

# GENERAL PRINCIPLES OF SOIL CULTIVATION AND OF METHODS OF MANURE APPLICATION TO TEA

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In recent years the Institute has done much to encourage lighter systems of soil cultivation than were previously adopted on the tea soils, and the position at present is that many conflicting views exist on the desirable type of cultivation, or even the need for any such operation at all. A common attitude towards cultivation is that it is an essential part of the combined operation of manure application, and in view of the probability of increasing frequency of manuring in the higher yielding tea it is very necessary that we should examine the relation between cultivation and manuring, drawing on all available assistance from experiments, theories of soil science, and practical observation in the field.

An economic aspect, inevitably, has to be considered and recently this has become of more importance. We refer to the rapidly increasing desire to broadcast manure, with no cultivation at all, which is a practice that the Institute has not previously recommended. Our reluctance to do so was based on the suspicion that the obvious advantages of broadcasting manure might easily lead people to ignore the possibility of disadvantages, which might not become evident for several years and by which time a fashion could be firmly established. Once a fashion has become accepted it is difficult to effect a change, particularly if that change necessitates an increase in costs. It is often appreciated that the Institute is gravely handicapped by being required to issue general recommendations suitable for all conditions of tea growing in Ceylon without having had sufficient experimentation under those varied conditions. It is not so generally appreciated that we are definitely limited by long term considerations when requested to give approval to this or that modification in a method of husbandry. Short term results may be obvious and attractive; long term effects, particularly where soil conditions are involved, may be less obvious, and in the extreme may even be damaging and costly to repair.

In the subsequent notes we shall attempt to keep this distinction emphasised throughout, and to bring about a revision in the present attitude to the relation between cultivation and manuring.

## A. Cultivation

1. *Principles of cultivation.*—There is no difficulty in deciding the basic function of soil cultivation. The aim is to keep the soil surface in a sufficient state of porosity to allow rain water to percolate into the soil instead of running off on the surface. At the same time as this is achieved the soil will be aerated. As far as observations and experiments have so far shown, cultivation should not be considered as an operation essential for the burying of manure. It is our opinion that

the soluble manures will follow the rain water down into the soil quite rapidly enough, and possibly in some circumstances too rapidly, so that there is no need to help this process unduly.

Although Ceylon tea soils appear to have a high natural porosity, the constant trampling to which the inter-row paths are subjected inevitably leads to compaction of the surface. Compaction may extend only to half an inch in depth, but this may be sufficient to impede percolation of rain water and to allow surface run-off to occur under very heavy storms. Compaction by virtue of compression under-foot is readily envisaged. What is not so readily realised is that a layer of fine dust on the surface can also be an important factor in the formation of a surface pan, simply by percolation into the pore spaces of the uppermost layer of soil and there remaining. The effect of treading likewise is purely superficial, and it can be assumed that soil below two or three inches in depth is quite unaffected by either of these processes.

We have attempted to discourage practices leading to the formation of a dust mulch, but it is not possible to eliminate the formation of dust entirely at certain seasons. Implements such as the weed scraper are the worst culprits, and even the three pronged drag hoe, which seemed at one time to be the answer for light cultivation, has been found to be equally damaging where the soil dries to a hard surface. A weeding implement used with a spudding action would be preferable, as it would thereby break the surface pan without producing very much dust. Treading itself is bound to break dry soil into dust, and the only way to prevent this would be to ensure that the soil itself were not trodden upon, namely, by having an effective mulch of organic matter. While a great deal of progress has been made towards this method of protecting the soil surface, it is realised that it will always be impossible to achieve complete protection economically over large areas. In particular, in the early stages of the cycle, once the pruning leaf has decomposed surface protection is most likely to fail to be adequate.

The most effective way in which to remove the ill effect of surface dust and the ubiquitous and inevitable effect of treading, is to incorporate the deteriorated soil into the lower layers where it will come under the influence of roots and microbes and will be aggregated into crumb-like units. A thick surface mulch of organic matter will produce a somewhat similar effect, but less efficiently. In other words, some form of cultivation which can break the soil open to allow a certain mixing of the top inch or two with the lower layers must be considered a necessity for the long term maintenance of healthy soil conditions.

It would be prudent to insert a warning at this point regarding cultivation in newly planted tea, whether this follows old tea, rubber, or virgin forest or grassland. The effect of uprooting previous crops is to loosen the soil very considerably, and the additional operations before planting tend to aggravate this disturbance. Virgin lands rich in readily decomposable organic matter and with surface layers of, usually, soil of good crumb structure and high porosity, while escaping much of the physical disturbance noted above will nevertheless undergo early internal changes which will lead to the formation of still more drainage channels. If these soils are thatched adequately until the newly planted tea is able to provide good branch cover together with vigorous root growth, it may be expected that their original high porosity will be retained for a considerable period, to be measured in years, and that cultivation with a fork may be unnecessary over this period. The necessity for dibbling in manure will be noted below. However, this fact should not lull us into a false sense of security, and a careful watch should be kept to see when the surface soil structure eventually deteriorates to the point when forking is required to allow heavy rains to penetrate without hindrance.

The brief answer to the question of how to achieve the soil rehabilitation aim by cultivation is, with a fork. From that point, however, we are unable to call upon either general scientific principles or upon controlled experiments in Ceylon.

It must be admitted that we suffer very badly from the absence of detailed cultivation experiments under the very varied soil conditions to be found associated with our tea. By their nature, such experiments would require a long, uninterrupted, life to produce worthwhile results, and extremely precise supervision. There is no lack of ideas on the design of such experiments, but until the organisation is available to carry out the work all our comments on details of cultivation must be based largely on accumulated observations.

We can say, however, that the above arguments hinge on preliminary experiments done by the Agricultural Chemistry Division, and on a very great weight of evidence supplied by similar work in other parts of the world. The general principles of soil science are widely applicable.

**2. Methods of cultivation in mature tea. (i) DEEP AND LIGHT FORKING.**—It would seem to be a justifiable assumption that the only effective cultivation which could provide sufficient mixing of soil layers, subject to the strict limitations imposed by the risk of damage to the tea roots, is the operation known as "deep forking." Although a well known operation, it would be advisable to state what we understand it to imply.

The tines of the fork are inserted to a depth of 12 to 18 inches, ideally, and the fork is then levered forwards. In practice this means that a block of surface soil is pushed a few inches downhill, leaving a crack behind it the width of which decreases rapidly with increasing depth. If the fork tines penetrate to 18 inches, it is most unlikely that the soil will be cracked below a depth of say, 9 inches.

The main effect at lower depths will result from the holes left by the tines themselves. Nearer the surface, of course, the shattering effect of the movement of the fork is considerable, and the soil in front of the fork usually comes to rest with a surface at a greater slope than it had originally. This slope, together with the shattering, and aided by the fact that the labourer usually treads on each freshly moved block when he inserts the fork for the next operation, means that some surface soil is immediately pushed into the deepest cracks available. After a very few showers of rain the cracks will no longer be visible and will not allow further admixture of soil layers. The filled cracks will, however, still provide excellent channels for the ready penetration of rain water, and the period over which this effect remains appreciable will depend on the soil type. Envelope forking of organic material will doubtless extend this period, but it is doubtful whether the organic residues would be of more value underground, rather than left on the surface to protect the newly disturbed soil. We incline towards the latter opinion, as we are here more concerned with the effect of organic matter on soil structure than with its relation to nutrient supply.

Experience in some districts has shown that deep forking when done in both rows together, and also in dry weather, can damage the tea bush. There are conflicting opinions on this point, as might be expected when considering the diversity of other factors involved. For the sake of prudence we continue to recommend that deep forking is done in alternate rows, and for ease of working, that this operation is done early in the pruning cycle in two stages. If deep forking can be combined with a manure application this may not be disadvantageous, as will be discussed later, but the main consideration in deciding the timing should be the suitability of the weather.

We are of the opinion that light forking, to a depth of 3 or 4 inches, with the fork preferably levered backwards, has little effectiveness in mixing soil layers, and that its main value lies in breaking a surface pan with only a small production of dust, thereby allowing free penetration of rain. It thus covers only one function of deep forking. Bearing this distinction in mind it may be said that deep forking represents an attempt to ensure long term retention of good soil conditions, while light forking should be regarded mainly as a short term palliative measure.

(ii) **SCUFFLING**— This unfortunate word was originally introduced to denote a type of soil disturbance common in European arable farming, and which is often referred to by the above term. It implies a type of shallow ploughing, to a depth of 2 to 4 inches, and can be very effective in mixing manure and soil. It was hoped that a small hand cultivator could achieve a similar purpose in Ceylon tea, but it is now all too apparent that good workmanship is not easy to obtain. Certain hard surfaced soils may sometimes be blamed for this, but probably more important is the ease with which a small cultivator can be scratched along the surface, giving the appearance of a job properly done. In fact, a more normal definition of the word "scuffling" is likely to be suggested, namely, pushing a layer of dust about. If this is to be the end and result of such "ultra-light" cultivation, then we have no more use for the practice than we have ever had for weeding scrapers, and more harm than good will probably follow. It is known that under some conditions the small cultivator, or drag hoe, can give good results when a chopping action is used, as opposed to scraping. As will be shown later, it seems probable that under these conditions even this light cultivation will not be required to accompany a manure application, and it certainly has no other value. Where soil conditions are such that the surface dries hard but readily scrapes to a dust, we suggest that a fork is the only implement to restore reasonable conditions.

We therefore propose to omit consideration of the small cultivator or drag hoe, and to reserve the term "cultivation" for an operation involving the use of the normal large fork, regardless of the length or type of the tines, provided that they are in the same plane as the haft.

**3. Cultivation in Young Tea.— DIBBLING.** This word is occasionally used in connection with manure application to young plants, and as we intend to encourage the practice of the operation which it implies it will be as well to give a precise definition to avoid any confusion, such as has arisen over the term scuffling. Dibbling involves poking a narrow rod straight into the soil and pulling it out with the minimum of leverage.

Various implements can be used, for example, a straight bladed weed spudder, a very small hand fork, or, and probably the most efficient and most popular, a straight pointed stick. The last is the safest type to use round very small plants, and the first is probably the easiest for larger plants where some cutting of roots is less harmful.

The effect is perhaps similar to that of deep forking on a miniature scale, since the action described above permits a fair degree of mixture of soil layers, and leaves long lasting drainage channels without unduly disturbing the roots. In relation to the size of the root system of very young tea plants, this operation may seem to allow manure to be placed deeply. For physiological reasons the Institute has always urged the adoption of the principle of "little and often" for the manuring of young plants, and if this is followed then it should be possible for a young plant to utilise manurial doses which have been dibbled in before they are washed below the reach of the roots. Again, while a mature tea bush may be able to cope with localised high concentrations of manure, a young tea plant seems to be in danger unless the manure is mixed with a large volume of soil without delay. Obviously, weather conditions play a large part in deciding the timing of this operation.

It will be noticed that whereas consideration of the two types of cultivation, namely, deep and light forking, paid little attention to manure application, the discussion on dibbling has emphasised that it is an essential part of manure application to young tea. Dibbling can not really be referred to as a general method of soil cultivation, although its consideration has had to be included in this section for convenience.

## B. Manure Application

1. **Principles of Manure Application.**— An attempt having been made to give the reasons for various types of soil management, the same must now be done for the methods of manure application. It can be said at once that this subject is of far greater complexity than that concerning cultivation, and that the experiments so far conducted afford no more than the beginnings of the accumulation of fundamental knowledge of soil chemistry and plant nutrition as pertinent to our particular interests, namely, the efficient utilisation of manure by the tea bush. In the following notes, full use will be made of results from experiments completed or in progress, and rather than having to repeat qualifying statements it will suffice to say at this stage that the ultimate fate of applied manure will be so dependent on detailed variations in soil conditions and bush physiology that any advice on application must be in the nature of a suggestion until a far greater volume of experimental data is available. It is proposed to commence a series of reports on some of the experiments, which will be given in subsequent *Tea Quarterly*s, and if modifications to the present suggestions seem to be called for at any time, they will be inserted in the appropriate report.

2. **Reaction of Manure with soil.**— Living as we do in an age where even the simplest phenomena can be shown to be explicable in terms of complex electromagnetics, it may not occasion surprise to learn that the behaviour of the soil system, manurial compounds, and even the absorbing surface of plant roots are all governed by similar rules. The formulation of these rules is a matter for scientists, but the ultimate object is intensely practical, namely, the forecasting of the necessity for specific manuring to meet specific requirements of the crop plant. The achievement of this object is still a long way off.

Once manure enters the soil it is no longer correct to think about it as though it remained an entity, although from sheer necessity of simplicity of expression we have to continue to speak of the fate of "manure" in the soil. In fact the manurial constituents separate into two groups with opposing electromagnetic properties. Ammonium, potassium, calcium and magnesium belong to the positive group while phosphate, sulphate, chloride (muriate) and nitrate belong to the negative group. It will be seen that what we so commonly refer to as "nitrogen" is in fact represented in both groups, and the conversion of ammonium to nitrate is merely one of the many processes complicating our studies. All the eight constituents named above are in regular use on tea estates; most are essential nutrients for the tea bush, and all require to be considered when deciding how best to apply manure.

Unfortunately, this consideration is bedevilled by the fact that they react with the soil in different ways, quite apart from what could be anticipated from the distinction into positive and negative groups. Some are more soluble in rainwater than others. Some in each group are held by the soil more firmly than others, and may even displace certain other constituents into the drainage waters. Soil pH affects such reactions, and may itself be affected by some of the constituents. Soil itself contains several different types of minerals in the clay and silt fractions which have their own types of reaction with manurial constituents, and in addition organic matter, humus, can play an important part in deciding what the final balance of nutrients will be. Even this is but one stage in the whole process of utilisation of manure, since the individual constituents interact with plant roots in ways which may have little relation to their interaction with the soil complex.

The scientist has two main methods of trying to disentangle these interwoven reactions. Soil can be treated by solutions of chemicals and an estimate made of the quantities of manurial constituents removed. A variety of chemicals can be used, and in various ways, and will extract different amounts of the same constituent.

Sometimes this difference in the estimated soil concentration of a certain manurial constituent is slight, but sometimes it may be surprisingly great. It is for such reasons that soil analysis alone has little value in this context, and requires to be supplemented by chemical analysis of representative parts of the crop plant itself, together with a practical estimate of the ultimate effect of the chemical reactions, that is, the recording of actual crop yields.

The above is a greatly simplified picture of the problems facing the scientist, and which must be overcome before practical recommendations can be put forward on a firm foundation. Soil and plant analysis must be linked together, and the information thus gained must be correlated with yield records. If this is not done, then the effect of unco-ordinated experiments will be to produce data relating to specific conditions and lacking the applicability to general practice which should be the aim of our research. The following suggestions must be read in this light, and on the understanding that co-ordinated experimentation is being done to provide additions and corrections in the future.

**3. Notes on Practical Aspects of Manure Application.—** (i) **RELATION TO WEATHER CONDITIONS.** Very dry soil can be expected to have little or no reaction with manure, which if broadcast will remain unchanged on the soil surface. If the manure could be placed below the surface of a soil which was still just moist enough to prevent wilting of the tea, it is highly probable that the bush would absorb some nutrients. It is also probable that chemical fixation of manurial constituents by the soil would proceed with little hindrance, and in some soils this process might be of greater effect than root absorption with an ultimate decrease in the efficiency of uptake of the manure. It is not suggested that deep cultivation would be contemplated in the middle of a prolonged drought, but if done immediately prior to the start of a drought and combined with manuring a similar situation could soon arise.

The nitrogen and potash components of the mixture are readily soluble in water and will be dissolved by very little rain. If the first rain after manuring were to run off on the soil surface, an appreciable proportion of the dissolved nutrients would follow the wash into the drains. If, as happens in the great majority of rainstorms, the rainwater penetrates the soil, the dissolved nutrients will also be carried below the surface. Some will react rapidly with both soil and roots, in the upper layers, while others may be carried to greater depths. It is the presence of these problems which makes it impossible to dispense with very detailed chemical analyses to decide what effect certain quantities of rain will have on manure applied on different soil types. It would be prudent to avoid manuring just before or during the most continuous rains of the year, particularly as the activity of the roots in absorbing manure may be suspected to be low in prolonged wet weather in many districts.

If the extremes of climate are to be avoided, then the optimum seasons for manuring when rainfall is moderate and bush activity high, may be all too short to allow manuring and other estate operations to be done just when desired. We suggest that manure could safely be broadcast late in a drought, provided that it is not anticipated that the first rains will run off on the surface. If this practice is followed, the rate of working will be high in the dry weather and with no diversion of labour to either cultivation or to "scratching." With the doses of manure which are at present favoured and with tea of reasonable vigour, the risk of manure scorch from broadcasting would seem to be negligible. Again, this practice would help to bring manuring as far as possible in advance of seasons of "rush crops," and it would take full advantage of an isolated shower of rain before the drought could really be said to have been broken.

It is suggested that the oldest fields, giving the greatest soil cover, are manured first in this scheme, if all fields can be dealt with in time, but if some manuring has

to be delayed into early monsoon weather then it would be preferable to carry forward the oldest fields. Young fields should take priority when adjusting the manuring programme to weather conditions, partly because the soil protection afforded is not great and partly because it is suspected that the root systems may have a lower storage capacity for nutrients than would be expected in older tea.

If it is necessary to fork the soil to prevent run off of rain, then manuring will have to be delayed until the cultivation can be safely done. If it is desired to fork in any event, regardless of risks of run off, there is no reason to object to broadcasting manure in dry weather, followed by forking several weeks later, since the cultivation in this instance has little bearing on the efficiency of manure uptake, and the two operations should be considered separately.

A fear is sometimes expressed that manure will be "lost" if it remains on the soil surface for more than a few days. This is not so. The two soluble components of the standard mixtures are capable of dissolving on a moist soil surface, within two days, even with no rain falling, and when generous doses are applied. Once dissolved in the topmost layer of soil the nutrients will remain there until washed downwards by succeeding rain. Occasionally the smell of ammonia can be detected in the manure shed, or in the field, especially if the bags become damp. Ammonia can be detected in minute quantities, and the slight odours referred to represent negligible amounts of nitrogen. No labour force could be induced to handle manure which was evolving appreciable quantities of ammonia. The residue of manure seen on the soil surface after a little rain consists of saphosphosphate, from the standard mixtures, and of course dolomite would behave in the same way as both manures are only slowly soluble.

(ii) FREQUENCY OF APPLICATION, SIZE OF DOSE, AND DISTRIBUTION. While we have no hesitation in recommending frequent small doses of manure to rapidly growing young plants, to the extent of three or four applications per annum, we are more limited in our ability to make the same suggestions for mature tea. It is so improbable that any soil or mature tea bush could store a year's supply of nutrients and release them steadily that we have equally no hesitation in referring to a frequency of manuring of twice per annum as being the minimum, regardless of the quantity of manure involved.

In the North-East monsoon districts, with a prolonged resting period and drought, it is probably not yet necessary to consider increasing this frequency of application, even if it were practicable to do so. However, when we eventually have to consider fields in the 2,000 to 3,000 pounds per acre per annum category, we may have to reconsider this question, but at present we do not know what capacity a very high yielding bush has to store nutrients over the shorter cropping season in such climatic zones.

Where weather conditions permit, it might be desirable to split annual manure doses in excess of say 120 pounds of nitrogen per acre, into three applications. Only extensive experiments can decide whether the increase in costs will be compensated by increased yield. Where broadcasting is adopted, more frequent application of manure, which can be timed to suit weather conditions, may be a more attractive proposition. Individual doses can, of course, be adjusted so that a greater proportion of the annual allocation can be put out at a particular season, for example to build up bush reserves prior to a "quality season."

It is quite impossible to say what is the optimum individual dose of manure, from the viewpoint of efficiency of utilisation, but if the above tentative figure of 120 pounds of nitrogen (manure equivalent) is accepted as the division between two and three applications a year, it is unlikely that the variations in the efficiency of the individual doses thus brought about will have an appreciable effect in practice. Further, a healthy tea bush is not easily damaged by even heavy applications of manure unless distribution is extremely irregular. Wherever practicable we suggest

that manure is distributed in both rows, because although it is known that a tea bush can obtain manure which has been applied at a little distance, it seems prudent to make distribution as uniform as possible to allow the greatest possible number of roots to absorb the nutrients before they are washed out from the soil or chemically fixed. Nor should we forget the impossibility of obtaining uniform distribution in practice. Unmanured strips in one row should on average be compensated by manure in either or both of the adjacent rows. We are, also, opposed to the various types of placement of manure, such as inclusion in envelope forking, which we consider to be too liable to abuse, and likely to waste the potentialities of the wide-spread fibrous root system of the tea bush. There would seem to be no necessity to try to distribute manure up to the bush centres themselves or into the spaces between the bushes in each planting row, as the difficulty of this operation would certainly lead to poor workmanship and possibly damage to the bark. In practice about two-thirds of the soil area in the inter-row path receives the manure when no attempt is made to govern distribution by certain types of cultivation, and we believe that this allows the most active tea roots to make the best use of the manure.

A qualification is required for manuring young plants. Here, as has often been stated, manure should be applied in a band round each plant, so that the manured zone lies under or just outside the spread of the branches. The width of the band should also increase as the plants increase in size, until eventually the mature tea type of distribution is necessitated. It is recommended that the utmost care be taken to keep manure from touching the bark, and also to avoid localised concentrations of manure because young plants very soon show the effects of excess manure. Manuring young tea requires closer supervision than for mature tea.

(iii) **RELATION TO PRUNING.** It has become increasingly evident that generous manuring close to pruning, before and after, is repaid by more vigorous recovery. In the shorter cycles where recovery is very rapid, it may be desirable to ignore the pruning gap when fixing the times of manure application, since the bush can never be said to be dormant over this period. In the longer cycles manuring may be timed to take into account a short period after pruning when the growth rate of the bush is obviously very slow, but it should be remembered that the bush late in a cycle can take up and store nutrients which will most probably assist bud break after pruning. The last manure application in a cycle of four years or longer could very well be made at not more than six months from pruning, depending always on weather conditions. If an economy in application should ever be required, we suggest that the first and last applications in a long cycle should remain intact in quantity and in timing. In a short cycle it may be that the manuring after pruning is of most importance, and that economies could be distributed over the remaining applications, including the last one.

In a very short pruning cycle, two years or less, there may be no necessity or justification for reducing the size of the manure application following pruning. However, in longer cycles a reduction in this application would usually seem to be called for. Once the buds have developed into discernible shoots it may be supposed that the bush is capable of absorbing manurial nutrients without much difficulty and with advantage. If manuring were desired at this very early stage, for the highest yielding and most rapidly growing tea for example, we suggest that a dose one-quarter of the annual average dose for the previous cycle be applied. If application were to be delayed until nearer tipping, this dose could be increased to one-third or even one-half. This presupposes that a normal cropping cycle has preceded pruning to give a guide to the annual manurial requirements. If cropping capacity appears not to have reached the maximum it would be good policy to base the size of the doses on an anticipated increase in yield and to make the applications as early as possible. This would thereby allow for errors of underestimating to be made up in the succeeding annual allocation of manure, without having deprived rapidly growing shoots at the critical stages after tipping.

It must be emphasised that the very early manuring referred to should preferably be associated with two other applications within about one year from pruning, weather permitting, since the object of this exceptional manuring would be to assist rapidly developing bushes. Where the first application is made at tipping, subsequent manuring within the year could be made in one or two doses according to the vigour of the tea.

Where normal mature tea is under consideration, with a known economic maximum cropping capacity and a known response to a "maintenance ratio" of manuring, it would seem reasonable to fix the first manure application at about one-third of the annual average dose for the previous cycle. It would not seem to be wise to talk in terms of "x" pounds of manure as "the tipping dose." Nutrient requirements by tipping growth can be expected to bear a relation to cropping potential, and it is well known by now that crop has a close connection with manure application.

In general, this extremely complex aspect of the allocation of manurial doses, can be expressed in the familiar phrase "little and often." The more probable it is that a long cycle field is capable of expanding its yield, the more frequently it should be manured early in the cycle, with no temptation to reduce the size of the doses simply because the bush is producing tipping growth and not "crop."

At the other end of a long cycle, assuming always that the last manure application remains close to pruning as mentioned earlier, we might take advantage of a well developed frame and root system by suggesting that the more vigorous the tea the less need there would be to consider splitting the manure allocations into frequent doses. In a three or four year cycle two applications in the final year would seem to be ample, under such circumstances, while in longer cycles the applications might be reduced to three in two years. It will be realised that the tendency of these suggestions is to distribute the manure allocation for the whole cycle over smaller and more frequent doses earlier in the cycle at the expense of distribution late in the cycle. This has a secondary advantage in that the labour can achieve greater efficiency of distribution in the younger tea. Even where it is not possible to forecast the manurial requirements for the whole cycle in tea of expanding cropping capacity, it is still practicable to work to the above scheme, and indeed this seems to be the only safe way in which such requirements can be worked out without running the risk of starving the bushes in the early part of the cycle, or else of going to the other extreme of excessive manuring.

(iv) DEPTH IN RELATION TO DISTRIBUTION OF MANURE. As has been hinted earlier in these notes, consideration of the optimum depth in the soil at which manurial constituents should be, for the greatest benefit of the tea bush, is so beset by a host of interacting factors that an answer can only be hazarded. When research has produced more evidence than at present, it will no doubt be found that different answers are given for different climatic conditions.

It would seem that the two soluble manures, containing nitrogen and potassium, are readily washed into the top few inches of soil from broadcast applications, and it is reasonable to suppose that they thereby come into contact with the greatest concentration of active tea roots. The two slowly soluble manures, saphosphosphate and dolomite, will not penetrate to the lower depths in their natural state unless cultivation provides assistance. When they dissolve and release their component nutrients, these may behave in the same manner as the two soluble manures, with the exception that the released phosphate ion is very active chemically and probably reacts with the soil to form yet other insoluble compounds. For this reason the operation of deep forking seems to offer a useful means of guarding against a concentration of some nutrients in the surface layer of soil. The slowly soluble manures here mentioned may be considered as long term manures, and there is no reason to suggest more frequent deep forking simply to mix them with the lower soil layers.

The suggestions given in the section on cultivation may be taken as adequate for this purpose.

Deep forking, by loosening the surface soil and roots, may encourage greater root activity at lower depths for a short while, and since manure or manure rich surface soil will tend to be moved into lower layers it will be appreciated that the efficiency of uptake of manure should not be impaired, unless forking has been very vigorous and rainfall immediately following is very intense. Under these latter conditions there would seem to be a real danger of some manurial constituents, for example nitrogen and potassium, being washed below the reach of most of the fibrous roots.

(v) RELATION TO ORGANIC RESIDUES. While we should not forget that humus, namely, the appreciably decomposed organic matter which is in intimate association with the mineral fraction of the soil, plays an important and beneficial part in regulating the efficiency of manuring, it is intended to restrict our consideration here to various bulky organic materials which may affect the actual application of manure.

Weeds can conveniently be grouped with the residues, because the growing weed eventually becomes such, either by natural death or as a result of weeding operations. If weeds remain in the field when they die, the nutrients which they have absorbed will be returned to the soil slowly. The residue will, in fact, be equivalent to compost and its effect will be beneficial. If, however, the weeds are removed from the field there will be a corresponding loss of nutrients. This fact must be taken into account when timing weeding and manuring. Weeds removed within a few weeks after manuring would certainly carry an appreciable portion of the manure with them. A vigorous growth of small weeds, for example *Oxalis*, annual chrysanthemum or *Drymaria*, may suffer scorching if manure falls on the leaves while they are wet, and the dead foliage can be considered as a useful manure in itself. If no such scorching occurs and if the weed growth has been deliberately allowed to flourish, as a soil protection, then there may be a temporary shortage of available manure for the tea. On a long term consideration that is not important, but if it is desired to obtain the quickest possible reaction to the manure application a dense growth of weeds, or for that matter small cover crops, should be chopped down before manuring.

Dead weeds, fallen tea leaves, shade tree loppings and grass thatch will all absorb some manure if this is spread on top of the residues. The amount retained is not great, unless the quantity of organic residue is very considerable. Such a situation may arise where young tea plantings are heavily thatched, but a temporary shortage of manure should not arise if it is distributed on the soil round the young plants as recommended, the thatch being moved if necessary to allow this. It will be repeated that we consider the main value of all these organic residues is to be found in the protection afforded to the soil surface. In addition they will return their mineral nutrients to the soil as they decay, and at the same time they will add to the humus reserves of the soil without the necessity of being buried. They represent a conversion of inorganic fertilisers into organic nutrients, usually at no extra cost, and in this respect they must be considered valuable assets as long as they are not removed from the tea field from which they obtained their nutrients.

Timber from shade trees represents a permanent loss of nutrients from the soil, as does the pruning wood from the tea itself. These unavoidable losses are, of course, allowed for in the rate of manuring adopted for each field, and have no bearing on methods of manure application.

Composts, of various types, and bulky animal residue manures can hardly be said to affect methods of application of the normal inorganic manure. Their own application should make full use of their value as protectors of soil structure, and, therefore, they should be applied in heavy applications of ten to twenty tons per

acre and may be allowed to remain on the surface. Tea after pruning would benefit most from this combined mulch and manure. If, for a special reason, an additional inorganic manure is to be applied, this could be more effectively done before spreading the compost, etc.

Other organic residues are occasionally suggested for use in tea fields, and advice should be sought beforehand, as some may have undesirable properties, and their consideration in a general article would not be justified.

### **C. Conclusions**

1. Distinctions are drawn between the various types of cultivation, emphasising their different effects on soil conditions, both long and short term.
2. It is suggested that cultivation should be practised primarily to maintain good soil conditions.
3. Special cases are noted where a form of soil cultivation is required to accompany manure applications.
4. Attempts are made to give general guidance in the problem of the actual application of manure.
5. Suggestions are given for concentrating manure applications in the earlier years of the longer pruning cycles.
6. Methods of achieving some economy in application of manure are suggested.