Coffee Nutrition—Part II. Plantation Survey.

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ABSTRACT.

The main findings of a nutritional survey of Arabica coffee plantations in the New Guinea Highlands are presented. Widespread deficiencies have been diagnosed using soil and foliar analysis and field survey methods. The important relations between cultural practices and nutrient requirements have been discussed.

INTRODUCTION.

IN the winter months of 1963, leaf and soil samples were collected from 120 *Coffea arabica* plantations in three districts—Western Highlands, Eastern Highlands and Morobe—in New Guinea. Previously only two surveys had been made of these European plantations.[1] [2] The first of these[2] provided recommendations on all aspects of coffee production. At this time (1956) the coffee industry was in its infancy and the majority of the present coffee had not been planted. It is understandable, therefore, that some of the predictions of this report have not eventuated and, in particular, coffee soils have proved to be more fertile than this report implies. The second survey[1] was essentially concerned with obtaining "factual, economic information" and reporting "upon the capital investment required for establishment of an efficient coffee plantation in Papua and New Guinea" and contributed few cultural recommendations.

The latest survey was specifically nutritional. Although general data about the plantations were collected, the main purpose was to provide a basis for advice on the use of fertilizer. A technical report of this survey and other coffee nutritional work will be published in a research bulletin.[3] The purpose of this paper is to summarize this bulletin and outline its practical implications.

CULTURAL PRACTICES.

The term coffee nutrition is not synonymous with soil nutrient supply or fertilizer practice. Many other cultural practices such as shading, mulching and pruning exert a strong influence on coffee nutrition.

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Most plantations in New Guinea utilize temporary and permanent shade. The shade requirement varies greatly both between and within districts and this may be one reason why unbalanced shade/fertilizer programmes are not uncommon.[3]

Shading requirements and practices in the Wau Valley are distinctly different from those in the Central Highlands. In the Wau Valley *leucaena leucocephala* (formerly called *L. glauca*) flourishes (altitude 3,500 ft.) forming an overhead canopy and providing excellent shade. It is difficult to envisage a more suitable shade tree under these conditions. In the Central Highlands *leucaena* is used with some success on a few plantations. However, the higher altitude (5,000 ft.) results in much slower growth and the trees must be planted in a hedgerow system to provide adequate shade. *Albizzia stipulata* and *Casuarina* sp. are the most popular and probably the most suitable species in this region. *Albizzia stipulata* is favoured in most areas, but *Casuarina* is preferred and is probably more satisfactory in some drier regions. Much has been written about the relative merits of these two species but few, if any, scientifically supported facts have been presented. The two most significant attributes cited are that *Albizzia stipulata* defoliates under very dry conditions and that *Casuarina* has a short life span. While both these facts have been demonstrated in many cases they are far from universal attributes so that the ultimate decision on which shade tree to use depends mostly on the characteristics of the particular locality being considered. Problems of management for both *Albizzia* and *Casuarina* are much greater than for *Leucaena.*

Crotalaria anagyroides is the most commonly used temporary shade tree and this appears to be

quite satisfactory. Bananas although widely used cannot be recommended. When planted close enough to effectively shade the coffee they rob the soil of large quantities of moisture and nutrients. When planted further apart they offer inadequate shade for the young coffee. Use of *Tephrosia candida* is inadvisable as it competes strongly with the coffee for moisture.

Several of the advantages of shade trees can be obtained by heavy mulching. One factor vital to satisfactory coffee nutrition is adequate moisture conservation and this is achieved at least as efficiently by mulches as by overhead shade. If the seedlings used are healthy, are hardened off in the nursery and provided with a good mulch in the field, temporary shade may not be necessary in some areas where rainfall is high (about 100 in.) and ample cloud cover exists. It is doubtful, however, if there are many areas in New Guinea where it is desirable to grow bearing coffee without some form of permanent overhead shade.

Increased light intensity generally increases nutrient requirement and uptake and tends to produce more crop. Thus coffee grown in the full sun requires a greater supply of most nutrients and particularly nitrogen, to maintain it in a healthy state. Nitrogen deficiency usually occurs under such conditions and can be alleviated by increasing either shade or fertilizer applications. Under dense shade nutrient uptake is greatly reduced, more foliage is produced and crop production becomes minimal. Under these conditions fertilizer application will not be advantageous. As shade is reduced, more nutrient is required and greater responses to fertilizer can be expected. It is of great importance to appreciate that the likelihood of responses to fertilizer is reduced as the amount of shading increases. Even though some form of shade is desirable, overshading is economically detrimental.

Shading must also be designed with reference to the pruning system used. For a progressive multiple stem type of pruning, which has been widely and successfully used and appears to be the system of choice, it is desirable to have flexible verticals (which bend over readily) in the early stage of growth. This is readily achieved with a good shade cover whereas sun-grown coffee develops a stocky habit with rigid verticals and these may split from the main trunk when forced apart.

SOILS.

For coffee growing, " satisfactory soil structure with sufficient aeration and organic content and good drainage are important so that a deep topsoil with a porous sub-soil is desirable ".[3] It is very important to draw a sharp distinction between soils which become easily saturated with water due to their fundamental structure and those which are waterlogged due to topographical position, e.g., some swamps. While the former are to be avoided where possible the latter are often favourable for coffee growing. These soils are deep and porous and the problem is to divert catchment from the adjacent hillsides, removing excess water in the soil and increasing soil aeration. Experience has shown that after surface water has been removed it often takes one or two years of cultivation before the soil is sufficiently aerated to support good growth. If coffee is planted it often remains dormant for this period. In some areas extensive deep ploughing has been used successfully in this soil conditioning. Planting sweet potato (the actual crop is probably not significant) for one or two seasons also has a beneficial effect. *Tephrosia* has been used to good effect in several areas. If planted after surface water has been removed, the penetrating root system and rapidly growing plant greatly increase the rate of drying and aeration of the soil. The one or two year old bushes can then be turned into the soil and coffee planted. Under these conditions it is possible that the *Tephrosia* can be used as temporary shade. It has been used successfully on some plantations but insufficient evidence is available for it to be recommended as a standard practice.

When waterlogging occurs due to a heavy clay sub-soil there is little hope of economic correction. These areas should be avoided in planting programmes. Much of the central part of the Wau Valley (*Figure* 1) is rendered unsuitable for coffee for this reason. It must be stressed that fertilizer application on these areas will not improve the coffee and application of other cultural practices will be equally unrewarding. With our present knowledge we are unable to offer an economical solution to this problem.

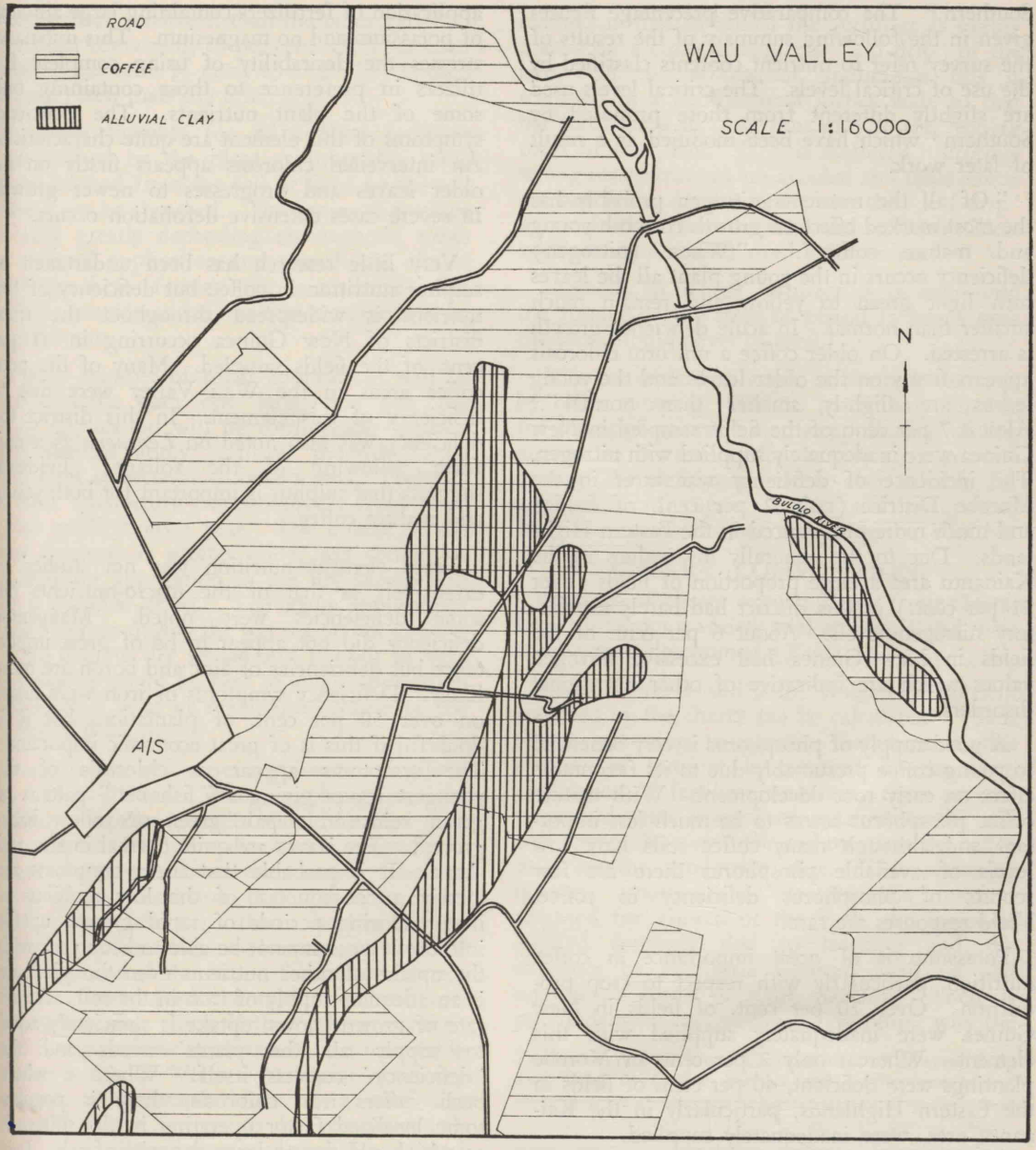

Figure 1.

PLANT NUTRIENTS.

Coffee requires a good supply of both macro-nutrients (nitrogen, phosphorus, potassium, calcium, magnesium and sulphur) and micro-nutrients or trace elements (manganese, iron, boron, zinc, molybdenum and copper). *Table* 1 shows the amounts of the macro-nutrients in various parts of the coffee bush.

The nutritional status of the coffee plantations in the survey has been assessed by methods outlined in the preceding paper by Southern [4] and which have been discussed in detail by Hart and

Southern.[3] The comparative precentage figures given in the following summary of the results of the survey refer to nutrient contents classified by the use of critical levels. The critical levels used are slightly different from those proposed by Southern[4] which have been modified as a result of later work.

" Of all the nutrients nitrogen probably has the most marked effect on growth for both young and mature coffee ".[3] " When (nitrogen) deficiency occurs in the young plant all the leaves turn light green to yellow and remain much smaller than normal. In acute deficiency growth is arrested. On older coffee a uniform chlorosis appears firstly on the older leaves and the young leaves are slightly smaller than normal ".[3] Almost 7 per cent. of the fields sampled in New Guinea were inadequately supplied with nitrogen. The incidence of deficiency was rarer in the Morobe District (only 2 per cent. of fields) and much more pronounced in the Eastern Highlands. Due to the generally low values in the Kainantu area a large proportion of fields (over 21 per cent.) in this district had barely satisfactory nitrogen levels. About 6 per cent. of the fields in New Guinea had excessive nitrogen values which are indicative of other nutritional disorders.

A good supply of phosphorus is very beneficial to young coffee presumably due to its favourable effect on early root development. With mature coffee phosphorus seems to be much less important and although many coffee soils have low levels of available phosphorus there are few reports of phosphorus deficiency in coffee. Yield responses are rare.

Potassium is of great importance in coffee nutrition, particularly with respect to crop production. Over 20 per cent. of fields in New Guinea were inadequately supplied with this element. Whereas only 2 per cent. of Morobe plantings were deficient, 40 per cent. of fields in the Eastern Highlands, particularly in the Kainantu area, were inadequately supplied.

Although the calcium nutrition of coffee is not well understood the significant amount in the leaves and cherry suggest that the coffee plant requires a considerable amount of this element.

Magnesium deficiency is widespread throughout New Guinea occurring in 30 per cent. of fields. This high incidence is partly due to application of fertilizers containing large amounts of potassium and no magnesium. This imbalance stresses the desirability of using complete fertilizers in preference to those containing only some of the plant nutrients. The deficiency symptoms of this element are quite characteristic. An interveinal chlorosis appears firstly on the older leaves and progresses to newer growth. In severe cases extensive defoliation occurs.

Very little research has been undertaken on sulphur nutrition in coffee but deficiency of this nutrient is widespread throughout the three districts of New Guinea occurring in 41 per cent. of the fields sampled. Many of the poor coffee areas in the Wau Valley were due to deficiency of this element. In this district the deficiency was also noted on *Leucaena* as a uniform yellowing of the foliage. Evidence suggests that sulphur is important for both young and mature coffee.

Trace element nutrition was not studied as extensively as that of the macro-nutrients but some deficiencies were noted. Manganese deficiency did not appear to be of great importance but deficiencies of zinc and boron are more likely. Deficiency symptoms of iron were noted on over 50 per cent. of plantations but it is doubtful if this is of great economic importance. The symptoms appear as chlorosis of the youngest leaves giving a " fish net " pattern of green veins on a pale green or yellow background. The leaves are quite normal in size and shape. It is probable that these symptoms are merely a consequence of the low mobility of iron. During periods of rapid growth uptake into the leaves may not be able to keep pace with the uptake of other nutrients even though there is an adequate supply of iron in the soil. As the rate of growth slows, uptake is sufficiently rapid to supply all the plants' needs and the ' deficiency ' corrects itself. Where a whole bush suffers iron chlorosis, there is possibly some localized factor operating in the soil such as a high pH due to large deposits of ash. It is doubtful if this can be corrected.

FERTILIZER APPLICATION.

Fertilizer use varies considerably throughout New Guinea. Fertilizer rate varies from 0 to 3 lb. per tree per year and applications vary from 1 to 12 per year. Type of fertilizer used is

probably more consistent than the other variables as fertilizer containing 13 per cent. N, 5 per cent. P and 17 per cent. K (i.e., 13 : 13 : 21) is used far more often than any other.

It is not possible for all applied fertilizer to be utilized by the plant as invariably some will be leached from the soil or fixed by the soil before it can be absorbed. The degree of wastage will vary greatly depending on methods, times and rates of application and one should aim at adjusting these factors (in accordance with economic considerations) so that wastage will be at a minimum.

A large number of small applications will be more effective than one large one but, the cost of application will be considerably greater. Some planters apply fertilizer monthly while others limit application to once a year. Probably the most satisfactory compromise is from three to four applications a year. The uptake of the major nutrients is greater under wet conditions and fertilizer application in the dry season will have a minimal effect. The main applications should be given during the wet season but in areas with no definite dry season and periods of very heavy rain it might be best to avoid application when rainfall is at its maximum because of the loss due to leaching.

Young coffee, of course, requires less fertilizer than older coffee. When applying straight fertilizers a smaller quantity should be used than with complete fertilizers due to the greater percentage of one nutrient in the former. There is a popular misconception that unhealthy trees need more fertilizer than healthy ones. Unhealthy coffee has a lowered power of assimilation and if the reason for sickness is not nutritional heavy fertilizer application will certainly be harmful. Even if the problem is nutritional it may well be aggravated if an unsuitable fertilizer is used. When a particular deficiency is proven a mammoth dose of a particular straight fertilizer is not to be recommended. Instead the fertilizer being used should be altered to include the nutrients required.

There are several methods of fertilizer application currently used. The desirable characteristics of any method are that it should be cheap to employ and that efficient use be made of the fertilizer, i.e., losses and harmful effects should be minimized. Probably as good as any other method is that in which the fertilizer is evenly placed on a circle around the ' leaf-drip ' of the tree. In the process of application this is scattered in a band several inches wide so that the fertilizer is in close proximity to the feeding roots of the plant. If it is scattered uniformly strong concentrations are avoided and toxic effects are not felt. As the tree grows the ' leaf-drip ' moves further from the stem and so the fertilizer application is spread over a larger area.

Methods in which fertilizer is thrown onto the foliage of the trees or placed in heaps near the stem should never be used.

It is convenient to apply some trace elements by foliar spraying. This is particularly suitable for the application of zinc as application of this element to the soil is often not effective in overcoming the deficiency. It is also suitable for application of copper, boron and manganese, but iron sprays do not appear to be effective.

CHERRY COMPOSITION.

Samples of cherry were collected from plantations and from a variety trial at Aiyura and their composition determined (*Table* 2).

From *Tables* 1 and 2 the amount of nutrient removed by the cherry can be calculated. " It is faulty reasoning to assume that because this amount of nutrient is removed by the crop, application of fertilizer containing these proportions and total amount of nutrient to the soil will restore the *status quo* and maintain the coffee in a healthy productive state. This reasoning ignores, among other factors, the nutrient required for growth of the bush, the losses of applied fertilizer due to leaching and the existence of equilibria between available and unavailable forms of some nutrients. There is no fundamental physiological reasoning why the

Table 1.—Approximate Composition of Leaves, Pulp and Bean of *Coffea arabica* and *Coffea canephora.*

—	N.	P.	K.	Ca.	Mg.
Coffea Arabica—					
Leaves	3.0	0.15	2.0	1.00	0.40
Pulp	2.0	0.14	3.8	0.50	0.12
Bean	2.2	0.20	1.7	0.15	0.20
Coffea Canephora—					
Leaves	3.2	0.15	2.0	1.50	0.45
Pulp	2.2	0.11	3.1	0.44	0.08
Bean	2.5	0.20	2.0	0.26	0.24

Table 2.—Composition of Mature Cherry of *Coffea arabica* (from plantations), *Coffea canephora* and varieties of *Coffea arabica* at Aiyura.

	Per cent. Moisture.	Per cent. Pulp.	Per cent. Bean.	Per cent. Mucilage and Husk.	Cherry Size (No. IKg.).	Bean Size (No. Ig.).
Coffea Arabica (12 samples)—						
Range	62.9-72.6	6.2-11.8	14.4-18.9	5.4-7.6	435-628	5.90-7.69
Average	70.0	7.5	17.0	5.5	555	6.45
Coffea Canephora (2 samples)—						
Average	61.5	11.0	20.0	6.3	554	5.40
Aiyura Variety Trial—						
Mocha	71.6	6.8	14,8	5.8	478	6.45
Arusha	73.1	7.6	13.9	5.4	395	5.71
Blue Mountain	71.7	7.2	15,8	5.3	435	5.48
Bourbon	71.5	8.1	15.2	5.2	480	6.30
Maragogipe	72.4	7.6	14.7	5.3	340	4.60
San Ramon	72.7	7.0	15.0	5.3	443	5.88

proportion of nutrients removed in the crop should bear a close relationship to the proportion of these nutrients required in the soil for optimum growth by the coffee. In any case, the proportion of nutrients applied to the soil in a fertilizer will not usually correspond to the proportion of nutrients which subsequently become available to the coffee roots."[3]

The pulp from six tons of cherry (corresponding to one ton of finished coffee) contains approximately the same amount of nutrient as 200 lb. of complete fertilizer. The wet weight of this pulp will be approximately one ton. " In short, 11 tons of wet pulp contain about the same amount of nutrient as one ton of complete fertilizer. Of course, the nutrients in the pulp are not as readily available as those in the fertilizer and the application of 11 tons of pulp to the soil will have a quite different effect from the application of one ton of fertilizer."[3]

CONCLUSIONS.

There are fewer nutritional problems in the Wau Valley than the Central Highlands. Sulphur deficiency, however, is common and application of this nutrient is essential to the maintenance of production. Sulphur can be conveniently applied as the element or as ammonium sulphate, potassium sulphate, gypsum (calcium sulphate) or magnesium sulphate (Epsom salts). The last is particularly suitable as the magnesium content of most coffee in the Wau Valley is low. The alluvial clay in the central part of the valley is not conducive to coffee growing and time and expense should not be wasted in an attempt to produce coffee on this soil.

Both the nitrogen and potassium content of much of the coffee in the Kainantu area are below normal and some revision of cultural practices in this region is desirable. Undershading and defoliation of shade trees contribute to this unfortunate position There are three major ways by which the harmful effects of this phenomenon can be countered or at least diminished—replacement of shade with another species, increased fertilization (particularly nitrogen) and mulching. The replacement of shade trees is possibly not a very practical solution but defoliation is a characteristic which should be given full consideration when the shade tree species is intially chosen. Fertilizer application will assist coffee to withstand the conditions of exposure which result after defoliation of shade trees. It is generally of little use fertilizing after defoliation has commenced as this usually occurs in marked dry periods when nutrient uptake will be minimal. Since it is not possible to accurately predict when such times of extreme stress are likely to occur, it is necessary to maintain the coffee in a healthy condition so that it is more likely to withstand such periods. The benefits of mulches in these drier areas are not widely appreciated. The conservation of moisture by mulches and the remarkable effect this has on coffee in dry periods have been clearly demonstrated. Mulches not only assist the coffee to withstand exposure but they tend to reduce defoliation of shade trees which makes the exposure less severe. If maintaining a thick mulch throughout the year appears too expensive a heavy mulch (about 1 ft. deep) should be applied uniformly over the coffee block at the

beginning of the dry season. Mulching should have additional benefits on soil structure in areas such as Kainantu where the lateritic soils become very hard on exposure to sun and rain. In dry areas where large returns are expected from mulching the claim that it is an expensive practice is a feeble argument. By this reasoning shade trees, fertilizer and labour might be dispensed with, for are not these also expensive commodities of management ? Some planters ask " Can we afford to mulch ? " when the question should really be, " Can we afford not to mulch ? ", for there are some regions where rejuvenating nutritionally weak coffee will be a long and difficult process, even with extensive fertilizer use, unless mulching is used.

On some plantations irrigation is used to counter dry periods. This, of course, is very satisfactory but indiscriminate and excessive irrigation can do more harm than good. It is preferable to use infrequent soakings rather than maintain a steady flow onto the coffee. The latter tends to favour leaching and waterlogging on imperfectly drained soils so that unsatisfactory aeration exists.

In assessing precise fertilizer requirements each planting should be considered individually but there are some features of fertilization which have widespread application throughout the three coffee growing districts in New Guinea. Inclusion of sulphur and magnesium in all fertilizers used appears a wise practice. Whereas the effects of magnesium deficiency are generally not noticed until production begins sulphur deficiency frequently prevents suitable growth of young and old coffee alike. The application of a single compound as a fertilizer (straight fertilizer) is not recommended as imbalance is readily produced with other nutrients. It is unfortunate that the so-called " complete " fertilizers are not literally complete as they often do not contain all the essential nutrients. For instance the majority of fertilizers contain neither magnesium nor sulphur. Both these nutrients occur in magnesium sulphate (Epsom salts) and this compound can be used in combination with a complete fertilizer to provide a suitable nutrient supply to most New Guinea coffee.

In the Wau Valley it is doubtful if young coffee needs fertilizer, except in a few regions where sulphur alone could be applied. In the Central Highlands fertilizers for young coffee should contain large amounts of nitrogen and phosphorus and some sulphur. Throughout the three districts fertilizers for mature coffee should contain nitrogen and potassium in large amounts (10 to 20 per cent.) and also magnesium and sulphur. Although trace elements have not been extensively studied there is sufficient indication to recommend use of fertilizers containing all trace elements as a wise practice.

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