

RECENT STUDIES ON THE MANURING OF COCONUTS
IN CEYLON*

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ALTHOUGH coconuts have been grown as a plantation crop in Ceylon for over half a century, it is only comparatively recently that an attempt has been made to study the crop on scientific lines. With the increased use of artificial manures and the possibilities of developing coconuts as the premier agricultural industry of the Island, the Department of Agriculture in co-operation with coconut planters made the first systematic attempts to organise field experiments on manuring.

In 1912, single-plot experiments to test different manurial treatments on old coconut palms at Peradeniya were commenced and the results published in 1918 by Bamber (3). A report on the trials to ascertain the possibilities of coconuts on lands under tanks in the North-Central Province under irrigation commenced in 1908 at Maha-Illuppalama were published in 1913 (4). Both trials were, unfortunately, confined to areas where coconut cultivation was not particularly successful owing to soil and climatic conditions. In 1918, Lyne (26) published the results of manurial experiments at Pitiaḱande estate, Kurunegala. A. E. Rajapakse had in the meantime commenced his own unique series of experiments at the Manuring Trial Grounds on the sandy cinnamon soils of Negombo and at Alexandra Estate, Ja-ela (32). In the Chilaw Coconut Experiments conducted by the Department of Agriculture, a heavy poorly-drained estuarine soil hardly representative of the general soil conditions of the district was selected and for the first time statistical methods were applied by Joachim (21) to the records of this experiment kept from 1919 to 1928.

When the Coconut Research Scheme was established and we were called upon to advise and make recommendations on the manurial programmes of estates, it was realised that the available experimental data were unreliable, and the conclusions unconvincing and conflicting. *The sites selected for the trials were unsuitable and represented extreme soil types. From experiments on such soils results of general applicability could not be obtained.*

Further, these experiments had been planned before the modern technique of field experimentation was developed.

Experiments carried out in other countries too were of little value, as the soil and climatic condition of estates in Ceylon differed considerably from those in India (28, 29, 30), Malaya, (6, 7, 8, 9), Philippines, West Indies

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(41), British Solomon Islands (46), or New Caledonia (20), where, certain manurial experiments had been carried out. Thus the work of Patel in India (28, 29, 30), was strictly applicable to the peculiar conditions of the sandy Malabar soils subject to prolonged periods of drought. Similarly the work in Malaya from 1931 to 1936 by Belgrave and others (6, 7, 8, 9), where no significant or economic response was obtained to manuring and cultivation on the heavy clays with large reserves of fertility and a shallow water table, would certainly be inapplicable to the lighter soils and lateritic gravels of medium and poor fertility on which the major area of coconuts is planted in Ceylon.

It may perhaps be an irony of fate that the Coconut Research Scheme began to function with its new laboratories and field experiments at Bandirippuwa estate soon after the economic depression had begun in 1930 and the copra market reached its rock bottom in 1933, and we were called upon to advise on problems of manuring and cultivation to suit the new conditions. The coconut industry faced with these new problems had to rationalise under scientific guidance the traditional agricultural practices to meet the new conditions.

It was under such circumstances that the first modern field experiment on the manuring of coconuts was commenced in November, 1934, at Bandirippuwa estate, and further experiments on similar lines followed in an attempt to study scientifically the manurial and cultural needs of the coconut palm.

Before discussing the results of these experiments carried out during the last 10 years and their practical and economic significance it would be useful to refer briefly to two important considerations: (a) The factors in coconut cultivation under Ceylon conditions, the physiological characters of the coconut palm that form the basis of its nutrition, and the soil and climatic conditions under which it is cultivated in Ceylon; and (b) the application of statistical methods to field experiments on coconuts.

(A) FACTORS IN COCONUT CULTIVATION

1. *Characteristics of the Coconut Palm.*—The coconut palm is grown in Ceylon under a variety of edaphic and climatic conditions so that a brief consideration of its physiological characteristics will help to gain a better understanding of the yield factors influencing its productivity, and therefore the problems investigated that form the subject-matter of this paper.

In contrast to dicotyledenous perennials such as orchard crops, the monocot, *Cocos nucifera*, once it comes into bearing at an age between five to ten years depending on its environment and cultural treatment, continues its unique perennial productivity yielding a bunch per month throughout the year. It may, therefore, be truly called a perennial both in growth and cropping. It produces at the axil of the frond a characteristic inflorescence (a spadix) monoecious, protandrous, with pistillate and staminate flowers borne on the same rachis. As the female flowers (button nuts) after fertilization are believed to take about 1 year to develop into mature coconuts ripe for picking, it may be assumed that manurial and cultural treatment cannot be expected normally to produce their response within one year.

There is no seasonal growth in the normal sense, either vegetatively or in crop, except that rainfall (its intensity and distribution) and its

anti-climax drought, influence leaf emergence and, particularly from the point of view of yield, the number of nuts per bunch and the weight of kernel (the copra-outturn).

It may be said that there are a few cultivated plants to compare with the coconut palm in its unique adaptability as shown by the physiology and anatomy of its root and leaf systems, to tolerate within very wide limits a range of adaphic and climatic conditions; so that as an ecotype, it can remain a xerophyte under dry conditions, or a mesophyte under wet and waterlogged conditions, or even a halophyte under saline conditions such as prevail on the littoral subject to high tide.

2. *Soil and Climate.*—As extensive planting took place in the Island from 1880–1910, the coconut palm happened to be established on a variety of soil conditions. In its original home, restricted to the coastal littoral of archipelagos and islands, coconuts in Ceylon have been adapted to an ubiquitous environment. Beginning with the sandy soils and loams overlying miocene limestone in the Jaffna Peninsula where the earliest plantations by European pioneers were established, to the light soils resting on a subsoil pan of calcareous and ilmenite sandstone and clay in the Eastern province, subject to poor rainfall during the North-East monsoon and long periods of drought, cultivation has been extended to all range of lateritic soils and gravels of poor and medium fertility of the Western and Southern provinces and the granitic outcrops of the Central Province under heavy rainfall. On the other hand the best estates are situated on the ideal loams of the alluvia of the Ma-Oya, Deduru-Oya, Bathulu-Oya and their tributaries in the North-Western Province, and the estuarine deposits of the silted-up Negombo, Madampe, Mundel and Puttalam lagoons with heavy and medium soils, often waterlogged, under conditions ranging from medium rainfall of 60 inches in the Chilaw district to barely 40 inches in Puttalam. Marine and wind-blown sand extending from Dondra Head to Kalpitiya, interspersed with reclaimed mangrove formations where the estuaries debouch into the sea, and the extensive cinnamon sands of the Negombo district and elsewhere, often overlying an impermeable sub-soil with an iron-pan, complete the range and variety of soil and climatic conditions under which the coconut palm has grown, sometimes thrived, and often led a lingering existence, in its attempt to prosper or survive as a hardy and adaptable perennial. It is therefore not surprising to expect a range of productivity and yield and a corresponding array of manurial and cultural problems that the soil investigator has to probe into.

3. *Cultural and Manurial Practices.*—Cultural practices were evolved during the early stage of development of coconut planting and then have been subsequently modified, particularly as a result of the development of the artificial manure industry. The manurial practices may be briefly summarized as follows: (i.) It was recognised that the palm responded to liberal manuring; (ii.) little attempt was made to substitute the more expensive organic manure, particularly oil cake, guano, fish meal and blood meal by cheaper synthetic nitrogen compounds, until the latter were advocated by us after the establishment of the Coconut Research Scheme (33, 34); (iii.) Bone meal was largely used, as much as 6 lbs. per palm and there was partiality to large applications of phosphoric acid, based on the view that

Ceylon soils were deficient in phosphoric acid and that phosphoric acid favours the development of the nut. (iv.) The proportion of N-P-K in manure mixtures was in the rate of 50 : 100 : 70, the rates per palm being 0.5 lb. N. 1.0 to 1.2 lb. phosphoric acid and 0.7 lb. potash.

THE APPLICATION OF STATISTICAL METHODS IN FIELD EXPERIMENTS ON COCONUTS

A consideration of the practical and statistical implications involved in the design and management of field experiments on coconuts is extremely useful in a study of the subject of coconut manuring. Indeed this aspect of the subject can form a separate paper by itself.

A perennial such as the coconut palm, producing bunches and nuts every month (in contrast to other dicotyledenous orchardcrop perennials producing only one seasonal crop annually) presents to the field experimentalist additional problems not encountered in dealing with experiments on annual arable crops. These may be summarized as follows :—

(a) The yield data come from a limited plant population. Coconuts are planted under estate conditions at no more than 60–70 palms per acre, compared to cereals or similar crops where a plot size of, say, $1/40$ of an acre may have a plant population of several thousands per acre. In this respect even out of perennial crops such as tea, rubber or cocoa, coconut palms are planted at the widest distance.

(b) The palms themselves are far from uniform in their genetic composition and hence in their potential yield capacity. Cheesman (12) has rightly stressed that for cross-fertilised heterozygous crops such as coconuts and oil palms, where the material is highly variable, a great deal remains to be done in carrying yield analysis much deeper than the somewhat superficial observations which in several cases are the best we have to date.

It is for this reason that it is absolutely necessary to record separately the yields of individual palms. An examination of such records, as shown by our own work, shows up interesting differences in the behaviour of palms in differential response to manuring as related to seasonal effects such as drought and rain, and other physiological characters. Some palms may give consistently higher yields, some appear to need a rest after bearing a heavy crop, some may give a consistently higher proportion of female flowers in relation to the nuts set, or the copra out-turns may be influenced.

In fact Patel (28) has indicated that there is a differential response to manuring of good and bad palms, *i.e.*, between potential high yielders and potential low yielders, and this is an important point which needs detailed examination from the point of economics of manuring—in fact the subject of selective manuring of palms.

(c) Rarely is it possible to get a uniform extent of soil over an area of even 10 to 12 acres. In our main experiment (a $3 \times 3 \times 3$ NPK factorial experiment) which occupies nearly 30 acres, even after the most careful preliminary selection of the sites for the 6 blocks of the experiment, the variation in soil uniformity is considerable and perhaps serious from the point of view of experimental accuracy, as shown by the very large Block Variance.

(d) In any mature plantation there always are several age classes. Some planted as supplies to vacancies created by lightning or beetle damage are quite a common feature on a mature full bearing coconut estate.

(e) Even when the trees are of the same age, some bear early and come into full bearing much earlier than others which may be slow in maturing and continue to yield heavily for a much longer period.

(f) *Plot size.*—The trees are widely spaced, 60–70 palms per acre and therefore only a relatively small number can be included in a single plot, as apart from the question of acreage available, if the plots are made too large, the major soil fertility differences within the blocks will counteract the advantage gained by increasing the number of palms per plot. This has been well illustrated in the uniformity trial worked out by Joachim (22) as well as by ourselves (31). On this basis 18 palms were selected as the plot size, consisting of 3 rows of 6 palms each, giving a minimum standard error. Even 18 palms represent an area over one-fourth acre and the effects of soil differences within plots will be bound to be considerable.

Belgrave and Lambourne (7) in their experiments in Malaya, using a split-plot design adopted a main-plot size of 16 palms for the cultivation treatments and a sub-plot of only 4 palms for the manurial treatments. With such a small sub-plot it is not surprising that no significance was obtained for the manurial treatments, but only for the cultivation treatments.

(g) *Guard Rows.*—It is well-known how diffuse and extensive can be the distribution of the root-system of the coconut palm, particularly on sandy soils. The provision of adequate guard rows is, therefore, absolutely necessary.

Belgrave and Lambourne (7) in Malaya adopted a system of deep drains separating one plot from another. Under our conditions this is not satisfactory, as coconut roots, on light soils can bypass the drain from below and encroach on the adjacent plot, thereby causing interfering border effects.

The most efficient system, but which utilises a large area is to establish separate guard rows around every plot, so that between the effective plot units there will be two guard rows. Unfortunately, this was not adopted in our experiments and exigencies of extent of land available has made the provision of even one guard row, a severe strain on the layout of the experiments.

In this system each tree in any one guard row is given the same treatment as the plot to which it belongs, but the yields of the border rows are not recorded. In our case when only one common guard row was adopted and manuring done in circular trenches, the half circle proximate to one plot was given half the manurial doses corresponding to that plot.

(h) *Demarcation of Plots, Organisation and Planning.*—What Hoblyn (19) calls errors of the “damn fool” order are very likely to occur in experiments with a perennial, where the crop is picked once in 2 months as in the coconut palm. For reasons explained before, separate records of the yield of every individual palm of each plot have to be kept. Unlike the sampling of the produce of one whole plot in one harvesting operation as, say with cereals, the greatest care is necessary when individual palms in different plots have to be separately recorded. This is made yet more difficult by the fact that nuts fall from mature bunches before the actual pick is due, and roll over to adjoining plots, particularly on sloping land.

(i) *Premanurial Records*.—In most of the experiments premanurial records for at least one year were kept to adjust yields of experimental years by Sander's method of co-variance analysis (36). That it is useful in a perennial like coconuts, is undoubted, and in view of the long-range nature of field experiments on coconuts, should be adopted.

Lucy (25) in an experiment on oil palms in Malaya kept preliminary records for six months and so arranged the plots that at the commencement of the experiment the mean yields for the treatments were about the same. This method of manipulation of data for statistical purposes is of course unpardonable. The only sound method therefore is to keep premanurial records for at least one year and correct by Sander's method.

(j) *Season, Soil and Climate*.—When the varied soil and climatic conditions under which coconuts are grown in Ceylon are kept in mind, the necessity of replicating manurial experiments on different soils assumes particular importance. It is hardly necessary to stress the importance of continuing the experiments during a number of years to study in detail the effect of season which is a very important factor influencing the yield of coconuts.

(C) PROBLEMS OF COCONUT MANURING

It will now be useful to classify at this stage the numerous problems that we have to investigate on the manuring of coconut palms. At the time our investigations commenced in 1934, manures were used on estates, more so empirically than scientifically, and cultural practices in particular have been implicitly followed without a *raison d'être* under a variety of soil and climatic conditions without adequate modification. In what directions such practices were wasteful and uneconomic, unnecessary and perhaps redundant, it was our duty and function to determine.

The following classification of such questions will prove illuminating, and may give an idea of the extensive field of investigation that a programme of research will have to include, if the subject of manuring and nutrition of the palm is to be based on a scientific foundation as against the uncertain vagaries of empirical tradition.

I.—BASIC MANURES

A. (a) The use of nitrogen, phosphoric acid and potash, to produce the most economic response. The physiological basis of mineral nutrition of the coconut palm.

(b) *Subsidiary manures and their uses*.—Lime and salt have been traditionally used.

(c) Quality of manures: Organics *vs.* inorganic nitrogen manures; Bone meal *vs.* Ground rock phosphates, *e.g.*, Saphos; cattle manuring *vs.* green manuring *vs.* artificials.

(d) Cover crops and their utilisation.

B. Time and frequency of application of manures.

C. Methods of application of manures, *e.g.*, in circular trenches; broadcast and ploughed or in long-line trenches between palms;

II. Use of husks for cultivation and manuring.

III. *Cultivation*.—Ploughing, soil turning, harrowing frequency in relation to soil and climatic conditions.

(To be continued.)