Leaf Analysis Applied to Cocoa

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"It would seem unlikely that with any other crop have results with fertilisers been so unsatisfactory or so unpredictable as with cocoa", (12). The problem remains—how best to determine the fertiliser requirements for optimum yield.

It will be appreciated that only a fraction of the world's cocoa crop of nearly one-and-a-half million tons* receives any fertiliser whatsoever. It has been estimated (2) that every ton of beans has removed from the soil on which the trees are growing some 48 lb. of nitrogen, 12 lb. of phosphorus and 40 lb. of potassium. This means that the world crop is removing annually from the soil some 37,000 tons of nitrogen, 9,000 tons of phosphorus and 31,000 tons of potassium. And of course, as fertiliser, these figures would be increased according to the proportion of the element present. That is to say, the requirement of nitrogen as ammonium sulphate is in the region of 185,000 tons. And this takes no account of the content of the pod shells which may or may not be left in the field. These have a particularly high content of potassium.

Cocoa is usually established in new land taken out of forest, and it benefits from the years of accumulated organic matter and leaf litter. On some young, immature soils breakdown of the parent rock will also release new sources of nutrients. However, in the course of time the constant loss of nutrients must be made good, and this applies more particularly to land where cocoa is being replanted. Problems arise when it is necessary to know what fertiliser to apply and how much.

In an article on "How useful is soil chemical analysis?" published in a previous issue of the *Bulletin*, A. J. Smyth (13) has dealt with the problems of interpreting soil analysis data in relation to cocoa nutrition. As he points out, soil analysis can give only partial answers to the fertiliser needs of the crop, and he mentions the need for other techniques and in particular the analysis of the plant itself. This may consist of samples of either leaves, bark or roots, but, in general, efforts are concentrated on analysis of the leaves.

Although soil analysis can measure the nutrient content, it often cannot estimate availability of these nutrients nor can it tell just what nutrients the plant will absorb. An example lies with iron nutrition. Even though there may be no shortage of iron in a particular soil, if the pH is above 7, i.e. the soil is alkaline, cocoa will show the striking symptom of iron chlorosis because the iron is not available to the plant. The basic idea behind the use of leaf analysis is to use the plant itself as a guide to what it is getting from the soil.

A considerable range of literature exists on techniques for leaf analysis for a wide range of crops. Different systems of interpretation of results have been worked out but in its simplest form the results of the analyses of the nutrients in the leaf are compared with standards. Thus, if it has been established experimentally that the standard level of nitrogen in a leaf for optimum growth is 2 per cent of the dry matter content, analyses showing levels lower than this

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* Tons referred to in this paragraph are short tons (2,000 lb.).

Taking leaf samples.

Using a torsion balance.

Leaf analysis in the laboratory.

would indicate the need for fertilising with nitrogen. In practice things are not so simple.

Before dealing with the establishment of standards, an outline of the technique will be given and then the problems involved in using the technique.

Technique of leaf analysis

Leaves are selected from the tree and oven dried at 100°C. for 24 hours. The dry leaf material is then ground to a powder in a hammer mill and is ready for chemical analysis.

In general, micro-methods of analysis are employed to save on the amount of leaf material required. Details of the methods used can be readily found in the literature. In a large laboratory handling hundreds of samples the procedures are routine, and most techniques employ colorimetric determinations for speed of final assessment. Leaves are usually analysed for ash, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg), all expressed as a percentage of the dry weight of leaf powder. In particular instances the analysis may be carried a stage further to cover the minor elements. Because of the small quantities of these nutrients in the leaf, copper, for example, in a cocoa leaf is only found at a level of ten parts in a million, the methods are difficult and usually involve spectroscopy. In general, therefore, in speaking of leaf analysis only the major elements are considered.

Practical application

It is obviously important in taking leaf samples that they should be comparable, i.e. be of the same age, come from the same part of the tree, etc. This is easy in monocots like the banana or sugar cane, where the third open leaf is specific for each plant. In a tree crop, matters are more difficult.

Referring to Fig. 1, the reason for precision in regard to age of leaf is shown diagrammatically. In a young cocoa leaf the levels of N, P, and K are high and diminish with increasing age. On the other hand, levels of Ca and Mg increase with age. This is a physiological fact and means that even on the same branch one leaf may show a low level of K as compared with another leaf merely because it is older and not because it is deficient in K.

The habit of growth of cocoa by flushes does not help with the problem but does serve as some guide in relation to time of sampling. Leaf samples may be specified as coming from the second and third leaves of flushes which have just hardened. A more precise method is to date the flushes as they expand and sample five or six weeks later, but this increases the time and labour required.

Only passing mention will be made of the effect of season and position on the tree, some of the most recent work being that of Acquaye (1). These problems are common to most tree crops.

There is one problem, however, that is associated with crops such as cocoa, coffee and perhaps tea, grown under shade. Light intensity affects the levels of nutrients in the leaf, particularly that of potassium. As shown diagrammatically in Fig. 2, samples of leaves from trees grown under identical soil conditions will show higher levels of nutrients when the trees are shaded as compared with when they are unshaded. This has led the writer to suggest that shade and nutrients are in some ways interchangeable, that is to say, low levels in the leaf may be corrected either by applying fertiliser or by increasing shade. Light intensity of course has important effects on yield as well.

Fig 1

Effect of age of leaf on content of N, P, K, Ca, Mg as percent dry matter (diagrammatic).

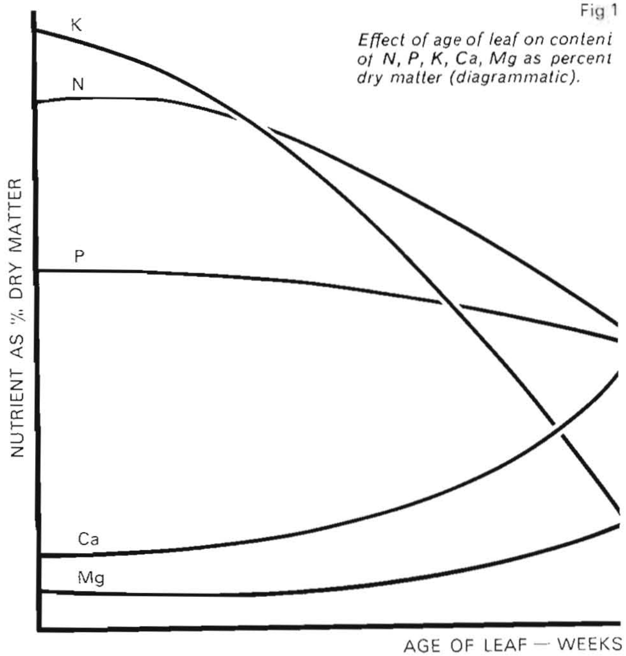
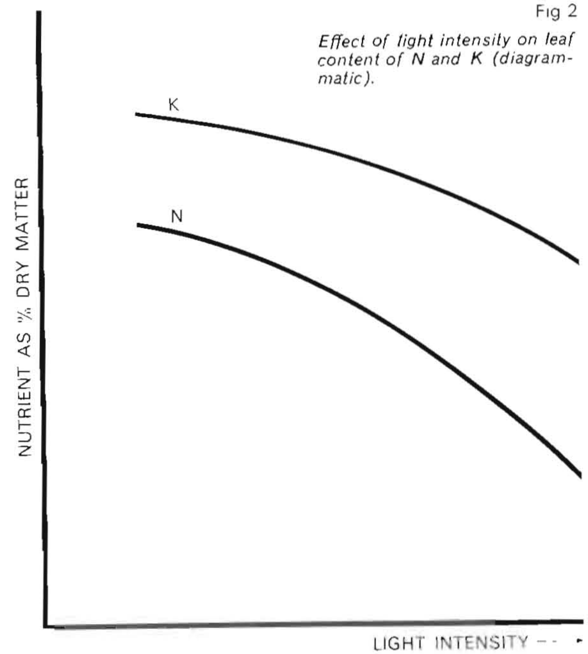


Fig 2

Effect of light intensity on leaf content of N and K (diagrammatic).



Leaf analysis for cocoa

Hardy *et. al.* (6) sampled leaves from terminal shoots which had just hardened and were turning green in a fertiliser experiment at River Estate, Trinidad. Using the values found for the different fertiliser plots, they stated that a close relationship existed between leaf composition and yield, high yield being associated with a high K content relative to N and P and a low P content relative to N and K. Instead of using the individual levels of N, P and K they expressed their results as ratios and gave as optimum ratios (1) $N/P_2O_5=4.66$: (2) $N/K_2O=0.89$ and (3) $K_2O/P_2O_5=5.21$. They indicated that in this particular trial high yields were associated with these values of the ratios and that departures from them resulted in lower yields. This would imply that corrections of the adverse ratios by the use of fertilisers would increase yield.

Later Murray (11), while showing the effect of shade on levels of leaf nutrients, found that Hardy's "ideal" values for the ratios did not apply on other sites. And at much the same time Fennah (5) showed that a difference of 0.1 in the N/K_2O ratio, which Hardy had indicated as distinguishing a high-yielding from a low-yielding tree, could occur through an age difference in the leaf of only a week or two.

Jones *et. al.* (7), as a result of the successful application of crop logging, which included leaf analysis, to sugar cane undertook a similar programme in another fertiliser trial at River Estate. Dealing with the results, Maliphant (9) demonstrated the difference due to season and shade and found correlations between yield and N/P_2O_5 ratios. These latter, however, varied with season and were of little practical value.

Machicado and Havord (10) applied the technique in Costa Rica but ran into similar problems of sample and seasonal variation. In Ghana, Burridge *et. al.* (3), sampling every four weeks, have shown the changes in nutrients with season and drawn attention to the fall in N and P in the leaves when the crop was developing. In addition to the major elements they also did analyses for the minor elements. Loué (8) has done leaf analysis in the Ivory Coast and shown widespread deficiencies of P and K in the field.

Despite the work that has been done, the technique remains of only limited value in planning fertiliser usage. If a marked deficiency exists, the low levels in the leaf will override problems of sampling and indicate the type of fertiliser required to correct the deficiency. In the more normal range, however, the technique lacks precision. It has been suggested that using leaf analysis is like trying to show the difference between a cart-horse and a race-horse by taking blood samples! Accepting the various limitations of the technique, Murray (12) has given the following table for normal levels in the leaf, low levels where growth is affected but visual symptoms do not appear, and deficient where visual symptoms will be seen.

Nutrient	Deficient	Low	Normal
N	1·80	1·80–2·00	2·00
P	0·13	0·13–0·20	0·20
K	1·20	1·20–2·00	2·00
Ca	0·30	0·30–0·40	0·40
Mg	0·20	0·20–0·45	0·45

Conclusions

Clearly, as with soil analysis, leaf analysis is not the final answer to determining the nutrient requirements of cocoa. As Smyth has said, there is no satisfactory substitute for field experimentation to establish the fertiliser requirements of cocoa. Even this, however, presents difficulties. For a field experiment to give reliable results it needs careful planning, a large acreage of uniform cocoa, trained staff and a considerable expenditure of time, money and effort. And the results only apply to the particular area, so that considerable caution must be exercised in attempting to apply the results elsewhere.

What, then, is the answer to the nutritional problems of cocoa? In a new area, soil analysis will give general indications of marked deficiencies and should include the minor elements. Leaf analysis will give confirmation, and considerable value should be placed on visual symptoms. Thus, in Ecuador, Tollenaar (14) found visual symptoms of boron deficiency in cocoa in new areas of land before any analyses were done. Symptoms of iron deficiency are so obvious that no other confirmation is necessary.

Leaf analysis will distinguish between visual symptoms which are rather similar, i.e. potassium deficiency and chloride toxicity. This may be done by the simpler technique of tissue testing. Normal chemical leaf analysis is expensive and time-consuming. In tissue testing the leaf tissue is chopped into fine pieces and extracted with Morgan's reagent. Very simple colorimetric tests are done on the extract, and while lacking the precision of proper analysis can give preliminary indications of not only deficiencies but toxicities in the crop.

In conclusion, it must be stressed that mineral nutrition is only part of the plant's requirement for optimum growth and yield. It is not always sufficiently appreciated that the most important soil nutrient is water and that when water stress occurs this will override fertiliser applications. Knowledge is slowly being gained of the physiology of the tree, and leaf analysis, though not yet satisfactory as a single practical tool, is one of many approaches to the problems of how best to achieve high yields.

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