A NEW LOOK AT FERTILIZER (NITROGEN) DOSAGE*

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This is a simplified account of the ideas behind a new policy of nitrogen dosage on estates. It must be stressed, however, that this new policy is a natural development from the older approach. The earlier scientists were placed in the position of having to advise estates on fertilizer applications with very few data to go on. In the circumstances, it is difficult to see what else they could have done except to advise that the estates at least replace what they remove in crop. This was essentially a pragmatic approach. This ratio method of applying fertilizer served the planting community very well, without a doubt.

But today we are in a more favourable position. For many estates we have fairly comprehensive data for, a dozen or more years, of yields, fertilizer applications, etc., division by division, and even field by field. It seems wiser to use these data to formulate, wherever possible, guides to fertilizer policy rather than to depend on a single arbitrary rule-of-thumb.

Ratio Manuring

The present practice on most estates is based on the idea that you ought to *replace* in the soil what you take away in the crop (Liebig's (1840) Law of Restitution). That is extended to allow some fertilizer for losses by leaching and so forth and some for increasing crop. Few estates use less than 8 lb of nitrogen (N) in a complete mixture per 100 lb of made tea. Many use a 10-lb ratio, some a 12-lb one, and a few even higher rates.

A decision is made by the owners or their agents on what ratio to use. Please notice that this is almost an arbitrary decision, which is usually not closely related to the biological facts of the estate as we now understand them.

Figure 1 shows graphically an 8-lb ratio, a 10-lb ratio, and a 12-lb ratio.

The line AB is the 8-lb-ratio line. The point to notice about this line is its *slope*. Reading from the line we note that:—

for a yield of 1000 lb of made tea, 80 lb N would be applied;
for a yield of 900 lb of made tea, 72 lb N would be applied.

Now the slope or gradient of the line is defined as the vertical rise divided by the horizontal distance, or $\frac{\text{ED}}{\text{CE}}$

i.e. $\dfrac{\text{the difference between 1000 and 900}}{\text{the difference between 80 and 72}} = \dfrac{\text{100 lb yield}}{\text{8 lb N}} = 12\frac{1}{2}$ lb yield per lb N.

*Based on an address to a combined General Meeting of District Planters' Associations of the Kandy, Pussellawa and Hewaheta Districts, given at the Kandy Club on Tuesday, 17th July 1962.

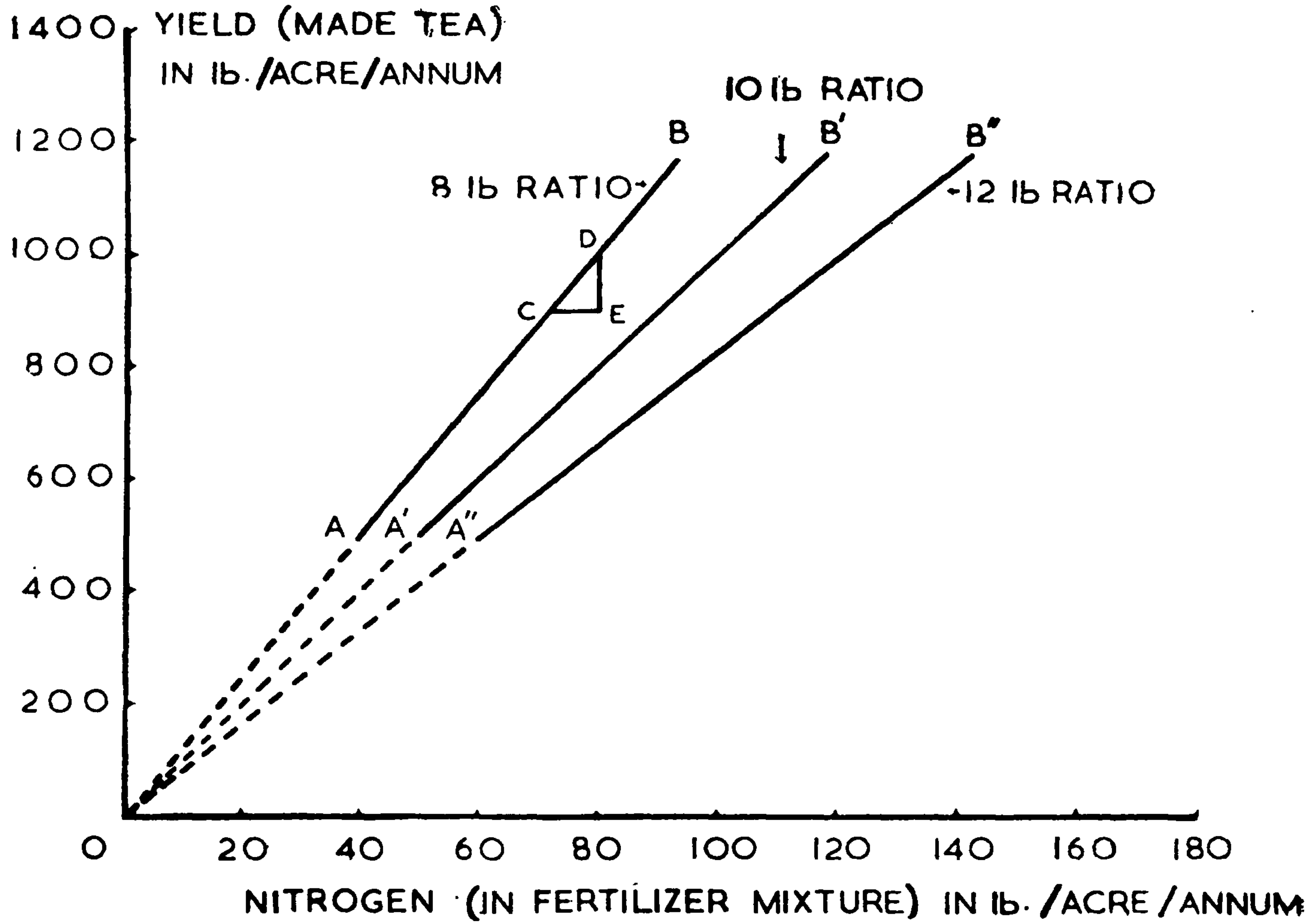

Figure 1. 8, 10 and 12 lb ratios

This slope is referred to, in statistical language, as the "regression coefficient" (see Joachim, 1961). Thus an 8-lb ratio would mean a slope of $\frac{100}{8} = 12\frac{1}{2}$. Similarly, a 10-lb ratio would mean a slope of $\frac{100}{10} = 10$, (Line A′ B′ in Fig. 1) and a 12-lb ratio would have a slope of $\frac{100}{12} = 8\frac{1}{3}$ (A″ B″ in Fig. 1). Thus the greater the ratio, the less the slope becomes. We shall return to these *slopes* a little later.

There is some variation in the manner of choosing yield for purposes of ratio manuring:

(*a*) the previous year's yield for the field;
(*b*) the anticipated yield for the year in question;
(*c*) the *post hoc* system.

The *post hoc* system on a 10-lb ratio works as follows: when a field has yielded 400 lb per acre since the last application of nitrogen, 40 lb of nitrogen per acre is applied. These and other methods differ somewhat in their results, but the principle remains the same: the amount of fertilizer applied shall be a fixed proportion of the yield.

The fallacies of ratio manuring

The fallacies of ratio manuring have been expounded within the T.R.I. by Dr H. N. Hasselo, and he is writing an account of them for publication. We have no doubt that the ideas behind the ratio system are not valid and the exposition is left to him. We shall now discuss the new approach to manuring.

Progress analysis

The basic idea is that we use all the information about how the estate *has* progressed in its yield over the past 12 years or so in order to obtain, in the first place, an index of its responsiveness. How has the yield of the estate been associated with increases of nitrogen? On the basis of past performance, what reasonable expectation of response can we have?

Let us start at the beginning with T.R.I. plot trials. How does tea behave in relation to nitrogen application? Let us take the figures from Eden's (1949) booklet on T.R.I. work in Agricultural Chemistry (Fig. 2).

Figure 2 shows the results from two complete cycles with N at zero, 20 lb and 40 lb/acre/annum, and three complete cycles with N at 40, 60 and 80 lb/acre/annum averaged over the cycles.

There is only one thing on which you should concentrate in Fig. 2: the *slopes* of the lines. Incidentally, the yields were only 600–800 lb then, compared to an average of 1,300 lb on St Coombs today; the fertilizer was applied in a *single dose*, once a year, and there were other important cultural differences between then and now.

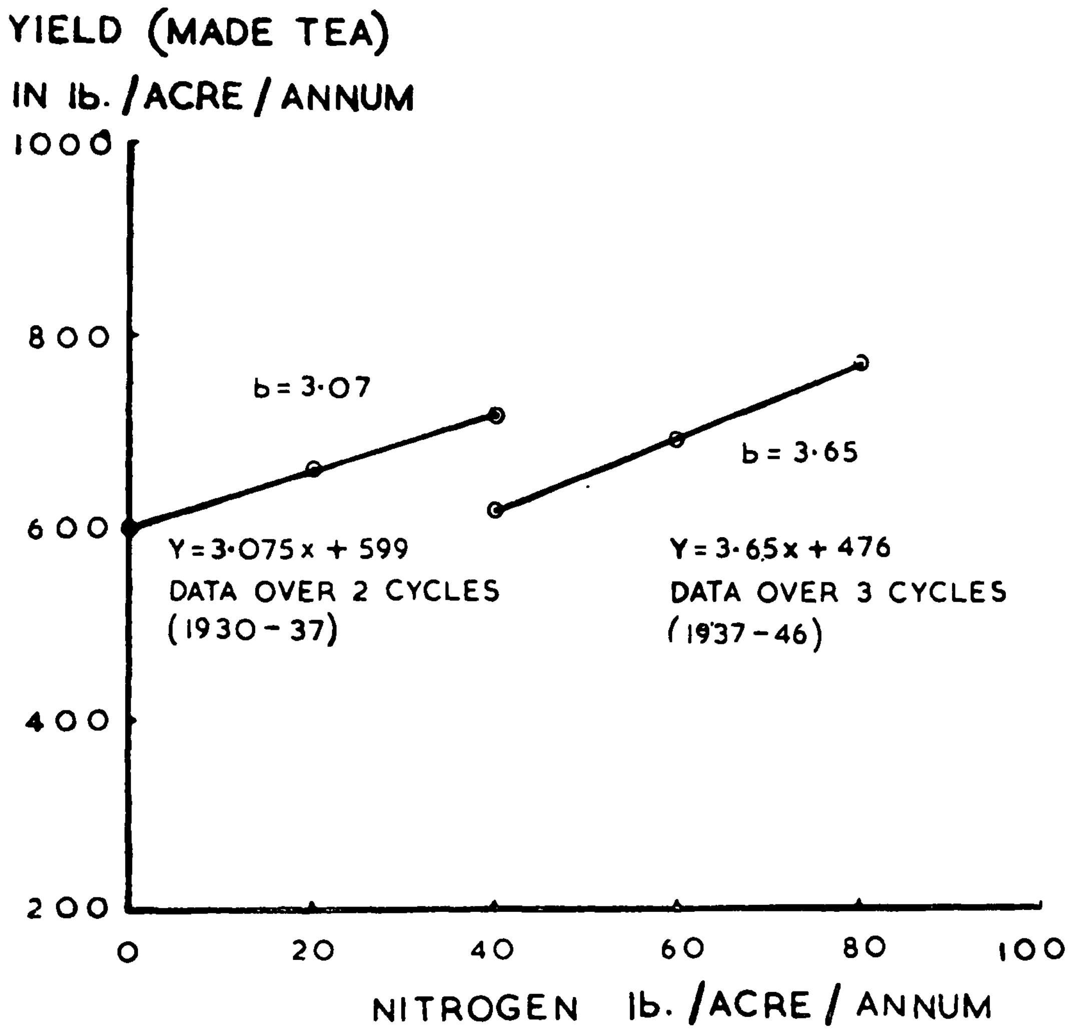

Figure 2. Nitrogen response lines

Now, what does the slope mean in this connexion? It is the average increase in yield associated with a unit increase in nitrogen. Averaging Eden's five cycles, the slope of the "yield-trend line" is roughly 3.4. This means that within the period under investigation (1930–1946), there was, on the average, an increase of 3.4 lb of made tea for each *extra* pound of nitrogen. When this figure is obtained from properly designed plot trials, it is a measure of the *TRUE NITROGEN EFFICIENCY* (TNE) for those trials—in this case, 3.4 lb of tea per lb of N.

Variation in true N.E.

Eden got these values of TNE for the two parts of his big experiment, but there is no reason to expect that other trials in other places or even trials today in the same place with other cultural methods, would give the same result. Since many factors tend to vary, especially in estate practice, the discovery of the true value of NE is virtually impossible. But—and this is the important point—underlying all the variations which obscure the true relation between yield and nitrogen, there *does exist* such a relation.

Ratio methods and progress analysis

In our theoretical analysis, therefore, we can assume that such a relation exists, but we cannot assign a particular value to it. Generally speaking, today, in Ceylon, we probably have TNE values ranging from zero up to about 8. For purposes of illustration we could take 4 or 5 as a mid-value. Let us take 5.

Position of yield-trend line

First of all, both experiments and field experience indicate that with no fertilizer applied you do get some crop. Further, an NE of 5 means that the yield-trend line has a slope of 5. But we have said earlier that a 10-lb ratio has a slope of 10. That is to say, the yield-trend line will start higher up on the left and will be flatter than the ratio line. Now, because the yield-trend line starts higher and is less steep than the ratio line, they must cross at some point. This cross-over point is called the CRUX.

Simplified case

Let us consider a theoretical highly-simplified case in which the response line represents what you actually get in crop at each level of nitrogen; and let us suppose the nitrogen is applied as a 10-lb ratio to the previous year's crop.

Suppose you start with 30 lb of N (N_1) and you get 600 lb of made tea, at A on the yield-trend line (Fig. 3). In the following year you begin to use a 10-lb ratio and you apply 60 lb of N (N_2) which is derived from the ratio line at B. Now, according to the yield-trend line, 60 lb of N will give you an expected yield of 750 lb of tea at C. You have thus not merely maintained your crop at the level of 600 lb, you have used extra nitrogen corresponding to AB (30 lb) which is available to increase crop.

In the next year, having had 750 lb of tea, on a 10-lb ratio you apply 75 lb N (N_3) (D on the ratio line). This not merely maintains the crop at 750 lb, it provides 15 lb of extra N corresponding to CD for increase of crop.

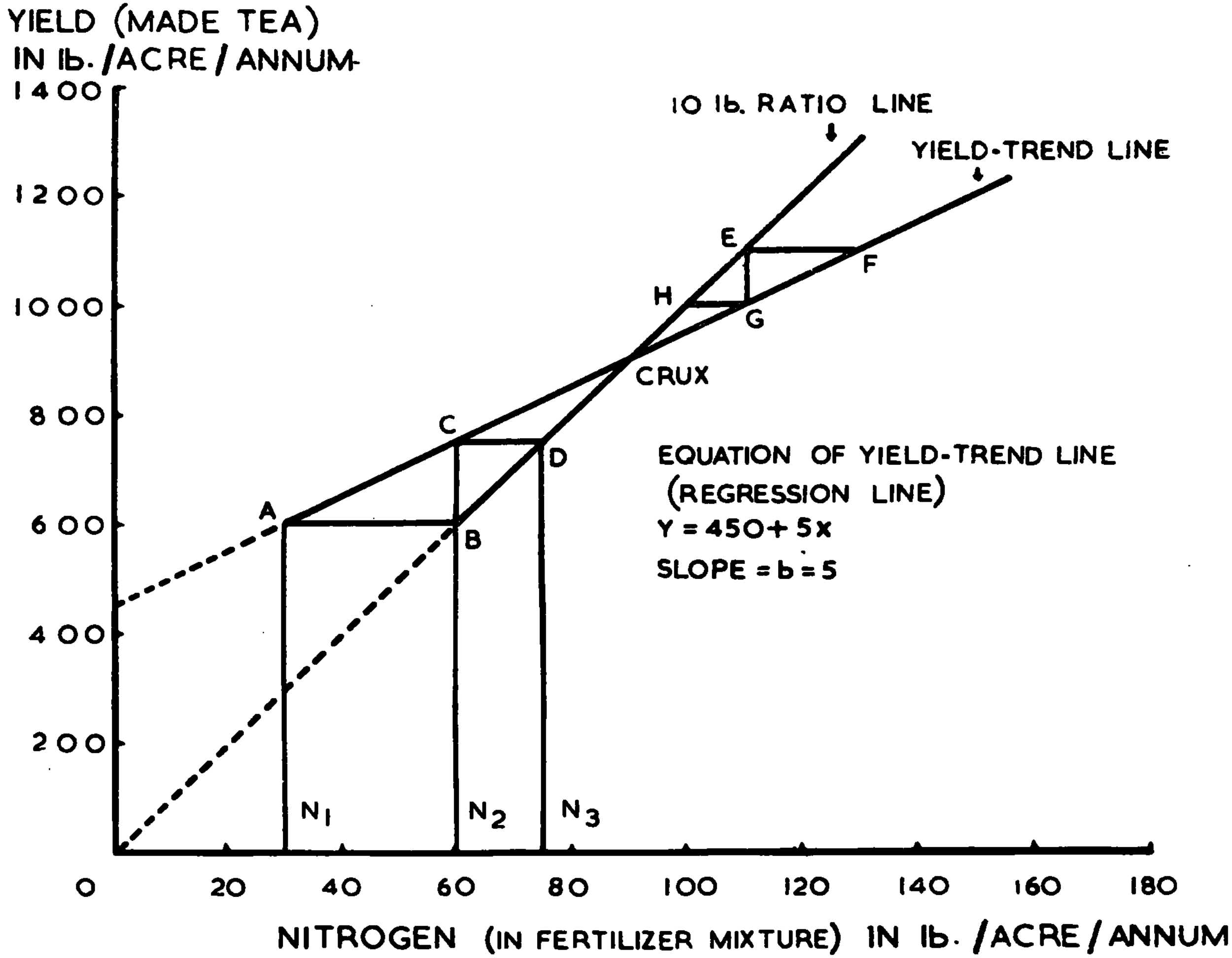

Figure 3. Regression and 10-lb-ratio lines

And so you go on. In the third year, the extra nitrogen for increase is only 7½ lb. As your yields go up and up, the extra nitrogen available for increase of crop gets less and less; until, at the CRUX, the nitrogen level on the 10-lb ratio is exactly what is needed to maintain the crop and nothing is left over for increase. Consequently, yield tends to get stabilised around the crux.

If, by chances of weather and so forth, you do get a higher crop, *e.g.* 1100 lb of made tea, then on the 10-lb ratio, you would apply only 110 lb N (E on ratio line). But to maintain this yield, you should have applied 130 lb N (F on yield-trend line). That is, you have under-manured by an amount equal to EF (20 lb). The consequence is that the expectation of yield drops, eventually to 1000 lb (G, on yield-trend line). If you therefore continue to use the 10 lb ratio, you would now apply 100 lb N (H on ratio line) and so on, There will, therefore be a *tendency* for the yield to drift back to the crux in a few years.

It does not matter if there are wide variations in the actual form of the yield trend, the general case will hold, in which the two lines will cross*, and thereafter your nitrogen and your yields will stop rising. This appears to be what has actually happened—the ratio system at first giving good rises and yields and then ceasing to give any rises at all.

Conventional graph of the simplified case

The method commonly used in the industry to study effects on yield is to plot time in years horizontally and put yield, nitrogen, and so forth vertically, on separate scales. If we do this for our theoretical case, we get a graph like Fig. 4.

Notice that the nitrogen dosage goes up rapidly at first and steadily levels off. And correspondingly the yield goes up fast at first, and then levels off.

In fact the 10-lb ratio was highly beneficial to yields at first, but later it resulted in only small increments of nitrogen being given, so that we got only small increments of crop.

Real Cases

You can see the theoretical effect that we have just described in the data of some estates or even of whole agencies—virtually static crops with virtually static nitrogen dosage. There is oscillation, but the effect is there. This is encouraging, so now let us get down to individual cases. Straight away, let us recognize that there is no simple general advice that can be given equally to all estates—like the ratio idea. This will not be strange to you, for superintendents, more than anyone else, know how very individual estates are—and even fields. You cannot expect some simple rule for action to apply equally to all of them.

Apparent nitrogen efficiency

Now the central idea today is *nitrogen efficiency*. The word "*nitrogen*" here refers to the nitrogen applied on estates in the complete mixture, which, of course,

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* There are exceptions to this. If the apparent nitrogen efficiency (ANE - *see* below) is equal to $\frac{100}{\text{ratio used}}$, the two lines will be parallel and hence there cannot be any crux. Thus, if the ANE is 8 and a 12½-lb ratio has been used, there will be no crux. This situation is however very rare.

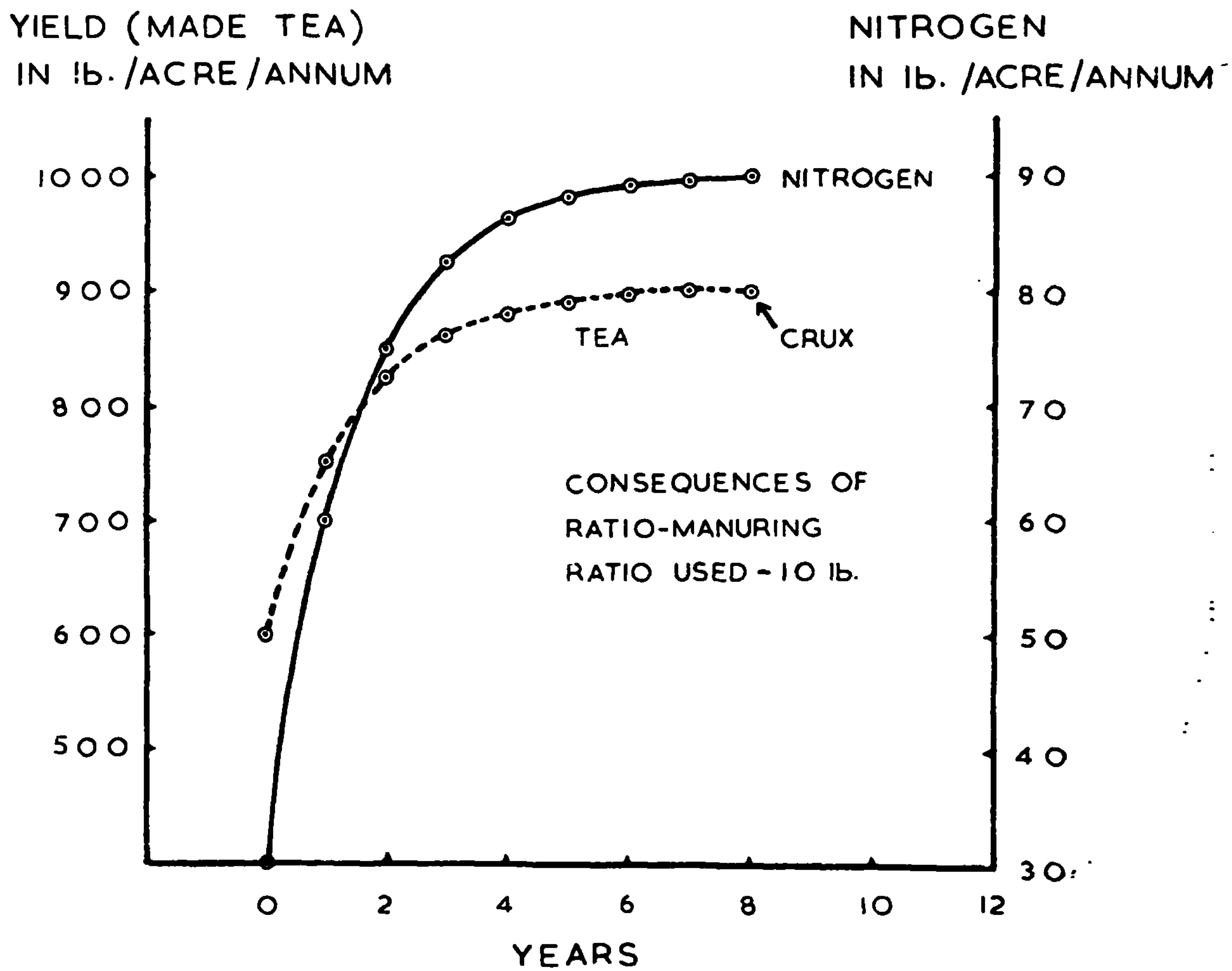

Figure 4. Conventional graph of yield and nitrogen on a 10-lb-ratio.

includes P and K in certain fixed proportions. How can you determine the nitrogen efficiency of an estate or field? The answer is: you cannot do so. You cannot find out what the *true* nitrogen efficiency (TNE) is, with any degree of accuracy. What you can do, however, is to find the *apparent* nitrogen efficiency (ANE). This is the slope of the line of yield and nitrogen (provided the trend is linear), but it is complicated and obscured by influences other than nitrogen. Does the line of *apparent* nitrogen efficiency give you useful information on which to decide action? Our experience so far has been that in many cases, for many estates, it does. In a few cases it does not help much.

Advisory Procedure

First we get from an estate the data of yield and nitrogen dosage over a period of years—usually twelve years. We ask for information about any considerable changes in practice during the period. Then the statistician plots the data on a *graph, yield against nitrogen, putting the year in pencil by each point. Then he calculates the straight line of best fit by the method of least squares, so finding the apparent nitrogen efficiency. The Chief Advisory Officer looks up the estate file, to find out what troubles they have come to us about. Then the three of us talk about it, following the yields year by year on the graph and trying to see what has been happening. We may then formulate some questions for the superintendent and he then comes up to see us at the T.R.I. We discuss the whole matter with him and we try to find a nitrogen-dosage policy that seems to us to fit our interpretation of the data, is acceptable to the superintendent, and is likely to be acceptable to his owners or agents. We incorporate this in a letter.

You can see that by this method, each estate takes up a lot of time. So please do not *all* rush your data to us, but come if you really want advice and are willing to act on it.

Let us now discuss some cases.

CASE GROUP 1

Suppose for an estate we actually get an apparent nitrogen efficiency of say, 6 with the actual yields lying fairly close to the yield-trend line. The number 6 for ANE is a common one.

We notice that increments of nitrogen have been decreasing and the yields tend to cluster around the crux. We can discover no large complications. We suggest: raise the application by about 10 lb./acre/annum each year. It is possible that you may not get the benefit of increased fertilizer applications in the first year —there is some evidence that this is in fact the case in the high country. If so, do not reduce fertilizer application, but at least keep it constant. If yields do go up, increase by another 10 lb/acre/annum.

This deferred effect of increased manuring is most troublesome when people use ratio manuring strictly. For example, from good weather, the crop bumps up—so in the *second* year, up goes the nitrogen. But the weather is average in the second year, and the effect of the nitrogen is deferred, so down goes the crop in spite of the increased N. In the third year, the nitrogen is correspondingly reduced, but the deferred effect of the second year's extra nitrogen occurs, so crop goes up in spite of decreased N. This fluctuation of N according to crop is most confusing, especially because of the deferred effect.

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* Special graph paper for this purpose, designed in the T.R.I., may be bought from Messrs H. W. Cave & Co., Ltd.

CASE GROUP 2

In this group, the apparent nitrogen efficiency is low, near zero, or anyway much below Eden's figure. It is then likely that some factor other than nitrogen is limiting yields. In such a case, we say: look for the limiting factor. It may be heavy shot-hole-borer attack, or magnesium or zinc deficiency, or too much shade. Remove the limitation and come again. This group may be 15–20% of estates.

CASE GROUP 3

In this group the points are so scattered about that no plausible line can be drawn even after allowing for strikes and big changes of practice. We do not know how large this group is, but so far about 10–15% of estates fall into it.

Summary

1. Ten-pound ratio manuring assumes that the responsiveness of the estate is 10. In the vast majority of estate data so far examined the responsiveness of estates is much below 10. The new method attempts to suggest an amount of fertilizer suited to the responsiveness of each estate.

2. Ratio-manuring depends on one year's yield, which is normally subject to wide fluctuations. The yield-trend method (or regression method) takes into account the performance of each estate over the past 12 years to obtain an index of its responsiveness. This index, in turn, is used, together with the history of the estate and the discussion with its superintendent, to formulate a fertilizer policy for the estate. We believe that yield increases in Ceylon can gain a new impetus by this method.

References

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