# THE PROBLEM OF SOIL ANALYSIS.

BY

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At the present time the assistant staff of the Soils Division of the Rubber Research Institute are occupied principally in the analysis of soil samples sent in for advisory purposes. This work must be regarded as of considerable importance, for an advisory centre is an absolute necessity to the planting industry and it is clearly part of the duty of the Institute to endeavour to fill that urgent need.

The questions asked of Soils Division may generally be expressed as one of two fundamental queries. Most usually the soil is known to present difficulties, and recommendations for amelioration are required: we are asked "How can this soil, of which I am sending you a sample, be made more suitable for the growth of rubber trees or a cover crop?" Or the potentialities of the soil are not known and we are required to state them. The second question therefore is "How suitable is this soil, of which I am sending you a sample, for the growth of rubber trees or a cover crop?" What actually happens in most cases, is that we receive a letter which states the problem and requests that a soil analysis be made to solve it.

More rarely the sample is simply accompanied by a request for a soil analysis, but our mere compliance with this request would certainly be followed by a demand for an interpretation of our figures. Quite obviously it is not the figures but the soil expert's opinion that is of value: in fact the figures are only sent to inquirers to be filed as an interesting souvenir. This remark is not a cynicism but a warning; for it is highly probable that in the not-too-distant future advisory soil scientists will be employing methods of soil examination which, while they will answer questions on fertility with greater precision than the methods at present in use, will not afford any neat tables of percentages to send along with a letter of recommendation.

Faced by a table of the results of a soil analysis, the planter runs his eye down the columns and enquires "What's bogey?" or words to that effect. Unfortunately the figures are not as easy to interpret as a golf card. It is the purpose of this article to comment on their interpretation and to discuss some of the problems that arise when an attempt is made to estimate soil fertility and manurial needs by means other than those of actual field experimentation.

SOIL FORMATION AND CONSTITUTION.

There are two kinds of soils, primary and secondary. A primary soil results from the decomposition *in situ* of an igneous rock such as granite or basalt, while a secondary soil is produced when a primary soil is washed away and deposited as mud or silt on a river flood area or in an estuary. Igneous rocks have a definite crystalline structure, the whole mass being a mosaic of very variously sized crystals of quartz and numerous other minerals. Under the influence of such factors as temperature fluctuations, the age-long action of percolating water and the attentions of numerous micro-organisms, the rock disintegrates wherever it is exposed. It is interesting to reflect that the rotting of a rock, though infinitely slower than the rotting of a mass of animal or vegetable substance, is at any rate in part, effected by very similar agencies.

When a rock rots, the minerals other than quartz break down to a substance known as clay, while the quartz crystals may remain quite unaltered and, as sand, constitute the coarser fractions of the primary soils thus formed. Clay is a substance which possesses many remarkable properties, and a word or two about modern notions of its physical structure may not be out of place. There is very sound reason to believe that each of the tiny particles of which it is composed has a hard mineral core, probably a flat flake of some mica-like substance, the rest of the particle being a thick jelly-like envelope surrounding this core. This mineral jelly or colloid (the soil contains also organic colloids of vegetable and animal origin) is of the utmost importance to the agricultural value of the soil, for it not only profoundly modifies its physical properties but is the store for the mineral food salts necessary to plant growth. Its composition and precise properties may vary within wide limits giving all sorts of different clays, but in its relation to plant nutrition one fundamental property is outstanding: this mineral colloid is able to absorb food salts from the soil water when they exceed a certain concentration and to yield them up again when the concentration falls below this value. The details of this process are highly complex and can hardly yet be handled mathematically, for the value of this equilibrium concentration alters with the innate properties of the particular clay in question, with the quantities and proportions of the salts already absorbed and with those present in solution. A given clay has a definite saturation capacity for food salts: when this is completely satisfied, the soil is slightly alkaline and when the clay is very unsaturated, i.e., contains a very small amount of absorbed plant food salts, the soil is very acid. As a generalisation one may say the degree of acidity of a soil depends

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inversely on the extent to which its colloids are saturated with so-called "available" minerals.

### The Micro-organic Population and its Functions.

In addition to its mineral constituents, the soil contains humus and a population, very varied as to number and species, of micro-organisms—bacteria, fungi and protozoa. These last would appear to feed on the first two groups and thus modify soil properties in quite a secondary fashion, but the bacteria and fungi exert very definite influences on plant growth, both beneficial and harmful. To explain briefly and rather crudely we may say (i) they decompose the soil minerals and make them available as food to the plant, (ii) they take nitrogen gas from the air and fix it in a form in which it may eventually become available to the plant and (iii) they decompose dead animal and vegetable matter so that its mineral content again becomes available in the soil and its carbon passes into the atmosphere as carbon dioxide gas to be again taken in by the plant leaves and built into vegetable substance. Under adverse soil conditions process (ii) may be reversed and certain minerals may be converted into a form in which they cease to be useful and may even be harmful, e.g. phosphates and sulphates may be reduced.

Thus the micro-organic population of the soil serve as the intermediaries between the stores of potential plant food and the plant. When dead vegetable or animal matter falls on to the soil, the activities of the micro-organisms cause it speedily to rot away making the minerals it contains available for the growth of other plants: not directly, of course, but by a very devious route; they are taken into the bodies of the organisms initially active in the decay and either excreted or remain in the organism until it becomes, living or dead, the prey of another tiny creature which by its own particular processes may excrete the minerals in one form or another. In the same way, should the decomposition take place under the right conditions, the nitrogen contained in the vegetable matter will become wholly or in part available as food to the living plants growing on the site. The carbon, hydrogen and oxygen contained in the decomposing tissue are finally liberated as gases and water. From the plant's point of view, this is all that could be desired, since plants themselves take their supplies of carbon, hydrogen and oxygen from the atmosphere or from rain, its condensation product.

### The Importance of Humus.

But there is an intermediate stage in the decomposition of vegetable matter that is of great indirect importance to the life

of the plant. This intermediate stage is the formation of humus, a dark brown structureless substance of great chemical complexity which has a remarkable power of absorbing water and swelling tremendously by so doing. It gives to a fertile soil, if unstained by iron, its characteristic colour and imparts valuable lightening and water holding properties. In a moist cool soil, humus has a high degree of permanence, its decomposition under the action of the soil micro-organisms being very much slower than the processes that lead to its formation. It has another remarkable property—its power of holding certain mineral salts, essential alike to plant and to micro-organic growth, in a loosely absorbed condition and of taking them into that condition from the soil water in which they are dissolved. Humus can thus be considered, quite properly, as a perfectly stocked caterer for the food requirements of a whole host of soil micro-organisms, supplying them with the main necessities of life while they work to meet the requirements peculiar to themselves and in so doing accomplish much of direct or indirect use to the plant.

### Nitrogen Fixation.

To take an important example, some devote their energies to the fixing of nitrogen from the air: they build it into their bodies and at their death increase the reserve of this important element available to the soil. Remark that they will only do this when the percentage of nitrogen in the humus falls below a certain value. Nitrogen is essential to the vital processes of all the micro-organisms, but the great majority, lacking the power to take this element from the air, must simply suffer a restriction of their activities should adequate supplies in the humus be lacking. Under these conditions, other foods being available in sufficient quantities, the nitrogen fixing organisms will respond to the slackening of competition by multiplying and flourishing exceedingly.

### Micro-organisms and the Mineral Nutrition of Plants.

Other organisms, it would appear, obligingly sit by and feed the plant roots; and in a remarkably simple and effective fashion. For a long time it has been established to almost everyone's satisfaction that plant roots absorb their food salts only as a water solution. More recent researches on the food requirements of plants, on the quantities of water a plant will "perspire" (its only excretory system) during its lifetime and on the quantities of these food salts present in the main bulk of the soil water, make it abundantly clear that the plant root must be able to tap a solution that is very much more concentrated. There is good

evidence to believe that what actually occurs is as follows: a colony of organisms grow around a soil particle that satisfies their mineral food requirements. Lack of a particular food salt develops in the fine feeding roots of plants a latent property known as chemotropism i.e. when in water containing a feeble concentration of the desired food they will grow towards the region where that concentration is highest. Now the carbon di-oxide gas excreted by the micro-organisms will make the region immediately around the soil particle, enclosed as it is by the film of slime they excrete, distinctly acid and this degree of acidity once imparted (i.e. the buffer effect of the soil solution once overcome) the traces of organic acids also excreted by the organisms will give a very high degree of acidity in a strictly limited region. This acid water rapidly removes all the food salts absorbed by the mineral jelly surrounding the soil particle and, acting through the protective layer of jelly, dissolves further the mineral core of the particle. Some of the solution produced, of much higher concentration than the surrounding soil water, diffuses out of the colony of organisms and forms a series of concentric zones of progressively decreasing concentration to lead the chemotropic feeding root to the mass of slime surrounding the particle. Here, as close as possible to the particle, the rootlet remains, flattening itself around it and feeding on a liquid of far greater concentration than anything that could be extracted by expressing or displacing the water from the bulk of the soil.

It should be pointed out that this process whereby colonies of micro-organisms dissolve and decompose soil mineral particles is not entirely independent of the presence of the plant root. By removing certain food salts as soon as they become available, the rootlets displace an equilibrium that would otherwise be set up and permit fresh quantities of the salts to be brought into solution. Sometimes the amount of one salt that can be brought into solution depends on the concentration in the solution of another substance. In this case, supposing a particular plant to have a high requirement for both, it would get ample supplies of both: but a plant of another species which needed much of one and little of the other would allow a considerable concentration of the unwanted substance to accumulate and this would set up a condition of equilibrium and prevent further supplies of the wanted substance from dissolving. Granted certain conditions, this soil would then be fertile for the one species of plant and relatively unfertile for the other.

And let it be noted that we know regrettably little about the food requirements of the rubber tree at the various stages of its growth.

In the absence of any plant roots, the solution process is still applied very effectively to the soil mineral particles, if less rapidly. A state of equilibrium is, it is true, set up but the gradual diffusion of the concentrated solution of food salts through the film of slime upsets the balance and permits of fresh dissolution, while the concentration of the external soil water is instantaneously reduced to normal by the action of the mineral and humus jellies both of which, as has already been noticed, have the power to absorb food salts from solution.

CHEMICAL ANALYSIS OF SOILS.

How then is a suitable system of soil analysis to be arranged? What is to be determined and how? A method that has been in use for many years is to boil the soil sample for a lengthy period with strong hydrochloric acid and, after filtering, to analyse for the necessary plant food salts the resultant acid liquid under the assumption that this treatment will not only decompose the humus and mineral jellies but will also take as much from the actual mineral fragments of the soil as would ever, in the course of many years, be made available to a growing plant. This treatment certainly decomposes the jellies or colloids and it certainly attacks the mineral fragments, but over any period of time during which it would be practicable to employ it in a laboratory it does not effect anything like a complete decomposition of the minerals. Apparently, one could reasonably argue that such treatment with a strong mineral acid must be far more effective than any treatment that plant roots or micro-organisms could bring to bear on the mineral particles, but experimental evidence indicates the reverse to be the case. Experiments have been described in which soils have been subjected to prolonged extraction with strong hydrochloric acid and subsequently well washed with pure water until all traces of the acid were removed and, even then, certain plants were able to make some growth and to extract mineral salts for the purpose from the soil. Incredible though this may, at first sight, seem, a little reflection will soon demonstrate that on a basis of known facts it is not so very remarkable. A digestion with strong acid for 48 hours would be a lengthy and inconvenient business not often resorted to, while for plant growth persistent action over 3 months or 3 years is all one for the patient processes of Nature. Her reagents, applied as I have already indicated, are less powerful as regards acidity but they probably have other subtler and more vitally destructive qualities and they are certainly applied more intimately and with an immediate removal of all the products of dissolution as soon as they are formed.

Methods of ultimate analysis—that is to say, methods that completely decompose the soil particles however large or resistant

they may be—can, of course, be employed with scarcely more trouble than the strong acid extraction. But such methods are quite obviously too violent for our purpose and the figures they yield represent a potentiality removed from practical significance by ages of geological time.

We might agree on some gradual method of decomposition, nevertheless capable of achieving complete solution of the soil particles in a reasonable period of time and, by making periodical analyses during the course of the decomposition, obtain figures showing the various rates at which all the potential food salts pass into solution. Such a method would be possible, but it would be a very complicated and lengthy process to perform on even a single soil sample. Let us assume that we have such figures available for a series of soils whose respective fertilities for a particular crop we wish to predict and compare. What further information, if any, do we require?

## Interpretation of Chemical Analyses.

We must first safeguard ourselves by admitting the possible existence of all sorts of unknown factors that may not be as yet suspected by Agricultural Science. Then we must know the plant's needs of each of the mineral food salts at the various stages of its growth, remembering that the absorption of a much needed salt present in adequate quantities in the soil solution may be seriously hindered if other materials are present in proportions to which the physiology of this species of plant at this stage of its growth objects: thus we need accurate information on this possibility also.

We must next inquire about the plant's accessory food requirements, i.e., whether it is necessary for healthy growth that mere traces of certain rare or unusual substances be present in the soil.

It is now of fundamental importance to consider the rate at which those decomposition processes which we have endeavoured to imitate in the laboratory will actually occur in the soil under natural conditions. For rapid decomposition of the minerals and preparation of the food supplies a healthy micro-organic population of marvellously diverse species, well balanced in numbers and in action, is required. The wrong species must be discouraged. This proper condition of the micro-organic population will be governed by the availability and proportions of the food salts present, by the humus content of the soil, by its physical structure and colloidal content, by the nature of the sub-soil, topography, local climate; in fact by everything that can affect soil temperature, drainage and aeration, not forgetting such important

matters as the nature of the vegetation carried and the extent to which it shades the soil and prevents evaporation and wash. Truly, where the factors governing soil fertility are concerned, there are "wheels within wheels". To say nothing of the now well-known fact that minute traces of rare minerals in the soil may either stimulate or inhibit a particular species of micro-organic activity to a remarkable degree.

It should be emphasised that while the existence and importance of all these factors has been demonstrated and even investigated in some detail, we are very far indeed from the position in which they can be handled mathematically for any given set of circumstances and the net effect of their interaction computed So, from what has just been written, any attempt to predict or compare soil fertilities by laboratory work would seem a very difficult matter indeed.

In actual practice, the position is somewhat ameliorated by the fact that nature is an adept at making the best of a bad job. So while it would be impossible to arrange a series of soil samples in order of fertility on the basis of such an analysis, the figures obtained merely by the analysis of the strong acid extract of a soil will furnish certain useful information. It will give a rough idea as to what is easily available to a strongly growing plant, assuming that other conditions concerning situation, climate and subsoil are favourable, and it will indicate any gross deficiencies. If there is a gross deficiency of any important food salt, the soil has obviously not even potential fertility: and since supplies of this food must be added before any sort of fertility can be developed, it also gives an indication of manurial needs. All the finer points of the complete problem of soil fertility are, of course, ignored e.g., the fact that a substance appears in the acid extract is no guarantee that most or indeed any of it is available to the plant root, and the fact that there exists a gross deficiency of a certain food salt in the soil is no guarantee that any addition of that food in artificial fertilisers will not immediately be locked up by this particular soil in an insoluble form in which the plant can make no use of it. The existence of both types of phenomenon is an established fact. But generally, if the site and climatic conditions are favourable and the necessary mineral salts are available at all, nature will contrive to arrange at least a fair degree of fertility. Beyond that, to attempt to arrange soils in order of fertility is quite impossible.

### Available Nitrogen.

A few further remarks must here be made about the nitrogen supplies of the soil, since although adequate supplies of this ele-

ment are essential for any sort of plant or micro-organic growth, mineral analysis of the soil cannot indicate whether a sufficiency would be available. Broadly speaking, nitrogen is present in the soil in three forms viz. (i) in undecomposed plant tissues and in the bodies of micro-organisms. (ii) in humus. (iii) as nitrate. It is only as nitrate that plants (other than legumes) can absorb nitrogen, but the nitrate content of a soil, though easily determined, can only be regarded as the currency of the moment, since the soil colloids, which have such valuable powers of absorbing and holding in reserve soluble plant foods, are unable to absorb nitrate which is consequently washed out very rapidly by the drainage water. An analysis of soil for total nitrogen can easily be made, but nitrogen existing in forms (i) and (ii) can only be made available to the plant by the action of a healthy micro-organic population. Further the replenishing of this nitrogen supply by fixation of nitrogen from the air, can only be effected by an active micro-organic population; which assumes a plentiful mineral food supply, and the presence of decomposing vegetable matter from either properly applied green or farmyard manure or from a previous growth of vegetation.

## Biological Methods.

From the foregoing paragraph it would seem that by far the simplest and most promising methods for the laboratory study of soil fertility and manurial needs would be those involving an actual study of the health, nature and activity of the soil micro-organic population. Such methods have, of course, been proposed and enough work has been done to show that this line of attack is a very promising one. In fact, so interesting are the results of this study that the need for research along these lines is of immediate importance to any organisation or industry interested in the laboratory examination of soil samples.

It has been written, and often quoted in this connection, that the plant's opinion of the fertility of the soil is to be preferred to that of the laboratory expert. In justice it should be added that this was written at a time when soil scientists were far less alive than they are to-day to the artificiality of conventional methods of soil analysis, to the reserve needed in interpreting them and to the fundamental importance of field observations to any such work. Even at the present time, the ultimate answer to the question "How fertile is this soil in this climate for this crop?" must depend upon direct experiment or experience in the field. In most cases, however, the cost of such trial in time, money and opportunity would be so heavy as to make it a commercial impossibility, so the ideal of the scientist has become

even more emphatically that of the commercial man who consults him. They both wish to be able, one day, to learn as much about a soil by a few days' laboratory work as could be learned by years of experience in the growth of the actual crop concerned.

We are already a good step nearer that goal when we decide that if we cannot get the plant's opinion of the soil we can at least get the opinion of his tradesmen and general caterers, the micro-organisms. And there is, as is very well known, an extremely valuable way of predicting the rubber tree's opinion when clearing forest for a new planting; it consists in a critical observation of the quality of the jungle remembering that Hevea itself is a native of tropical jungles.

## Mechanical Analysis.

At the present time, any sort of laboratory soil examination is or should be preceded by a mechanical analysis. When the practical man examines soil in the field he classifies it, according to the fineness of the particles which predominate, as clay, loam, sandy clay, sand, etc., His experience enables him to predict much from his observations—how the soil will respond to cultivation, whether it will drain well and be properly ventilated permitting free root growth yet at the same time affording adequate mechanical support for the crop, and storing and leading up from the water table adequate moisture. Subconsciously too, as well as weighing the conditions as regards the air and water supplies of his crop he considers their effect in keeping the soil active (that is, maintaining a healthy and useful micro-organic population) and he realises that while an excess of clay will tend to make a soil foul and stagnant it is the clay and its associated humus that hold the food and water supplies. It is, as a matter of fact, a sound generalisation that the coarser particles of a soil have no actual or potential value as a source of food salts since they are simply grains of quartz. Now this field classification of a soil is subject to the errors and variations of personal judgment, so in the laboratory a rigid mechanical classification is substituted by subjecting the soil to a violent dispersive process to disintegrate all aggregated particles and then determining what percentages of the particles fall into the different size ranges.

## Some Inherent Difficulties of Laboratory Examination.

In the case of every laboratory method for soil examination there is one fundamental difficulty—that the soil is disturbed by removal from the field and preparation in the laboratory, it being, of course, impossible to replace it in its original structure. Such disturbance is bound to upset the equilibrium of the micro-organic

population and to affect seriously the permeability to air and water. All properties vary with each layer of soil from the surface downwards, yet a sample can give only an average figure, since thorough mixing is essential. The alternative would be to examine a large number of samples from progressively increasing depths—this would be impossibly long for routine determinations and so vertical division is made only into "top-soil" and "sub-soil". The necessity of mixing together a number of samples and re-sampling to get a material representative of a large area further complicates the issue.

Another difficulty, and perhaps one of the most serious yet mentioned in this connection, arises directly from the necessity of studying a soil sample removed from its normal environment. A few words only must suffice to indicate it. There is every reason to believe that the store of food salts held by the mineral and organic jellies of the soil is replenished not only by further solution of the soil particles on the spot but by absorption from the dissolved matter in the ground water which may flow along beneath the surface for a great distance or may rise from great depths. In such circumstances the value of a chemical examination would be still further reduced.

## Field Observations.

We are now in a position to take a comprehensive and understanding glance at the position from the soil expert's point of view when he is asked one of the two questions previously referred to. He will first of all need all the field information available and, since it is quite impossible for him to make the observations himself in every case, he must rely on all relevant information being accurately supplied to him by the estate manager or assistant.

The soil scientist can consider only one soil type at a time—every variation constitutes a separate case. If he is unable to visit he should first be supplied with a contour sketch map of the area in question on which the extent of the soil type or types should be indicated. Since it is of first importance to get the plant's opinion of the soil, the quality of the jungle or particulars of previous crops and the life history and present condition of the existing crop should be accurately described and any unusual treatment or circumstances should be clearly emphasised. For each soil type a profile should be described in detail, i.e. the nature, sequence and dimensions of the various strata visible in a vertical section: such a profile should be as deep as possible and may be obtained from a road or stream cutting, from the wall of a hill side slip or in unfavourable cases, by digging. It should

also be clearly indicated whether great variation in the profile occurs over the area covered by the given soil type.

An elementary knowledge of geology is of great assistance here and much useful information may be obtained with relative ease by using a simple boring tool. This can be made in any workshop by screwing together sections of ¾″ iron piping with coupling collars as required, the lower section terminated by a carpenter's auger and the upper by a simple cross-bar, the soil can easily be explored down to a depth of several yards. The tool is screwed down into the soil and loosened every few turns, by lifting it several inches and working it up and down in the hole. A sample of the soil in which the auger is actually engaged may be recovered from the twisted blade by simply pulling it straight up.

### Soil Sampling.

After considering this information, the expert may decide that a laboratory examination of a particular horizon of the soil profile would be helpful. In this sampling, a considerable amount of care is needed if the sample is to be truly representative of the soil type to be studied: a monograph could be written on the innumerable accidents that could make the properties of the soil in any particular spot most misleading as regards the whole area. A root or a piece of wood may have rotted there, a small animal may have died there, a fragment of bone might get included, or the whole nature of the soil may have been altered by the work of ants or worms, or soil from lower strata may thus have been brought up. The tearing up of the roots of a great tree, long since rotted and disappeared, may have brought up a large amount of the subsoil. These few of the many possibilities must serve as examples of the pitfalls that are set for the unwary soil sampler. In practice they are avoided by using every care that the spot selected for sampling shall appear thoroughly normal for the area in every way and sampling at least six such spots scattered at random over the area. Thus a number of samples are taken and carefully mixed and the final samples taken from the mixture—usually after first air-drying and crushing.

A soil sample is always taken as a block: that is, a volume of the soil is isolated from the rest and everything within that volume is taken. There are several convenient ways of doing this. For surface samples a piece of stove piping, a piece of thin-walled metal tubing or a cylindrical tin is forced down vertically and then dug out or withdrawn together with the core of earth it contains. Such a core is generally 2 ins. to 3 ins. in diameter and is taken from the surface down to a depth of 9 ins. or 1 ft.

A more elaborate and convenient tool may be made by sharpening the end of a piece of suitable steel piping, splitting it down one side and fixing it to an iron rod with a wooden cross-bar. This is screwed down into the soil, drawn up, and the core forced out by working with a screw-driver or pointed iron rod through the slit.

The following method is convenient when subsoil samples are required:—dig a pit down to a little below the required depth and smooth off vertically one wall of the pit. Take an empty cigarette tin and after piercing a small hole in the bottom to permit enclosed air to escape, knock it horizontally into the soil profile at the required level until it is flush with the vertical surface and then dig it out with the enclosed soil.

## The Present Position.

Unfortunately it is not possible to treat every soil type examined as a separate research investigation and to apply such of the most modern methods as would seem most appropriate: the demands on the advisory services of the Soils Division are too heavy. The length of time it takes to carry out even the simplest determinations is not generally realised by those who have had no experience of laboratory work. Efforts are being made in the Division to study the most modern methods of soil examination as regards their usefulness for local soil types, to devise others, and by careful selection and experiment finally to arrive at a routine programme that could be applied, rapidly and conveniently, to any soil sample by trained assistants, and that would at the same time permit of as accurate an estimation of relative fertility and manurial needs as the present position of Soil Science allows. The need for that sort of correlation work is keenly felt today by the advisory soil scientist. The most gratifying progress has been made by specialised research along particular lines but, if a metaphor may be permitted, the cross-country communication is still somewhat poor. This is far from being a matter for adverse criticism: it is the normal result of the rapid progress of a new science. Such work normally falls to the lot of those who undertake research work in the interests of industry and in performing this service for the rubber planting industry in this country, the Soils Division of the Rubber Research Institute has great opportunities.

In the meantime we try to satisfy the pressing present need for advisory work by the liberal and progressive interpretation of the results of field observations together with, in certain cases,

the results of a simple and conventional routine laboratory soil examination. A mechanical analysis is made to determine the percentage of sand, silt and clay and thus to permit the classification of the soil and the making of certain deductions depending on soil texture and structure. The loss of weight after strong heating is noted and a determination of the amount of organic matter and of total nitrogen is made. A portion is treated with boiling hydrochloric acid and the extract is analysed for potassium and phosporus. Thus any gross deficiences of nitrogen, potassium and phosporus are indicated, and the indication is of some value since if any such gross deficiencies exist the soil cannot be even potentially fertile. These three elements are those which temperate zone agriculturists have found to be most frequently limited in quantity and the addition of which, together with lime, has been found to be a practicable and paying proposition. In the absence of definite information, workers in the tropics must be content to follow this temperate zone practice. The need for research here is obvious, but research takes time. If and when the need is felt for other fertilisers, they will be manufactured and marketed. Until then, in our advisory capacity, we seek only soil deficiencies that can be met with the fertilisers available. On the research side, it is another matter, but one which is outside the province of this paper.

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In conclusion the writer would end on a practical note, since he has endeavoured to write for the practical man. Although the determinations we make in the routine examination of a soil sample are definitely old fashioned, no pains have been spared to make the means by which they are carried out as modern, and consequently as rapid and as economical, as possible. Even so, such an examination of one soil sample takes 3 hours of one man's time and 5 hours of another's, to say nothing of work done in preparing and storing the samples, interpreting the results and drafting the reports. With the trained assistance at present available the capacity of the laboratory is thirty samples a month. If this work were done on a business footing, paying its own cost by the fees charged, a fee of from fifty to seventy dollars would have to be charged for each sample examined.

In the foregoing paragraphs the very obvious need for a laboratory method for determining soil fertility and manurial needs has been indicated. While emphasis has been laid on some of the difficulties of applying schemes of chemical analysis and other "dead" methods to this problem, and attention has been directed to the very promising micro-biological methods which have as their basis a study of the growth of living organisms in

the soil, it has also been pointed out that the results of even a simple chemical analysis can be of great value if liberally interpreted to supplement field observations. Such a simple analysis is, however, a relatively lengthy and costly process. These remarks will, it is hoped, afford data by which Estate Managers in Malaya may realise the nature of the services they ask for and justify themselves for the courtesy and patience they invariably show in their demands upon the advisory services of the Soils Division.