Fifteen Years of Fertilizer Trials in Coconuts, Cocoa and Coffee

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This paper was presented by Mr A. E. Charles, Chief Agronomist, at the ANZAAS Congress, Port Moresby, in August, 1970. Mr Charles emphasized that he was reviewing the work of a large number of officers of the Department of Agriculture, Stock and Fisheries.

THE programme for fertilizer trials by the Department of Agriculture in Papua and New Guinea was started in the mid-fifties by the late Mr Frank Henderson with a firm direction that the purpose was economic. It was not enough to demonstrate that crop plants would respond to fertilizer; the trials had to show that the use of fertilizers would bring increased profits. This provision demanded a fair standard of precision in trials, sufficient size for reliable estimation of per acre yields, and siting of trials on areas representative of extensive plantings of the crop. On several occasions, field trials have been preceded by extensive surveys aimed at identifying problems and selecting suitable sites. The programme began at a time when the Department's chemical services were in their infancy and early trials were diagnostic : they aimed to show whether all the major and minor nutrients were adequately supplied. More detailed studies followed to learn more of the quantities of additional nutrients needed. Nowadays most of our field trials study rates and methods of application of a few nutrients already identified as deficient, either in earlier field trials or by soil and foliar analysis.

Trials in coconuts, cocoa and coffee present a number of problems not shared by trials in temperate crops. One of the greatest problems is yield recording. The temperate zone agronomist can usually get his yield recording over in a period of a few weeks or make a yield estimate at a single inspection of a tree. Coconuts, however, produce all the year round—a new fruit bunch ripens approximately once a month on each palm. Our records are generally based on estimates of nut numbers made by inspection with binoculars twice a year. This permits us to place trials on properties where problems occur, without our having to ask the managers to keep yield records which are more detailed than they require themselves. Cocoa crops mature in "flushes" but some pods are harvested throughout the year, and timing of flushes is somewhat variable. We have found no alternative to recording yields at each of 12 to 15 harvests per year, which means it is impractical to do much work outside our own experiment stations. Coffee likewise produces some crop all the year round: although there is usually one main flush producing 75 per cent of annual yield, this may be spread over a period as long as six months. We have to record yields over 10 to 12 harvests per year and have had to restrict trials to our own stations. The number of recordings forces the agronomist to rely heavily on field workers and also generates a heavy load of arithmetic. These factors severely restrict the number of trials to be handled.

A second problem lies in the area occupied by field trials. Genetic variability is high, so one cannot work with fewer than 30 to 50 trees per treatment. Coconuts are mostly planted at 56 per acre; a 16 tree plot with a single guard row therefore occupies two thirds of an acre and the simplest trial covers 10 acres. Within this area variability may be formidable. Cocoa presents similar problems on a reduced scale, being planted at 220 to 350 trees per acre. Coffee, at 600 to 1,200 trees per acre, does not have this problem, but it has others. For example, coffee is unusually sensitive to impeded drainage; even minor variations in drainage can cause big differences in yield. To ensure that different treatment responses are not just due to chance, each treatment in a coffee trial has to be repeated more times than with most crops.

Temperate zone workers no doubt think of tropical plant growth as exceptionally fast, yet some tropical crops are depressingly slow. The coconut takes 6 to 7 years to start bearing; its fruit takes 12 months from pollination to maturity. Coffee cherries take 9 to 10 months to mature and cocoa pods 5 to 6 months. Thus yield responses tend to be slow. The effect of a fertilizer application may not appear until more than eighteen months later.

As in other perennial crops, biennial bearing can be a problem. Coconut is not particularly prone to this and cocoa less so than many temperate orchard crops. Coffee shows full biennial tendencies and in some situations yield in one year may be two to three times as great as in the succeeding year. In coffee trials at Aiyura, we have coffee on drained swamp soil showing marked biennialism while nearby coffee of similar age and treatment but on a different soil shows no such pattern. One or two of our trials have been complicated by certain plots getting out of phase with others, so that treatment contrasts may reverse in alternate years. Coffee sometimes bears so heavily in the peak year that the tree loses its leaves at the end of the cropping season. Usually it stages a remarkable recovery and, after a year's rest, bounces back for another massive yield; but should unfavourable conditions follow the defoliation, the trees may die, playing havoc with field trial analyses.

Those are some of the problems. Some of them can be overcome by mathematical analysis, comparing yields before and after treatment.

Coconuts

Coconut fertilizer trials began in 1955 in New Ireland where large acreages showed severely declining yields, while appreciable areas had been abandoned. A soil survey showed that almost all palms were on coral-derived clayloam soils, with the decline most evident on older, acid, generally deep, yellow-brown soils. Younger, neutral, generally shallow red-brown soils with free coral in the profile usually supported healthy productive palms. Following a survey by an agronomist, comprehensive diagnostic trials were put down on both soil types. The trial on the older soils demonstrated a response to potassium with an increased copra yield giving a profitable, though not exciting, return. The trial failed to show appreciable response to any other nutrient and the trial on the younger soils did not demonstrate response to any nutrient. Yield response was not evident till the second year after fertilizing and did not reach a maximum until the third year. Subsequent detailed trials with potash have shown better response from broadcasting fertilizer over a larger area rather than a small ring round each palm; as good or better response from two-yearly rather than annual application; increase in nut size as well as nut number; marked growth response in young seedlings; and better response (on at least some sites) to potassium sulphate than potassium chloride. In all trials pretreatment yield records were made and proved very useful in reducing error variance. Most New Ireland plantations are now using potash as a standard practice.

A survey of Papuan plantations in 1956 showed the most important soils to be base saturated alluvial loams and black sands. A trial on a loam gave an indication of potash response but not at an economic level. A more recent trial on a site where leaf analyses showed very low potassium levels has given an economic response. A trial on a black sand where palms were yellow produced the rather odd result of no response attributable to any individual nutrient but a notable improvement in colour of all palms in the fertilizer trial block. This may have been due to poaching between treatments but more probably was a sulphur response, as most fertilizers were sulphates and subsequent experience confirms that the yellowing was typical of sulphur deficiency.

The above trials confirmed economic responses to potash, known from overseas work to be a vital nutrient for coconuts. Pioneer work by our chemists has shown widespread incidence of sulphur deficiency in Papua and New Guinea. Replicated trials on seedling coconuts in pumice soils in the Rabaul area have shown major growth response to sulphur and especially to sulphur plus nitrogen, while urea on its own proved virtually lethal. Recent trials on palms on high pH alluvials in the Markham Valley have shown yield response to nitrogen plus sulphur, but it has not yet been clearly established that the responses are economic.

Cocoa

A comprehensive trial on cocoa under standard Leucaena shade at our cocoa station, Keravat, in 1955, produced evidence only of slight response to nitrogen. About that time, results were coming in from overseas showing that much greater fertilizer responses could be expected in unshaded cocoa; and local trials were showing that shade removal gave increased yields without serious tree deterioration. Our subsequent fertilizer work has been either based on unshaded or lightly shaded cocoa or has specifically studied shade/nitrogen interactions. Trials in New Britain have shown major and very profitable response to nitrogen on unshaded cocoa but little response under standard shade. The need for nitrogen is recognized by growers and its use is standard in most areas. A trial on cocoa growing under coconuts on a pumice soil has shown much greater response to four applications per year (F4) than to two (F2); yields in 1969 to ratios of 1 and 4 lb urea per tree were in the following proportions:—

Control	100
N1F2	135
N4F2	150
N1F4	172
N4F4	187

Response to nitrogen, at least in the early stages, has shown up almost entirely as an increase in pod production about six months after fertilizer application. In the first year, using a low rate of nitrogen, the response was clearly present but quite ephemeral. It was several years before fertilized trees showed consistently better yield than controls and even after ten years the main effect of six-monthly fertilizer application comes in the seasonal flushes, with yield falling back near control levels in the intervals between flushes. However, three-monthly fertilizer has given yield increases remaining more consistently above control levels. It appears that the cocoa tree tailors the size of its flush crops to the amount of nitrogen available.

Most of our cocoa trials have been with nitrogen. In the trial for which results are quoted above, superphosphate was included as a factor for several years but no response was obtained. In New Ireland, cocoa interplanted in a coconut trial block showed a growth response to potassium but yields were not recorded.

Coffee

Because coffee yields more than cocoa (up to 1 ton dry beans per acre compared with seldom more than half a ton for cocoa) it tends to exhaust the soil more rapidly, while its high value ($750 per ton) makes the economics of fertilizing very much more favourable than for coconuts. Many growers use rates as high as ½ ton compound fertilizer per acre per year.

Coffee is grown on a variety of soil types and as it has not been possible to put in trials off our stations, our approach has been to demonstrate the levels of yield increase likely to be obtained and to use our station trials to provide information on the nutrient content of leaves associated with deficiency and response. We have demonstrated yield increases of as much as 100 per cent with nitrogen and potash, even on shaded coffee. In one trial response to muriate of potash has increased at rates up to 4 cwt per acre, while in unshaded coffee we have response to nitrogen increasing proportionately up to 4 cwt per acre of sulphate of ammonia, indicating that the optimum could be appreciably higher. Like cocoa, coffee tends to yield more and respond more to fertilizer in the absence of shade and our only demonstration of phosphorus response (and that quite small) has been on unshaded coffee. An interesting feature of the trial concerned has been that the fertilizing has induced biennial bearing and fertilized plots give all their response in alternate years with sometimes lower yield than controls in the "off" year. This no doubt indicates some other limiting factor, very likely moisture, although possibly boron or zinc. Recent trials, which have not run long enough to give clear yield trends, show visual response to soil applied borax and a small early yield increase; and an early yield increase with magnesium on plots which have been fertilized with potash for many years. A zinc sulphate spray treatment in a trial at Aiyura showed a dramatic yield decline to one third of the yield of unsprayed plots. The spray apparently caused fruit shedding, possibly because it had not been neutralized. A surprising feature was that foliage was not injured and there was a definite amelioration of deficiency symptoms on treated trees. As in other crops, sulphur deficiency appears to be very patchy in incidence—one tree may die from it while a tree 30 ft away remains healthy and productive. This makes demonstration of sulphur response difficult, but strong indications of response in more than one trial, coupled with chemical evidence, leave no doubt that there have been genuine yield increases due to sulphur.