## Selected Articles.

# Soil Bacteria in Relation to Cultivation and Manuring.

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THE object of this article is to point out the importance of bacteria as a definite factor in the cultivation and manuring of the tea bush.

The soil is usually considered as a mixture of particles of various sizes which are classified as coarse sand, fine sand, silt, fine silt, and clay, together with small amounts of organic matter and salts necessary for the growth of plants. This type of analysis gives the idea that the soil is a dead substance acting merely as a support and a reservoir of food for the roots of plants.

A brief examination of the facts shows that this view is incorrect. It is well known that plants can only take up from the soil substances in solution. Being soluble in water, these substances can all be washed out by rain, though in some cases, this leaching takes place very slowly. In any case it is obvious that unless some factor is constantly at work converting complex insoluble substances into simple soluble salts, all plants would sooner or later die of starvation.

A normal top soil contains bacteria and fungi in very large numbers, and these are quite indispensable for agriculture. Not only are they engaged in breaking down manures and dead matter, and in producing soluble phosphates from the soil particles, but certain groups take nitrogen from the air and leave it in the soil in a combined form, thus helping to preserve the fertility of the soil.

*Types of Micro-Organisms in the Soil.*—Three large groups of micro-organisms are found in the soil. These are called Fungi, Actinomycetes and Bacteria. The fungi, are mainly concerned with the destruction of wood, and their efficiency in this respect may be judged by the rate at which tea prunings disappear after hoeing in. These fungi must not be confused with those which produce diseases of the tea bush. The latter attack living tissues, frequently causing the death of the bush. The true soil fungi only attack matter which is already dead, and are unable to grow on living tissues except in rare cases.

With the actinomycetes or "ray fungi" we are not particularly concerned in this article. They are chiefly of interest because they are responsible for the "earthy" smell of soil, which is most marked after rain.

The bacteria carry out a much wider range of changes. Certain of them break down complex manures and the remains of dead plants and animals, converting the nitrogen to ammonia; others convert this ammonia to nitrate. Others take the nitrate out of the soil while engaged in breaking down green manures and jungle which has been hoed in. Another group changes the soil nitrates and ammonia to free nitrogen which goes into the air and is lost;—the activities of these bacteria must be controlled. Nitrogen-fixing bacteria fix nitrogen from the air,—one of the most valuable processes known. Sulphur bacteria convert sulphur to sulphuric acid—hence the treatment sometimes advised, of adding sulphur to a soil to increase its acidity.

In short there are few processes connected with agricultural practice in which bacteria do not play an important part.

*The Causes of Soil Deterioration.*—The conditions in a normal jungle soil, before cultivation is commenced, are as follows. Bacteria in the soil produce nitrates, which are taken up almost completely by the heavy growth of plants and trees. From the trees, dead leaves and branches fall on the soil, adding large quantities of organic matter and nitrogen.

The organic matter is attacked by fungi and bacteria, the major portion being decomposed and given off into the air as carbon dioxide, which is again taken up by the green jungle. The nitrogen in the remainder is converted to nitrate by bacteria, and in this form once more enters the plant through the roots. The presence of organic matter in large quantities stimulates nitrogen fixation, and the soil steadily becomes richer, jungle growth increasing in proportion.

The increasing growth of jungle roots, however, has the effect of restricting bacterial activities, so that the amount of available nitrogen becomes progressively less. Eventually a point is reached at which the mineral food supplied, through the agency of the bacteria, is just sufficient to support the existing jungle, which in turn supplies little more organic matter than is necessary for the bacteria themselves.

Equilibrium having been established in this manner, there is the minimum of wastage, and soils in this state will remain for long periods without radical change in their composition, unless the cycle is upset, *e.g.*, by fire or floods.

The jungle is now cut down to form a tea garden. The trees and branches are removed and the smaller plants are buried or burnt. The soil is thus deprived of its normal source of organic matter. The land is hoed to destroy shallow rooted jungle and, the bacteria being now free to act without hindrance, decomposition sets in at a tremendous rate. Nitrates are formed much more rapidly than they can be absorbed by the tea and are washed out by rain. According to Mann, new tea gardens on very rich soil may give poor quality for some years, on account of the excessively coarse growth brought on by the accumulation of nitrates.

The amount of nitrogen lost in this way may reach alarming proportions as may be seen from the following figures (Mann):—

| Period under tea | Weight of nitrogen in virgin soil. lbs. per acre | Loss of nitrogen in lbs. per acre | Annual loss of nitrogen in lbs. per acre. |
|---|---|---|---|
| (1) 10 years | 7,000 | 1,500 | 150 |
| (2) 35-40 years | 10,000 | 5,500 | 157 |
| (3) 28 years | 7,000 | 1,500 | 57·7 |
| (4) 20 years | 13,000 | 3,000 | 150 |

The amount of nitrogen removed in an eight-maund crop is about 30 lb. per annum and a little more is used in building the frame of the bush so that a total loss of up to 130 lb. per acre per annum may occur. During the early life of the garden this annual loss is probably very much higher, since the most readily available nitrogen is attacked first.

Much of the nitrogen in a soil is very resistant to bacterial attack, so that a soil which still contains 3,000 lb. of nitrogen per acre may grow very poor tea, while the addition of only 40 lb. per acre of a soluble form of nitrogen, *e.g.*, sulphate of ammonia or sodium nitrate, may bring about a 50 per cent. increase of crop.

In soil No. 2 above, for instance, the loss of 5,500 lb. out of 10,000 lb. per acre may represent almost complete exhaustion of the available nitrogen in the soil.

Cultivation also brings about a marked increase in the rate of decomposition of the soil's organic matter, and in a comparatively few years a rich soil may deteriorate considerably.

To preserve the fertility of the soil, the nitrogen and organic matter content must be maintained and this is best effected by making use of the soil bacteria.

The loss might be made good by the extensive use of artificial fertilisers alone, but the cost would be prohibitive. To take an example let us assume that the soil is losing annually 100-120 lb. of nitrogen per acre. To replace this with ammonium sulphate would require 5 cwt. per acre which, at the price of Rs. 180 per ton, would cost Rs. 45 per acre, plus freight.

This, however, would do nothing towards maintaining the content of organic matter, apart from stimulating the growth of jungle and bush. If oilcake were used to supply both nitrogen and organic matter the quantity required would be 28 maunds per acre at a cost of Rs. 105. Any attempt to preserve soil fertility by the sole use of artificial manures is thus economically unsound.

*The Nature and Habit of Bacteria.*—The importance of bacteria is nitrogen from the air and making it available for plants. An important group of these consists of well known legume bacteria, which are found in the nodules on the roots of green crops such as Boga medeloa, cowpeas, dhaincha, and the like. Others live a free life in the soil and obtain their food from fresh organic matter, fixing nitrogen in return.

The most successful agricultural practice thus resolves itself into making the greatest possible use of these bacteria, and it is hoped that this article will show how these, and other valuable organisms, may be best encouraged.

*The Nature and Habits of Bacteria.*—The importance of bacteria in the soil having been established, their nature and mode of life will be considered, together with the application of this knowledge to agricultural practice.

Although commonly referred to as "bugs", bacteria are in reality not animals but plants of a low order, being even lower down in the scale of life than the fungi. Like the fungi, they are devoid of the green colouring matter of plants and therefore they cannot use the energy of the sun's rays directly.

In point of fact, direct sunshine is nearly always fatal to bacteria, which probably accounts for the lower numbers of these organisms in the top inch or two of soil (see below).

Their inability to use the energy of the sun direct determines their mode of nutrition. They must obtain their energy second-hand, by breaking down substances with a high energy content, *i.e.*, residues of plants and animals.

For this reason the majority of bacteria fall naturally into two groups, according as they live on living or dead matter. The first group contains the bacteria which cause diseases of living animals and plants, and the second group those which reduce the dead material to simple bodies which can once more be absorbed by plants. It is the failure to distinguish between these two groups which has given rise to the idea that all bacteria are harmful and should be suppressed where possible. Actually, were all bacteria and fungi destroyed, life on the earth would become extinct.

The soil bacteria belong almost entirely to the second group, with the exception of a few species which live on mineral salts only.

*Form of Bacteria.*—Bacteria occur in a variety of shapes, the most common being rods of varying length, and small spheres. In addition there are "comma" and spiral shapes. They are usually found in "colonies" which may consist of a few hundred or many million bacteria. A colony of five million typical bacteria would occupy the space of a pin's head. In the soil, these colonies are usually found surrounding small particles of lime.

Although they are plants by nature, bacteria are able to move about in the soil water. By special staining methods they are seen to have long waving "arms" of flagella, and these are lashed violently backwards and forwards in the liquid, causing the organism to move at a considerable speed in relation to its size. These flagella are of special interest in connection with the bacteria of green crops.

*Growth and Reproduction.*—In bacteria the simplest and most efficient form of reproduction is met. When a cell has grown to its full size it divides in two, and each of the resulting cells is exactly the same as the parent. Sexual reproduction is absent and in consequence, cross-breeding being imposible, bacteria tend to maintain their characteristics. For example, there is little difference between the nitrifying organism of Assam and that of England.

Certain bacteria also form spores which are very resistant to heat and may be boiled in water without loss of vitality.

Under favourable conditions a single cell can form two cells in half an hour. At this stage, after two days the descendants of a single cell would number 281,500,000,000. Under ordinary conditions, lack of food soon slows down this rate of increase, though if food is available in large quantities the effects of bacterial growth may be marked.

This is brought out by the temporary depression of crop noticed when a green manure or paddy straw is hoed in. Enormous quantities of cellulose are put into the soil, and the cellulose bacteria increase rapidly. In so doing they remove almost the whole of the nitrates from the soil, and until the nitrogen in the green material starts to decompose, the tea suffers from nitrogen starvation. The same fact has been brought out in a laboratory experiment with oilcake. When this manure was added to soil at the rate of 8 tons per acre there was an immediate loss of 90 lb. nitrate per acre, probably the whole of which went to feed the cellulose bacteria. All the nitrogen removed is returned to the soil when the bacteria die off, after their work is done.

*Bacteria in the Soil.*—In the soil, the bacteria occur in incredible numbers, a normal fertile soil containing about 100,000,000 to the ounce, or approximately five thousand million per acre. These great numbers are somewhat discounted by size—the average bacterium measuring about one twenty-thousandth of an inch in length—but they are nevertheless sufficient to make all the difference between a naturally fertile soil and one on which tea culture is only possible by constant resort to artificial fertilisers.

*Distribution of Bacteria in Soil.*—The numbers vary greatly with depth. The following table shows the distribution in the top two feet of soil :—

| Depth | Number of bacteria per ounce of soil. |
|---|---|
| 2 inches | 24,500,000 |
| 4 ,, | 40,800,000 |
| 6 ,, | 40,800,000 |
| 12 ,, | 1,820,000 |
| 18 ,, | 525,000 |
| 24 ,, | 100,000 |

Here is the explanation of the well known infertility of the subsoil. The reasons for the failure of bacteria to survive in any but the top few inches are several. Lack of air in the subsoil is one of the main factors; another is the almost complete lack of available organic matter. In addition, the soil itself behaves as a very efficient filter in preventing the bacteria from being washed down by rain acting in the same way as the earthenware candle in the filter which is to be found in every bungalow.

These figures act as a strong condemnation of the practice of digging drains and piling the excavated earth upon the tea on either side. If new drains are to be opened in an area already under tea, the subsoil should be spread thinly over the soil for some distance on either side. Whenever it becomes necessary to deal with subsoil in large quantities it should be freely mixed with cattle manure, which will have the effect of increasing the content of organic matter while supplying a very large number of bacteria.

The same applies when it is necessary for any reason to plant up land from which part of the top soil has been removed *e.g.*, by wash.

This infertility of the subsoil is one of the main arguments in favour of terracing on steep slopes in an exposed position. The top soil with its attendant bacteria and organic matter is easily lost and may take years to replace. On gardens where the top soil has already been lost, the continued use of artificial fertilisers such as sodium nitrate and ammonium sulphate is merely putting off the day of reckoning, and the health of the bushes will be maintained only while these manures are present. The counsel of perfection would be to build up a new top soil by heavy dressings of cattle manure, green crops, and decay-jungle.

## The Conditions Necessary for Bacterial Life.

*Air.*—There are two groups of bacteria in the soil, one of which requires abundance of air for its life processes while the other can live in entire absence of oxygen. The members of the first group carry on most of the valuable processes in the soil, while those of the second group are on the whole undesirable. One species of the latter has the power of destroying nitrates and giving off free nitrogen-causing a very serious loss to the soil. When the oxygen supply is insufficient these and other bacteria actually produce plant poisons so that their harmful effect on plants is twofold. It is thus necessary to restrict their activities as far as possible.

(a) by keeping the soil in good tilth and so allowing air to penetrate freely to the greatest possible depth.

(b) by preventing waterlogging of the soil by an adequate drainage system.

*Moisture.*—Bacterial activity is dependent on a sufficient supply of moisture in the soil. For the best working, the moisture content must lie between certain limits. Thus at Tocklai the optimum moisture content for the nitrifying bacteria is near 14 per cent. (*i.e.,* 35 per cent. of saturation). When the moisture content falls to 10 per cent. (25 per cent of saturation) in the cold weather, bacterial action is checked, and the bush is left without its normal food supply. Similarly when the moisture content rises to near the saturation point, the activities of bacteria are greatly restricted, and unless steps are taken to remove the excess water by drainage, a race of harmful bacteria may take possession of the soil. The disappearance of excess moisture from a well drained soil is brought out by the following figures :—

| Date. | Rainfall | Percentage of moisture in soil. |
|---|---|---|
| May 27th | 0·24" | 18·41 |
| " 28th | nil | 17·27 |
| " 29th | 0·05" | —— |
| " 30th | nil | 16·30 |
| 31st | nil | 14·40 |
| June 1st | nil | 13·89 |
| " 2nd | 1·72" | 18·38 |

Thus under dry conditions the moisture content of the soil falls fairly rapidly until it reaches the optimum. From other figures it is found that below this point the soil holds on to its moisture with greater tenacity.

The actual degree of saturation most favourable to bacteria appears to vary in different soils, usually lying between 40 per cent. and 60 per cent. The following figures illustrate this point.

| Degree of saturation. | Production of nitrates from peptone by bacteria (milligrams per 100 gms. of soil). | | |
|---|---|---|---|
| | Tocklai. | Amluckie. | Red Bank. |
| 35% | 7·36 | —— | —— |
| 40% | 6·05 | 7·14 | 8·52 |
| 45% | 4·90 | 8·24 | 9·89 |
| 50% | 4·39 | 8·79 | 16·48 |
| 55% | 3·57 | 10·44 | 13·20 |
| 60% | —— | 12·36 | 7·70 |

To preserve the maximum fertility, the soil moisture must therefore be kept as near as possible to the optimum :—

(1) by adequate draining to remove excess water during the rains.

(2) by the use of the cold weather mulch to maintain the moisture content at the highest possible level during the cold weather.

Prolonged droughts such as occur fairly frequently in the tea districts of the Terai and South Sylhet may cause a serious destruction of soil bacteria, leading to a slow recovery of the bush. When possible it is as well to apply a dressing of cattle manure on weak sections after a severe drought, as this will have the double effect of supplying food for the bush while adding a large number of active bacteria to the soil. If the drought has not been too severe, the effect of the first rain is most marked. The nitrate content of the soil, which has remained at a very low level throughout the cold weather, suddenly jumps up to nine or ten parts per million. This sudden increase doubtless plays a considerable part in bringing on the first flush.

*Food.*—The food requirements of the majority of soil bacteria may be placed under two headings, *viz.* :—

Organic matter.

Lime.

Lime does not act so much as a true food, but rather as a neutraliser of the acids produced by the bacteria in their normal life. This will be discussed below.

Organic matter is used by bacteria in enormous quantities. For example, American workers have found that the nitrogen fixing bacteria when supplied with straw as their food fix 7¼ lb. of nitrogen from the air while decomposing a ton of straw. When the green matter from clover was supplied instead of straw, the amount of nitrogen fixed was about 27·5 lb. per ton of material decomposed. It is probable that the results with the green manures in use in the tea districts would be comparable with the latter figures, but work on this point has not yet been carried out.

From these figures it appears that the amount of nitrogen fixed by the soil after a green crop has been hoed in would be in the neighbourhood of 80 lb. per acre, apart from the 20 lb. fixed by the crop itself. It must be pointed out that these figures were obtained as a result of laboratory experiments and in the field different results might be obtained. From a good crop a gain of at least 100 lb. nitrogen per acre is to be expected, which compares very favourably with the usual dressing of 30 lb. given as ammonium sulphate.

The organic matter requirements of bacteria are seen to be very large. Under jungle conditions, these requirements are supplied by the annual leaf fall from trees and by the succession of low-growing grasses. On the tea garden, however, jungle must be suppressed for it competes with the bush for food. The depression caused by jungle is well brought out by the following figures obtained from the Borbhetta cultivation plots.

| Plot No. | Treatment | Relative efficiency of nitrifying bacteria | Crop 1926. |
|---|---|---|---|
| 87 | Monthly cheel | 201·0 | 10·60 |
| 93 | 6 light hoes | 176·7 | 10·16 |
| 88 | 1 light hoe. Extra manure | 141·3 | 6·16 |
| 95 | Sickled only | 100·0 | 3·68 |

Plot 87 is kept free from jungle. 93 is nearly free while on 88 and 95 jungle is plentiful. It is interestng to note that the presence of jungle has had harmful effects on the soil bacteria as well as on the tea. This is possibly due to toxins given off by the jungle roots.

On the contrary, the practice of growing shade trees is very beneficial. The roots of the trees are too far below the surface to have much effect on the bacteria in the top few inches of soil. The wide-spread root system does much to minimise the loss of nitrates and soluble salts which would otherwise take place through leaching, and finally the tree itself deposits annually a large amount of organic matter, containing some 3 per cent. of nitrogen.

From the figures given above it is clear that the suppression of jungle is one of the most important factors in tea garden management. Undoubtedly the best method of effecting this is to grow tea bushes that touch each other so that jungle has no chance to grow—while the organic matter content of the soil is partially maintained by leaf fall and prunings. This is a counsel of perfection not easy to follow on gardens with a large percentage of deteriorated tea and vacancies, but approximated to on very large areas of good tea.

Jungle is usually eliminated by the use of the light hoe. Unfortunately the light hoe is very wasteful of the soil reserves for it is followed by a sudden increase in nitrate amounting to some 20 lb. per acre (on Tocklai soil). A heavy fall of rain following cultivation will remove almost the whole of this and the soil will be poorer in proportion. The destruction of organic matter is stimulated in a similar manner.

This loss after light hoeing is avoided to a considerable extent by substituting "cheeling" or cultivation with a spring-time harrow and buffalo, both of which effectively suppress jungle while disturbing the soil to a depth of a few inches only. The possibility of using either of these forms of cultivation depends largely on circumstances, labour being concerned in the former case, and the drainage scheme, transport facilities, and distribution of shade trees in the latter.

The fact remains that cultivation causes considerable losses of nitrogen. These can be made good in two ways, *viz.*—by addition of manures and by nitrogen fixation. Nitrogen fixation is, however, dependent on the amount of available organic matter. It is therefore clear that above all things the organic matter content of the soil must be kept up, if the bacterial population is to be kept in good working order. This fact is so important that a manuring scheme taking no consideration of the soil bacteria may be considered incomplete.

The tendency of late years has been to rely more and more on the purely artificial fertilisers such as Sulphate of ammonia and Calcium cyanamide for the nitrogen supply, chiefly on account of their low cost. It is important to remember that these manures are added solely with the idea of increasing the crop, and that they have little or no direct beneficial effect on the soil bacteria. A programme incorporating these manures must always include regular green cropping or dressings of cattle manure, preferably well rotted with paddy straw.

*Lime.*—For the majority of bacterial processes a neutral or slightly alkaline soil is required. Tea requires an acid soil and anything approaching neutrality appears to be definitely harmful. On the other hand, the fertility of the soil depends largely on the activities of the bacteria, to which lime is an essential. The difficulty is met by a compromise, lime being added in quantities insufficient to change the reaction of the soil, but under conditions where it will have most effect on the bacteria. To take an example, let us consider a typical tea soil with a "Hopkins acidity" of 400. This means that 400 lb. of lime would be required to bring 1,000,000 lb. of soil to a condition of neutrality. Taking the weight of an acre of soil to a depth of nine inches as 3,000,000 lb., we find that this soil would require 1,200 lb. lime per acre to make it neutral.

Now five maunds of crushed limestone contains about 200 lb. of free lime, so that this amount could be supplied per acre without making any appreciable difference to the acidity of the soil, although being of great value to the bacteria. The best time to add lime is before sowing a green crop, so benefiting the green crop itself and also the bacteria on whose presence and activity the efficiency of the crop depends. The lime should be distributed only in the rows where it is intended to sow the green crop, and preferably in the seed-bed itself.

Experiments conducted at Borbhetta showed that on this particular soil, Rahar would not grow at all without lime. When this deficiency was made good the crop obtained increased with increasing amounts of lime, until a dressing of 80 maunds of crushed limestone produced a Rahar crop of 250 maunds per acre.

The Tocklai lime policy thus becomes comprehensible when considered in terms of bacteriology. Continual applications of lime over a period of years, or the application of a large dressing is seldom, if ever, advised, but small dressings are recommended from time to time to satisfy bacterial requirements.

The conditions for optimum bacterial working may now be summarised :—

Aeration of the soil.

Ample moisture, but avoidance of excess by draining.

Plentiful supply of foodstuff in the form of organic matter.

Supression of jungle.

Small amount of lime at intervals on the more acid soils.

*Green Manuring.*—The space available will not allow of a description of all the bacterial processes taking place in the soil. As the practice of green manuring is of great importance in tea soils, the relation of bacteria to green manures will be dealt with more fully here, and a discussion of other bacterial processes will be left till later.

It is generally realised that bacteria are intimately connected with green manures. On the roots of all members of the legume family may be found small nodules. These vary in numbers with different species of plants, and with different conditions of growth.

If one of these nodules be cut in two, it is found to consist of an outer white layer of firm consistency, surrounding an inner mass, often pink in colour, which is soft and slimy. This inner mass is seen under the microscope to consist of enormous numbiers of slender bacteria, entirely filling the cells of the nodule. It is to these bacteria that the legumes owe their value as green manures, for, as stated above, they have the power of taking nitrogen from air, building it into complex soluble substances, and passing these on to the plant. In return form these substances, the plant supplies the bacteria with sugars, water and salts—substances which enable the bacteria to carry out their work of nitrogen fixation.

There is here a perfect example of division of labour.

*The necessity of bacteria for economical growth of green crops.* The ordinary green plant takes up its nitrogen as nitrate or ammonia. On this account jungle competes with the tea bush for food, and as it has its roots mainly in the top few inches of soil, where bacterial action is at its highest, the jungle has first call on the food supply. Hence, apart from reasons of convenience, jungle must be suppressed.

A green crop without nodules acts in the same way as jungle, the rate of growth and final crop being determined by the amount of nitrate and ammonia in the soil. Consequently any growth of a green crop without root nodules is at the expense of the tea.

If nodules are present on the roots, the position is altered. The bacteria in the nodules draw relatively large quantities of nitrogen from the air, and with the aid of this nitrogen the plant grows far larger than it would were it living on soil nitrates alone. For successful green crops the requirements of the bacteria must be studied and met.

The bacteria are mainly present in the soil in an inactive state. They possess no power of moving through the soil and little power of infecting roots of legumes. When a soluble phosphate is supplied the bacteria develop flagella, become highly active and are able to infect the plants readily. The use of phosphate is therefore a wise policy wherever green crops are to be sown, and many cases of failure may be put down to the neglect of this precaution. The best phosphates to use are Basic slag, Superphosphate, Belgian flour phosphate and Algerian phosphate. The quantities usually recommended are as follows :—

| | |
|---|---|
| Superphosphate | 2 mds. per acre. |
| Basic slag | 2 " " |
| Belgian phosphate | 3 " " |
| Algerian phosphate | 2 " " |

*Inoculation of Green Manures.*—From the above remarks it is clear that the value of a green manure depends on the extent of infection by bacteria. The question now arises, whether the legume bacteria in the soil are present in sufficient numbers to secure the maximum infection. In some districts it is found almost impossible to grow a good green crop and the idea suggests itself that lack of bacteria may be the cause. If this is so, artificial inoculation of the soil or the seed might be restored to with success. So far, little work has been done along these lines in the tea soils. A few isolated trials were made in the Tocklai district this year with varying results. The bacteria were grown on an agar (china-grass) jelly, and just before planting, the seed was moistened with a suspension of these bacteria in water.

Cowpeas gave poor results. Not only was it found difficult to grow the bacteria, but the inoculated plants were barely as good as the uninoculated. Boga medeloa was unsatisfactory owing to unfavourable climatic conditions and practically the whole crop failed. With dhaincha more promising results were obtained. The results of the experiments were :—

| Yield from 11 rows uninoculated. | Yield from 11 rows inoculated. |
|---|---|
| 590 lb. | 918 lb. |

Increase from inoculation 328 lb. = 55 · 6 per cent.

The seed was planted in alternate rows, alternate rows of seed being inoculated. Phosphate was not supplied and the soil in that section was poor. In almost every case, an inoculated row gave a greater weight of green material than the uninoculated rows on either side.

Definite conclusions cannot of course be drawn from a single experiment of this nature. This Department will be pleased to get into touch with any planter who has continual difficulty in establishing a green crop and who would like to carry out experiments in inoculations.

The science of agriculture has passed through three main stages in the course of its development. In ancient times the Mechanical stage held the field. Improvements were chiefly along the lines of cultivation and drainage, although a considerable amount was known about fallowing and the use of green manures such as clover in a crop rotation. At the beginning of the nineteenth century agriculture passed definitely into the Chemical stage and tremendous advances were made in the science of manuring; during the closing years of the same century the Biological era arose and gained favour in so rapid and sensational a fashion that there was a tendency in certain circles to regard bacteria as the beginning and end of agriculture.

Actually there are no hard distinctions to be drawn. The mechanical, chemical and biological phases are all intimately connected and interdependent, and a change which affects one will affect all.

In this article the claims of the bacteria have been put forward. Their importance in soil fertility has been brought out and the conditions they prefer have been enumerated. No attempt has been made to deal at length with individual bacterial processes in the soil, but the importance of organic matter has been emphasised, since this substance is the chief food, directly or indirectly, of the majority of soil bacteria; and on these, eventually, the economic cultivation of the tea bush depends.—*Quarterly Journal of the Scientific Department of the Indian Tea Association,* Part III, 1927.