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# THE MIXTURE AS PRESCRIBED

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This article is frankly popular in style, and is meant to convey broad principles only. The intention is to discuss the wider aspects of manuring and plant nutrition and, since so little, relatively speaking, is known about the subject, it is of necessity highly speculative. Much nonsense has been written about 'artificial' or 'chemical' fertilisers, about their poisonous action on the soil, on human beings and animals fed on crops grown with their aid, about the destruction of earth-worms and organic matter. We propose, therefore, to give an unprejudiced view of this infinitely complex subject, and, as a demonstration of good faith, we will admit that artificial or chemical manures, which we prefer to call mineral manures, are capable through misuse of causing harmful effects upon soil and that accusations of an 'N.P.K.' mentality amongst some modern agriculturists are not wholly unjustified. Most agricultural malpractices are, however, due to ignorance or indifference, and the blame should be placed fairly and squarely upon the users of mineral fertilisers and not on the materials.

An 'N.P.K.' mentality infers preoccupation with the three nutrients nitrogen, phosphate and potash. For every 1,000 pounds made tea removed per acre per annum the permanent loss (crop and prunings) of these three nutrients is approximately as follows :—

| | | |
|---|---|---|
| Nitrogen | ... | 64 lb. |
| Phosphate ($P_2O_5$) | ... | 16 lb. |
| Potash ($K_2O$) | ... | 35 lb. |

In all manurial calculations the common practice is to refer only to nitrogen, $P_2O_5$, and $K_2O$. If TRI-500 is used as recommended by the Tea Research Institute the following quantities of N.P.K. will be returned to the soil following the removal of 1,000 pounds of crop :—

| | | |
|---|---|---|
| Nitrogen | ... | 80 lb. |
| Phosphate ($P_2O_5$) | ... | 39 lb. |
| Potash ($K_2O$) | ... | 47 lb. |

This appears to be generous treatment and, as a matter of fact it is, but the N.P.K. figures reveal only a part of the balance between removal and replacement.

Calcium (lime) and magnesium also are essential for plant growth. There is every reason to believe that in tea there is a very close relationship between these two elements and potassium. In any case, magnesium is part of the 'life blood' of plants, an essential constituent of chlorophyll and the parallel of iron in haemoglobin of animal blood. It is estimated that some 50 lb. of calcium and magnesium are removed by a 1,000 lb. crop. It is possible, therefore, that our acid soils are low in calcium and magnesium ; certainly their drainage waters have been shown to contain only one hundredth as much of these two nutrients as normal drainage from temperate regions. We suggest, therefore that the calcium and magnesium reserves are much less than the nitrogen reserves, which are remarkably high in Ceylon tea soils. For example, St. Coombs No. 1 field contains 0.27 per cent. of nitrogen in the top 6 inches, and 0.24 per cent. in the next 6 inches, amounting to some 10,000 lb. per acre in the top foot, equivalent to 50,000 lb. of sulphate of ammonia. And yet, because so much of this nitrogen reserve is locked up in a form unavailable to the tea bush at sufficient rate, we have to add more nitrogen to maintain an economic crop return. Surely, therefore, there is all the more reason for supplying calcium and magnesium to offset the dwindling reserves of these two nutrients.

How much calcium and magnesium are we in fact returning to the soil ? Many planters would probably answer 'none', adding something to the effect that liming tea soils was abandoned years ago. In actual fact we do add considerable quantities, because saphosphosphate is principally calcium phosphate (phosphate of lime) and with the 39 lb. of phosphate ($P_2O_5$) we are in fact adding 60 lb. of lime (CaO), up to 12 lb. of which may be in the form of chalk (calcium carbonate). The saphosphosphate will in addition supply 1.84 lb. of magnesia (MgO). Muriate of potash also contains some magnesium and 47 lb. will contribute about half a pound of magnesia (MgO) in a highly soluble form.

When the magnesium content of plants is on the border-line of minimum essential requirements high potash manuring may depress the magnesium content still further, and induce a magnesium deficiency. This illustrates very well the complexities which must be taken into account in manuring.

Sulphur is another element which is essential to the growth of plants, and is apparently of particular importance to tea. One of the first clearly recognised widespread deficiency diseases occurred in tea in Nyasaland. The disease known as tea yellows was cured by sulphur in the form of sulphate of ammonia, and since our manurial mixtures contain liberal amounts of this ingredient there is no cause for any further discussion of this element.

Iron and manganese are essential nutrients, and we have no fear for the supply of iron from tea soils, the content being virtually inexhaustible. Saphosphosphate returns a large proportion of the manganese removed by the crop.

With regard to trace elements such as copper and zinc the tea bush, judging from analysis, requires such large quantities that they are worth special consideration. The fact that tea leaves contain such large amounts of copper and zinc does not necessarily mean that these amounts are essential for growth ; this is one of the great difficulties in the study of plant nutrition. Plants do not normally excrete minerals, and may accumulate them apparently quite unnecessarily. However, copper is known to be essential for fermentation, as it was clearly proved at the Tea Research Institute some years ago that the principal enzyme (ferment) responsible for fermentation is a copper protein compound. Ceylon exports the equivalent of over 3 tons of copper metal every year in tea and a rather larger quantity of zinc. Although it is possible that the supplies of copper and zinc in the soil are sufficient the continuous and, at present, increasing cropping of tea land make it desirable to consider whether the supplies of these materials are in fact adequate. Saphosphosphate contains 0.013 per cent. of copper and 0.02 per cent. of zinc which means that both elements are practically fully replaced, or at least supplement the soil supplies to a very generous extent. The copper supplies are, of course, most adequately ensured where copper fungicides are employed to control blister blight.

The general conclusion is, therefore, that TRI-500, applied at the recommended rates is an adequate general nutrient mixture, and not merely an N.P.K. mixture. From time to time suggestions are made that trace elements should be incorporated in the mixture, but we cannot support this idea. Both saphosphosphate and muriate of potash contain other trace elements and field experiments have so far failed to show any response to further additions of the most important trace elements.

Nothing is further from our intention than to suggest that TRI-500 is the last word in manurial mixtures for Ceylon tea. It is frankly nothing more than a compromise, but it at least has a quarter of a century of quite intensive research behind it, and is based on facts and considerations which are far more complicated than is generally realised. We have mentioned only a few of the many intricate considerations behind a seemingly simple N.P.K. mixture.

It is also perhaps as well to counter the idea that the chemical analysis of plants can always give a reliable guide to field requirements. As already pointed out many of the minerals in a plant may be present in amounts far in excess of the requirements for normal growth ; they may be in excess to the extent of slowing down growth or being actively toxic. Also the amounts of minerals in the plant at harvest time give little idea of the amounts which should be applied in manure for optimum crop levels. For instance turnips usually need large applications of phosphate to ensure a good crop, but the amount of phosphate in the turnip, when pulled, is very low. Some manures have a very low efficiency in certain soils ; soluble phosphates, for example, are quickly converted to relatively insoluble forms in alkaline soils, and also in acid soils containing reactive iron and aluminium, at least after periods of drought. Nitrates are very rapidly washed out of soil by heavy rain.

Nevertheless, plant analysis will, if systematically employed, give information about the minimum amounts of nutrients required by any particular crop, and if the nutrients are not present in available form in the soil, they must be supplied as fertilisers. The relation between the amount of fertiliser and yield can only be worked out by accurate field experiments. So far, chemical analysis of plant material and field experiments have been employed in gaining information on which to formulate manure mixtures for tea. This is not the end of the story by any means. Present and future research on the manuring of tea must be carried out by co-ordinating plant and soil analysis with field experiments, which brings us back to the subject of calcium *and magnesium status of soils.* Coupled with this, is the subject of possible harmful effects of sulphate of ammonia when applied to soils over long periods.

Before the difficulties and dangers we have in mind can be understood, it is necessary to explain what happens when sulphate of ammonia is added to a soil containing clay and organic matter. If it were added to pure sand it would wash straight through. Sulphate of ammonia is highly soluble in water and a few showers of rain would wash it beyond the reach of any plants which could survive in pure sand. Clay and organic matter have a capacity for holding certain nutrients called base exchange capacity. This is a definite physical property and can be measured. It is quite easy to understand if a simple parallel of fabrics and dyes is taken. Some fabrics stain very easily and strains are very difficult to remove. These fabrics have, according to this parallel, a high base exchange capacity. Other fabrics do not stain so easily and stains are easily washed out—these have a low base exchange capacity. The dyes in different fruit juices also vary in the way they will stain any one fabric, and in the same way different nutrients such as ammonia, potassium, calcium, etc. vary in the strength by which they stain different clays.

When sulphate of ammonia, dissolved in rain or soil moisture, comes into contact with clay and organic matter, the ammonia is held by this physical force, (base exchange capacity), which also holds other bases such as potassium, calcium, magnesium, iron, aluminium and so on. The sulphate combines with another base, usually calcium, which is washed out of the soil in drainage water. Some of the sulphate is, of course, used by the plant in which case the amount of loss is reduced.

Every addition of sulphate of ammonia is, therefore, possibly depleting the reserves of calcium in the soil. This is certainly the case in the temperate soils which have been most closely investigated. In the acid soils on which tea is grown the mechanism may be rather different and the drain on calcium less, but it needs investigation. Work is in progress both in Ceylon and North East India.

Recent research at St. Coombs has indicated that the tea bush, almost certainly, is not able to take up its nitrogen directly as ammonia, but that the ammonia held by the clay has to be nitrified by soil bacteria and converted to nitrate. The nitrates usually again combine with calcium to form calcium nitrate and, since nitrates are not held by base exchange, they are easily washed out of the soil and thus may lead to further losses of calcium. In countries such as England and America, where soil research has been far more intensive than it has been in tropical areas, these losses of calcium have been closely investigated. It is estimated that the addition of each 100 pounds of sulphate of ammonia causes the loss of between 100 and 120 pounds of calcium carbonate under field conditions. Expressed as lime (CaO, the unit used earlier in the article), this means that the 400 lb. of sulphate of ammonia applied in TRI-500 for each 1,000 pounds of crop causes the loss of 225 pounds of lime (CaO).

As already explained, the lime added as calcium phosphate, (Saphos), only little more than compensates for that removed by the crop. Since our tea soils are of low lime status, (tea will not grow in calcareous soils, i.e. soils of high lime status), prudence suggests that the whole question of lime status should be investigated. Soil research, like medical research, should be primarily designed to keep the patient healthy rather than to discover the causes of the diseases. There is no cuase for immediate alarm, since, although the calcium content of our soils may be low, there are one million pounds of soil per acre in each 3 inch layer, and if the tea bush feeds in only the top two feet of soil it has 8,000,000 pounds of soil from which to draw its nutrients. In most areas there is also much undecomposed, and partly decomposed rock which supplies nutrients as it weathers. There is very little information about the composition of parent rock in the tea areas. Table 1 is compiled from a paper on the Geology of Ceylon.

Table 1. *Rock analyses(Adams).*

| Rock | Site | PERCENTAGE | | | | |
|---|---|---|---|---|---|---|
| | | CaO | MgO | $K_2O$ | $P_2O_5$ | $Al_2O_3$ |
| Charnockite | Nuwara Eliya | 3.4 | 1.4 | 3.4 | 0.8 | 12.5 |
| ,, | Hatton | 4.5 | 2.3 | 1.3 | 0.6 | 11.2 |
| ,, | Bulutota | 2.0 | 0.4 | 5.3 | 0.1 | 11.7 |
| Norite type | nr. Pussellawa | 3.4 | 0.6 | 2.2 | 0.2 | 11.1 |
| Diorite type | Nuwara Eliya | 8.3 | 2.0 | 1.1 | 0.2 | 18.7 |

There is still less information about partly decomposed rock, but Mr. Ramaswamy of the Chemical Division has analysed a few samples recently to give some idea of the position. Rotten rock is a familiar sight to all who live and work on tea estates, and the description of reddish brown, and black rotten rock is adequate. Sample No. 3 was a deposit rather than ordinary rotten rock, but similar material can frequently be seen in fresh road cuttings.

Table 2

| | Sample 1 | Sample 2 | Sample 3 |
|---|---|---|---|
| Colour | Reddish brown | Black | Black |
| Loss on ignition | 28.97% | 12.20% | — |
| Moisture | — | — | 3.40 |
| Silica ($SiO_2$) | 3.01 | 3.69 | 66.76 |
| Aluminium ($Al_2O_3$) | 8.60 | 1.35 | 14.72 |
| Iron ($Fe_2O_3$) | 58.25 | 81.15 | 2.13 |
| Calcium (CaO) | 0.02 | 0.01 | 0.44 |
| Magnesium (MgO) | nil | nil | 1.03 |
| Manganese ($MnO_2$) | nil | 0.02 | 8.43 |
| | 98.85 | 98.42 | 96.91 |

The rocks from which our soils are derived are of an acidic nature and the weathering processes tend to remove bases such as calcium, magnesium and potassium.

If we continue to use sulphate of ammonia we may have to consider the use of ground limestone in addition to TRI-500. The dolomitic limestone available in Ceylon also contains considerable quantities of magnesium which is a probable advantage. However, the quantity used must not affect the acidity of the soil and needs careful investigation. We do not advise estates to attempt application of limestone until further information is available. It may not even be necessary.

Urea as an alternative to sulphate of ammonia is a possible future development especially as we understand that the production of urea has certain technical advantages over the production of sulphate of ammonia. Urea does not cause the same drain on calcium in the soil, but, even if it should prove satisfactory as a source of nitrogen for tea, prudence suggests the use of some source of sulphur with it. Although there is no urgent need for changes in the practice of manuring there is urgent need for intensified research.

Sulphate of ammonia is subject to some quite ridiculous accusations. One is that it poisons earthworms. The truth of the matter is that earthworms do not thrive on acid soils and are not found in the virgin jungle or patna which preceded tea, except in litter or the less acid mulches which occasionally form on the jungle floor. They are only very rarely found in our soils and play no great part in forming humus. In fact animals and insects appear to have little to do with the breakdown of organic matter in tea soils, or in the parent jungle or patna. So far as is known at present the organic matter in our soils is formed *mainly* by fungi, and is of a different nature to the humus formed by the aid of earthworms. This is by no means peculiar to Ceylon. The type of humus found on the forest floor in Ceylon, where the soil is acid and low in calcium, corresponds approximately to *MOR*. Mor formation occurs on the surface of the forest floor as distinct from *MULL*, where the litter is rapidly incorporated in the soil by a variety of creatures including earthworms. Mull is commonly known as 'Leaf mould' and is highly prized by enthusiastic gardeners. The term Mull or Mor can perhaps only be legitimately applied to temperate conditions, but the breakdown of organic matter in Ceylon tea areas, both up-country and the low-country, resembles Mor formation.

The notion that sulphate of ammonia burns away organic matter in the soil is also without foundation. The amount of organic matter in tea soils, where sulphate of ammonia mixtures have been used continuously for many years, remains at a very high level and there are indications of an actual increase in patna soils[1]

1. Eden, T.-Monographs on Tea Production in Ceylon, No. 1, p. 51.

where the level of organic matter is initially very high. The oldest field on St. Coombs Estate, originally opened from jungle, contains 5 to 6 per cent. of organic matter in the top six inches of soil, 4 to 5 per cent. in the next six inches, gradually diminishing to 2 per cent. at 60 inches. The organic matter in virgin jungle soil alongside, is almost exactly similar in amount. How the organic matter is carried down in the soil is at present a mystery. Attempt have been made to count the various moving creatures in the jungle soil ; total numbers are low even in the surface soil, and practically none were found deeper than a few inches. As explained in the earlier reference to Mor formation, decomposition takes place on the surface of the soil and it must be assumed that the decomposed organic matter moves down through the agency of water movement and micro-organisms.

The organic matter in well managed low-country soils is also surprisingly high and over 5 per cent. has been found in soils that have been under tea for 30 years. Organic matter is more easily lost in the low-country, but there is no evidence that this is specifically due to the use of sulphate of ammonia. Lack of a good cover of tea, due to inadequate manuring, can lead to destruction of organic matter in the exposed soil, more particularly in the low-country. A normal tea soil which has been under tea for half a century may contain over 100,000 pounds of organic matter per acre in the top six inches. This illustrates the futility of using slaughter house waste products (commonly called 'Organics') at least from the point of view of their alleged humus forming properties.

It is possible that the large amount of organic matter found in our tea soils is due to slow breakdown under acid soil conditions. Sulphate of ammonia may, by contributing ammonia supplies to soil organisms, particularly fungi, actually add to the formation of organic matter.

Apart from large amounts of organic matter, as already mentioned, our soils contain a surprisingly large amount of nitrogen (viz. 10,000 pounds per acre in the top foot of St. Coombs No. 1 field). The amount of ammonia held by base exchange capacity is very high although several other investigations on tropical soils have revealed a similar state of affairs. Nitrifying bacteria require a good supply of calcium and phosphate, (as well as adequate amounts of iron, copper and zinc), for their activities, and their action tends to slow down under acid conditions. It is, therefore, possible that low calcium status in our soils may hinder the activities of nitrifying organisms and account for the comparatively large amounts of available ammonia, even to the point of limiting the rate at which nitrate is available to the tea bush. An investigation of the rate of nitrification in our soils is at present in progress.

As a final note of warning, however, against indiscriminate use of lime on tea soils, it must be pointed out that nitrates are readily washed out of soil and that excessive nitrification would lead to heavy losses of nitrogen. Excessive nitrification might even begin to oxidise away the organic matter in our soils, and since organic matter is at least as important, perhaps even more important, than clay in so far as base exchange capacity is concerned, it might reduce the capacity for holding nutrients. This would lead to a serious decline in fertility and be yet another example of the danger of interfering with natural conditions without due consideration of all the possible consequences.