the one-room cottages are arranged in blocks of six around an open courtyard in which four trees have been planted to provide shade. The quarters are fumigated and whitewashed once a year when any petty repairs to the roofs and brickwork are attended to.

After a storm-proof room, the next essential is a supply of good drinking water and a separate well for washing. The water used for drinking is raised by a simple wheel pump; the well is provided with a masonry coping about two feet high; no drinking vessels are allowed to be dipped into the water. In this way the risk of cholera is greatly reduced. Once a simple wheel pump is installed, the labourers and their wives never attempt to lower a bucket by means of a rope.

#### *Provident Fund*

So far no provident fund for the workers has been instituted. The existing provident fund only applies to the permanent staff of the Institute drawing Rs. 30 per month or more. Till the completest confidence between the workers and the management has been achieved, any suggestion of keeping back the pay of a labourer for a provident fund is likely to be misunderstood. It was decided to start a provident fund for the educated staff and gradually to extend its benefits to the labour force if and when a demand comes from the workers themselves.

*Medical Arrangements*

The workers and staff employed at the Institute obtain free medical attendance. In addition, the workers and the staff drawing less than Rs. 30 per month obtain free medicaments. The workers are examined weekly by the doctor so that any precautionary treatment or any advice can be given in good time. In cases of childbirth the services of a nurse are provided free of charge. The personality of the Sub-Assistant Surgeon dealing with Indian labour is very important. The workers deal with an unpopular man in a very effective fashion—they never make use of his services.

*Certificates of Efficiency and Promotion*

An experimental station, like any employer of labour, needs some system by which the labour force can automatically renew its youth. The annual export of trained labour to centres at which improvements are being taken up is one of the important functions of the Institute. For these reasons, therefore, a supply of promising recruits must be arranged. To bring this about some system of promotion for proved efficiency had to be devised. At first this took the form of an annual promotion examination for the ploughmen. As they increased in efficiency and could manage and assemble their implements and also plough a straight furrow, their pay was increased by Re. 1 per month. This system is now being superseded by the certificate plan. All the permanent workers in the Institute are eligible for special training so that they can earn efficiency certificates for such operations as : (1) cultivation and sowing ; (2) compost making and the care of the work cattle ; (3) improved irrigation methods, including the cultivation of sugar-cane by the Java method ; (4) the manufacture of sugar (Plate XIV). A certificate of efficiency (with suitable illustrations) signed by the Director can be awarded for proficiency in all these items. Each certificate which is awarded annually will carry with it an increase of Rs. 1 per month on the basic pay. When a member of the labour force has gained all four certificates, he will become eligible for transfer to other centres on higher pay. In this way the Institute holds out hope and places it within the power of any man to increase his starting pay in four years by about thirty

INSTITUTE OF PLANT INDUSTRY, INDORE

# CERTIFICATE OF EFFICIENCY

IN  
COMPOST MAKING AND  
CATTLE-SHED MANAGEMENT



(Photograph of certificate-holder)



Labour Certificate issued to

trained at the Institute of  
Plant Industry, Indore,  
in compost making and  
cattle-shed management.

19

Director



per cent. It also enables an ambitious labourer to save enough money in a few years to purchase a holding and to become a cultivator. This is now taking place. Every year a few of the labourers return to their villages with their savings to take up a holding on their own account. Others are deputed for work in the Contributing States on increased pay. The vacancies are automatically taken either by younger members of the same family or by volunteers on the waiting list of temporary workers.

#### CONCLUSION

It is possible that the system described in this article is only fully realizable on a farm working under model conditions. Nevertheless, there are a certain number of elements in this experiment which the writer feels are of universal validity in dealing with primitive labour. From the point of view of the worker it is perhaps most essential that he should feel that he is receiving a square deal. From the point of view of the management the best results are obtained by scrupulous attention to pay, by short hours of intensive work, by proper housing and medical care, and by interesting the worker in the undertaking through giving his work an educational value.

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