Ceylon Cocon. Q., (1981) 32, 72—79
Printed in Sri Lanka

Response of Coconuts to Fertilizer and Advice to Sri Lankan Growers: An Aggregative Approach

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ABSTRACT

Aggregative approach appears to be an useful alternative in modelling fertilizer response under non-experimental conditions. The results obtained using this approach seem to support some of the earlier findings on economically optimal rates of application.

Response of palms to fertilizer under non-experimental conditions appear to be encouraging. For moderate rainfall conditions the profit maximising quantity of fertilizer appeared to be markedly stable under the market conditions which prevailed during 1956 to 1981. The simple estimation procedure developed here can be extended to measure profitability under different rainfall conditions if field data is available for coconut growing areas giving the nut production from unfertilized coconut lands under different rainfall conditions. Once this information is available definite statements on profit maximising quantity of fertilizer and the profitability aspect of fertilizer use in coconut production can be made in advisory pamphlets.

INTRODUCTION

Widespread use of fertiliser appear to be the best short term method of increasing coconut production in Sri Lanka. Field studies and experimental findings of the Coconut Research Institute of Sri Lanka (CRISL) show that even the neglected stands of coconut in nearly all coconut growing regions of the island respond significantly to application of fertilizer. These studies revealed that with the use of fertilizer yield increases in the range of 30 to 200 per cent can be obtained from palms grown in moderate to virtually poor soil types. Palms grown in poor soils or those receiving little or no field care have shown 100 per cent improvement in the yield over a period of 3 to 5 years when fertilized annually at the rate of 1.58 to 2.26 kg per palm (De Silva, 1973).

Pamphlets issued by CRISL advise coconut growers of optimal application rates of fertilizer (on an average 3 kg of the complete NPK mixture (CRISL, 1980) for palms. However, no specific mention is made of economic factors (in the pamphlets) as an influence on the optimal application rate. The recommended application rate has varied over the years. Initially it was 1.58 kg per palm but was doubled in 1956 to 3.16 kg again increased to 4 kg in 1968 and was then reduced to 3 kg in 1980. Recently, Abeywardena (1978) on the basis of his economic evaluation concluded that an application of 2.5 kg per palm rather than 4 kg would be optimal from an economic point of view. According to a recent survey by Perera and Ranbanda (1981) in the three main coconut growing districts of the country a large number of farmers (40%) believe that it is uneconomic to fertilize coconuts under prevailing market conditions.

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The purpose of this paper is to explore what evidence is available on this matter using aggregative (national) data to estimate the response of coconut production to fertilizer application. The results suggest that a fertilizer application rate of approximately 2.27 kg (5 pounds) per bearing palm is on average likely to be most profitable. Thus this independent method of approach tends to support Abeywardena's conclusions that a 4 kg per palm application rate is not economically optimal on average, and that 2.5 kg (5.5 pounds) may be closer to the optimum.

While the aggregative approach has limitations (because of heterogeneity of production conditions) allowance is made for a number of these limitations in the present analysis. The alternative of using experimental data to determine optimal rates of fertilizer application also has limitations. The experimental conditions may not be representative of actual farm conditions and this can result in a bias (Johnson and Gustafson, 1962). If on-farm production functions differ from experimentally obtained production functions by other than a constant, optimisation procedures can be biased by the use of experimental data. Hence, the aggregative approach taken here is more defensible in some circumstances.

Estimating the aggregate response of coconut production to fertilizer and rainfall

The aggregate data used in the present analysis covers the 26 year period from 1956 to 1981 inclusive. The annual aggregate yield of coconuts depends on several factors. Some of these can be controlled by farmers and others are non-controllable. Only the factors which affect yield in the short run *viz.*, quantity of fertilizer applied in each year and the weather are considered in the present analysis. The effect of long-term factors cannot be disregarded in an analysis of 26 years' data because of the variability that arises due to (*a*) change in the extent of the bearing area and age composition of bearing palms, (*b*) shift in the relative proportion of bearing acreage in different agro-climatic regions (*c*) impact of technological changes and (*d*) structural changes. The data has been adjusted for these factors, in the following ways :

Bearing acreage and age composition Ceylon Tall (*Cocos nucifera* variety *Typica* form *typica*) is the most extensively cultivated type of coconut in Sri Lanka. It has a pre-bearing period of 7—10 years and a relatively long and stable optimum productive phase of over 40 years out of a total life span of about 60 years (Menon and Pandalai, 1958; Labys, 1973). The long and stable optimum productive phase makes the estimation of annual bearing acreage of coconut relatively simple compared to the methods adopted by Bateman (1965) for cocoa and Etherington (1973) for tea. The bearing capacity throughout the optimum productive phase was considered to be stationary for coconut as against non-stationary bearing capacities which must necessarily be included for other perennials. Therefore the bearing acreage estimated in this study covers palms of 10 to 50 years of age. Annual increment of bearing acreage was estimated using data on coconut seedlings issued since the inception of seedling distribution programme in 1949 and the annual loss of bearing area as reported in Nathanael (1968) and Muthubanda (1972). The figure for bearing area in 1970 (Census and Statistics, 1970) was adjusted using annual increment of bearing area to estimate the bearing area for each year.

Shift in acreage in agroclimatic regions of Sri Lanka The distribution of bearing area in different agro-climatic regions in the island appears to be an important controllable factor which contributes largely to aggregate yield in the long run. Expansion of the extent under coconut in agroclimatic areas which are best suited for coconut relative to sub-optimal and agro-climatically unsuitable areas of coconut would give rise to higher average annual yields. Converse is true if a reduction in the extent under coconut takes place in the area best suited for coconut. Resulting fluctuations in the relative weight or importance of high yielding area and hence the effect of the shift in production is adjusted by means of weighted averages using the method outlined by Johnson and Gustafson (1962) and taking 1956 as the base year.

Technology Technological changes in planting material or agronomic practices in coconut growing during the 26 year period under review are assumed to have had minor effects on nut production. Ceylon Tall continued to be the dominant type of coconut grown throughout the period. Hence no adjustments were made to take account of technological changes.

Structural changes Extensive changes in ownership of coconut land occurred in 1972 and 1975 as a consequence of the implementation of Government's Land Reform Laws. The impact of fragmentation of ownership of coconut land (which resulted from the above laws) is not accounted for in the model. Its long term effect is assumed to be only marginal. However to take care of the sudden changes in the production and fertilizer utilisation trends during the years 1972—1975, it was necessary to include a dummy variable (u) as follows:

$u = 0$ for years affected by Land Reform Laws and
$u = 1$ for the other years.

Aggregate yield, amount of rainfall and quantity of fertilizer applied Having adjusted the data for long-term influences, it is possible to consider the most important shorter-term influences on coconut yield namely the amount of rainfall and quantity of fertilizer applied. Rainfall is the most important weather factor which gives rise to yearly fluctuations of coconut yield (Cooke, 1953). Therefore the only weather factor included in the model is rainfall. Abeywardena (1968) points out that the harvest of coconut in a given year is influenced by rainfall of at least one year previously. The effect of rainfall is therefore considered in the analysis lagged by one year from the year of harvest. Fertilizer variable is included in the model with a two year lag as evident from studies made by Smith (1968).

The annual aggregate yield of coconuts for the average bearing area on the island is therefore assumed to be represented by the following functional relationship:

$$Y_t = g(R_{t-1}, F_{t-2}, u) \qquad (1)$$

where Y_t = yield in year t in millions of nuts
R_{t-1} = rainfall in mm lagged one year
F_{t-2} = fertilizer applied in year t-2 in metric tons
u = dummy variable

Several forms of yield relationship (1) were estimated using Sri Lankan data. These included a number of quardratic forms and semi-logarithmic forms but the following log log inverse function was selected as most relevant for a priori reasons and because of its explanatory power and statistical significance:

$$\text{Log } Y_t = 9.7719 + 0.01177u - 16072.75 \frac{\log R_{t-1}}{F_{t-2}} - 1.3075 \log F_{t-2} + 0.00404\, R_{t-1} \qquad (2)$$

(5.166) (3.248) (2.623) (3.845)

$R^2 = .73$

In this equation, all the variables are significant (t-statistics in paranthesis) and the coefficient of determination explains almost three fourth of the variation in aggregate yield. The signs of the coefficients of the fertilizer variable in its inverse as well as the log transformation are as expected in a log log inverse type of a function (Moore, 1972).

The uncertainty caused by Land Reform Laws appear to have had a slight impact on the aggregate nut production of the country. The equation indicates that nut production is significantly affected by the interaction of fertilizer and rainfall with the absolute response to fertilizer being greatest in years of good rainfall (Abeywardena, 1978).

Fertilizer Application and Coconut Yield per hectare for a given rainfall

By using equation (2) and additional information, it is possible to estimate yield of coconuts per hectare as a function of the quantity of fertilizer applied supposing that a particular rainfall level prevails. In this section, the yield per hectare given a 1625 mm annual rainfall is considered for reasons which will be made clear later in the section.

Yields of coconuts as a function of fertilizer applied were obtained in the following way: The 1625 mm value for rainfall was inserted in equation (2) along with the quantities of fertilizer used on coconut land to give an estimate $\hat{Y}_t$ of Y_t, that is of aggregate coconut production. The estimated coconut yield on unfertilized coconut land was deducted from $\hat{Y}_t$ to give the estimated yield on fertilized coconut land. This was divided by the number of hectares fertilized to give the yield, y_t, per fertilized hectares. A quadratic function was fitted by least squares to these estimates and fertilizer applied per hectare of fertilized land to estimate the yield function.

Yield per fertilized hectare was estimated from the relationship

$$y_t = \frac{Y_{ft}}{A_{ft-2}} = \frac{\hat{Y}_t - kA_{ut-2}}{A_{ft-2}} \qquad (3)$$

where Y_{ft} = aggregate yield on fertilized areas in year t
A_{ft-2} = number of hectares fertilized in year t-2.
A_{ut-2} = number of hectares unfertilized in year t-2
k = yield per hectare on unfertilized land in t

Yield data for unfertilized coconut holdings for most parts of the island could only be obtained for moderate weather conditions (Abeywardena, 1978). Abeywardena's estimate excludes areas marginal for coconut and arrives at a figure of 4580 nuts per hectare of unfertilised land. Because of the exclusion of marginal areas, the use of 4580 as k in the estimation of yield Y_{ft} in equation 3 would result in an upward bias. This is avoided by discounting the above figure using the information reported in De Silva and Perera (1976). The value of k used in the analysis is 2840 for a rainfall of 1625 mm.

Results of the regression on yield response is as follows :

$$y_t' = 666.051 + \underset{(16.713)}{66.942X_{t-2}} - \underset{(14.229)}{0.09496X^2_{t-2}} \qquad (4)$$

$$R^2 = .96$$

where X represents amount of fertilizer applied per acre (= 0.405 hectares) in pounds (1 1b. = 0.453 kg). T-statistics are given in parenthesis. These are significant at 1 per cent level.

Yield relationship (4) is graphed in Figure 1. The relationship is a good fit within the observed range of fertilizer application on fertilized coconut land, namely in the range of 205.19 kg per hectare to 477.78 kg per hectare. However, it could be unreliable to extrapolate beyond this range. For example, the intercept of the regression equation used in this analysis is 666.051 but ideally this should have been 2840. To avoid the inconsistency the method used by Savoie and Kabay (1980) can be used. The estimated regression using their method gave a low R^2 value and hence was not used in the analysis. This suggests that the actual yield function over its lower range may follow a relationship like that of the dotted line shown in Figure 1.

The economically optimal application of fertilizer

From equation (4) it can be deduced that coconut production per hectare is at a maximum when 394.217 kg of fertilizer per hectare are applied. This is because

$$\frac{dy_t}{dx_{t-2}} = 66.942 - 2 \times 0.09496X_{t-2} = 0 \qquad (5)$$

for $\hat{X}_{t-2} = 352.446$ lbs or $352.446 \times \frac{0.453}{0.405} \doteq 394.217$ kg.

Assuming 173 palms to the hectare this implies an application rate of around 2.27 kg per palm.

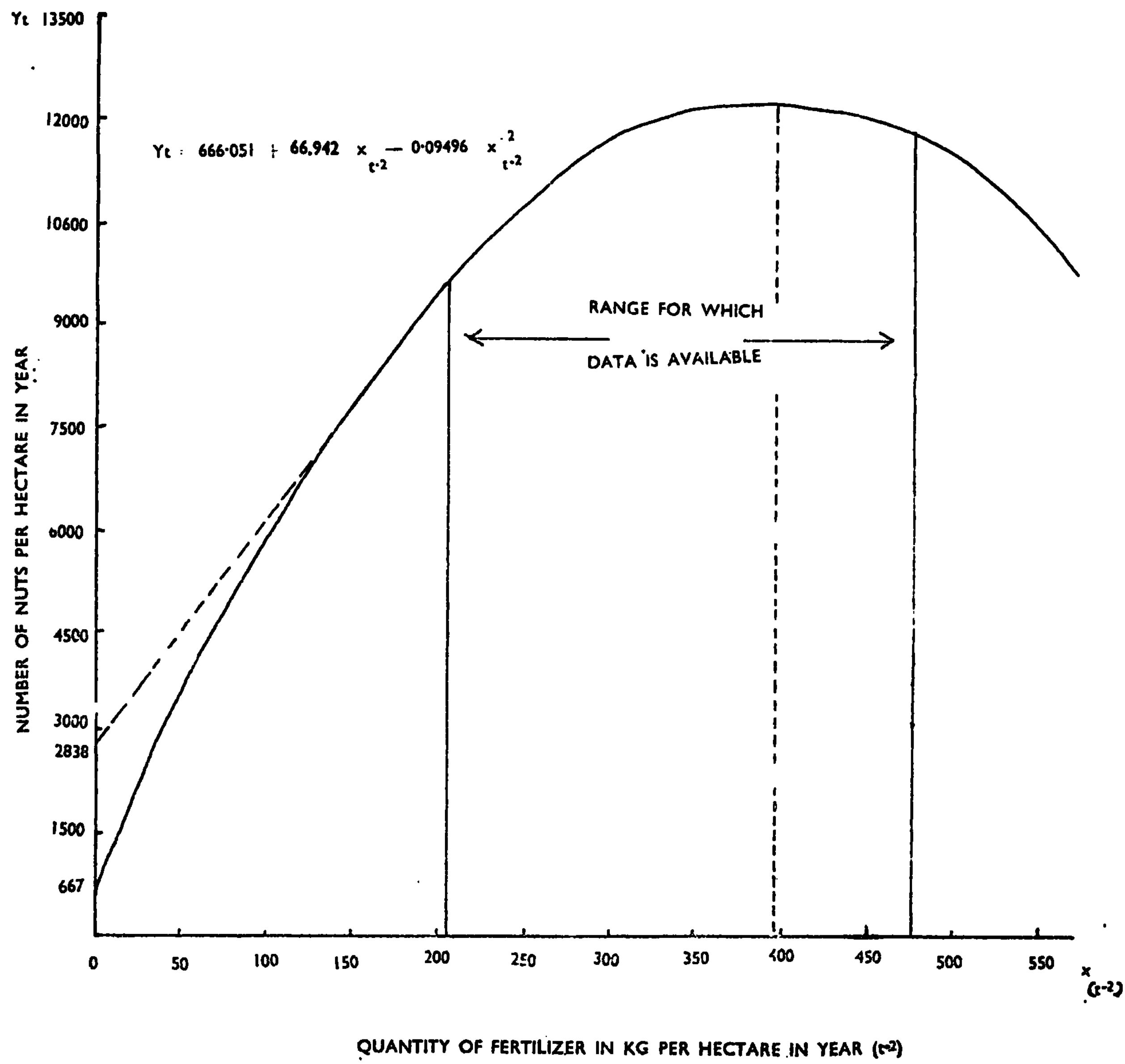

Fig. 1. Estimated relationship between coconut yield per hactare and fertilizer applied in kg per hectare.

However, profit, or the surplus of coconuts over the cost of producing them is likely to occur at a lower rate of fertilizer application. If fertilizer is assumed to be the only significant variable input in coconut production, profit per hectare of coconuts can be expressed as

$$\Pi = p_y y_t - p_x x_{t-2} - A \qquad (6)$$

where p_y = price per nut in t in rupees
p_x = price per pound of fertilizer or 0.453 kg in t—2 in rupees
A = fixed costs.

A necessary condition for a maximum of profit is that

$$\frac{d\Pi}{dx_{t-2}} = 0 \qquad (7)$$

Substituting equation (4) into (6), this maximum occurs for

$$\overline{X}_{t-2} = 352.48122 - 12.9954\, p_x / p_y, \qquad (8)$$

and thus depends on the price of fertilizer in relation to the price of nuts. In the 26 year period this price ratio ranged from 0.265 to 1.719, and the profit maximizing quantity of fertilizer per hectare therefore ranged between 369.5 kg and 390.6 kg per hectare or assuming 173 palms per hectare from 2.13 kg per palm to just under 2.26 kg per palm. The profit-maximizing variation was therefore slight.

Allowance should really be made for the fact that funds are tied-up in fertilizer applied to coconuts for two years before the yield is obtained. This can be allowed for by discounting the price of coconuts by the rate of interest. In equation (8) p_y, the price of coconuts, needs to be replaced by the discounted price,

$$\begin{aligned} \hat{P}_y &= p_y/(1 + i)^2 \\ &= p_y/(1 + 2i + i^2) \end{aligned} \qquad (9)$$

Other things being equal, the higher is the rate of interest the lower is the profit-maximising quantity of fertilizer needed. If a 20 per cent rate of interest is supposed, the profit-maximizing application of fertilizer ranged in the 26-year period from 358.56 kg per hectare to 389.01 kg per hectare, or from 2.07 kg to 2.24 kg per palm assuming 173 palms to the hectare. The band of variation in optimal was still very small. A farmer who applied between 2.04 kg and 2.26 of fertilizer in the period would have approximately maximized profit throughout the period under the conditions assumed.

Implications for extension advice and conclusion

This analysis indicates that coconuts respond markedly to the application of fertilizer. A maximum yield of just under 12,463 nuts per hectare can be obtained by applying 394 kg of fertilizer per hectare. This compares with a yield of 2838 nuts per hectare on unfertilized land. Yield responses of such higher magnitude (about 12,500 nuts per hectare) have been recorded for fertilizer applications of 1.8 to 2.26 kg per palm on the island's best coconut growing area (CRISL, 1967, p. 2). The high yields obtained in this analysis perhaps suggests that the coconut lands fertilized during the period under review have remained concentrated in the island's best coconut growing area. One drawback of the aggregative method is that it is influenced by the changing pattern of distribution of fertilizer between lands highly responsive to fertilizer and those less so.

Assuming typical rainfall conditions of 1625 mm it was always profitable to apply fertilizer to palms at rates ranging from 2.07 kg per palm to 2.26 kg. This was so even after discounting coconut prices.

In only four of the 26 years (namely, 1968,1970, 1971 and 1972) was fertilizer application on fertilized lands of sufficient quantity to maximise profits from coconuts.

The profit-maximising rates of application of fertilizer were relatively insensitive to observed variations in fertilizer/coconut price-ratios. From a profit point of view, it would have been 'safe' to have recommended a 2.04 to 2.26 kg application rate to growers.

The current recommended rate of application of 3 kg per palm appears on average to be too high to maximise profit and greater than that necessary for maximum coconut production per hectare.

The stepwise analysis developed here can be used in estimating profits under different rainfall conditions. For this purpose the only other information needed is the aggregate nut production from unfertilized lands in different coconut growing districts of the island under different rainfall conditions. Once this information is available, definite statements on the profit maximising quantity of fertilizer and as to whether or not fertilizer use in coconut is profitable under different rainfall conditions can be made in the advisory pamphlets.

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