Ceylon Cocon. Quart. (1969) **20**, 111-122

ISOTOPE STUDIES ON EFFICIENCY OF FERTILIZER UTILISATION BY COCONUT PALMS

By T. S. BALAKRISHNAMURTI

Soil Chemistry Division,
Coconut Research Institute, Lunuwila,
Ceylon.

Two experiments are described. The First a preliminary trial, showed that the variation in uptake of P 32 by leaves 3 to 9 is small. Hence it is advantageous to take samples from any leaf between 3 and 9. On practical considerations, leaf 6 is a convenient choice.

The treatments in the main experiment consisted of placements at four distances (0.5, 1.0, 2.0 and 3.0 m) and four depths (10, 30, 45, and 60 cms.). Each treatment was replicated thrice. The 48 palms were grouped into 3 blocks of 16 palms each and the treatments were randomized. The P 32 was placed at the appropriate depths in 16 equally spaced points along a ring at the appropriate distances from the palm. Samples were taken from the 6th leaf on the 10th, 23rd, 30th and 40th days after the application of P 32. Only palms 17 to 48 were sampled on the 10th day.

Radioactivity on the 6th leaf was used as the criterion of efficiency of uptake. Of the 16 treatments, uptake from placement at a depth of 10 cms. distant 0.5 m from the palm was the most efficient. The uptake decreased with increase in distance as well as depth of placement and time. The uptake from "deep" placements "near" the palm was as good as that from "shallow" placements "near" the palm.

INTRODUCTION

Most experiments on the fertilizer needs of the coconut palm have been on the quantity of fertilizer needed and the most beneficial formulation. Very few experiments have been conducted on (i) the fertilizer material, (ii) time of fertilizer application, (iii) frequency of fertilizer application, and (iv) method of placement. Usually in the study of fertilizer problems, statistically designed experiments depending on yield data are employed. With annual crops such methods give the desired information in the space of an year. But with a perennial like the coconut palm statistically designed field experiments are laborious, time consuming, expensive, and require a large extent of land. The use of radioactive isotopes in the study of the problems listed earlier offers a tremendous advantage over the statistically designed field experimental method.

Early methods of application were based on visual observations of the root system of the palm. Believing that extensive development of absorbing rootlets would be promoted, Sampson (1923) suggested broadcasting the fertilizer over the whole area of the plantation. Coghlan and Hinchley (1917) recommended placing fertilizer in ploughed furrows midway between palms.

In Ceylon the traditional practice is to apply the fertilizer round the palm in 3 feet wide circular trench 3 feet away from the stem. On a well drained sandy soil Nalliah (1959) found no difference in effect between the traditional circular trench system and broadcast application of fertilizer in the entire area between rows of palms. Salgado (1955) and Nethsinghe (1956) reported on the root system of young palms, about 4 years old. They observed a prolific growth of roots, widely distributed and running horizontally at a depth of 9 inches. Roots of adjacent palms crossed at several points. A mat of roots round the base of the palms extended up to a

distance of about 4 feet. Roots encroached even into the manure circles of adjacent palms. On gravelly soils most of the roots were below 6 inches but they showed a restricted growth and did not spread evenly.

Nethsinghe (1964) reported that on a lateritic soil surface application of fertilizers in 3 feet wide strip 3 feet away from the palm was as effective as the traditional method of application in a 3 feet wide circular trench 3 feet away from the palm.

Using radioactive phosphorus, Nethsinghe (1963, 1964, 1965) compared three methods of placement, viz. (i) the traditional 3 feet wide circular trench 3 feet away from the base of the palm (ii) squares (9.2 ft. square) or circles (radius 5½ feet) at the centres of squares between rows of palms, and (iii) basin round the palm extending to a distance of 5.2 ft. from the bole of the palm. Of these three methods he found that placement (iii) was superior to the other two. He also compared application of fertilizer in half circle and full circle round the palm and found the latter method 40 per cent more efficient than the former.

DESCRIPTION OF EXPERIMENT

1. *Experimental Site :*

A preliminary trial was carried out on a well-drained sandy soil at Bandirippuwa Estate, Lunuwila. Mechanical analysis data for the soil are given in Table 1. Since 1965, the palms had been treated biannually with NPK mixture containing saphos phosphate, the fertilizer being applied on the surface in the entire area up to a distance of 5 feet from the palm, and turned in. Between 1960 and 1965 fertilizer had been applied in circular trenches 3 feet wide, 3 feet away from the base of the palm. From 1956-59 application of fertilizer had been done in a 2-2 1/2 feet wide circular strip 2 feet away from the palm. In the period 1950-1955 the fertilizer had been applied on the surface in the entire area round the palm up to a distance of 2 feet from the palm. The palms are 17 years old and are planted 26 x 26 feet.

TABLE 1.

MECHANICAL ANALYSIS OF SOILS

Soil Fractions	*Bandirippuwa Soils*	*Marandawila Soils*
% Coarse sand	61.3	63.7
% Fine sand	26.8	30.0
% Silt	1.4	1.3
% Clay	8.6	4.1

The main experiment was carried out on a well-drained sandy soil at Marandawila Estate, Bingiriya. Mechanical analysis data for the soil appear in Table 1. The available phosphorus content of samples of soil taken from the placement holes is recorded in Table 2. The palms had not been manured in 1966 and 1967. Between 1960 and 1966 NPK fertilizer was broadcast in the entire area. From 1948 to 1960 an experiment on methods of placing manure had been carried out, the methods being broadcast application and full circle manuring. The palms are about 45 to 55 years old and are planted 26 x 28 ft.

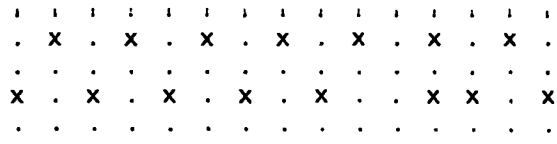
TABLE 2

AVAILABLE PHOSPHORUS (OLSEN'S BICARBONATE METHOD)
ppm. P

Distance Metres	*DEPTHS Cms.*			
	10	30	45	60
0.5 ...	4.35 5.75 2.33	4.28 3.42 1.71	3.89 3.58 1.55	2.34 3.81 1.64
Mean ...	4.14	3.14	3.01	2.60
1.0 ...	4.82 7.92 3.27	3.50 3.11 2.41	3.90 3.42 2.34	6.71 2.25 3.03
Mean ...	5.34	3.01	3.25	4.00
2.0 ...	10.73 3.89 2.49	2.40 3.26 2.03	2.48 3.50 2.02	4.05 2.40 2.03
Mean ...	5.70	2.56	2.67	2.83
3.0 ...	2.95 3.81 2.72	2.80 2.48 1.63	1.79 1.63 1.47	1.71 2.25 1.87
Mean ...	3.16	2.30	1.63	1.94

2. *Placement*

The Radioactive material used was P 32. For the preliminary experiment four palms with similar growth characteristics were selected. The selected palms were separated from each other by an untreated palm (see diagram below). Each palm was treated with 5 mC of P 32. The radioactive isotope was placed at a depth of 10 cms. in 16 points along a ring of radius 100 cms. around the palm, the points being equally spaced along the ring.



x Treated palms . Untreated palms

For the main experiment the treatments consisted of placements at 4 distances (0.5, 1.0, 2.0 and 3.0 metres) and 4 depths (10, 30, 45, and 60 cms.), each treatment being replicated 3 times. The 48 palms were grouped into three blocks of 16 palms each. In each block the treatments were randomized (Table 3). The treated palms were separated from each other by untreated palms.

TABLE 3

TREATMENT CHART

Treatment No.	*Distance Metres*	*Depth cms.*	*Rep. I*	*Rep. 2*	*Rep. 3*
1 ...		10	16	32	41
2 ...		30	6	26	40
3 ...	0.5	45	2*	25	43
4 ...		60	12	27	33
5 ..		10	14	28	42
6 ...		30	10	24	46
7 ...	1.0	45	15	22	44
8 ...		60	9	18	34
9 ..		10	4	17	37
10 ...		30	7	23	48
11 ...	2.0	45	11	31	39
12 ..		60	5	30	47
13 ..		10	8*	21	36
14 ...		30	13	20	38
15 ..	3.0	45	3*	29	45
16 ...		60	1*	19	35

* untreated

The P 32 was placed in 16 equally spaced points along a ring round each palm at the required distance and depth. Each palm was treated with 5 mC of P 32. The placement was carried out with the help of an injection tube. The ampoule containing the P 32 was dropped into the injection tube, crushed by turning the inner tube and the radioactive solution washed down with 50 ml. of distilled water.

To eliminate the risk of handling 240 mC of P 32 in the laboratory, the radiosotope was supplied in sealed glass ampoules, each ampoule containing about 5 ml. of 300 micro-curies of P 32 solution.

In the injection operation the two coaxial tube injector was found to be disadvantageous. Soil got embedded between the tubes and prevented the crushing action. Several times the tube had to be pulled out of the hole and the embedded soil pushed out.

3. *Sampling and Preparation of Sample :*

In the preliminary experiment samples were taken from fronds 1, 3, 6, 9, 12, 15 and 18, 1 being the youngest fully opened frond. Fronds 1 and 6 were sampled 10, 20, 30 and 40 days after the application of P 32. On the 20th day samples were taken from fronds 3, 9, 12, 15 and 18 as well. Samples were taken from untreated palms also. These served as checks on natural radio-activity (K 40) and any radioactive fall out.

In the main experiment samples were taken from the 6th frond of the treated palms and also from a few untreated palms in the area. On the 10th day after the application of P 32, samples were taken from palms 17 to 48 only. On the other dates samples were taken from all the 44 treated palms.

Unskilled labourers who were instructed on the method were employed for leaf sampling. The labourers climbed the palms, counted the leaves in order of maturity, and removed from the mid-portion of the selected frond, 5 leaflets from either side of the rachis.

The mid-rib of the leaflets were removed and from each sample such quantity as was sufficient to give about 20 g. of dry matter was dried at 70°C. for about 24 hours in a dehydrator. The dried samples were cut to pieces about 5 mm. in length and stored in polythene bags.

The employment of unskilled labourers entails the risk of the wrong frond being sampled. But, as will be seen later, the variation in uptake of P 32 between fronds 3 to 9 is small and the erroneous selection of frond 5 or 7 in place of the 6th frond is of no serious consequence.

4. *Analysis*

10 g. of the oven-dry material were dry ashed and extracted with 15 ml. of 2N HCl.

P 32 was measured by the liquid counting technique using 10 ml. of the filtered extract. At least two countings and a minimum of 1000 counts were done on each sample. In addition to the usual corrections, the counts were corrected for interference by K 40.

Total phosphorus was determined by the colorimetric vanadomolybdate method. Potassium in the extract was measured with the Eel Flame Photometer.

RESULTS

Uptake of P 32 with Time :

The results of the preliminary experiment to study the uptake of P 32 with time are recorded in Table 4.

TABLE 4

UPTAKE OF P 32 WITH TIME
SPECIFIC ACTIVITIES OF LEAVES 1 AND 6
Counts per min. per mg. P

Palm No.	*1st Leaf*				*6th Leaf*			
	10 days	*20 days*	*30 days*	*40 days*	*10 days*	*20 days*	*30 days*	*40 days*
1	2.19	3.21	14.77	11.97	6.28	7.64	11.45	19.44
2	4.98	4.93	10.89	12.70	5.20	6.58	16.24	17.91
3	8.53	11.75	14.05	12.91	20.74	2.47	23.82	23.82
4	2.27	6.63	7.14	14.11	4.63	7.39	15.43	20.71

It will be noted that the uptake of P 32 increases with time and is such that 10 g. of oven-dry sample is sufficient to make accurate counts.

Effect of Maturity of Frond on Uptake of P 32 :

The results of the preliminary experiment to study the variation in uptake of P 32 with the maturity of frond appear in Table 5.

TABLE 5

EFFECT OF MATURITY OF FROND ON UPTAKE OF P 32
SPECIFIC ACTIVITIES—COUNTS PER MIN. PER mg. P

Leaf No.	*Palm 1*	*Palm 5*	*Palm 6*	*Palm 4*	*Mean of Palms 1, 2, & 4*
1	3.21	4.93	11.75	6.63	4.92
3	8.22	5.38	14.48	8.39	7.30
6 ...	7.64	6.58	12.47	7.39	7.20
9	7.00	5.93	10.30	8.21	7.04
12	5.56	5.55	9.17	7.32	6.15
15	7.25	5.39	9.47	6.86	6.50
18	5.48	5.48	9.93	6.16	5.71

The samples were taken 20 days after the application of P 32.

Palm 3 shows a much higher uptake than the other three palms. The youngest and the very mature fronds show the lowest specific activities. The mean values of the specific activities of leaves 7, 6 and 9 from palms 1, 2 and 4 are nearly the same, suggesting that the uptake of phosphorus by leaves 3 to 9 varies over a narrow range. Nethsinghe (1966) reported similar results.

The mean specific activity of the leaf samples taken at specific times after the application of P 32 are presented in Table 6. The analysis of variance is given in Table 7. For the analysis of variance the results of palms 17 to 48 only were used.

TABLE 6

ISOTOPE STUDIES ON EFFICIENCY OF FERTILIZER UTILIZATION
EXPERIMENT 2
Mean Counts per min. per Gram. DRY MATTER

Distance of Placement	10th Day					20th Day					30th Day					40th Day				
	10	30	45	60	Total	10	30	45	60	Total	10	30	45	60	Total	10	30	45	60	Total
(metres)																				
0.5	68.9	31.7	23.8	12.2	136.6	164.4	108.1	74.7	38.3	385.5	267.5	213.7	151.1	71.7	704.0	395.7	298.3	183.8	92.6	970.4
1.0	96.0	25.2	14.5	9.5	145.2	225.5	90.8	60.7	26.7	403.7	373.3	182.2	127.0	45.1	727.6	540.0	203.7	189.1	64.5	997.3
2.0	30.9	7.6	2.4	6.9	47.8	85.3	28.5	9.8	20.6	144.2	137.8	55.4	19.5	36.8	249.5	199.7	85.1	31.0	46.3	362.1
3.0	12.0	4.7	4.1	1.9	22.7	28.3	14.4	16.7	8.2	67.6	47.8	24.9	31.9	12.7	117.3	70.8	33.1	55.4	17.8	177.1
TOTAL	207.8	69.2	44.8	30.5	352.3	503.5	241.8	161.9	93.8	1001.0	826.4	476.2	329.5	166.3	1798.4	1206.2	620.2	459.3	221.2	2506.9

TABLE 7

ANALYSIS OF VARIANCE

Source	10th Day				20th Day				30th Day				40th Day			
	D.F.	S.S.	M.S.	V.R.	D.F.	S.S.	M.S.	V.R.	D.F.	S.S.	M.S.	V.R.	D.F.	S.S.	M.S.	V.R.
Replicates	2	357.14			2	2032.41			2	20951.27			2	29401.54		
Distances	3	8635.86	2878.62	5.54**	3	64818.87	21606.29	7.11***	3	219408.67	73136.22	8.79***	3	395903.16	131967.72	6.96**
Depths	3	14900.81	4966.94	9.57***	3	72321.59	24107.20	7.94***	3	178016.36	59338.79	7.13***	3	396253.40	132084.47	6.97**
Dist.xDepths	9	6806.78	756.31	1.46	9	32590.75	3621.19	1.19	9	87577.76	9730.86	1.17	9	191620.16	21291.13	1.12
Error	30	15577.78	519.26		30	91114.53	3037.15		30	249641.54	8321.38		30	568653.69	18955.12	
Total	47	46278.37			47	262878.15			47	755595.60			47	1581831.95		
Correction Factor		23289.24				C.F. 187887.70				C.F. 606420.48				C.F. 1178540.70		
Coefficient of variation	$=\frac{22.7872}{22.0271}\times 100=103.45\%$				C.V. $\frac{55.1103}{62.5646}\times 100=88.09\%$				C.V. $=\frac{91.2216}{112.4000}\times 100=81.16\%$				C.V. $=\frac{137.6776}{156.6938}\times 100=87.86\%$			

** Significant at P 0.01
*** Significant at P 0.001

From the variance analysis it will be noted that whereas the between depth variance is significant for the 10th day sample the between distance variance is significant for the subsequent times of sampling.

The pattern of uptake becomes clear from an examination of the variance ratios (i.e. F values) given below :—

Variance Ratios

Factor	*10th day*	*23rd day*	*30th day*	*40th day*
Distance ...	2.66	3.67 *	3.89 *	4.18 *
Depth ...	8.50 *	2.56	2.08	1.80

Uptake with Time :

With time, the between distance variance ratio increase whereas the between depth variance ratio decreases.

Variation of Uptake with Distance of Placement and Time :

The following table summarises, according to the various distances of placement, the uptake on the different dates of sampling.

Specific Activity per Palm :

Distance of Placement Metres	*10th day*	*23rd day*	*30th day*	*40th day*
0.5 ...	2.30	4.88	6.34	7.41
1.0 ...	2.41	4.37	5.32	7.38
2.0 ...	1.34	2.48	2.91	3.55
3.0 ...	0.61	1.20	1.41	1.67

For all distances of placement the uptake increases with time. This increase is greater for placements close to the palm than for distant placements. This feature is reflected in the increase with time of the between distance variance ratios. Fig. 1 clearly demonstrates these features.

Variation of Uptake with Depth of Placement and Time :

The following table gives, according to the various depths of placement, a summary of the uptake on the different dates of sampling.

Specific Activity per Palm

Depths of placement Cms.	*10th Day*	*23rd Day*	*30th Day*	*40th Day*
10 ...	3.82	4.27	4.54	4.54
30 ...	1.55	3.95	5.18	6.12
45 ...	1.01	3.58	4.69	6.87
60 ...	0.30	1.14	1.57	2.58

The uptake on the early dates of sampling (10th and 23rd day) is better from depth of placements close to the surface than deeper placements. But with the passage of time uptake from deeper placement (not below 45 cms.) is as good as, if not better than, from placements close to the surface.

The increase in uptake with time from placements at depth of 30 cms. and 45 cms. is clearly seen in Fig. 2. While the 10th day curve is convex to the X — axis the other 3 curves are concave.

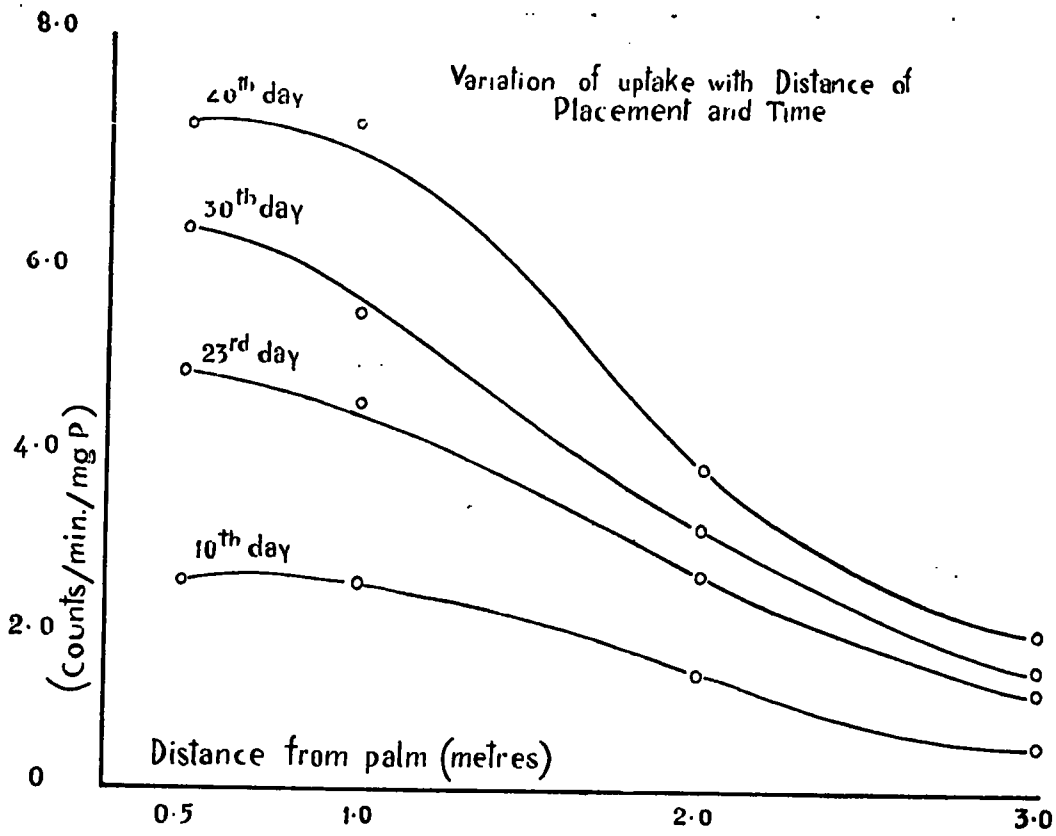
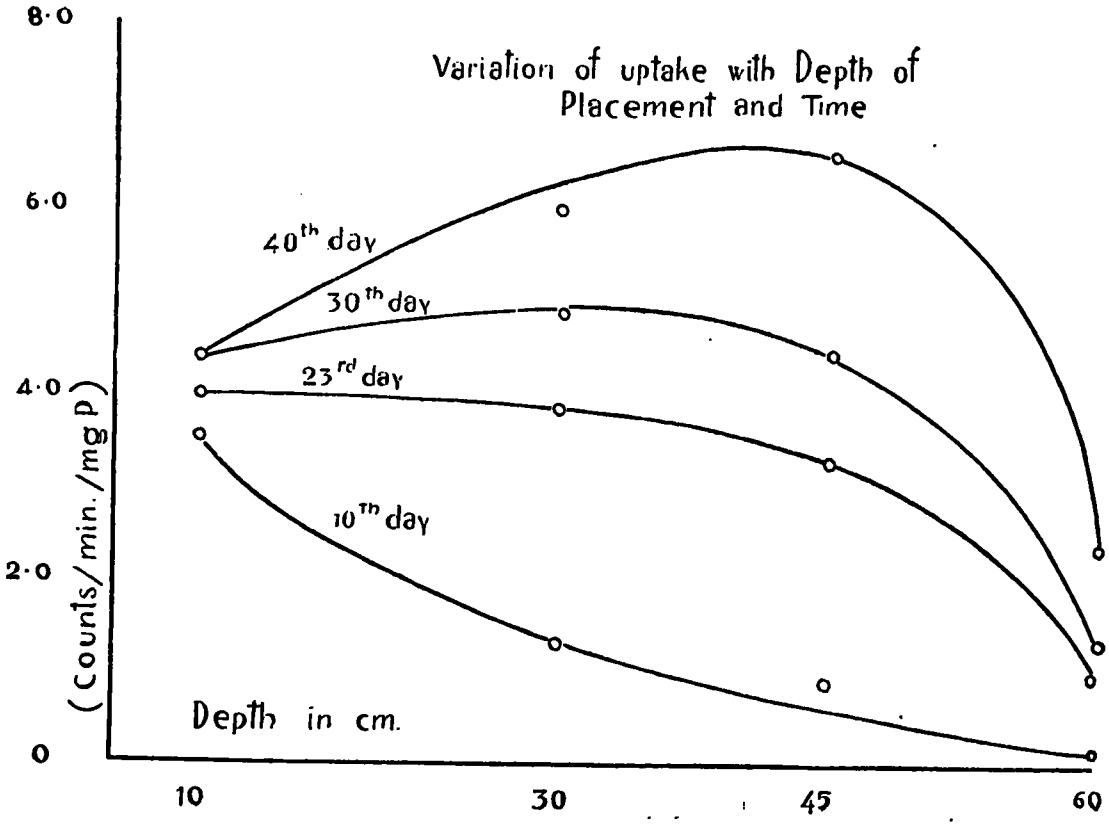


FIGURE I



FIGUREII

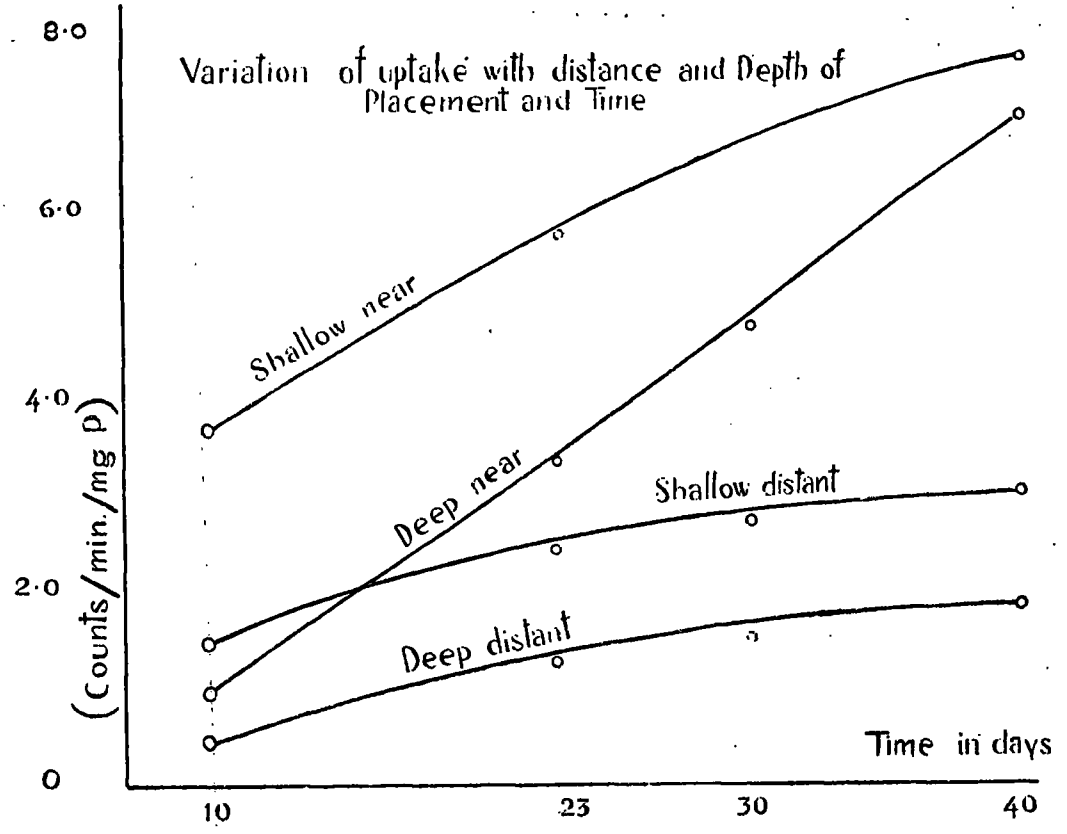


FIGURE III

Variation of Uptake with depth of placement, distance of placement and time interval.

The accompanying table has been prepared by grouping the depths of placement as " shallow " and " deep " and the distances of placement as " near " and " distant ".

Specific Activity per Palm

Placement		*10th Day*	*23rd Day*	*30th Day*	*40th Day*
Shallow-near	...	3.8	5.8	6.9	7.6
Deep-near	...	0.9	3.5	4.8	7.3
Shallow-distant	...	1.6	2.4	2.8	3.1
Deep-distant	...	0.4	1.3	1.5	2.2

In the above grouping distances 0.5 and 1.0 metres are considered " near " and distances 2.0 and 3.0 metres " distant ", depths 10 and 30 cms. are considered " shallow " and depths 45 and 60 cms. " deep ".

It will be seen that the uptake increases with time. For about 10 days the uptake from shallow placements, whether near or distant is better than from deep placements. However, with time the uptake from even " deep " placement " near " to the palm reaches almost the same level as from " shallow-near " placement. With " distant " placements, whether "shallow" or " deep ", the uptake is lower than " near " placement.

Fig. 3 clearly shows this characteristic in uptake.

DISCUSSION

The efficiency of uptake was assessed by measuring the radioactivity taken up by palms when equal amounts of radioactive phosphorus were applied according to the different treatments.

Earlier it was stated that the uptake of phosphorus by leaves 3 to 9 (Table 5) varies over a narrow range. Thus for sampling purposes it would be advantageous to choose any leaf between 3 and 9 as the error introduced by an erroneous count of the leaf sampled would not be great. From considerations of convenience in sampling leaf 6 would be a good choice.

The available phosphorus (Table 2) varied from 1.35 to 10.73 ppm. P. and so the uptake would have been underestimated. However, when the specific activities are compared with the corresponding available phosphorus contents no consistency in the dilution effect is noticeable. This may partly be due to the differential uptake resulting from the heterogeneity of the palms.

The wide variation between the specific activities of replicates is attributable to the difference in uptake of P 32 by the replicates (e.g. 591, 2042 637 counts per minutes). Perhaps the difference in uptake is due to genetic differences between palms. This illustrates the difficulty in choosing uniform experimental material. Very rarely does one come across a block of uniform stand.

On the 10th day the uptake from placement at 10 cms. depth is much larger than the uptake from the other depths of placement. Also for placement at the same depth the increase in uptake from the 10th day to the 40th day is small. This suggests that the uptake is quick when placement is near the surface and that most of the uptake takes place within a few days of the application.

The uptake from placements at 30 cms. and 45 cms. depths indicates that though the initial uptake is small it increases with time and after a sufficiently long time the uptake is greater than that from placement at 10 cms. depth. Thus where time is not a matter of consideration placement at a depth is as good as, if not better than, placement near the surface. Hence, for the coconut palm which is a perennial and the nuts are harvested at regular intervals throughout the year, deep placement of the fertilizer (not below 45 cms.) is immaterial so long as it is near the palm (within a metre).

It is possible that at a distance of 0.5 metres from the palm the density of the roots is such that the amount of soil round the roots is small. If it be so, then it is likely that the P 32 came in direct contact with the roots and so was absorbed quickly whereas absorption from placements at the other distances would have been through the soil solution and so relatively slower.

CONCLUSIONS

Of the sixteen treatments, uptake from placement at a depth of 10 cms. distant 0.5 metres from the palm has been the most efficient. With time the uptake from " deep " placements " near " the palm is as good as " shallow " placements " near " the palm.

ACKNOWLEDGEMENT

I acknowledge with thanks the financial assistance provided by the International Atomic Energy Agency, Messrs H. L. de Mel & Co., for permission to conduct the experiments at Marandawila Estate, Mr. V. Nalliah and other members of the Staff of the Soil Chemistry Division for their assistance in the field and laboratory, and Mr. V. Abeywardena for his assistance in the statistical analysis of the results.

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