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THE MANUFACTURE OF HUMUS BY THE INDORE PROCESS

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BY

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THE MANUFACTURE OF HUMUS BY THE INDORE PROCESS

By Sir Albert Howard, C.I.E., M.A.

I. Introduction

Two years ago, in a lecture to this Society, I dealt with the conversion of the waste products of Indian agriculture into humus by means of a process, worked out at the Institute of Plant Industry, Indore, Central India, of which an account was published in book form in 1931[1]. The publication of this book and of the lecture[2] has led to the adoption of the Indore process at a rapidly growing number of centres. Not only have all kinds of agricultural wastes been converted at a trifling cost into valuable manure, but further work, carried out at the Indore Institute after my retirement in 1931 by Mr. F. K. Jackson, my successor, and Mr. Wad, has resulted in the utilization in India, Ceylon, East Africa and other countries of municipal and village wastes on similar principles.[3]

This evening I shall endeavour (1) to summarize the more important practical results which have been obtained all over the world since *The Waste Products of Agriculture* was published in 1931, (2) to give some account of the work in progress and in contemplation, and (3) to emphasize, as a matter of principle, the importance of properly fermented organic matter, not only in agricultural production, but also as one of the factors involved in the health and well-being of our crops, of our domesticated animals, and of our human population. In order to set out these matters in a readily understandable manner it will be necessary to make a brief reference to the nature and rôle of humus in agriculture and in horticulture and at the same time to emphasize the main bio-chemical principles underlying the Indore process. These preliminaries are all the more necessary because the large stock of the issue of the *Journal* of this Society of December 8th, 1933, and of the reprints of the lecture, was exhausted some months ago.

What is humus and what part does it play in soil fertility?

The humus or organic matter found in the soil is very similar to the old leaf mould which often accumulates on the surface of our woods and forests and which is so greatly prized by all garden lovers. It is a mixture of substances consisting of (1) the remains of plants and animals which are undergoing decomposition in the soil, (2) substances like lignified cellulose which are more resistant to decay, and (3) a number of valuable materials which have been

(1) Howard, A., and Wad, Y. D., *The Waste Products of Agriculture*, Oxford University Press, 1931. Price 7s. 6d. net.

(2) Howard, A., "The Waste Products of Agriculture: their Utilization as Humus." *Journ. of the Royal Society of Arts*, December 8th, 1933.

(3) Jackson, F. K., and Wad, Y. D., "The Sanitary Disposal and Agricultural Utilization of Habitation Wastes by the Indore Process," *The Indian Medical Gazette*, lxix, No. 2, February, 1934.

synthesised by the groups of micro-organisms which form the soil population. Humus thus arises from a mass of heterogeneous substances which are constantly undergoing oxidation. When this oxidation slows down and the mass becomes more or less homogeneous it can be described as humus and is then capable of being incorporated in the soil.

Humus is a manufactured product with a carbon : nitrogen ratio of about 10 : 1, prepared from vegetable and animal wastes with a carbon : nitrogen ratio of about 33 : 1. The conversion, which is carried out by fungi and bacteria, is naturally accompanied by the evolution of large volumes of carbon dioxide and requires a corresponding amount of atmospheric oxygen. Besides air, the organisms concerned in the manufacture also need water, a base to neutralise excessive acidity, and sufficient minerals, particularly combined nitrogen. Their demands are almost identical with those of the roots of plants. It follows, therefore, that any attempt to prepare humus in the soil itself is almost certain to interfere with the crop. Hence the injurious effects on growth which almost invariably follow the addition of straw and, very frequently, of green-manure to the soil. In such cases the decomposition of these materials impoverishes the soil solution, contaminates the soil atmosphere, and often depletes the soil moisture. The result is that the soil is overworked and a poor crop is obtained. This overwork can be avoided by taking care to prepare humus outside the field rather than in the soil itself, and to restrict green-manuring to localities where all the factors can be relied on to yield a satisfactory result. The Chinese were the first to grasp and act upon the master idea that the growth of a crop involves two separate processes: (1) the preparation of humus from vegetable, animal, and human wastes, which must be done outside the field, and (2) the growing of the crop.

The utilisation of humus in the soil is a much less intense oxidation process than that which is involved in its manufacture. A slow oxidation, which proceeds without harm to the growing plant, converts the nitrogen of the humus into ammonia and then into nitrate. This nitrate (and sometimes the ammonia) in dilute solution in water is then taken up by the roots of the crop. Besides furnishing the plant with combined nitrogen, humus influences soil fertility in other ways:—

(1) The physical properties of humus exert a favourable influence on the tilth, moisture-retaining capacity and temperature of the soil.

(2) The biological properties of humus offer not only a habitat but also a source of energy, nitrogen and minerals for various micro-organisms.

(3) The chemical properties of humus enable it to combine with the soil bases and to interact with various salts. It thereby influences the general soil reaction, either acting directly as a weak organic acid or, by combining with bases, liberating the more highly dissociating organic acids.

These properties—physical, biological and chemical—confer upon humus a place apart in the general work of the soil, including crop production. It is not too much to say that this material provides the very basis of successful soil management and of agricultural practice. Humus has one drawback: it is steadily lost. Any method like the Indore process by which it can be continuously restored to the soil therefore deserves the most careful consideration.

The Indore process itself is very simple. It consists in using the fungi and bacteria, which occur in Nature, as agents to break down suitable mixtures of vegetable and animal wastes—the residues of the operations of the farm itself. By arranging these mixtures in the proper way and in the right proportions, and by controlling by the simplest means, namely, by watering and turning, the supply of moisture and air, these wastes are transformed in about ninety days into finely divided humus, rich in the foods required by growing crops. The process can be adapted to climate by manufacture either in shallow pits or low heaps. No buildings or expensive plant are required, nor are pure cultures of the organisms concerned necessary, as they occur everywhere; incidentally, therefore, any idea of a patent would be a fraud on the cultivator. The practical details of the process have been printed as a set of instructions for the tea gardens in India and Ceylon, which is appended (*see* Appendix II, pp. 40–47).

When the Indore process in its final form was devised between the years 1925 and 1930, the scientific approach to the utilisation of crude organic matter left much to be desired. The chief organic residues—farmyard manure, green-manure, vegetable residues, municipal wastes, sewage sludge and crude sewage—were being studied separately and not as parts of a single subject. Much of the scientific work had been done, but the various fragments were lying round in the literature very much like the materials in a builder's yard before the building itself is erected. On the practical side difficulties were being experienced. The results of green-manuring were erratic; most of the methods of managing agricultural residues resulted in a waste of valuable nitrogen; some were elaborate and some expensive; there was no idea of examining the experience of old cultivation systems like the Chinese—the very continuance of which over several thousand years is a proof of efficiency—and illuminating them in the light of modern science.

It is claimed that the Indore process has solved these difficulties. What was needed was the welding together of the separate fragments into a single well-ordered method, elastic enough to be introduced into any system of agriculture. In the course of its working out the Indore process has been founded on correct bio-chemical principles, and is not far from Chinese or other more primitive practices evolved empirically in many parts of the world. It can be adapted to different circumstances; it is sanitary. It secures extra nitrogen by fixation from the atmosphere. At the Indore Experiment Station itself the conversion of the wastes from 300 acres of land into about 1,000 cartloads of valuable humus every year resulted, at the end of a five-year period, in so rapid an increase of fertility that that station stood out like an oasis from the surrounding country. No further demonstration was needed to prove that one of the chief factors involved in raising crop-production to a much higher level throughout the world was the orderly utilisation of the waste products of agriculture itself.

II. Plantation Industries

Up to the present the most spectacular applications of the Indore process have taken place in the plantation industries—coffee, tea, sugar, maize, sisal and so forth. The recent fall in prices has naturally been followed by drastic reductions in overhead expenditure, including the amount spent on fertilisers. For some years past, more and more attention has been given to organic manures. When, therefore, the Indore process was brought to the notice of the plantation industries the ground was already prepared for its sympathetic consideration. Trials were at once set in motion. The first results obtained have led to its rapid adoption.

Coffee.—In my previous lecture (p. 103) I drew attention to a possible improvement in coffee growing on the red soil area near Nairobi, in Kenya, and stated: "The chief line of advance in coffee growing in this locality appears to be the adoption of the Chinese principle that the successful growing of a crop involves two things which are best kept entirely separate—the preparation of food materials for the plant from waste products and the actual growing of the crop. If this is carried out I am certain that a great improvement in the yield and also in the quality of Kenya coffee will be a matter of a very short time."

Two years have passed. The pioneering work carried out since 1933 by Major Belcher, the manager of the Kingatori estate near Kyambu, has proved invaluable in establishing the process in East Africa. During the last twenty-eight months, 1,660 tons of compost, containing about 1·5 per cent. of nitrogen, have been manufactured on this estate and applied to the land. The cost per ton works out at 4*s*. 4*d*.—chiefly the expense involved in collecting material. The work in progress has been shown to a constant stream of visitors from other parts of Kenya, the Rhodesias, Uganda, Tanganyika and the Belgian Congo; Major Belcher has lost count of the actual numbers.

Many new centres in East Africa have taken up the process. The rapid spread of the method is summed up by Major Grogan, the proprietor of the Kingatori estate, in a letter dated Nairobi, May 15th, 1935, as follows:—

> "You will be glad to know that your process is spreading rapidly in these parts and has now become recognised routine practice on most of the well-conducted coffee plantations. The cumulative effect of two years on my plantation is wonderful. I have now established all round my pits a large area of elephant grass for the purpose of providing bulk, and we have made quite a bit of pocket-money by selling elephant grass cuttings to the countryside. I am now searching for the best indigenous legumes to grow in conjunction with the elephant grass and am getting very hopeful results from various *Crotalarias* and *Tephrosias* which I have brought up from the desert areas of Taveta. They get away quickly and so hold their own against the local weeds."

Major Grogan, in referring to the spread of the Indore method in East Africa, has omitted one very material factor, namely, his personal share in this result. He initiated the earliest trial on the Kingatori estate and has always insisted on the process having a square deal in Kenya. In Tanganyika the influence of Sir Milsom Rees, G.C.V.O., has led to similar results.

One drawback, which sometimes prevents the maximum benefit from being obtained on the coffee estates in Kenya and Tanganyika, has disclosed itself. Humus can only be incorporated from the surface and therefore exercises its chief influence on the roots in the upper portion of the soil. For this influence to be effective there must be adequate moisture, otherwise oxidation and absorption will stop. Moisture, therefore, during the period when the coffee crop is maturing must be adequate in amount and reasonably well distributed. Unfortunately, the rains often fail after the flowers have set and a long period of drought ensues. This not only lowers the yield and interferes with the development of quality, but also in severe cases brings on the trouble known as "over-bearing." The trees exhaust their reserves in the effort to ripen the crop and sometimes never recover from the strain. Over-bearing appears to be a natural result of the resting condition into which the copious surface root system of the coffee plant passes whenever the moisture in the surface soil is exhausted. The trees then have to obtain their supplies of water and minerals by means of the sparse deep root system only. But the true function of this root system is to maintain the tree in the dry season, and it is unable to do double duty. The coffee plant is naturally overworked; the reserves are then called upon, and the plants begin to exhaust themselves. The obvious remedy for over-bearing is to maintain the surface roots in action during the drought by means of furrow-irrigation whenever a supply of water exists or can be secured. I understand that a few of the coffee estates in Tanganyika are so situated that irrigation water can easily be obtained. In such cases, the optimum results from humus both on the yield and quality of coffee are certain to be secured. It is the rule in the tropics for trees to be provided with a double set of roots—a well-developed set near the surface for the rainy season: a much more restricted set in the deeper layers for the hot weather.[1] At Pusa, in India, I found that fruits like the peach when budded on the local plum stock (which had two root systems) only gave fruit of high quality towards the end of the dry season when the surface root system was kept in action by means of furrow-irrigation. Heavy crops of magnificent fruit were then the rule. When the trees were not irrigated, the crop was meagre and of poor quality. I anticipate that similar results will be obtained with coffee in Kenya and Tanganyika and that the best results with humus, both as regards yield and quality, will only be obtained when the surface root system can be kept in action during the whole period while the coffee berries are developing.

Tea.—The East African results with coffee naturally suggested that something similar should be attempted with regard to tea. In August, 1933, I succeeded in interesting a former member of the research staff of the Indian Tea Association, Dr. C. R. Harler, just before his appointment as Research Officer to the Kanan Devan Hills Produce Company in Travancore. On taking up his new duties in South India, Dr. Harler at once set to work and started a model compost

(1) Howard, A., "The Effect of Grass on Trees," *Proc. of the Royal Society*, B, Vol. 97, 1925. pp. 284–320.

factory at his headquarters at Nullatanni. No difficulties were met with in working the Indore process: ample supplies of vegetable wastes and cattle manure were available, the local labour took to the work, and the estate managers at once became interested and soon enthusiastic.

At this point, in September 1934, I secured the interest and assistance of Mr. James Insch, one of the Managing Directors of Messrs. Walter Duncan and Company, and of Mr. John Still, then Secretary of the Ceylon Association in London, who agreed with me that further trials should be made in India and Ceylon wherever the local conditions were favourable. At Mr. Insch's request a paper of instructions for the use of the managers of the Duncan group was drawn up and 250 copies were printed. The directors of other groups of tea estates, notably Mr. G. H. Masefield, Chairman of the Ceylon Tea Plantations Company, soon began to consider the Indore process, and 4,000 further copies of the paper of instructions were distributed. In less than a year many trials have been carried out in India and Ceylon. On the estates of the Duncan group, for example, trials were completed on fifty-three estates in 1934 in Sylhet, Cachar, the Assam valley, the Dooars, Terai and the Darjeeling district. In all, over 2,000 tons of compost were made and distributed. These results are naturally only preliminary. All that could be attempted in the short time available in 1934 was to stimulate the interest of the managers in the Indore system and to begin to make them compost-minded, as it were. Much more imposing figures are expected from this and other groups when the results for 1935 are available.

The great possibilities of the Indore process in reducing the cost of production of tea will be evident from the following summary of a report by Dr. Harler dated 23rd September, 1935, which Messrs. James Finlay and Company have very kindly allowed me to print.

Indore Compost in the High Range, Travancore

High Range conditions.—The estate herds are housed in central sheds at night, and in some cases central milking sheds have been successfully installed. Each animal voids from 10–15 lb. of dung nightly. On most estates ravine and other land not under tea yield abundant green wastes for composting. The tract is served by both monsoons, the rainfall varying from 56 to 156 inches.

Composting.—The standard charge per layer in the pit is 3 inches sun-dried green matter (540 lb.), 6 baskets urine earth (168 lb.), 2 baskets wood ashes (36 lb.), 2 inches soiled bedding (320 lb.), 16 baskets fresh dung (500 lb.), 60 to 100 gallons of water. Temperatures are taken regularly and are used to control the operations. Twenty-one days after charging, a temperature of 150° F. is expected. If insufficient earth is added a premature fall in temperature occurs. Each head of cattle produces at least eight tons of compost per year if the standard charge is adopted.

Where the South-West monsoon is very heavy, Lincoln composting is carried out during the rains. The floor of the cattle shed is first covered with a foot of earth, well tampted down. The cattle are then bedded down nightly with dry grass. The farmyard manure thus made is taken up with the saturated urine earth after three or four months and a very good product is obtained. In a year 3 tons of Lincoln manure per head can be made as against 8–9 tons per head by the Indore method.

Costs.—The cost varies from Rs.1 to Rs.2 per ton. A fair average is Rs.1/8/– per ton. The cost of transport to, and distribution in the fields is Rs.1 per ton, so that a dressing of 5 tons per acre costs Rs.12/8/– to make, transport and distribute.

Composition.—Over 60 analyses have been made by the chemists of the United Planters' Association of Southern India. The average percentage composition is as follows: moisture 55 to 60; nitrogen 0·45 (wet), 1·33 (dry); potash 0·5 (wet), 1·5 (dry); phosphoric acid 0·2 (wet), 0·6 (dry); ash 50 to 60. Five tons of wet compost contain 50 lb. nitrogen, 20 lb. phosphoric acid and 50 lb. potash.

Field results.—It is too early to give a final opinion on the system. Managers consider that the tea has very definitely benefited. In one case an area which often suffers from drought showed little distress last year although the dry period was longer than usual. On bungalow gardens the effect of Indore compost has been amazing.

In the course of introducing the Indore process on tea estates in Ceylon, two objections have had to be met. The first of these, put forward by the Tea Research Institute, was the high cost of making humus. Figures were printed in the *Journal* of this Institute estimating the cost of making compost at the high figure of Rs.8 per ton. This objection was soon found to be devoid of substance. An important group of tea estates in Ceylon is now making humus at an average cost of Rs.1·87 per ton. The second objection is, however, a real one. The centre of the tea area in Ceylon is so closely planted that there is a scarcity of vegetable wastes except prunings and green-manure. There is very little cow-dung. Only one answer to such an objection is possible, namely, that every possible waste from the estate itself, including the green-manure and prunings, as well as all residues from the tea factories, bungalows, coolie lines, cattle sheds and so on should be utilised. In all probability it will be found more advantageous to reap the green-manure crops for composting than to dig them into the soil. On most tea gardens in India, however, there is no dearth of waste products.

The large-scale trials which Dr. Harler has initiated in Travancore leave little doubt that the general introduction of the Indore method is certain to improve the fertility of the gardens and to lower the cost of production of tea. What the effect of humus will be on quality remains to be seen. One could deal with this point more definitely if more were known about the root system of the tea plant and the manner in which the plant and the soil come into gear throughout the year by means of the absorbing roots.

Among the men engaged in the production and sale of tea an uneasy feeling can be detected that the use of artificial manures has been followed by loss of quality. One of the planters in the Darjeeling district, Mr. G. W. O'Brien, the proprietor of the Goomtee Tea Estate, who continues to produce tea of the highest quality, has never used artificials since the estate came under his management thirty-one years ago. The only manure used is cattle manure and vegetable wastes.

Sugar-cane.—Sugar-cane, like all grasses, only develops well when provided with a supply of combined nitrogen. As there has been an over-production of sugar for some years, with correspondingly low prices, the cheapest and most efficient source of manure is an important matter. The problem is how to convert the waste products of the cane into humus on the spot and to make the areas which produce cane as nearly as possible self-supporting as far as manuring is concerned.

Is it possible to make the average sugar-cane estate produce most of the manure it needs? The answer is in the affirmative, as will be evident from the results obtained at Shahjahapur, at the Institute of Plant Industry, Indore, and at Bundi in Rajputana. The first step towards the goal was taken by Mr. G. Clarke, C.I.E., who successfully adopted green manuring with *sann* hemp (*Crotalaria juncea L.*) for the cane crop. Ample moisture, by means of irrigation, was provided for the first stages of the decay of the green crop. The rainfall after ploughing in was carefully watched. If it was less than five inches during the first fortnight of September, the fields were irrigated. Later on nitrification was prevented by drying out the surface soil until the cane was planted under irrigation in March. In this way crops of over 30 tons of cane to the acre were grown without the aid of any manure beyond the hemp, grown on the same land during the previous rains and treated in the manner indicated above.

The next step was taken by the United Provinces Agricultural Department in 1933, when Mr. R. G. Allan adopted a suggestion, published in 1931 in *The Waste Products of Agriculture*, that the green-manure crop should be reaped and used to mix with cane trash before composting according to the Indore method. The results obtained were very satisfactory and were referred to in my 1933 lecture (p. 102).

A technique for dealing with large masses of cane trash was then developed at the Institute of Plant Industry, the results of which have just been published in the *International Sugar Journal* of July last.[1] Cane trash, in an unbroken condition, is composted during the rains with various mixtures of weeds, to which a slurry made up of cowdung, molasses, wood ashes and soil has been added. The mixed material is arranged in heaps 8 feet wide, 3 feet high, and any length that is desired. After the first turn crops of *sann* hemp are raised on the heaps themselves. The development of roots and nodules is very marked. When the hemp is about a foot high, the heaps are turned, when the leguminous plants, by raising the C : N ratio of the mixture, assist decay. This is repeated once or twice during the rains, after which the compost is ready in 140 days, in time for planting cane in February. A similar technique is now in operation on the lands of the Bundi Agricultural Syndicate in Rajputana, where the trash of 250 acres of cane has been successfully converted into humus by Mr. E. F. Sykes.

On large estates, provided with light railways for transport, with power at the factories and with trained chemists, it should be a very simple matter to improve very considerably the technique worked out at Indore and Bundi, which, however, is quite suitable for small sugar estates or for large cultivators or cane farmers. On ordinary sugar estates there should be no difficulty in converting cane trash into humus on a large scale in ninety days at a very small cost. If the cut canes were stripped, not on the field but at a convenient site near the factory, the trash and all kinds of other vegetable wastes which are available, including fresh and dried green-manure and spare megass, as well as all the farmyard manure that can be collected, could be passed through a chaff cutter, when a mixture which would not pack like cane trash would be obtained. These mixed wastes, as they leave the chaff cutter and before they are transported by rail to the composting strips on both sides of the light railway, could be sprayed with a slurry composed of molasses, water, wood ashes and soil. The material could be stacked in long heaps 8 to 10 feet wide and 3 feet high. This would facilitate turning from one end and also the transport of the finished humus. Two or at the most three turns would be necessary. After the first turn, suitable leguminous plants could be grown on the heaps. Arrangements would have to be made for periodical watering. In this way large sugar estates could be made practically self-supporting as regards manure: the cane fields would manure themselves. From the Indore figures it appears that 100 tons of stripped cane will yield about 45–50 tons of moist compost containing about 40–50 per cent. of moisture and 1 per cent. of nitrogen (dry basis).

(1) Tambe, G. C., and Wad, Y. D., "Humus Manufacture from Cane Trash," *Inter. Sugar Journal*, xxxvii, 1935, p. 260.

Once the Indore process has been adopted for converting the waste products of the cane into humus, the research work on this crop will have placed cane in an exceedingly strong position. The first great advance in cane production was the discovery of the Java method of growing this crop, by which the plant was enabled to renew its root system from the lower nodes in such a manner that adequate soil aeration was automatically provided. The next step was the breeding of improved disease-resisting canes by utilising one of the wild *Saccharums* as the pollen parent. The third step is the conversion of the trash and spare megass and molasses into humus, by which the sugar-cane can be made to provide most of its manure. I am convinced that if the contest between the sugar-cane and the sugar-beet could be fought out without the intervention of tariffs, quotas and so forth, cane would win and win easily.

Maize.—The somewhat light and open soils which the maize crop requires need a constant supply of humus; otherwise there is a rapid falling off in yield. Wherever maize soils show any tendency to pack, another requisite for heavy yields is ridging, which encourages the development of new roots from the lower nodes.

In Kenya the need of humus for maize appears to be even more insistent than in other parts of the world. Consequently, the Indore process was instantly taken up by many of the maize growers in this part of Africa. The results obtained have been uniformly successful, although the recent fall in prices has compelled the growers to adopt somewhat rough-and-ready methods.

At Rongai, Mr. J. E. A. Wolryche Whitmore has adopted the Indore process on three farms. The working oxen are kept under cover for about ten hours nightly and bedded down with dry maize stalks, wheat straw, grass and any other roughage available. After a week under the cattle, this is put into pits with a sprinkling of wood ashes, some earth from under the cattle and, when available, 10 lb. of rock phosphate per ton of compost. If insufficient earth is added a high temperature is not maintained. Two turns at intervals of a month yield a satisfactory product after ninety days. The effect on the maize crop is very marked, but in dry areas dressings should not exceed five tons per acre ; otherwise the crop produces too much leaf for the available soil moisture.

Mr. J. P. Hill, at Hoey's Bridge, has also obtained very good results with compost and is now engaged in a number of trials designed to reduce the cost of labour. Maize stalks are stacked on the field to dry. After the cobs are removed, the stalks are left where they are and composted on the field with urine earth carted from the kraals, the strips of land occupied by the process being left uncropped except for lupins between the heaps, which are cut and added to the fermenting mass. The position of the lines of heaps is altered from year to year. Mr. Hill is trying out a modified method of green-manuring for the maize crop. Compost is spread on the green crop before ploughing in, a modification which is likely to prove very successful provided the supply of moisture is adequate.

Sisal.—As is well known, the leaves of the sisal plant yield about 95 per cent. of waste material and a very small amount of usable fibre. These wastes are removed from the decorticators by a stream of water which renders their utilisation as humus very difficult. The problem of composting sisal waste is a two-fold one : (1) the removal and utilisation of the surplus water, and (2) the aeration of the solid residues, to prevent the development of acidity and so enable fungi to break down the cellulose. The need of humus on sisal estates is a very urgent one, as the plant only does well on land maintained in good condition. Till quite recently few efforts appear to have been made to convert sisal wastes into humus, this potentially valuable material being either run into streams, dumped into ravines, or used as fuel.

During 1935 a serious attempt has been made at Major Grogan's sisal estate at Taveta in Kenya (1) to use the water in the waste material for growing crops, and (2) to convert the solid residue into humus. Major Layzell, the manager of the Taveta estate, has very kindly sent me details of the work in progress, which only began during the present year.

The method adopted is as follows. The combined sisal waste and the water from the decorticators is first filtered. The water, or soup, after neutralisation with crude limestone, is run into properly graded earth furrows for growing maize, bananas and elephant grass (for use in composting the sisal wastes). The solid waste is loaded on slatted trucks and allowed to drain, and is then moved to the composting area by means of a light railway. Here it is spread on a foundation of dry sisal poles (to promote aeration from below) in heaps, 15 feet by 4 feet and 2 feet high, the material being interlaid with elephant grass and mixed with a little soil and some old compost and any animal wastes that are available. After the first turn, suitable leguminous plants are grown on the heaps. At each subsequent turn, the green crop becomes incorporated and the C : N ratio of the mass is improved. (Figs. 1 and 2).

A portion of the sisal waste, when dried, has been used by Major Layzell for running a gas producer plant for driving 110-h.p. gas engines. This was started in 1921, and the plant is still running successfully. One ton of dried waste was used for every ten-hour shift ; a valuable ash of a similar composition to wood ashes and containing 4·42 per cent. of potash and nearly 40 per cent. of lime was obtained. This material will be of the greatest use in reducing the acidity of the compost heaps.

On the Taveta estate the finished compost will be railed about the estate to the points where it is required by means of the trucks employed to bring the leaves to the decorticators. The use of this manure should help to solve two of the chief problems in sisal growing, namely, (1) maintaining the fertility of the soil high enough for the sisal plant to do itself justice as a producer of fibre, and (2) keeping the lead to the decorticators within reasonable bounds. It must never be forgotten that the sisal plant needs intensive rather than extensive cultivation. Whenever this is forgotten, the enterprise ends in bankruptcy.

III. The Adoption of the Indore Process Outside Plantation Industries

The spread of the Indore process among the cultivators of India and other tropical countries is nothing like so spectacular as the extremely rapid progress that has been made in the plantation industries. A little consideration will show why this is so. The plantation industries are highly organised, and the estates are often arranged in large groups controlled by a small London directorate. The consideration of any new process or any new idea likely to benefit these industries is quickly undertaken, and a decision at once leads to action. London is the place where things happen, even in agriculture.

In peasant agriculture there is no similar organisation for taking corporate decisions over wide areas. All that is possible is to interest individuals with local influence, so that a number of centres are firmly established for the demonstration and propaganda of a new principle. In course of time these local centres will exert their influence on the countryside.

A large portion of the money spent on working out the Indore process was contributed by the cultivators of India in the form of a small cess on raw cotton, which cess is administered by a body known as the Indian Central Cotton Committee. The cotton crop is not in the East a plantation industry ; it is grown by peasant cultivators or larger individual landowners. The process was originally devised to help these growers to combat a factor which limits the great possibilities of India as a producer of raw cotton. This factor—poor soil aeration after the cotton is sown—operates both on the black cotton soils of the Peninsula and also on the drier areas of the alluvium of North-West India where this crop is grown.

On the black soils no statistical study of the yield of cotton is needed to establish the supreme importance of organic matter in cotton-growing. The results can be seen in every village. The highly-manured lands near the houses yield good crops of fine healthy cotton. On the outlying unmanured fields the

A
B
C

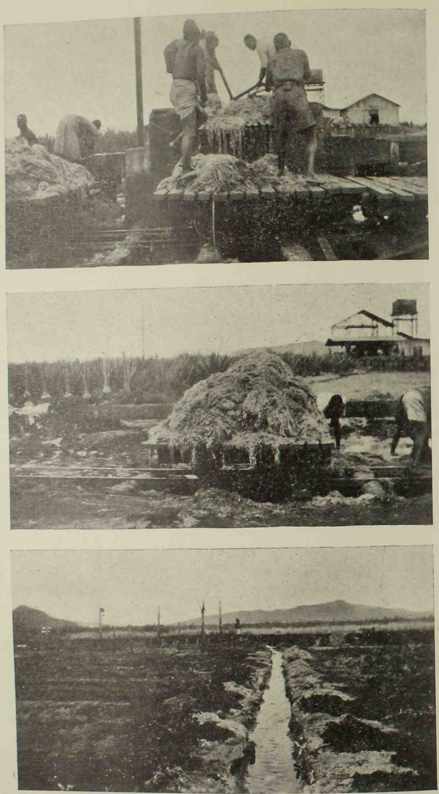


Fig. 1. Conversion of Sisal Waste
A. Filtering the waste. B. Draining. C. Irrigation with waste water

A
B
C

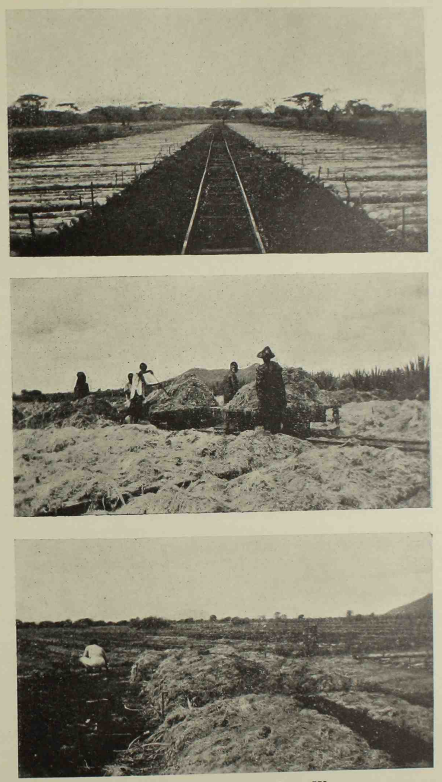
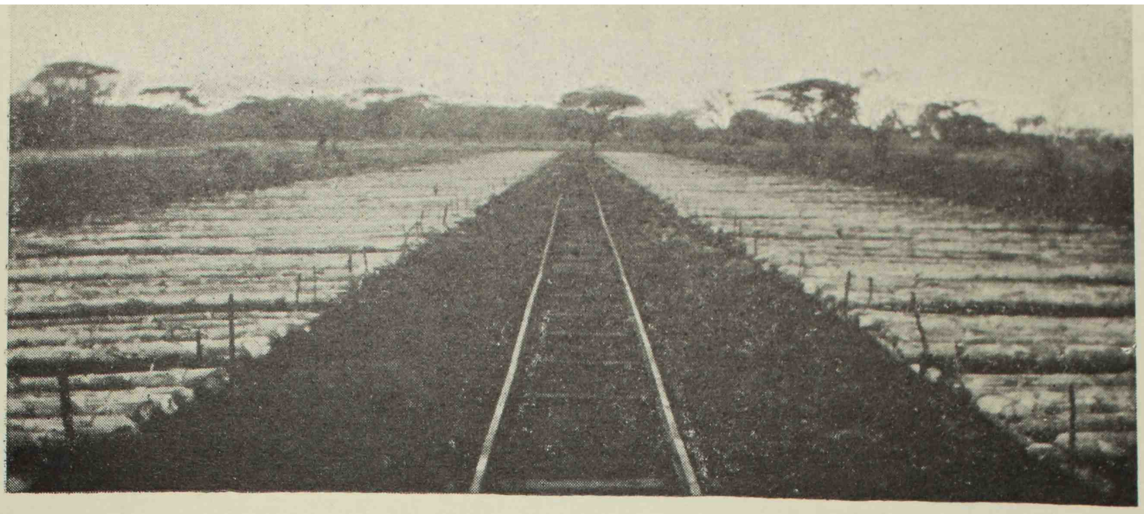


Fig. 2. Conversion of Sisal Waste
A. Light railway and foundation of sisal poles. B. Spreading. C. Turned heaps with layers of elephant grass



A

B

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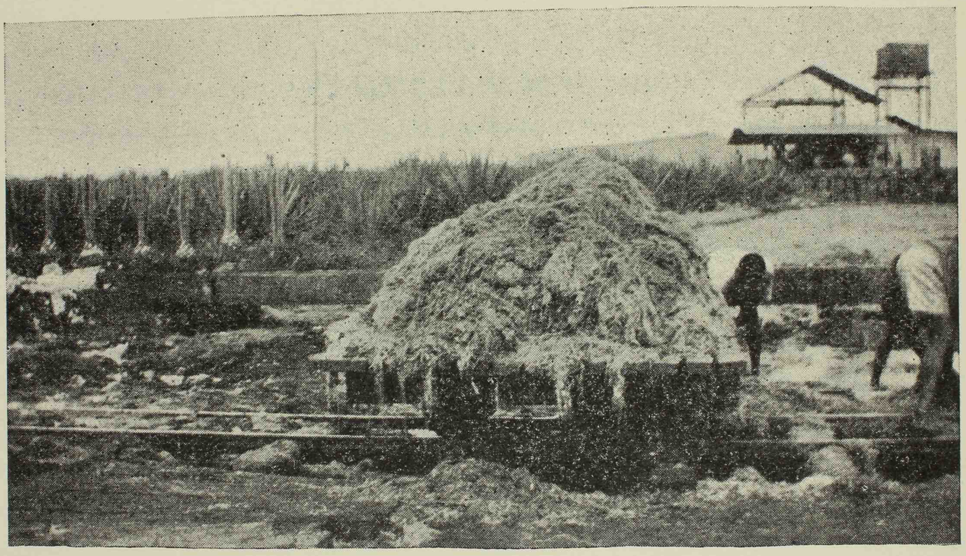
FIG. 2. CONVERSION OF SISAL WASTE

A. Light railway and foundation of sisal poles. B. Spreading. C. Turned hea
with layers of elephant grass

A


B


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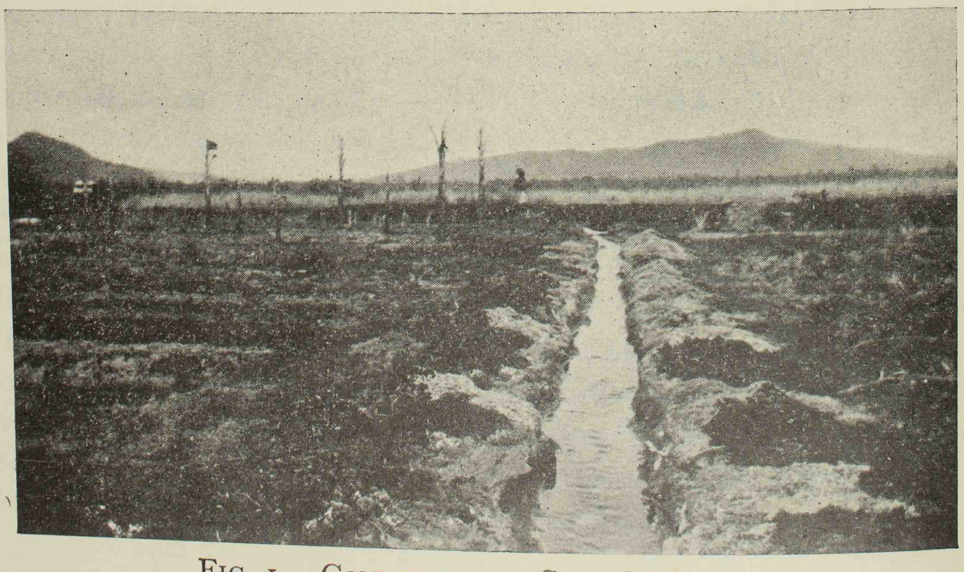


Fig. 1. Conversion of Sisal Waste
A. Filtering the waste. B. Draining. C. Irrigation with waste water

cotton plants are, by comparison, dwarfed and miserable specimens. In very wet seasons these differences are accentuated. The limiting factor which is at work is a colloidal condition of the soil, which establishes itself about the middle of the rains in normal years and still earlier in wet seasons. The colloids interfere with aeration, the chemistry of the soil slows down ; first root development and then growth suffers. Dressings of compost help to remove this difficulty by improving the permeability of the soil.

On the alluvium of North-West India, a similar limiting factor occurs. Here cotton is grown mostly on irrigation, which causes the soil particles to pack, and in due course the plants, particularly American varieties, show by their growth that they are not quite at home. The anthers often fail to function properly, the plants are unable to set a full crop of seed, the ripening period is unduly prolonged and the fibre lacks strength, quality and life. The cause of this trouble is again poor soil aeration, which appears on these soils to lead to a very mild alkali condition. This, in turn, prevents the cotton crop from absorbing sufficient water from the soil. One of the easiest methods of preventing this packing of the soil particles is to apply dressings of humus.

At the Sakrand Experiment Station, Mr. W. J. Jenkins, the Chief Agricultural Officer in Sind, who was one of the first in India to adopt the Indore method, has already proved that humus is of the greatest value in keeping the alkali condition in check, in maintaining the health of the cotton plant and in increasing the yield of fibre. The Indore process is now well established on all the Government farms in Sind. At Sakrand, for example, no less than 1,250 cartloads of the finished product were prepared in 1934–35 from waste materials such as cotton stalks and crop residues. In a report, dated October 1st, 1935, Mr. Jenkins writes :—

> " It is already abundantly evident from the results obtained at Sakrand and other centres in the barrage areas that the scientific utilisation and adequate supply of organic manures must play an important part in the ultimate solution of the problem of maintaining soil fertility and preventing the accumulation of alkali salts."

The manufacture of compost in Sind has now spread from the Government farms to the demonstration areas, which are cultivated on the share system by the zamindars themselves. From the interest shown by these cultivators, it is obvious that it is only a question of time before the Indore system becomes well established in the villages.

Equally interesting results have been obtained by Colonel Cole, C.B., C.M.G., at Coleyana in the Montgomery District of the Punjab, where a compost factory on the lines of the one at the Institute of Plant Industry, Indore, was established in June, 1932. At this centre all available wastes are regularly composted. The cotton crop has distinctly benefited by the dressings of humus ; the quality of the fibre has improved ; higher prices are being obtained ; the irrigation water required is now one-third less than it used to be. The neighbouring estates have all adopted composting, and inquiries about the process are being received from the large cultivators in the neighbourhood.

A promising beginning, therefore, has been made in the removal of the factor which is holding up the yield and depressing the quality of Indian cotton. It is unfortunate for the multitude of small cotton growers in India that the resources of the Indian Central Cotton Committee are not being energetically employed in getting the Indore process taken up all over the country. The funds of this body are now largely devoted to matters of only secondary importance. Large sums are being spent every year on entomological schemes, from which the men who contribute the cotton cess are not likely to derive any great benefit. Far too much attention is being paid to plant breeding and to the distribution of seed. It is true that, on the Government farms and in areas of high fertility, improved varieties of cotton have done remarkably well, but it should be borne in mind that to expect the plant breeder to find a variety which will withstand the consequences of a colloidal condition on the black soils and an incipient alkali phase on the alluvium is to ask the impossible. To achieve any lasting and permanent improvement in the production of cotton in India, the facts must be squarely and honestly faced. The factor limiting growth, namely, poor soil aeration, must first be removed so that the work of the plant breeder can produce its full effect. It is only by the combination of better soil conditions with improved varieties that the cotton growers of India can materially benefit from agricultural research.

In the United Provinces the impetus given to the compost movement in 1933 by Sir Malcolm Hailey, G.C.S.I., G.C.I.E., when Governor, and by Mr. R .G. Allan, the Director of Agriculture, has led to very encouraging results. The work done during the years 1933–35 has been summed up by Mr. Allan in a memorandum, dated October 5th, 1935, from which the following summary has been compiled :

The policy of increasing fertility by means of compost has had a good effect, and the process is being gradually taken up throughout the Provinces. The practice is fully established on all Government farms and gardens, has been included in the programme of the better farming movement in the villages, and is being steadily adopted by many of the landowners and by the better farming societies. The spread of composting has been stimulated by three other developments which have recently taken place : (1) the hydro-electric scheme which has provided tube-well irrigation water in Rohilkhand and some of the Western districts ; (2) the adoption of intensive agriculture on the area commanded by the new Sarda Canal and the Hydel tube-wells ; and (3) the general expansion of the sugar industry, including the formation of zones of intensive cultivation round the sugar factories. All these developments need a constant supply of organic matter, which the Indore process supplies.

Sugar-cane trash is the chief source of compost. This is supplemented by *sann* hemp, by miscellaneous wastes and by the water hyacinth. This latter, when mixed with a quarter of its weight of *sann* hemp, yields a satisfactory product.

Every year the amount of compost has markedly increased. On the Government farms of these Provinces in 1932–33 the total amount produced was 28,000 maunds. In 1933–34 the quantity rose to 80,000 maunds. During the last year, 1934–35, nearly 100,000 maunds have been prepared.

A very satisfactory feature has been the effectiveness of the method in increasing the total volume of organic manure. On some farms the original stock of manure has been increased as much as four to five times, a circumstance which has proved very encouraging to the owners of the many private farms in these Provinces. Manurial trials with compost have been carried out on cane, wheat and cotton, when, as was expected, results equal to those obtained with cattle manure were secured.

In H.E.H. the Nizam's Dominions the Indore process has been definitely adopted at the Leper Home and Hospital at Dichpali. The Superintendent, the Rev. G. M. Kerr, in a letter dated 10th October, 1935, sums up his experience of the method in the following words :—

> " Indore compost is one of the material blessings of this life, like steam, electricity and wireless. We simply could not do without it here. It has transformed all our agricultural interests. We have 43 acres under wet cultivation, and most of the land three years ago was of the poorest nature, large patches of it so salty that a white alum-like powder lay on the surface. We have now recovered 28 acres, and on these we are having a bumper crop of rice this year. There have never been such crops grown on the land, at least not for many years. The remaining 15 acres are as before, with the rice scraggy and thin. By means of our factory of 30 pits we keep up a supply of compost, but we can never make enough to meet all our needs. We are now applying it also on our fields of forage crops with remarkable results. Compost spread over a field to the depth of about one-quarter of an inch ensures a crop at least three or four times heavier than otherwise could be obtained."

The above results, which are easily possible throughout the length and breadth of India, are certain to be copied elsewhere. An excellent beginning has already been made in the Central India and Rajputana States, Bihar and Orissa, the North-West Frontier Province and the Punjab. The great success which has followed the adoption of composting on the tea estates in Travancore is bound to have its effect in South India before very long, while the work in progress in the tea districts of Bengal and Assam is certain to influence agricultural policy in Eastern India. A great deal, however, remains to be done before the cultivators of the Indian Empire as a whole reap the benefit of a piece of work which was originally undertaken on their behalf and at their expense.

As was to be expected, a number of modifications of the original technique have been suggested. A few of these are very definite improvements which could with advantage be generally adopted.

One of the chief difficulties in composting is the maintenance of the air supply ; hence the adoption of shallow pits or low heaps, as it is found in practice that air does not penetrate more than 30 inches at the most. Excessive trampling often prevents the air getting into the mass to more than a few inches. Dr. Harler has abolished this danger altogether by the use of a broad plank laid across the pits

from which charging is carried out. The fermenting material is never trodden upon at all.

Mr. E. F. Watson, the Superintendent of the Government Estates in Bengal, who has successfully adopted composting at the Governor's residences in Calcutta, Barrackpore and Darjeeling, has devised a simple method for increasing the aeration of the pits from below. Aeration drains, 10 inches by 3 inches, are dug in the floor of the pits. Down the centre of this trench another trench, 6 inches by 5 inches, is cut. Old bricks are then laid, open jointed, in the upper trench. Copious aeration, followed by fungus development, rapidly spreads in the mass lying over these drains to a distance of two feet all round. In all cases where composting is done on a large scale it would probably pay to lay these aerating drains under the whole system of pits and to provide them with the requisite number of aerating chimneys. Mr. Watson has also introduced an ingenious arrangement for getting still more oxygen into the mass from the atmosphere. Temporary V-shaped partitions, made of old scrap perforated corrugated sheets, bolted together above and below, with a bamboo separator at the top, which also serves as a handle, are placed in the heaps, at a distance of 6 feet apart, and left till the compost has settled, when they are lifted out and used elsewhere. The details of these modifications will be clear from Fig. 3. Where they are adopted, deeper pits will be possible.

For canal-irrigated tracts, where a continuous supply of water is not available, Messrs. Jackson, Wad and Panse[1] have worked out a suitable technique, which has been successfully introduced on the new Gang Canal in Bikanir State. These authors have also devised a simplified method for use in the monsoon, which does away with watering from wells. The disadvantage of this modification is that it is far less efficient than the original process. Further, the compost becomes available at the wrong time of year, just before the cold season crops are sown, instead of during the month of May, when humus exercises its maximum effect in those areas which are fed by the south-west monsoon. It is not the custom to manure the ordinary cold season *rabi* crops for a number of reasons, chief among which is the impossibility of incorporating the manure without serious loss of soil moisture and of getting it nitrified in time. The best time for composting in India is the period between the end of the rains and the close of the hot season. Raw material is then available in quantity, and the operation fits in well with the general work of the holdings. The finished material becomes available just when it can exercise its greatest effect on the soil, namely, at the beginning of the rains. The only difficulty is water, which must be raised from wells which sometimes give out towards the end of the hot season. This can be met by a vigorous campaign for the improvement and extension of well-irrigation, a matter which hitherto has been delayed on account of the shortage of manure. Now that it is easily possible, by means of the Indore system, to multiply the available manure at least three times,

(1) Jackson, F. K., Wad, Y. D., and Panse, V. G., " The Supply of Humus to Soils," *Empire Cotton-growing Review*, XI, 1934, p. 111.

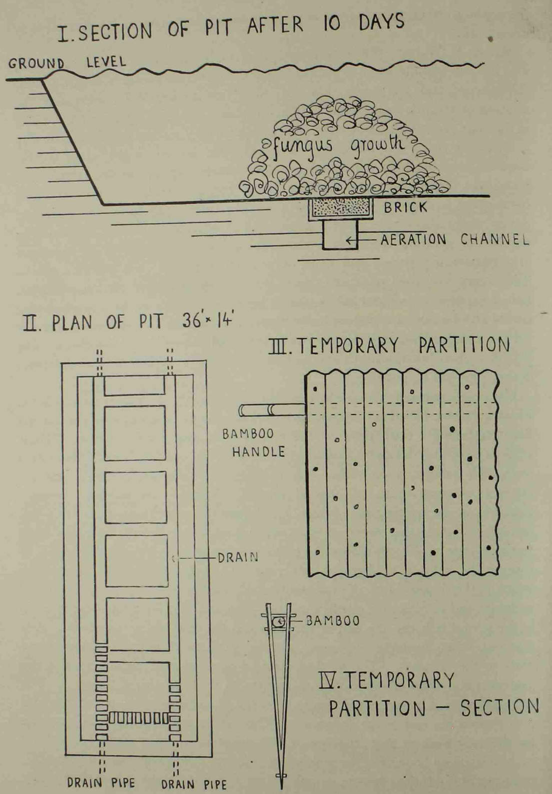


FIG. 3. AERATION CHANNELS UNDER PITS AND V-SHAPED PARTITIONS

this limiting factor no longer exists. An excellent area for a bold forward policy in up-to-date well irrigation is the Malwa plateau in Central India, with its very gentle slope towards the north, which enables a perfect control of the monsoon rainfall to be secured at a very small cost. We owe a very inexpensive and a very practical method of accomplishing this to a previous Maharajah of Indore, who showed his subjects how to retain the surplus monsoon rainfall on the surface behind earthen embankments. The water thus held up percolates into the trap rock below and feeds the wells till the next rainy season. These old embankments need repair and modern spill ways; many more are required; the existing wells need deepening; new wells must be sunk. Practically all this work can be done by the cultivators themselves. They only need leadership and a little technical advice. On these well-irrigated areas splendid crops of sugar-cane, wheat and vegetables could be raised with the help of compost, as well as early-sown cotton.

In Kenya a very interesting modification of the process, to suit the needs of the native reserves, has been devised by Mr. H. E. Lambert, formerly District Commissioner at Embu. The original Indore technique has been simplified so that the ordinary illiterate African can keep it in his head. No preparation of the materials is attempted. These are collected, lightly watered and stacked near the pits, so that ample material is available when manufacture begins. The procedure followed in charging is very similar to that at Indore, except that urine earth is replaced by dung and wood ashes. Every operation which a pit requires is repeated on the same day of the week, and the complete manufacture is got through in eight weeks. The operations after the initial charging merely involve an alternation of moving and watering. To make the process continuous, the pits are arranged in series of four—each series corresponding to a specified day of the week.

In a letter dated September 20th, 1935, Mr. Lambert, after describing his technique in detail, wrote:

> "The results were unquestionably excellent from the agricultural point of view. I never managed to get the compost analysed, but the results of its use in vegetable, flower and banana gardens were remarkable. I am not so sure that the medical people would be so satisfied. I found that the Indore process, as adopted at Embu, was followed carefully, the temperatures obtained were high (approximately the same as at Indore), but there were occasional instances, for which I could not entirely account, when the temperatures reached were scarcely satisfactory to the sanitarian, though I never personally found any tendency to fly-breeding or noticed any unpleasant odour. There were certainly some differences between Embu and Indore in the rapidity of the onset of intense fermentation. The high temperatures after the charge and after the first turn were rarely achieved so quickly at Embu. But agricultural results were uniformly excellent.
>
> You ask me to what extent the method has been taken up by the natives. I am afraid I have to be very disappointing in my answer. A very great interest was shown by certain chiefs and others, and my own garden boys almost fought one another in their haste to get the compost into their respective spheres. But the ordinary agriculturist has not taken to the method, not because he has any objection to the method as such, but

because, generally speaking, he has neither the education nor the need to use organic manures (or any manures) at all. Shifting cultivation is still the vogue. But the pressure on land will alter all this, in some places rapidly, and the Indore method (which is being preached far and wide in many District Headquarters, local Native Council farms, European estates, etc.) is ready for him when the native wants it. Personally, I have no doubt that the African will have Indore to thank for the solution of a problem which, though not pressing at the moment, will become increasingly so in the future."

On Monday last, in his second Heath Clark lecture (University of London), Sir Daniel Hall, K.C.B., F.R.S., dealt with the place of the Indore method in African agriculture under the title—*Regenerative Systems of Farming*—and sketched what is almost certain to be the evolution of crop-production in Africa. Shifting cultivation is now the rule; manuring is practically unknown. Under a settled Government, however, the population is increasing and the pressure on the land is beginning. It is no longer so easy to take up a fresh piece of ground.

Permanent cultivation must soon take the place of the old system. But for this some simple and inexpensive method of manuring is needed. Sir Daniel Hall and the men on the spot consider that the Indore method solves the problem.[1]

I should like to mention one possible improvement in the Indore method, the discovery of the precise conditions needed for the maximum fixation of nitrogen during the later stages. That a large amount of fixation does take place was proved at Indore before I left in 1931. There was, however, no time to work out the optimum conditions. I hope this work will be done as soon as possible. Once it is completed, we shall have a solid basis on which a real improvement of the original technique can be founded.

IV. Town Wastes

In my 1933 lecture an account was given of Messrs. Jackson and Wad's work on the application of the Indore method to municipal wastes (town refuse and night-soil), and its successful adoption at three centres near Indore—the Indore Residency, Indore City and the Malwa Bhil Corps.

During the last two years this work has been taken up in India by the following Central India and Rajputana States, arranged in order of date: Indore, Rewa, Jaipur, Alwar, Bharatpur and Datia, and by the following municipalities: Neemuch Cantonment, Secunderbad Cantonment, Nanded (Hyderabad, Deccan), Shahjahanpur (United Provinces) and Sabour (Bihar and Orissa). In Ceylon some of the urban district councils have begun to convert their municipal wastes into humus.

The most interesting development in the transformation into humus of the waste products of a town has recently taken place in Kenya. A factory, erected and managed by the Express Transport Company, is now at work at Nairobi converting the following wastes into manure: coffee parchment, *boma* manure, tannery waste, hair, wool and fleshings, horn and hoof, bones, cotton seed residues, chaff, wood ashes and crude limestone. When necessary these materials are first finely ground before mechanical mixing (Fig. 4), then moistened and composted in pits according to the technique laid down in the *Waste Products of Agriculture* (Fig. 5). Nothing, however, is left to chance: the proportions of the various ingredients are suitably adjusted; the correct degree of acidity is maintained in the fermenting mass; everything is done to turn out an ideal fertiliser. The conversion takes ninety days, when a rich, finely divided humus of the following composition (expressed in percentages) is produced: moisture 25·0, organic matter 62·15, nitrogen 1·5, phosphoric acid 1·5, potash 1·5, lime 4·0. The content of soluble humus is 14·0 per cent.; the carbon: nitrogen ratio is 15 : 1. The plant has a capacity of 20 tons a day; in 1934 the sales amounted to 3,500 tons; the price at the pits is 14*s.* a ton. In a letter, dated Nairobi, September 26th, 1935, the managing director of the company reports:

" The results obtained on controlled experimental plots of flowers, vegetables, maize, grassland and coffee have been amazing."

The Nairobi enterprise started as a simple commercial proposition suggested by the results which followed the adoption of the Indore method on the coffee estates in Kenya. It proved an immediate success for the simple reasons that the product is just what the soil requires and the price is reasonable.

(1) Beckley, V. A., *Organic Manures with special reference to Composts.* Bulletin No. 9, Kenya Department of Agriculture, Nairobi, 1934.

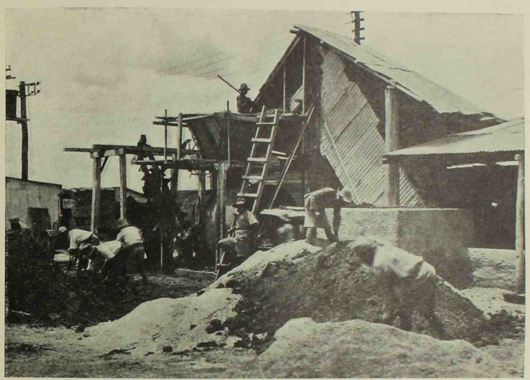


Fig. 4. Preparing Town Wastes at Nairobi

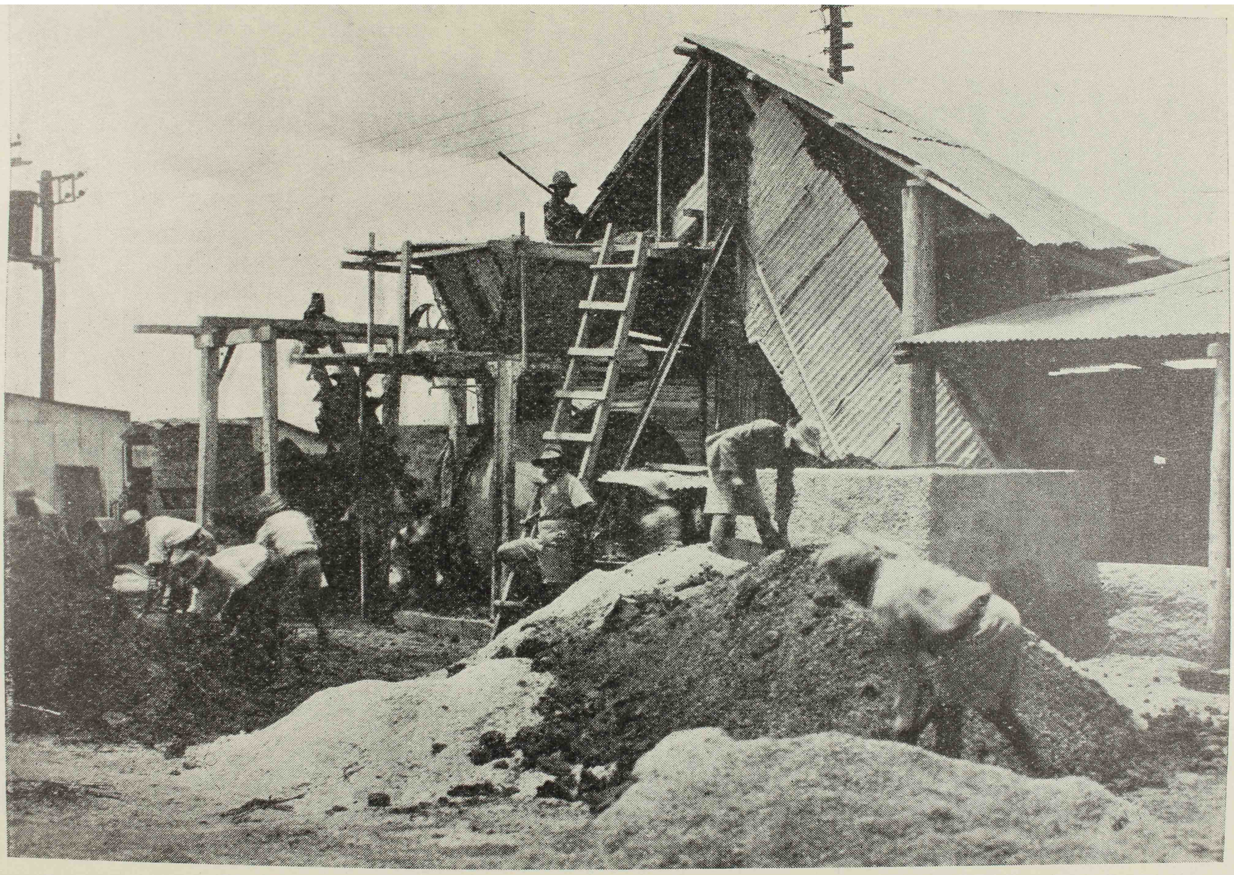


Fig. 4. Preparing Town Wastes at Nairobi

Fig. 5. Fermentation of Town Wastes at Nairobi

The results of this Nairobi experiment are of unusual interest, because they indicate very clearly the solution of the manurial problem in all parts of the Occident: how a successful working compromise between the rival claims of inorganic and organic manures can be achieved.

The first step is to obtain a steady supply of humus. This can be secured by converting all the organic residues which are now either running to waste or are hardly utilised at all. These are municipal wastes, crude sewage, sewage sludge and peat. The conversion of these materials into humus is a simple matter. The town wastes and peat, when sprayed with sewage sludge, will produce the

FIG. 5. FERMENTATION OF TOWN WASTES AT NAIROBI

conditions necessary for the first stages in humus manufacture. The limiting factor will be the oxygen supply. The chief practical problem will be how best to draw from the atmosphere the large quantities of oxygen needed by the fungi and bacteria. Simple diffusion will not suffice. I envisage the use of compressed air as the next big development in the application of the Indore process to urban areas. This compressed air will be needed to start and to maintain the intense oxidation which is involved in the first part of the process. Such speeding up of the conversion would have other advantages; the area of land required for the composting factory would be automatically reduced (an important consideration on the outskirts of large towns); the output would be increased. Once the air supply is arranged for, the mechanisation of the rest of the process involves nothing more than the adoption of well-known labour-saving devices, such as rotary mixers, conveyers and so forth.

While the organic wastes of urban areas are being converted into humus, we can take a further step in improving our manure supplies. We can follow the lead of Nairobi and prepare the ideal fertiliser, containing a basic amount of humus (obtained from vegetable and animal wastes) fortified by the necessary addition of artificial manures, preferably added to the mass before fermentation begins. In this way these additions would do double duty; firstly, by providing the fungi and bacteria with inorganic food materials; secondly, by improving the chemical composition of the final product.

It should not be beyond the resources of an organisation like Imperial Chemical Industries to acquire for a term of years the waste products of one of the Special Areas, preferably one with extensive peat deposits in the neighbourhood, and create a new local industry, which is certain to spread throughout the country.

In any case the present water-borne methods of sewage disposal should be given up in all new towns, in all extensions of existing towns, in all new land settlement schemes and new villages, and replaced by a more rational system which does not also waste large volumes of valuable water. In this way the losses involved in our present wasteful system could be restricted. In the course of time our water-borne system will, in all probability, be replaced by something much more sensible.

V. GENERAL APPLICATION TO BRITISH AGRICULTURE OF THE PRINCIPLES INHERENT IN THE INDORE PROCESS

There are a number of directions in which the principles underlying the Indore process can be made use of in the agriculture and horticulture of this country.

Field crops and vegetables require the same thing—an extensive, and at the same time, an effective, pore space in which the root hairs can live and work. In other words, the internal surface of the soil must be made as efficient as possible. For this purpose a continuous supply of humus is essential. How is this to be obtained?

Has it been generally realised that in the turf of our grasslands and clover leys we have, just where they are wanted, vast stores of crude organic matter which merely await utilisation on the lines of the Indore process?

A suitable technique is already being carried out by at least one farmer in this country. During a recent visit to Cornwall, Mr. F. A. Secrett showed me his method of treating old clover leys so as to convert the crude vegetable matter in the turf into humus. The leys are well manured with farmyard manure after the last clover crop. The land is then ploughed in strips so that the inverted turf and the undisturbed strip come together with a layer of farmyard manure in between. What amounts to the Indore process is then set in motion above and below the layer of manure. The crude vegetable matter in the turf is rapidly converted into humus. When the ploughed field is cross-disced, the humus is incorporated in the soil and at the same time the danger of wireworm is substantially reduced. I understand that Mr. Hosier exploits his turf in a somewhat similar way by means of the animal droppings left on the surface. Professor Stapledon, in some of his pasture improvement work, uses artificials like nitro-chalk and basic slag for converting the vegetable residues of derelict grassland into humus for the benefit of his improved seed mixtures. While all these methods yield a good result, I prefer Mr. Secrett's technique, as he is saving time and is also making his farmyard manure do double duty: firstly, by converting the crude vegetable matter in the clover ley into humus; secondly, by providing his vegetables and flowers with humus of animal origin, which is so essential for high quality.

When it is remembered that a large area of this country is now under grass, it will be evident there is no dearth of crude vegetable matter, delivered at site free of charge as it were, and only waiting to be made into humus. That it pays to carry out this conversion is proved by the practical experience of men like Messrs. Secrett and Hosier, and by the farmers who are adopting Professor Stapledon's ideas. In the years to come an additional reason for such conversion will, I am confident, be quoted. The health of our livestock will require supplies of high quality grass and fodder raised from land which has been under the plough. The present system of keeping land in grass indefinitely will have to be given up. Such a system cannot be good for the grass or for the animals which feed on it. Grass needs cultivation or the soil gets pot-bound as it were. Animals, as I know from long experience, need food of high quality if they are to withstand disease. Further, it cannot be economic to allow large reserves of valuable vegetable matter to remain unused on the surface of the country, or to fail to re-create these reserves by means of the temporary ley.

How can the large amounts of farmyard manure be obtained which are needed to convert turf into humus? The answer is provided by the experience of the seed farms in the United Provinces of India. At these centres the utilisation of all the vegetable wastes that can be collected has increased the volume of manure as much as four or even five times. The miscellaneous wastes of an ordinary English farm—such as weeds, hedge trimmings, bracken, old straw, damaged fodder and so forth—which are now largely burnt or wasted, would, if properly used, at least double, and perhaps treble, the volume of the manure available.

Another possible source of humus is green-manuring on improved lines. Instead of ploughing in catch crops of green-manure in the early autumn, these should be first manured with farmyard manure or compost, and then disced so as to mix the vegetable matter and the manure with the upper two or three inches of the soil. This would provide the fungi and bacteria which make humus with all the food materials they need—combined nitrogen, water, oxygen and a base to neutralise excessive acidity. If this idea is tried out for a few years on the potato lands of Lincolnshire, I am convinced we shall hear very little about the eel-worm disease of potato, the true cause of which, I suspect, is bound up with too much N P K.

I suggest that these simple methods of introducing the gist of the Indore process into British agriculture and of increasing the humus content of the soil be tried by enterprising private individuals who possess the necessary resources. It would

not be a very difficult matter to evolve a completely new national system of land management, the alternation of temporary pastures and clover leys with the different types of arable farming. In this way the land could carry not only a much larger quantity of straw, but also the large head of stock whose waste products are essential in any effective and permanent system of agriculture.

The balance sheet of the land must be considered as well as the profit and loss account of the man who farms it. The recent fall in prices has made everybody connected with British agriculture think too much about making both ends meet and too little about the safety of their real capital—the land.

VI. Agricultural Research Now and To-morrow

In concluding this lecture I shall attempt in a few words to explain the place of the Indore process in the scheme of things, and how it bears on agricultural research generally.

Nature's round—the wheel of life—consists of two processes: the process of growth and the process of decay. Both are integral to her activity; both are equally important; neither can be omitted. Man is accustomed, however, to devote most attention to growth because of its obvious usefulness; far less heed is paid to decay.

When in the eighteen-forties Liebig, followed by the Rothamsted experiments, set in motion a train of thought which rapidly led to the stimulation, by means of artificial manures, of Nature's growth activities, the pace at which agriculture could be carried on noticeably quickened. Nothing, however, was done to speed up decay. In the Occident a one-sided development of agriculture resulted, which rapidly developed, in the experimental stations and to a great extent in practice as well, what may briefly be described as the N P K mentality. In the Orient, however, the new ideas have had no influence; at least one thousand million cultivators have never heard of artificial manures. It is a most fortunate circumstance that their agriculture preserves intact the essential balance between growth and decay.

The one-sided development of agriculture which has taken place in the Occident has encouraged a point of view which has had great disadvantages. The increased harvests obtained from artificial manures have caused investigators to focus their attention on the crop immediately in front of them: to strive after still more output; to compare yield with cost; to introduce statistical methods for discovering results not apparent to the eye; to breed and distribute new varieties of crops which can extract the uttermost ounce of produce from the soil; to investigate and, on the plea of interference with output, to prevent from doing their proper work in pointing out the crops which are imperfectly nourished, the insects and fungi which are Nature's faithful censors.

In pursuing their one-sided chase after quantity, the experiment station workers are not only misleading practice, but are unconsciously doing the greatest possible disservice to the true cause of agricultural research. They have failed to insist on the effective return to the soil of the waste products contributed by the plant, by the animal, and by the community. They have speeded up the wheel of life over one-half of its revolution without due thought of the other half. The steering is thus bound to be erratic ; the sense of direction is certain to be lost.

If we speed up growth, we must also accelerate decay. The object of the Indore process is to assist decay and to make the most of all our waste products. But the moment we begin to deal with our wastes in a rational and common-sense way we shall once again balance the wheel of life ; the essential processes which are complementary to an increased tempo in growth will have been initiated. Mother Earth's increase will then take care of itself. There is no need to trouble so greatly about yield. It is surely unnecessary to lumber up still further the world's congested markets with produce which none can buy.

Freed from our preoccupation about quantity, we can devote our attention to the study of quality—the one subject in agricultural research which really matters at the present day. The study of quality ; the determination of the factors which go to produce it or to prevent its development ; the effect of high quality on the diseases of plants, of animals and of mankind, must be investigated. We can then add quality to quantity. Let us consider for one moment our grasslands, the foundation of the agriculture of the island in which we are living.[1] The neglect of this great possession is lamentable. These grasslands are in a most unsatisfactory state ; they are often undrained ; seldom either limed or manured ; they yield feeble crops, indifferent in nutritive power ; they are rarely cultivated or rotated ; the vast stores of valuable organic matter which accumulate on their surface are scarcely ever exploited. With all this before our eyes, we as a nation are spending large sums every year on the study of the diseases of our livestock—such as tuberculosis and foot and mouth disease—in the vain hope that laboratory science will find a remedy for what common-sense should prevent. The microscope and the methods of Pasteur and of his successors can never hope to achieve a permanent and effective cure of such diseases. The cause lies much deeper than anything which is likely to be ascertained in the laboratory. It is in all probability malnutrition following closely in the wake of long-continued mismanagement of the land. We must attack diseases like tuberculosis and foot-and-mouth disease at the source, see that our animals get grass and fodder worth eating, that the breed is kept robust, and that the hygiene is satisfactory. We must develop the splendid work which Professor Stapledon and his band of devoted assistants have done at Aberystwyth, and make our grasslands really efficient. We shall then introduce real quality into our milk, into our milk products, into our meat, and so lay one of the foundations of a sound system of preventive medicine.

We must at the same time take up quality in vegetables (and incidentally learn all Mr. Secrett has to teach us), in fruit, in cereals and so forth. As this work

(1) Stapledon, R. G., *The Land, Now and To-morrow*. Faber and Faber, 1935, price 15s.

yields results, and when a government and a financial system arise in this country with the wit to deal with abundance and the courage to insist on the effective distribution of the products of the soil of our island to its people, we shall soon spend far less on diseases because disease will disappear. Then we shall be one step nearer to the goal which Science should set for herself—the making of this earth ready to receive her children.

DISCUSSION

The Chairman, Professor Henry E. Armstrong, LL.D., D.Sc., Ph.D., F.R.S., in introducing the lecturer, said : Beyond question, we are at the beginning of a new and rational epoch in agriculture ; we have too long wandered in the unimaginative wilderness of mineral (inorganic) fertilisers. John Bennet Lawes the Great, in his tilt with Liebig in 1843, began in a measure to put Nature aside, when he used ammonia or nitrate as his source of nitrogen in showing that cereals must have extra nitrogen to secure an economic crop. He was logically forced to use these salts, because they contributed nothing else but nitrogen, and so enabled him to obtain unequivocal results. Liebig had shown that the mineral elements in the ashes of a plant must be in the soil or added to it to maintain fertility. Lawes, making experiments with bones and finding that they were of manurial value, became a manufacturer of superphosphate. So it came about that his chief interest lay in the use of mineral salts. He was fully alive to the value of farmyard manure ; but, unfortunately, cereals happen for some strange reason to do without added organic matter ; nothing stimulates them except added nitrogen. So Lawes paid no special attention to organic manure.

Again, the celebrated Rothamsted experiments on Broadbalk field caught the fancy of the farming world. They were so telling, so systematic, so spectacular, that a fashion was set of using ammonia salt especially, and of paying almost exclusive attention to grain crops. In recent years, research workers have been further misled by a devastating outbreak of statistical mania : the plant has been put aside in the worship of figures which are of no consequence to a growing entity. Only the Chinese and the less civilised peoples have kept their heads and left both artificial fertilisers and figures alone. They have worked for edible food, but the idea of agricultural products being used as food scarcely entered into the mind of the academic research worker. Quality in food, whether for plant, farm-animal or man, was little taken into consideration.

At long last, however, but only perhaps during the past twenty years, quality has been brought to the fore. We now begin to see that our chief care must be to produce quality, little as we can as yet define what quality is. To produce quality, we are going back to the neglected experience of ages—probably to use all fertilisers in conjunction with organic matter, in forms akin to farmyard manure, now an ever dwindling asset. Our land is in revolt. Deprived of manurial rights by the invasion of the road hog, it is fast losing fertility, to an extent which even the few probably do not yet realise.

Sir Albert Howard has already won his spurs in India as a champion of fertility against figures. He came forward here two years ago and described his method of using organic waste ; to-night he is to tell you of further applications that have been made of this method.

I will now call on him to sound the loud trumpet of humus manure.

Mr. G. H. Masefield said: I think that agriculture in the East, and, indeed, agriculture in general, owes Sir Albert Howard a great debt of gratitude for his development of the Indore process. We have started to adopt his methods in Travancore State, and in one small company in which I am interested we hope to produce this year—the first year that we have really got started—2,800 tons of composting material, which probably would have been wasted had it not been for Sir Albert. That is a valuable contribution in itself, but far beyond that, I think we have every reason to expect that the outcome of this Indore method will be to increase quality in tea; possibly it will be of value to rubber, and to all the other agricultural products in which we, as a nation, are so largely interested it should prove of the highest benefit. The process is being developed very slowly in Ceylon, but undoubtedly it is one that has come to stay and that will continue in an increasing ratio, with the greatest possible advantage to all agriculturists in the East. Loss of humus is the most serious problem we have to deal with on the majority of Eastern estates, and this simple method of restoring soil fertility cannot but prove of inestimable value.

Sir Alfred Chatterton, C.I.E., said: I have no practical experience of agriculture and I can only speak from an economic point of view of the results that are likely to be achieved by Sir Albert Howard's work. During the whole of the time I was in India I was very much interested in the economic problems arising out of the agricultural situation there. The most important of these was the fact that the population of India at the present time is increasing so rapidly that new means must be found for increasing the fertility of the soil. In India the area of land required to support an inhabitant is about one acre, whilst in China and Japan they manage to do it on about one-fifth of an acre. We have over 300,000,000 people in India now, many of whom are not too well fed. If we were cultivating our soil in the way the Japanese and Chinese are doing, we should have room for about 1,500,000,000 people at the same standard of living as now prevails in these countries. It is not a very high standard, and it is not, of course, a very desirable thing that we should provide means for increasing the population in that extraordinary way without at the same time raising the standard of living.

In Japan, besides converting practically all their organic waste materials into humus, they import very large quantities of mineral and artificial fertilizers, but in China the quantity of imported fertilizers is very much smaller. In India, during the last few years, there has been some development in the same direction, especially in the South, but owing to the fall in the value of produce the quantities imported have fallen off very much.

One of the most important problems which has arisen in India at the present time is due to the development of sugar-cane cultivation. Within the last three or four years something like ten million pounds sterling has been expended on putting down milling plant, and owing to the results of the cane-breeding work done out there, the quantity of cane grown is very rapidly increasing. Such a crop requires a very large quantity of manure, and as an example of the sort of efforts that are being made to deal with the situation, I have heard that in Mysore State they are contemplating the establishment of a factory to supply special manures for the new areas of cane which are being cultivated with irrigation from the Kannambadi reservoir on the Cauvery River. It seems to me, after listening to Sir Albert's paper, that they will probably do very much better to introduce his methods of making humus, and, as far as possible, make the cultivation of the sugar-cane self-supporting. Some move in this direction has been made on the advice of Dr. Fowler in respect to the utilisation of the night soil and town waste of Mysore City.

One of the questions in India that we have always been rather interested in, and about which there has been much discussion in the past, is whether the fertility of the soil has increased or decreased within the period during which the British have had dominion over the country. The general idea, I think, has been arrived at that conditions in India are to a large extent static, that is to say, year by year the soil yields what nature and the comparatively simple means of cultivators can supply to it. My own opinion is that, owing to economic changes in the country, the fertility of the soil has been slightly decreasing for the last thirty or forty years. Formerly larger quantities of oil-seeds were grown for internal consumption than now, and with the large export of oil-seeds the quantity of oil-cake which is available is probably, in proportion to the population, considerably less than it was. This is almost entirely due to the introduction of kerosene oil for lighting purposes.

In the sugar industry the recent changes which have taken place have introduced power for crushing instead of cattle. We have heard this evening that you can get a crop of about 30 tons to the acre with the use of humus. That crop, when it comes to be crushed, has hitherto been crushed by cattle, and it takes a pair of cattle about three weeks to do the job. Many hundreds of thousands of tons of cane are being crushed by machinery to-day, and the demand for cattle power is considerably less, with the result that there will probably be a big decrease in the number of cattle in those areas where sugar-cane cultivation is largely growing. These changes may affect to some extent the supplies of manure which are available in the country.

No reference has been made to the fact that India uses almost the greatest portion of its most valuable manure in a way which does not contribute to the fertility of the soil at all. As in England 700 or 800 years ago, so it is in India to-day: they dry nearly all their cattle manure on the walls of the villages or on the ground round their cattle sheds and convert it into fuel. If we could only find some substitute for these cow-dung cakes which are manufactured to the extent of millions of tons, it would greatly facilitate the improvement of agriculture; and if this cattle manure could be used by the methods which Sir Albert Howard has introduced, the benefit would be very much greater still.

I am sure I shall be voicing your opinion in saying how much we appreciate this extremely valuable lecture, and there is no doubt whatever that Professor Armstrong made no exaggerated statement when he said that we were listening this evening to the story of an epochal development in the history of tropical agriculture.

Mr. F. A. Secrett, F.L.S., said: I have been wondering how an audience of, say, thirty-five years ago, would have reacted to the lecture we have heard to-night. I am speaking as a farmer, and can look back over a period of thirty-five years to the time when all the humus we required was given to us, and we were often paid to take it away. In all the vegetable growing districts of England, which were situated chiefly outside the towns, we were growing vegetables on land which had been manured every year for generations with anything from 40 tons to 80 tons of horse manure to the acre. With the coming of the motor car this horse manure was difficult to obtain, and a change came over the industry. Science stepped into the breach and taught us that we could do with inorganic manures what we had been doing in the past with organic animal manure. To a very large extent the industry was successful, and successful for this reason: that there is such a thing as accumulated fertility; and for a number of years those growers who were using artificials were expending the accumulated fertility which had been put into the soil by their forefathers. With urban development that land has now all been covered with houses, and to-day vegetable growers are being forced further and further out into the country. The land that we are using to-day for vegetable growing has no accumulated fertility, and we have to rely upon what manure and inorganics we can obtain. Now, how has that affected the industry ? I believe that quality has suffered ; in fact, I am sure it has suffered. I notice that in Covent Garden and in the larger provincial markets those stands are favoured where the produce has come from farms which have received organic animal manure. Although higher prices are charged for this produce, it is sold out first. Our difficulty to-day is to obtain the humus which we know is necessary. We cannot keep on expending our soils without replacement, and I feel that Sir Albert Howard's method may be the solution to our difficulties.

A few years ago I bought some land in Cornwall. I had often wondered why the Cornish people had never exploited their county more. They have a wonderful climate, with a high soil temperature in winter time, and there seemed to be no reason why a considerable amount of vegetable produce should not come from there. After farming in Cornwall now for four years I have come to the conclusion that it is entirely a question of humus content in the soil. We are not able to do the work because we cannot obtain the humus. I felt when I came into contact with Sir Albert—he has spent many days on my farms and I have received much useful instruction from him—that by his process we could solve the difficulty we were experiencing in Cornwall. I therefore approached the County Council to know whether they would call a conference of all the local growers and farmers to see if they would be prepared to use this humus if it were produced. There are many waste products in Cornwall, and I hope that this county will show England how the process can be used for the benefit of English agriculture.

I am convinced that the only way in which quality can be obtained in vegetables is by the use of organic animal manures.

Mr. John Harrison said : I was rather amazed to hear Sir Albert state that it was as cheap to gather and cut green manure and make it into compost as it was to plough it in as a green-manure. We in England have long practised green-manuring in one form or another, and I can hardly visualise that it is possible to gather green-manure, carry it off to be put through a process and return it in the form of a compost, and be economic.

The Lecturer replied that the answer to the last speaker was really contained in the section of the lecture dealing with British agriculture which he did not have time to read. In that section he had dealt with the point raised, and had suggested a new method of green-manuring for this country.

Dr. H. J. Page said : I should like to add my congratulations to those of the other speakers for Sir Albert Howard's interesting talk, and for the advance which the introduction of his process has made possible. At the same time, I should like, if I may, to enter a protest against the tendency I have detected in some of the remarks of the speakers in referring to artificial fertilisers and organic manures as two things which are mutually exclusive and entirely apart. We all realise that an adequate supply of organic matter is necessary to the soil. On farms, such as those of Mr. Secrett, where they can afford to use such high dressings of organic matter, they can manage to use only organic materials, but the general run of agriculturists who farm on a much lower plane have got to be content with smaller quantities of organic matter, and then, to get the best crops, a supply of plant food in the form of fertilisers is essential. I am in agreement that everything practicable should be done to increase the supply of organic matter to the soil, but

I think all of us realise that artificial fertilisers, if they are used with an adequate supply of organic matter, are not to be regarded as harmful, but as having a very definite place in farming.

Captain W. H. Cadman said : There are just two points I wish to raise. The first is that some twenty-five years ago I remember visiting the Experimental Station at Rothamsted during the time of Sir Daniel Hall, and there I saw experiments being carried out on very similar lines for the conversion of waste material into compost as a substitute for cattle manure. Arising from that I believe a process has been evolved called the "Adco." I should like to ask the lecturer whether that process differs from the Indore Process ?

The Lecturer replied : Yes, it differs a great deal. When I was in India I tried the Adco process, and found it did not work so well as the Indore method. With Adco it is difficult to maintain the high temperature required, and to coax the necessary moisture into the vegetable wastes. These difficulties in working are got over by the Indore process. The main reason, however, why the Adco process, in my opinion, is bound to fail, is this : that it suffers from similar disadvantages to those which are associated with the use of chemical manures. I am convinced from a long practical experience in farming, that no permanent or effective system of agriculture will ever be devised without the use of the waste products of the animal. It is necessary to complete, as it were, the circle of symbiosis in the scheme of things. I received an interesting confirmation of this view the other day. One of the most experienced land agents in England told me that he always found that both the farmers and the smallholders who kept animals were never behind in their rent ! Those who used artificial manures were often in arrear. This was the opinion of a man of forty years' experience of agriculture in this country.

Captain Cadman, continuing, said : With regard to another factor in connection with soil fertility, the Chairman very rightly pointed out the danger of using too much artificial manure. That is largely tied up with the effect of "Hydrogen Ion Concentration," or soil acidity, upon plant growth. It used to be taught that there is a danger in the continuous use of farmyard manure and nothing else, because in the course of time you would get such an acid condition of the soil that unless it was followed by an adequate dressing of lime to neutralise the acidity, the soil fertility would be reduced. Could the lecturer inform us whether there may not be a danger in using repeatedly, year after year, this humus compost as the only manure ?

Before I sit down, I wish to congratulate Sir Albert Howard on his successful process for the manufacture of humus, and for the delightful way in which he has described it to us to-night. I have had a good deal of experience in the East, and I am quite sure that the one thing needed more than anything else for the improvement of crops generally is the utilisation of more and more organic material, such as he has described to us to-night. I venture to say that the same thing is equally applicable at the present time to agricultural conditions in many other countries and particularly in this country where so little farmyard manure is now available.

Mr. H. J. Heywood-Smith said : I wish to thank Sir Albert Howard for his exposition of the subject of organic manuring. I wonder if he is aware of the biological-dynamic process originated by Rudolf Steiner ? During the summer I had the pleasure of visiting a number of very large farms on the Continent which were being run on those methods. The process is based on the special preparation of compost and manure, and on farms of over 1,000 acres I saw enormous quantities of compost lying on the fields being prepared. No artificial manures are used. There are also farms in Holland which are being most satisfactorily run on the same principles, and it has been observed that on these farms the animals are practically immune from tuberculosis and foot-and-mouth disease. The quality of the products is very high, so much so that they are in great demand, especially by hospitals and schools.

The Lecturer, replying to the discussion said: With regard to Sir Alfred Chatterton's remarks about the use of cow dung in India for fuel purposes, that matter was dealt with in the early stages of the Indore investigations. Three-quarters of the cow dung of India can be used as fuel, as the other quarter is quite sufficient to transform all the vegetable wastes. If we add too much cow dung to the mixture to begin with, we are apt to lose nitrogen, but if the mixture is rather poor in nitrogen to begin with, we get a greater amount of nitrogen finally through fixation. It is always better to spread the available cow dung over the largest possible amount of vegetable waste and so get the maximum fixation of nitrogen from the air.

With regard to the question of cattle power and the reduction in the number of animals now used in crushing sugar, I agree that in the old days when the crop was small, cattle were employed for crushing. But when the Java method was introduced, production of cane was increased to such an extent in Rohilkhand that it was impossible to deal with the crop by the old methods. Engines, therefore, had to be brought in; but this is no disadvantage, because we get more cane trash, which the Agriculture Department of the United Provinces has shown the people how to convert into humus.

With reference to Mr. Secrett's remarks about Cornwall, I think it would be an exceedingly good county in which the utilisation of waste products could be taken up. I trust, therefore, the County Council will adopt Mr. Secrett's proposals.

With regard to Dr. Page's suggestion about artificials and organic matter, I think that in the future any artificials which are necessary will be added to the vegetable wastes before their conversion into humus, when these substances will do double duty. They will help the fungi and bacteria in their work, and will add to the value of the final product. With regard to Captain Cadman's remarks as to what is going to happen when large quantities of humus accumulate in the soil, I do not think that will ever arise. Humus is constantly being lost through oxidation, so that a dangerous soil condition is most unlikely. There will always be more land than humus.

I am in touch with the Rudolf Steiner movement, and have seen the work that is being done on those lines in this country. Steiner believed that artificials were harmful to the plant and to the health of the consumer, and that we ought to obtain our crops in a natural way. If we could get figures from the anthroposophical centres abroad, where they produce high quality vegetables and food, and if we knew the incidence of disease in the population which consumes those vegetables, we should have definite information to bring before our legislators in England. I tried to get this information in England, but the experiments in this country have not gone far enough. I hope soon to visit some of the centres in Holland, Germany and Switzerland where this work is in progress.

Sir Daniel Hall, K.C.B., F.R.S., in proposing a vote of thanks, said: I have been particularly interested in the question that Sir Albert has brought before us to-day, because I am at present delivering a course of lectures on the improvement of native agriculture, in Africa in particular. There a system of shifting cultivation prevails. A patch of bush or jungle is cleared by a tribe, and cropped for two or three years, and then the tribe moves on somewhere else. That means, of course, that something like three to ten times as much land as is in actual cultivation is required by the tribe to maintain the system. With the growth of population that cannot prevail, and I have pointed out in these lectures that you have to establish amongst these primitive tribes a system of fixed cultivation which will maintain the fertility of the soil when the same piece of land is cropped continuously, as is done in Europe, and has been done in China and India for many, many centuries. It is the adoption of Sir Albert's composting method that will give the African native cultivator an opportunity of maintaining the fertility of his land and of increasing his output and obtaining a better standard of living than he now enjoys. I need not enlarge upon that point, but I do regard this particular method, and the experiments that have already been made to adapt it to the conditions prevailing among the African tribes, as the only means of rescuing that great native population from impending disaster.

As to the particular points that have been raised this evening, I join with Dr. Page, and although perhaps I may be obsolescent and possess an NPK mentality, I still maintain that in this country of ours, in Western Europe, we are going to be still more greatly dependent upon artificial fertilisers; and for this reason largely. We have in an imperfect way utilized the fundamental scientific basis of Sir Albert Howard's process for a very long time. Our old agriculture, before there were artificial fertilisers, was built up on two processes, the fixation of nitrogen from the air by means of a leguminous crop, and the restoration of humus back to the soil by means of farmyard manure.

This brought about a certain level of fertility, measured by an average yield of about 20 bushels of wheat to the acre. The advent of artificial fertilisers raised that level to something more than 30 bushels. We need an even higher level, but with our climate and our labour conditions we cannot count on reaching that higher level by the natural processes of nitrogen fixation alone. It will be cheaper to supplement these natural processes by the introduction of extraneous sources of fertility.

I think, too, that Sir Albert and one of the other speakers this evening are a little too sanguine in expecting to abolish tuberculosis and foot-and-mouth disease by a different system of growing fodder. The millenium is not so nearly round the corner as that.

The Chairman, in seconding the vote of thanks, said: I am sorry my old friend Sir Daniel is so pessimistic. Our proceedings to-night, all will admit, I think, are an important contribution to the great subject of food conservation, which must eventually include that of the recovery of salts from sewage. The subject is for the immediate future, and must be insistently brought before the Government. To this end, the Ministries of Agriculture and Health should be reorganised as scientific departments. Hitherto they have mainly served political ends and to check enterprise; they have been without imagination.

That malnutrition is at the root of most disease is more than probable. The production of foods of high quality, therefore, is a matter of prime importance to the community. Agriculture and horticulture become lifted above all other interests—we must have food, whatever our work; the better our food, the better will be our work.

To secure such an end, education must be improved in every direction. The schools of agriculture, in particular, are hopelessly inefficient. The universities are giving no adequate training for any branch of scientific work. Most inadequate of all is that given to prospective medical men. As to agricultural research, I would "scrap the lot" and begin afresh, with a set of new workers prepared to pay some attention to life and growth. Only men highly schooled in chemistry and physiology are fit for this task. The miserably small output of competent workers from the schools is the clearest proof of their inefficiency. We cannot be the fools we seem to be. Somehow, by some means, we must develop our intelligence and make our knowledge tell more rapidly, on our own behalf. We are squandering our resources with reckless wantonness. "Waste not want not" is to-day a non-existent proverb. If we do not act upon it soon, our civilisation is doomed. We cannot well continue at the present thoughtless rate, mainly in pursuit of the trivial.

The vote of thanks having been put to the meeting and carried unanimously, the proceedings terminated.

Below are given some additional notes by the Chairman :—

Humus.—At present we know nothing of humus, beyond that it is good food for plants—the best they can have. This is the experience of ages. Leguminous plants cannot do without it, for they become "sick" in its absence. Unfortunately, this fact has long been treated with considered disregard by academic workers, who are obsessed by the worship of mineral fertilisers and bacteria. As to its nature, the question is, whether it be not largely a vital product, not a mere organic residue. The tendency in farmyard manure towards an average nitrogen ratio is an indication that the finished product largely consists of decayed organisms. To what extent the ærobic and the anærobic forms differ, we have yet to learn. Probably the great value of humus manures lies in the fact that nitrogen (and other components) are let loose gradually. Ammonia salts act "brutally," too suddenly and intensively.

Salts.—Wood ashes are used in the Indore process, as a source of potash. Is a supply of these assured ? The need of keeping all mineral salts at a properly balanced level probably cannot be overlooked. Nor should the value of lime as frequent surface dressing be forgotten.

Green-manure.—Except in special cases, such as the cultivation of rice in mud, the direct use of green-manure as such, or of raw straw, is probably to be deprecated as wasted effort. It rots at the expense of the soil and provides an excitant at the wrong time, leaving the prematurely developed plant with insufficient soil food at its disposal. The growth of a leguminous plant upon the compost heap, thereby adding to the supply of nitrogen, is ingenious and should be most valuable in practice. The water hyacinth has been found to be valuable material in composting. To what extent does this furnish phosphate, potash and even iodine ? It is important to know to what extent these are extracted from water and assimilated during the growth of the weed. The cultivation of rushes and seaweeds in estuaries may well prove to be of importance in making compost. Enclosures for the purpose might easily be made. The only feasible way at present foreshadowed of recovering phosphate and potash from sewage—a task we must soon undertake—is to impound it in ponds in which water-weed can be grown. The study of water-weeds from this point of view is a most urgent need.

Quality.—The effect of humus manure on quality, particularly in tea and coffee, is to be watched with especial interest. It should encourage growth. It may well discourage the formation of tannin in the tea plant, and in this particular improve it. Whether flavour will be developed is more open to doubt, as this probably is a consequence of encouraged maturity of growth. Quality in coffee is probably a more complex issue, as this is in part due to roasting. Wherever succulence and rapidity of growth are desired, it is beyond question that humus manure has an altogether especial value, serving as it does as a continuous source of nutriment apart from any physical effect.

APPENDIX I

(*Reprinted from the* Journal of the Royal Society of Arts, *Dec. 18th,* 1936.)

Rapid developments have followed the publication, in the issue of this *Journal* of November 22nd, 1935, of a lecture on the above subject. A German version appeared in *Der Tropenpflanzer* of February, 1936. A Spanish translation is in preparation.* The object of this note is to record some of the more important results and lines of work of the last twelve months.

Results obtained Overseas

Plantation Industries.—In tea, many of the Agencies have definitely adopted the Indore process and a large number of estates are in full humus production. The cost of manufacture per ton has steadily fallen and varies from Rs.1 in the most favoured areas, as regards ample supplies of raw material, to Rs.2·25 in distinctly unfavourable localities, such as the highlands of Ceylon. Some of the estates are giving up the purchase of artificials and are raising their tea crop on humus only : applications of this material have been followed in a number of cases in Assam by a marked increase in resistance to insect pests.

In South India, the adoption of the Indore process on the estates of the High Range of Travancore has been accompanied by developments in the villages of British India, where the cultivators are following the lead set by the plantations.

In Malaya, the effect of humus on the rubber tree has been very similar to that obtained in tea and coffee. The growth of the trees has improved : a marked increase in disease resistance has been observed, even on newly replanted areas where the first plantings were destroyed by root disease.

Water Hyacinth.—A satisfactory technique for converting the vast supplies of water hyacinth in the delta of the Ganges into humus for the benefit of the rice and jute crops of Bengal has been worked out at Barrackpore by Mr. E. F. Watson, O.B.E., Superintendent of the Governor's Estates, Bengal. An account of this work appeared in the issue of *The Commercial and Technical Journal*, Calcutta, of July, 1936.

Results in Great Britain

Practical experience has shown that the three objections to the adoption of the Indore process in British agriculture, which have been advanced by writers on agricultural topics in this country, are unfounded. These objections were : (i) the high cost of labour, (ii) the general absence of waste products on the farms and (iii) the danger of spreading insect and fungous diseases.

A wide variety of wastes, including bracken, water-weeds and seaweed, has been composted successfully at a number of centres in Lincolnshire, Norfolk, Suffolk,

* This appeared in the issue of the *Revista del Instituto de Defensa del Cafe de Costa Rica* of March, 1937.

Kent, Hampshire, Surrey, Sussex, Middlesex and Staffordshire during the last year, the output in some cases exceeding 2,000 tons. The cost of conversion is less than was anticipated and is steadily falling: exact figures will be available about the end of 1937. It may be possible to reduce the cost very materially by suitable mechanisation. The volume of waste materials has turned out to be much greater than was expected. No cases of insect or fungous disease have followed the application of humus.

A New Method of Green-manuring.—One of the problems in this country is to use the humus, when made, to the best advantage. A considerable portion has been employed in a new method of green-manuring, which promises to be of great value to the farmers of this country. As is well known, green-manuring, as ordinarily practised, has not proved a success for the reasons set out in *The Waste Products of Agriculture*, Oxford University Press, 1931. Failure, however, can be turned into success provided: (1) the green-manure crop is itself manured with compost or farmyard manure just before ploughing in and (2) ample time is allowed for decay before the next crop is sown, or, in the case of permanent crops like fruit and hops, before the next crop comes into leaf.

In the case of catch crops, such as beans, vetches or mustard, the procedure followed is either sheet composting (i.e., composting in a thin layer on the surface) immediately after the catch crop is sown, or the direct manuring of the green crop itself with compost or farmyard manure just before it is ploughed under. A brief description of sheet composting a catch crop of beans in South Lincolnshire will serve to explain the system. After the pea crop is harvested in July for canning, the land is at once sown with beans, covered with a thin layer of the crushed pea haulm from the shelling machines, followed by a thin layer of compost or farmyard manure at the rate of 5 to 7 tons per acre. *The Indore process then starts on the surface of the soil.* The beans grow through the fermenting layer and by the end of September are in full flower when they are ploughed in with the layer of finished humus. Decay is rapid and by the following April the land is in excellent shape for the potato crop.

In the case of permanent crops like fruit and hops, the weeds, which grow after cultivation ceases in the summer, are regarded as a green-manure crop and are manured with compost before ploughing in in the early autumn. By the time the fruit and hops come into leaf in the spring, the weeds are converted into humus without any interference with growth.

The chief opening for this method of green-manuring is, however, in the green-manuring of grassland—permanent grass or leys—by means of the old grass turf itself. Here the wastes are available in vast quantities at site, free of all cost of collection and distribution. The old grass should be closely grazed during September and at the end of the month manured either with compost, farmyard manure or by the concentration of a large head of stock on the area to be ploughed. Ploughing should be done about the end of September before the soil gets too cold and the land should be managed as if oats were to be sown in the spring. A suitable

grass mixture, containing about 2 to 3 lb. to the acre of hardy green turnip seed, should be sown in the spring. The young grass should be grazed with sheep to begin with to consolidate the surface and then treated as an ordinary pasture or used for the production of dried grass of the highest quality. Several trials of green-manuring some of the best of our dairy and fattening pastures on the above lines are in progress. The method has already proved successful on one of the best farms in New Zealand.

Vegetables and Flowers.—The application of the Indore process to the production of high-quality vegetables at the Iceni Nurseries, Surfleet, near Spalding, by Captain R. G. M. Wilson a year ago is turning out a product in the open up to the standard reached at the Institute of Plant Industry at Indore. The present annual output is in the neighbourhood of 1,000 tons; the all-in cost per ton is about 6s. Artificials and spraying machines are no longer employed.

Humus and Earthworms.—Observations have been started in Lincolnshire on the effect of humus in re-attracting the earthworm population to lands previously receiving large annual applications of artificial manure; on these lands the earthworm population had retreated. Examination of the tunnels of these worms shows that the worm casts attract the roots of the potato crop in a remarkable way; it seems probable that these casts contribute something of value to the crop. The place of the earthworm in agriculture is a subject ripe for investigation from the standpoint of soil fertility.

Town Refuse.—For the land surrounding urban areas, immense supplies of raw material for conversion into humus are at present almost entirely wasted. In a few localities only, such as Southwark in South-East London, is this material sorted—to remove tin cans, bottles and other refractory materials—before being broken up in a disintegrator for use in agriculture. The whole of the crushed refuse prepared by the Southwark Borough Council now finds its way to the land either as a manure used directly or as one of the constituents of a compost heap. The widespread utilisation of town refuse, by helping to provide high-quality vegetables at a reasonable cost, would do much to improve the nutrition and health of the urban population.

ALBERT HOWARD.

APPENDIX II

THE MANUFACTURE OF HUMUS FROM THE WASTE PRODUCTS OF TEA ESTATES

The advantage of a continuous supply of leaf mould (humus) for the tea plant needs no argument. It is well known to every tea planter.

The object of this memorandum (which has been drawn up at the request of Mr. James Insch, Messrs. Walter Duncan & Co.) is to show how to manufacture humus from the waste products of any tea estate in India. The method which must be adopted is a composting process—known as the Indore method. It was perfected at the Institute of Plant Industry, Indore, between the years 1924 and 1931 and is described by Messrs. Howard and Wad in *The Waste Products of Agriculture: Their Utilisation as Humus*, published in 1931 by the Oxford University Press, Bombay. The Indore method has been taken up at many centres all over the world, including practically all the coffee estates in Kenya. It has proved to be a thoroughly practicable method and elastic enough for a wide range of conditions.

The Humus Factory

A suitable area, conveniently situated for supervision, must first be selected for making humus. The humus factory itself is a very simple affair. At Indore it consists of thirty-three pits, each 30 ft. by 14 ft. and 2 ft deep with sloping sides, arranged in three rows with sufficient space between the lines of pits for the easy passage of loaded carts. The pits themselves are in pairs, with a space 12 ft. wide between each pair. This arrangement enables carts to be brought up to any particular pit. Ample access from the humus factory to the main roads of the estate is also necessary, so that during the carting of the humus to the fields, loaded and empty carts can easily pass one another, and also leave room for the standing carts which are being filled.

It is often a great advantage to have water laid on, so that the periodical moistening of the compost can be done by means of a hose pipe. At Indore water is pumped through a 3 in. pipe into a pressed steel tank, 8 ft. by 8 ft. by 8 ft., holding 3,200 gallons, which is carried on walls, 4ft. above the ground, to provide the necessary head. This supply lasts about a week. Water is led by 1·5 in. pipes from the tank to eight taps, to which the armoured hose (fitted with a suitable nozzle) can be screwed. Each tap serves about six pits. The general arrangement will be clear from Figs. 1 and 2.*

* The illustrations to this memorandum are reproduced by the courtesy of the Oxford University Press, from *The Waste Products of Agriculture*, by Albert Howard and Y. D. Wad.

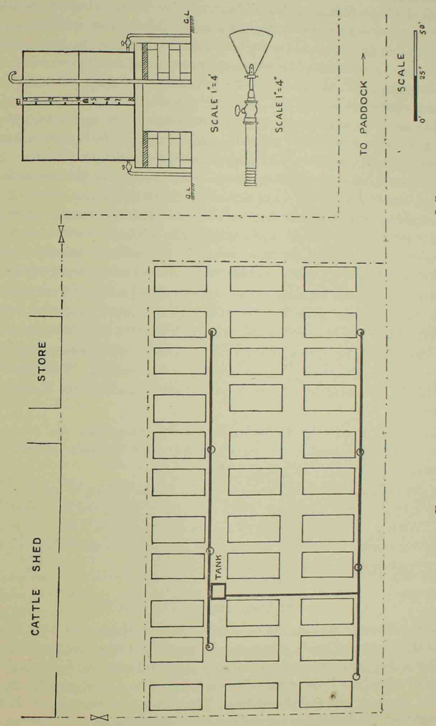


Fig. 1. Plan of Compost Factory at Indore.

The Collection and Storage of Waste Products

The materials needed for the manufacture of humus are the following :—

1. *Mixed plant residues.* All available vegetable matter of every description from the tea estates—such as weeds, green-manure, fallen leaves, the light prunings of tea bushes and shade trees, trimmings from the road sides and hedges, paddy and other straw and chaff, damaged tea leaves, tea waste, wood shavings, sawdust, waste paper, old gunny bags and so forth—must be carefully collected and stacked. All hard woody materials—such as the lighter tea and shade tree prunings and pigeon pea stalks—are first crushed (by placing on the estate roads) and reduced by the traffic to a condition resembling broken up paddy straw. *All fresh green materials—such as weeds and green-manure—must be withered before stacking.* To ensure proper mixing all these dried plant residues must be stacked alongside the humus factory as received, layer by layer—under cover during the rains—so that these materials may be thoroughly mixed. To ensure even mixture, the stacked material is removed to the pits from one end of the stack. The mixing and withering of these plant residues is important for two reasons : to ensure a suitable chemical composition and to prevent undue packing (which cuts off the air supply) in the pits.

2. *Cattle, buffalo and horse dung* (including all soiled bedding from under the animals). This material as well as the droppings of poultry should be collected every morning and broken up into small pieces as it is added to the compost pits.

3. *Urine earth.* The earth under the cattle, buffaloes and horses should be dug out and renewed to a depth of 6 in. every three or four months. This urine earth should then be powdered in a mortar mill and stored under cover alongside the humus factory.

4. *Ashes.* All wood ashes from the tea factory, bungalows, and coolie lines should be carefully collected and stored under cover alongside the powdered urine earth.

5. *Water and air.* Water and air are essential for the making of humus and for the fixation of atmospheric nitrogen which takes place during the latter part of the process. Water is most easily applied by an armoured hose pipe with a nozzle which breaks up the stream. An ample supply of air is ensured by the proper mixing of the plant residues and by the use of shallow pits, 2 ft. deep.

Charging and Watering the Compost Pits

Charging. The pits are charged as follows. A layer, about 3 in. deep, of mixed plant residues is spread lightly and evenly by means of a rake over the floor of the pit. This is then well sprinkled with the dry powdered urine earth to which a few handfuls of ashes have been added. This is followed by a layer, about 2 in. deep, of broken up dung and soiled bedding. The contents of the pit are then well moistened with the hose, care being taken not to flood the pit or to use too much water. The charging process is then continued until the pit is filled to a depth of 30 in. in all, each layer of dung being watered with the hose as before. Care must

be taken to finish off each pit with a layer of dung and soiled bedding, followed by a good sprinkling of urine earth, ashes and water. The charge must be again watered in the evening and the watering must be repeated the following morning. By applying the first watering in three stages time is given to the mixture to absorb sufficient moisture to start the intense fermentation which rapidly establishes itself. In the charging process it is important to arrange the materials lightly and to avoid consolidation by excessive trampling, which is certain to cut off the air supply. The level of the contents of the pit, when first charged, is higher than ground level, but rapid shrinkage sets in during the composting process.

The best way of adding the powdered urine earth and ashes and also the amount which will give the best results is a matter of experience. These materials are needed to feed the fungi and bacteria and also to check excessive acidity. There must therefore be sufficient for these purposes. On the other hand, too much powdered earth and ashes tends to consolidate the heap and to cut off the air supply.

Watering. The subsequent waterings are most important. The heaps should be watered once a week and at the time of the first, second and third turn.

Correct watering is a matter of experience. If too little water is added, the fermentation will stop. If watering is too heavy, the air supply will be interfered with and valuable time will be lost. An important consideration in watering is the absorption capacity of the mixture. At the beginning the plant residues absorb water slowly, so that small doses separated by intervals of twelve hours are necessary. As the fermentation progresses, water is absorbed much more readily. The aim should be to maintain the heaps moist and mellow (rather than wet) and the temperature high.

Turning the Compost

To ensure uniform mixture and decay and to provide the necessary amount of water and air it is necessary to turn the material three times.

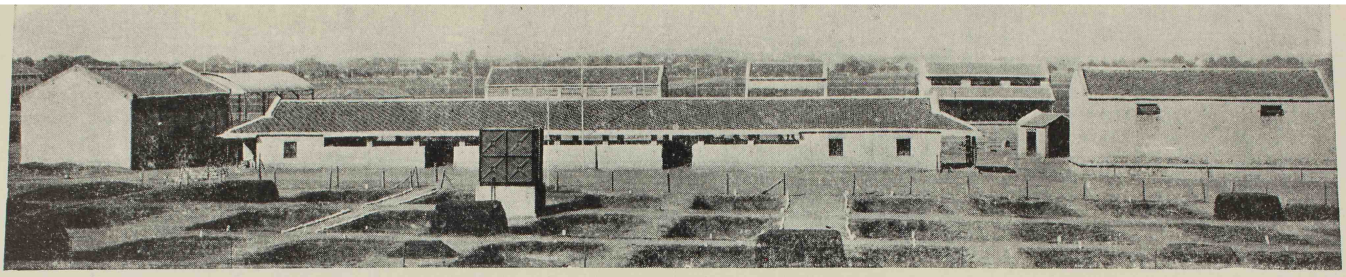
First turn. When the pit is from ten to fourteen days old it should be turned. Half the pit is dug out with a fork, the contents are moistened and doubled length-wise over the undisturbed half (Fig. 3). The half-turned heap is then watered, care being taken to apply sufficient water and to arrange the materials on the windward side of the pit to prevent cooling and excessive drying.

Second turn. Fourteen days after the first turn, i.e., one month after charging, the material is again turned, watered and piled up loosely along the empty half of the pit (Fig. 3).

Third turn. When the pits are two months old, the dark crumbling material is removed from the pits, moistened and stacked in rectangular heaps—10 ft. broad at the base, 9 ft. wide at the top and 3·5 ft. high—to ripen for a month when it is ready for the fields.

Humus Manufacture During the Rains

As the pits are full of water during the greater part of the rains, the humus must be made in heaps on the surface between the pits during the heavy monsoon period.



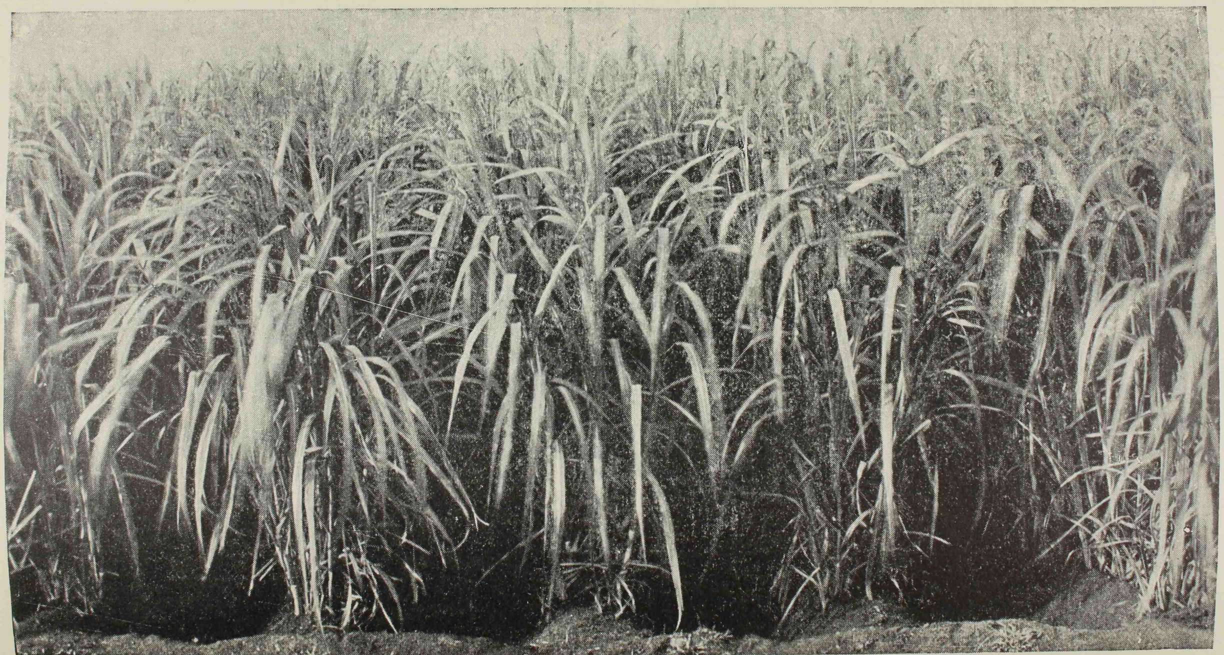


FIG. 2. (1) GENERAL VIEW OF THE COMPOST FACTORY AT INDORE. (2) THE EFFECT OF COMPOST ON SUGAR-CANE.

A

B

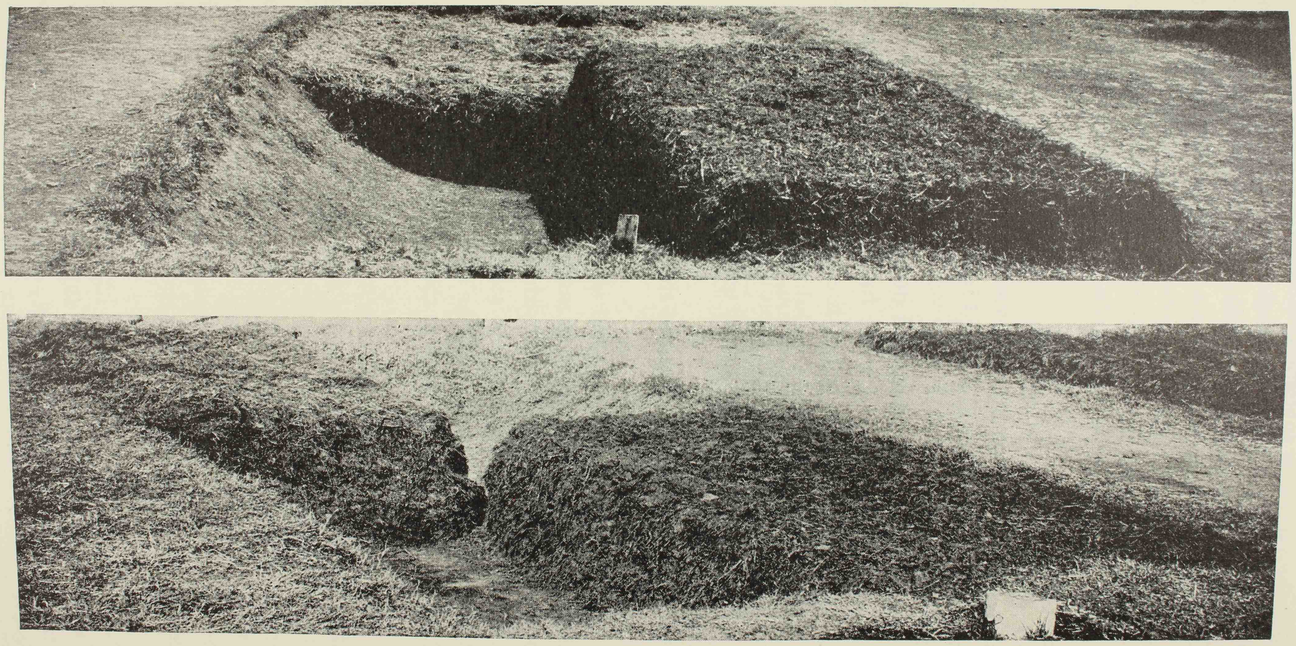


FIG. 3. TURNING THE COMPOST. (A) FIRST TURN. (B) SECOND TURN

On estates where the rainfall is moderate, the dimensions of the heap should be 8 ft. by 8 ft. at the bottom and 7 ft. by 7 ft. at the top and 2 ft. in height. Where the monsoon is very heavy, composting should either be carried out under cover or, where this is impossible, the manufacture may have to be suspended during the period of very high rainfall—June to September.

During the early rains, all material in the pits must be transferred to heaps on the surface. This is most conveniently done at the time of the first, second or third turn.

Some Simple Means of Testing the Efficiency of Working

The efficiency of the process can be tested by observation and without recourse to chemical or biological analysis.

During the first month fungi are engaged in breaking down the organic matter. The heaps should then be a mass of white fungoid growth and the temperature should be high. A simple method of testing the temperature is to insert a metal rod which should be hot to the touch when withdrawn.

After the third week the mass darkens rapidly and becomes crumbly while there is a slight fall in temperature. Bacteria from now onwards take an increasing share in humus manufacture.

If at any time the fermentation stops and the pits cool, want of moisture is the most likely cause.

Should the heaps begin to smell, flies will at once be attracted and will proceed to lay eggs followed by the development of maggots in large numbers. This only happens when there is some interference with the air supply. The remedy is to turn the heap at once and to add dung and ashes. The chief causes of insufficient aeration are excessive trampling, the addition of too much urine earth and ashes, over-watering or failure to turn the mass at the proper times.

Applying the Humus to the Fields

A month after the third turn the humus is ready for the land. If kept in heaps longer than this, nitrogen is certain to be lost.

Humus can be applied to the land and mixed with the surface soil by the processes of weeding and cultivation at any time of the year except during the monsoon, when it is almost certain to be washed away and lost. The best results will be obtained by the applications during the hot weather and immediately after the rains.

The optimum dressing per acre for tea is likely to be a counsel of perfection for some time for the simple reason that the supply of humus will be insufficient. Generally speaking, the aim should be to apply not more than 5 tons of moist humus per acre once every year. As organic matter is likely to be in defect in most tea soils, the best results will probably be obtained by light dressings of moist humus rather than by heavier applications which might easily produce high yields of poor quality tea.

Future Developments

The seeds of weeds are always destroyed in the composting process by the intense fermentation. After two or three years, the growth of weeds among the tea may therefore show a distinct falling off. This will save money in weeding, but the amount of material for composting will decrease. To maintain the output of the humus factory, it may be necessary to grow special green-manure crops for composting.

To begin with, the manufacture of compost should be carried out at some convenient spot in the neighbourhood of the tea factory so that the process can be supervised. Later on, when the staff of the estate become compost-minded as a result of experience in manufacture and of the increased crops of better quality tea which are almost certain to be obtained, it will be possible to consider the preparation of humus at one or two outlying centres on each estate in addition, as this may, in certain cases, save labour.

The Author of this paper would like to get into touch with organizations and individuals who have adopted, or who propose to adopt, the Indore process.

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