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RESPONSE OF COCONUT *(COCOS NUCIFERA)* TO N,P AND K FERTILIZER APPLICATION FROM THE TIME OF FIELD PLANTING ON A LATERITIC GRAVEL SOIL IN SRI LANKA

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ABSTRACT

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The results of a long term 3x3x3 NPK field experiment with coconut from the seedling stage upto the initial bearing period on a lateritic gravel soil in Sri Lanka, where the rates of fertilizers were progressively increased upto the 16th year, are discussed. The data from the 23rd to the 26th year showed that the optimum yield was obtained for an application of 1.818 kg sulphate of ammonia, 1.136 kg saphos phosphate and 2.043 kg muriate of potash/palm/yr from the 16th year. Application of 1.362 kg each of sulphate of ammonia, saphos phosphate and muriate of potash between the 9th and the 16th years produced an yield of 20.7 kg copra/palm/yr from the 13th to the 16th years, which is about 150% higher than the plots which received no fertilizer from the seedling stage.

The data suggest that in the current fertilizer recommendations, for both young and adult palms, the rate of N could be reduced and that of K increased.

INTRODUCTION

Experiments in Sri Lanka and other countries have shown that coconut responds to application of N, P and K fertilizers. Several fertilizer field experiments have been carried out under different environmental conditions on adult palms, in India (Thampan, 1970; Muliyar and Nelliat, 1971), Jamaica (Smith, 1969), the Philippines (Magat *et al.*, 1976) and Malaysia (Soon and Wat, 1972), and on young palms in Ivory Coast (Fremond and Ouvrier, 1971) and the Philippines (Prudente and Mendoza, 1976). However, the results of these experiments are not directly applicable to Sri Lanka as the agroclimatic conditions are not the same as in these countries.

The first statistically designed factorial NPK field experiment on coconut in Sri Lanka was commenced by Salgado in 1935 (Salgado, 1946) with adult palms at Bandirippuwa Estate, Lunuwila on a lateritic gravel soil (Ultisol) which is typical of the large proportion of the coconut growing areas in Sri Lanka. This has been analysed and reported elsewhere (Eden *et al.*, 1963; Abeywardena, 1965). In addition, Salgado (1950) commenced a similar fertilizer experiment with coconut seedlings at Ratmalagara Estate, Madampe on a soil similar to the one at Bandirippuwa. The results of this experiment during the vegetative phase have been recorded elsewhere (Salgado, 1953, 1954). This paper discusses the yield of the palms in the early years immediately after bearing commenced.

MATERIALS AND METHODS

Soil and Climate

The experiment was laid down on a newly cleared secondary jungle land at Ratmalagara Estate, Madampe in a 16 ha block where the soils are generally well drained loamy sand to sandy loam overlying sandy clay loam with lateritic ironstone gravels, the content of which increases with depth. The gravel layer passes into a hard lateritic basement which occurs at varying depths. The soils are classified as, Red Yellow Podzolics with soft and hard laterites (Ultisols). The characteristics of the soil are shown in Table I.

Table 1. *Characteristics of Ratmalagara soils* (0–30 *cm*)

Chemical		
	pH (H_2O)	4.4
	Total N (%)	0.042
	Available P (Olsen's bicarbonate, ppm)	3
	Exch. K (me/100 g)	0.16
	Exch. Ca (me/100 g)	0.49
	Exch. Mg (me/100 g)	0.26
Physical		
	Coarse sand (%)	68
	Fine Sand (%)	15
	Silt (%)	5
	Clay (%)	11

The experimental area is in the intermediate rainfall zone of Sri Lanka with annual rainfall of about 1600 mm. It receives both South West (April to June) monsoon and Inter-monsoonal (October to December) rains.

Design and Treatments

The experimental design consists of a 3 x 3 x 3 factorial arrangement for the three nutrients N, P and K in 6 blocks of 9 plots each, where the higher order interactions are confounded with that of blocks. There are 18 palms in each experimental plot and each plot is separated by a single row of guard row palms. The planting distance is at 9.3 m x 9.3 m on the square system (136 palms/ha).

The experiment was commenced in 1948 with 6 months old coconut seedlings (variety *typica*). Fertilizer applications were made according to the treatments shown in Table 2.

Table 2. *Fertilizer treatments*

Year	Sulphate of ammonia (20.6% N) (kg/palm/yr)		Saphos phosphate (27.5% P_2O_5) (kg/palm/yr)		Muriate of Potash (60% K_2O) (kg/palm/yr)	
1949–1952	N_1	0	P_1	0	K_1	0
	N_2	0.227	P_2	0.227	K_2	0.227
	N_3	0.454	P_3	0.454	K_3	0.454
1953–1954	N_1	0	P_1	0	K_1	0
	N_2	0.341	P_2	0.341	K_2	0.341
	N_3	0.681	P_3	0.681	K_3	0.681
1955–1956	N_1	0	P_1	0	K_1	0
	N_2	0.454	P_2	0.454	K_2	0.454
	N_3	0.908	P_3	0.908	K_3	0.908
1957–1964	N_1	0	P_1	0	K_1	0
	N_2	0.681	P_2	0.681	K_2	0.681
	N_3	1.362	P_3	1.362	K_3	1.362
1965–1973	N_1	0.681	P_1	0.454	K_1	0.681
	N_2	1.362	P_2	0.908	K_2	1.362
	N_3	2.043	P_3	1.362	K_3	2.043

Upto 1956, the rates of fertilisers were progressively increased in accordance with the age of the seedlings. By 1957, all palms had come into bearing and the fertilizers were supplied at the rates of 0,0.675 and 1.250 kg/palm/year till 1964. In 1965, the rates were increased to test the response to higher rates.

Fertilizer was applied annually after the heavy rains, the methods of application varying over the years. The following methods were practised:-

(i) 1949–1955. In circles round the seedlings, the circles being progressively widened with the years.

(ii) 1956. Broadcast over the square formed by 4 seedlings.

(iii) 1957–1963. Half circular trench manuring, the half circles being alternated every other year.

(iv) 1964. Round the palm in a 0.9 m wide ring at a distance of 0.9 m from the palm.

(v) Since 1965. Surface application round the palm in the entire area within a circle of radius 1.2 m from the palm.

After application, the fertilizers were turned into the soil.

Analysis of data

The number of leaves produced per palm during the period 1950 to 1952 and the proportion of palms which were in bearing in 1955 were recorded.

The yield data for the years 1961–1964 and 1972–1975 were statistically analysed. Because the levels of fertilizers were stepped up in all plots in 1965, a seven year period, 1965-1971 was allowed for this change in the treatments to stabilize. The function fitted is a quadratic production function of the form

$$y = a_1 + a_2N + a_3P + a_4K + a_5N^2 + a_6P^2 + a_7K^2 + a_8NP + a_9NK + a_{10}PK$$

where y = yield (number of nuts or kg copra/palm/yr) and N, P and K represent the weights (kg) of sulphate of ammonia, saphos phosphate and muriate of potash respectively applied/palm/year and $a_1 \ldots\ldots\ldots\ldots\ldots\ldots a_{10}$ represent partial regression coefficients.

RESULTS

Yield response

The partial regression coefficients of the response components for the copra and nut yield data are shown in Table 3. The reasonably high multiple correlation coefficient suggests that the quadratic equation chosen fits the data satisfactorily. From these equations the expected yield (copra or nut) for the different combinations of N,P and K were calculated. Fig. 1 and 2 show the expected copra yield for the periods 1961–1964 and 1972–1975 respectively.

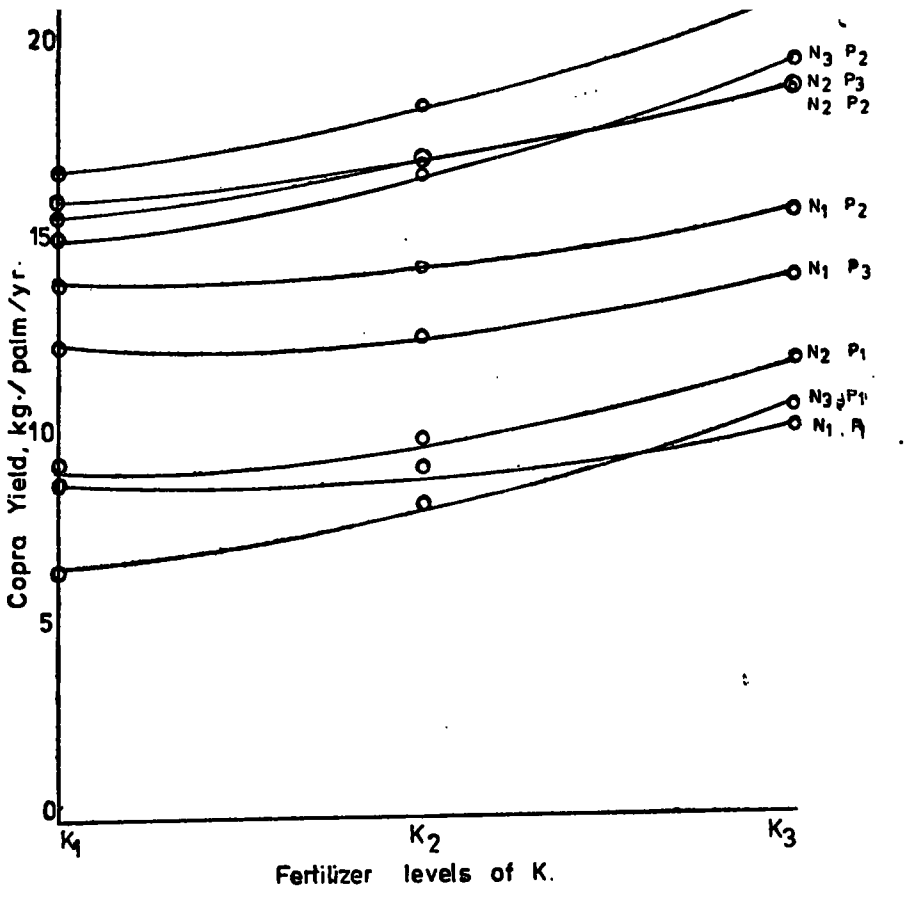

Fig. 1. Yield responses to N, P and K during 1961—1964.

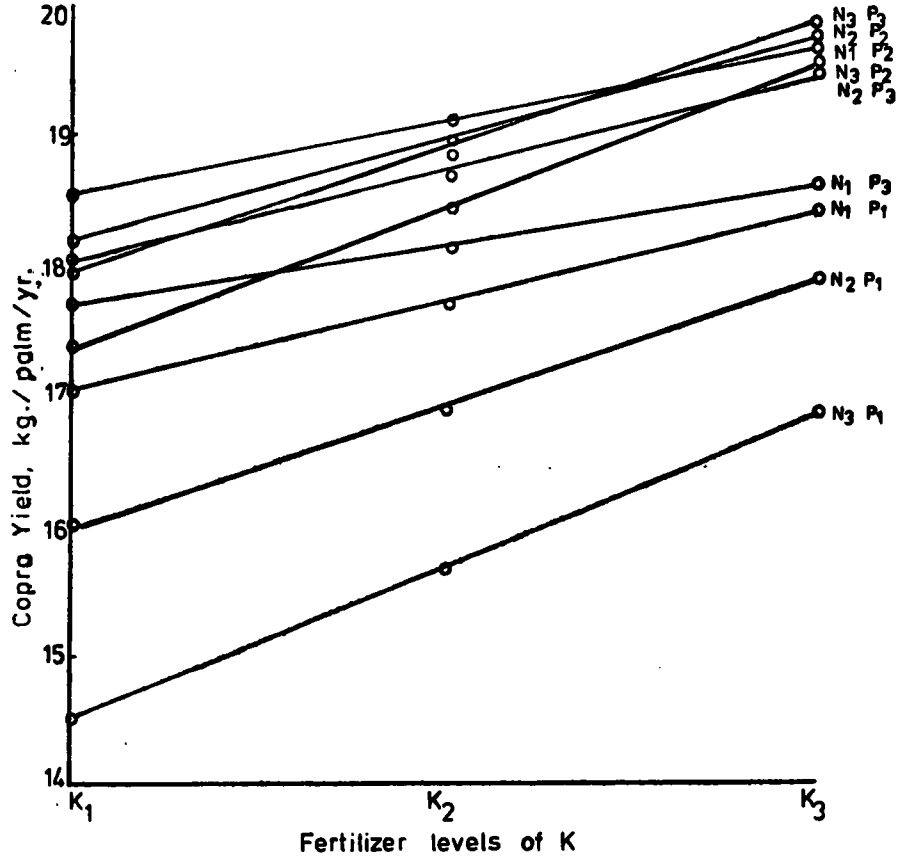

Fig. 2. Yield responses to N, P and K during 1972—1975.

Table 3. *Partial regression coefficients of the production function*

Partial regression coefficients	1961–1964 nuts	1961–1964 Copra	1972–1975 nuts	1972–1975 Copra
a_1	35.593**	8.659**	70.789**	14.186**
a_2	7.253	2.679	-10.313	-1.979
a_3	51.064**	13.315**	45.782*	9.543
a_4	-6.386	-0.553	-10.211	0.541
a_5	-9.588	-3.089*	-1.817	-0.475
a_6	-20.396**	-7.805**	-24.727*	-5.578*
a_7	5.104	1.112	2.340	0.082
a_8	14.515**	3.584**	10.850*	2.249
a_9	7.185*	1.469	5.697*	0.563
a_{10}	-0.366	0.205	-1.119	-0.355
Multiple Correlation Coefficient	0.964	0.960	0.894	0.784

*, ** significant at P = 0.05 and 0.01 respectively

The data for 1961–1964 show a significant positive NP interaction indicating that the response to N or P is better in the presence of the other (Fig. 1 and Table 3). Positive linear components and significant negative quadratic components for N and P indicate a diminishing pattern of response for N and P. The response to K, although not significant, is positive at higher levels of K. As a result of the positive NP interaction and positive response to K, maximum yield was obtained for the $N_3P_3K_3$ combination (1.362 kg each of sulphate of ammonia, saphos phosphate and muriate of potash). As these are the highest levels tested, the true levels for maximum yield are expected to be equal to or higher than $N_3P_3K_3$.

The only nutrient factor which showed significant influence in 1972–1975 was the quadratic component of P (Table 3). Response to P showed a diminishing return as shown in Fig. 2. At high levels of N, this pattern of diminishing return is not so pronounced. This is due to the small positive NP interaction, though not significant. As in the earlier period, here too there was response to increasing levels of K. For this period too maximum yield was obtained at $N_3P_3K_3$ (2.043 kg each of sulphate of ammonia and muriate of potash and 1.362 kg of saphos phosphate) which are the highest levels tested. Therefore the actual levels for maximum yield at Ratmalagara is expected to be equal to or higher than $N_3P_3K_3$.

Optimum levels of fertilizers

The coconut cultivator is more interested in the levels of fertilizers for optimum yield (maximum profit) than on maximum yield. The levels of fertilizers for optimum yield can be obtained mathematically only if the following conditions are satisfied (Colwell, 1974).

(i) the mathematical solutions to N,P and K must be positive and be within the range of levels tested.

(ii) $\frac{\partial^2 y}{\partial N^2}, \frac{\partial^2 y}{\partial P^2}$ and $\frac{\partial^2 y}{\partial K^2}$ must all be negative

As $\frac{\partial^2 y}{\partial K^2}$ for the production function for both periods are positive, the mathematical

approach cannot be used for the Ratmalagara data. However a less precise estimate of the optimum levels of fertilizers can be obtained by inspection of the data. Tables 4 and 5 show the profits one would expect at different levels of fertilizers for the periods 1961–1964 and 1972–1975 respectively. The calculation was based on the fertilizer prices as at 1976 and at a reasonable copra price of Rs 2.50/kg. The optimum levels for the period 1961–1964 were N_3 P_3 K_3. As these were the highest levels tested it cannot be known whether levels higher than N_3 P_3 K_3 would give higher profits.

Table 4. *Profit of fertilizer application* (1961–1964)

Levels of Fertilizers	Cost of Fertilizer (Rs)	Copra Yield (kg/palm/yr)	price of Copra (Rs)	Profit (Rs)
$N_1P_1K_1$	0.0	8.66	21.65	21.65
$N_1P_1K_2$	0.47	8.80	22.00	21.53
$N_1P_1K_3$	0.95	9.97	24.93	23.98
$N_1P_2K_1$	0.30	14.11	35.28	34.98
$N_1P_2K_2$	0.77	14.35	35.88	35.11
$N_1P_2K_3$	1.24	15.61	39.03	37.79
$N_1P_3K_1$	0.60	12.30	30.75	30.15
$N_1P_3K_2$	1.07	12.63	31.58	30.51
$N_1P_3K_3$	1.54	14.00	35.00	33.46
$N_2P_1K_1$	0.53	9.05	22.63	22.10
$N_2P_1K_2$	1.00	9.87	24.68	23.68
$N_2P_1K_3$	1.48	11.73	29.33	27.85
$N_2P_2K_1$	1.12	16.16	40.40	39.28
$N_2P_2K_2$	1.60	17.08	42.70	41.10
$N_2P_2K_3$	2.07	19.04	47.60	45.53
$N_2P_3K_1$	1.72	16.02	40.05	38.33
$N_2P_3K_2$	2.19	17.04	42.60	40.41
$N_2P_3K_3$	2.67	19.09	47.73	45.06
$N_3P_1K_1$	1.06	6.57	16.43	15.37
$N_3P_1K_2$	1.53	8.07	20.18	18.65
$N_3P_1K_3$	2.01	10.61	26.53	24.52
$N_3P_2K_1$	1.65	15.35	38.38	36.73
$N_3P_2K_2$	2.13	16.95	42.38	40.25
$N_3P_2K_3$	2.60	19.59	48.98	46.38
$N_3P_3K_1$	2.25	16.87	42.18	39.93
$N_3P_3K_2$	2.72	18.57	46.43	43.71
$N_3P_3K_3$	3.19	21.30	53.25	50.06

Price of Copra = Rs. 2.50/kg, Price of sulphate of ammonia = Rs. 0.78/kg, Price of saphos phosphate = Rs. 0.44/kg, Price of muriate of potash = Rs. 0.69/kg

Table 5. *Profit of fertilizer application* (1972–1975)

Levels of Fertilizer	Cost of Fertilizer (Rs)	Copra Yield (kg/palm/yr)	Price of Copra (Rs)	Profit (Rs)
$N_1P_1K_1$	1.20	17.06	42.65	41.45
$N_1P_1K_2$	1.67	17.69	44.23	42.56
$N_1P_1K_3$	2.15	18.41	46.03	43.88
$N_1P_2K_1$	1.40	18.52	46.30	44.90
$N_1P_2K_2$	1.87	19.05	47.63	45.76
$N_1P_2K_3$	2.35	19.65	49.13	46.78
$N_1P_3K_1$	1.60	17.69	44.23	42.63
$N_1P_3K_2$	2.07	18.10	45.25	43.18
$N_1P_3K_3$	2.54	18.60	46.50	43.96
$N_2P_1K_1$	1.73	16.00	40.00	38.27
$N_2P_1K_2$	2.20	16.90	42.25	40.05
$N_2P_1K_3$	2.68	17.87	44.68	42.00
$N_2P_2K_1$	1.93	18.17	45.43	43.50
$N_2P_2K_2$	2.40	18.96	47.40	45.00
$N_2P_2K_3$	2.88	19.82	49.55	46.67
$N_2P_3K_1$	2.13	18.03	45.08	42.95
$N_2P_3K_2$	2.60	18.70	46.75	44.15
$N_2P_3K_3$	3.07	19.46	48.65	45.58
$N_3P_1K_1$	2.26	14.51	36.28	34.02
$N_3P_1K_2$	2.73	15.67	39.18	36.45
$N_3P_1K_3$	3.21	16.90	42.25	39.04
$N_3P_2K_1$	2.46	17.37	43.43	40.97
$N_3P_2K_2$	2.93	18.42	46.05	43.12
$N_3P_2K_3$	3.40	19.54	48.85	45.45
$N_3P_3K_1$	2.66	17.93	44.83	42.17
$N_3P_3K_2$	3.13	18.87	47.18	44.05
$N_3P_3K_3$	3.60	19.68	49.10	45.50

The 1972–1975 data show that the fertilizer combination $N_1 P_2 K_3$ (0.681 kg sulphate of ammonia, 0.908 kg saphos phosphate and 2.04 kg muriate of potash) gives the highest profit of Rs 46.78 (Table 5). More precise combinations of fertilizer for maximum profit could be obtained by calculating the expected yield from the production function and examining the profits at other rates of fertilizers within the range tested. Such calculations showed that profits of above Rs 46.00 are given by a number of combinations (Table 6). Thus the choice of the optimum combination is not unequivocal. But out of these combinations if

Table 6. *Optimum rates of fertilizer*

Rates of fertilizer (kg/palm/yr)			Profit on sale of copra	Profit on sale of nuts
Sulphate of ammonia	Saphos phosphate	Muriate of potash	(Rs/palm/yr)	(Rs/palm/yr)
1.136	0.909	2.043	46.83	41.86
1.136	1.136	2.043	46.70	42.35
1.591	1.136	2.043	46.62	44.01
1.818	1.136	2.043	46.65	44.69
0.682	0.909	2.043	46.78	40.45
1.364	0.909	2.043	46.67	42.47

one considers the profits obtainable from sale of nuts, as well, the choice of the optimum combination becomes quite clear. The mixture, 1.818 kg sulphate of ammonia, 1.136 kg saphos phosphate and 2.043 kg muriate of potash gives the highest profit, from sale of nuts (at Rs. 0.50/nut which corresponds to a copra price of Rs 2.50/kg). Therefore these rates are selected as the best levels. Here the N and P rates lie between the second and third levels tested and the optimum rate of K is equal to the third level tested.

DISCUSSION

Salgado (1953, 1954) used leaf counts, leaf length and initial flowering data as measures (parameters) of the effectiveness of a treatment during the vegetative phase. But the produce that is of the greatest value to a planter is the nut. Hence the number of nuts or the weight of copra is used in this paper as the index to determine the effectiveness of any treatment even during the vegetative phase.

The 1961–1964 data clearly show the beneficial effects of fertilizer application to coconut. Application of 1.362 kg each of sulphate of ammonia, saphos phosphate and muriate of potash had given an yield of 21.3 kg/palm/yr compared to 8.7 kg/palm/yr for the plots which received no fertilizer from the seedling stage. This is a 150% increase in yield. This kind of comparison cannot be made for the 1972 – 1975 data, as after 1965 there were no plots receiving zero N, P and K.

The results also show the importance of applying a balanced fertilizer mixture. For both periods the combination $N_3 P_1$ gave the lowest yield - an yield which is even lower than the control plots. This shows that an increase of N without a corresponding increase of P would be detrimental. The positive NP interaction indicates that the benefit from an increase of N could be obtained only if P also is increased and vice versa. The first 25 months yield data of young coconut in the Philippines too showed that application of N without P would give an yield even less than the plots which received no fertilizer (Prudente and Mendoza, 1976).

In the various optimum combinations of fertilizers shown in Table 6, the rate of K is always 2.043 kg muriate of potash whereas P ranges from 0.909 to 1.136 kg saphos phosphate and N from 0.682 to 1.864 kg sulphate of ammonia/palm/yr. Abeywardena (1965) analysing the data on the 3x3x3 NPK factorial experiment on adult palms at Bandirippuwa, arrived at the optimum fertilizer combinations of about 0.9 to 1.1 kg sulphate of ammonia, and 0.7 kg muriate of potash/palm/yr. (There was no response to P for most part of the experimental years). The rate of sulphate of ammonia obtained at Ratmalagara is not very different from the one obtained at Bandirippuwa, but the rate of 2.043 kg muriate of potash at Ratmalagara is very much higher than at Bandirippuwa, inspite of the lower level of exchangeable K in the soils at the former estate, 0.2 me compared to 0.02 me K_2O/100 g (Nethsinghe, 1963). The highest level of muriate of potash tested at Bandirippuwa was 0.675 kg/palm/yr and therefore it is not known whether higher rates such as 2.043 kg/palm/yr would have given higher yields as at Ratmalagara. The maximum yield of 13.6 kg copra/palm/yr at Bandirippuwa compared to 20.0 kg copra/palm/yr at Ratmalagara suggests a potential for higher yield at Bandirippuwa, had higher levels of potash been applied. Another possible explanation is the difference in age of the experimental palms in the two areas. The palms at Ratmalagara (during the experimental period) being 13 to 25 years old, have potential for higher yield and therefore higher fertilizer requirement, mainly potash, than the 30 to 60 years old palms at Bandirippuwa. In the Philippines, applications of 5 rates of KCl to adult palms on a clay loam soil showed that the highest rate of 3.33 kg muriate of potash /palm/yr gave the maximum yield as well as maximum profit (Magat *et al.*, 1976). Considering this, the rate of 2.043 kg muriate of potash/palm/yr obtained for the poorer soil at Ratmalagara does not appear to be too high.

Table 7. *Copra yield, flowering data and leaf counts for selected programmes of fertilizer applications*

	Rates of fertilizers* (kg/palm/yr)							Copra yield (kg/palm/yr)		% palms in flower	Number of leaves/palm/yr
	Age (yr)							Age (yr)		Age (yr)	Age (yr)
	1–2	2–3	3–4	4–6	7–8	9–16	17–26	13–16	23–26	7–8	3–5
Current fertilizer recommendation	0.40 0.30 0.20	0.60 0.45 0.30	0.80 0.60 0.40	1.00 0.75 0.50	1.00 0.75 0.50	2.27 0.91 1.36	2.27 0.91 1.36				
Control N_1 P_1 K_1	–	–	–	–	–	–	0.68 0.45 0.68	8.66	17.06	17	6.9
N_2 P_2 K_2	0.23 0.23 0.45	0.23 0.23 0.45	0.23 0.23 0.45	0.34 0.34 0.68	0.45 0.45 0.91	0.68 0.68 1.36	1.36 0.91 2.04	19.04	19.82	75	7.9
N_3 P_3 K_3	0.45 0.45 0.45	0.45 0.45 0.45	0.45 0.45 0.45	0.68 0.68 0.68	0.91 0.91 0.91	1.36 1.36 1.36	2.04 1.36 2.04	21.30	19.88	70	7.8

* From top to bottom the order is sulphate of ammonia, saphos phosphate and muriate of potash.

Table 7 gives the current fertilizer recommendation by the Coconut Research Institute of Sri Lanka for conditions similar to those at Ratmalagara, the treatments $N_2 P_2 K_3$ and $N_3 P_3 K_3$ within which the optimum dose lies and the control. The figures suggest that in the current fertilizer recommendations, for both young and adult palms, the rate of N could be reduced and that of K increased.

The number of leaves produced per palm per year for the period 1950 to 1952 and the proportion of palms in flower by 1955 for the above treatments are also given in Table 7. Of the twenty seven treatments tested, seven produced a relatively high number of leaves per palm per year and in five, over 70% of the palms were in flower. Treatments $N_2 P_2 K_3$ and $N_3 P_3 K_3$ are among these two sets. The optimum dose lies within these two combinations. Thus one could expect the optimum rate to produce good vegetative growth during the juvenile stage as well.

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