EXTRAIT DE LA BROCHURE ANALYSE DES PLANTES
— ET PROBLÈMES DES FUMURES MINÉRALES —

THE NUTRIENT CONTENT OF NUT WATER IN RELATION TO AVAILABLE SOIL NUTRIENTS AS A GUIDE TO THE MANURING OF THE COCONUT PALM

(Cocos nucifera)

A New Diagnostic Method

by
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In determining the manurial needs of crops the modern view is that the plant itself is the best indicator of what it can absorb from the soil and in the utilisation of available nutrients. (Goodall and Gregory 7).

Methods based on this principle are already replacing the older classical procedures of so called « *Soil Analysis* », based on extraction of the soil with various reagents such as citric acid (Dyer), dilute nitric acid, dilute acetic acid etc. used in well known methods of determining available soil nutrients.

The techniques of Lagatu and Maume (11) for diagnosing mineral deficiencies of crops by determination of mineral nutrient contents of plant organs (in particular leaf analysis) has ~~only been~~ recently applied to tropical crops ; e.g. Rubber (Chapman 3 ; Constable 6) ; oil palms (Chapman and Gray 4 and Prevot and Ollagnier 17) ; groundnuts (Prevot, Ollagnier, Gillier 16 ; Scheidecker and Prevot 24) ; Tea (Portsmouth 15) ; and Cocoa (Homes 9 ; Hardy 8).

Leaf sampling of tropical perennial crops, in particular the Palmae (Coconut, oil palms), subject to seasonal nutrient level fluctuations, caused by vagaries of climate (rainfall and drought), and their height from ground level, present considerable practical difficulties, mainly connected with accurate and expeditious sampling of plant material (leaflets) for analysis, to be applied for routine diagnostic purposes.

Thus in the case of oil palms, both Chapman and Gray (4) and Scheidecker and Prevot (24) have shown that the physiological age of the palm leaflets, is important in foliar diagnosis. There is also considerable seasonal and diurnal variations in foliar nutrient proportions as shown by these authors.

« But whatever sort of examination is made, there is always to be faced in its application to practical agriculture an array of factors influencing the growth of crops, and many of these factors can only be crudely predictable or are too little understood to be assessed. Thus the improvement of crop production by fertiliser applications of potassium or other elements rest on combining and interpreting knowledge and experience of many kinds. » (Hoagland : Inorganic Plant Nutrition, p. 163).

Nut Water

... palm *(Cocos nucifera)*, in its physiology and nutrition ... of unique interest. The characteristics of this perennial ... and physiology complicate exact studies as would help ... quick methods of plant diagnosis.

... seasonal growth in the normal sense, except that rainfall ...d distribution) and its anti-climax drought influence leaf ...d particularly from the point of view of yield, the number ... bunch and the weight of kernel (copra-out-turn) — producing as a rule a bunch per month throughout the year.

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...ut palm has been confirmed by
...nstituent tends to be concentrated
...s of the nut — the husks forming
coconut water in contact with the
...e thick shell (*endocarp*).
...ut palm such as leaflets, petioles,
which can be easily sampled for
...f curing the nuts for copra, nuts
...e matter to obtain a representative
...tiliser status has to be determined)
are split in the normal course of
...te sample for analysis.
...ng errors can be kept at a minimum

...ental

refer mainly to potash as a plant
...ent of its availability in the soil in
for the coconut palm.

...osition ... *...conut Water.*

...antage of ... method ... that the potash can be determined ...avimetric cobalt...ite method without any preliminary treatment, such as evaporation to dryness, ashing of the sugars, which normally amount to 4 % volume etc., processes which are time consuming and unsuited for a routine method.

A further advantage is that, should there be delay in carrying out the filtration, no errors are involved if the cobaltinitrite reagent is quickly added, stirred and kept for several days or even weeks. The method was critically examined by adding pure KCl to coconut water samples and determining the recovery of added potash.

A quick method based on centrifuging the mixture of nut water and cobaltinitrite reagent based on the technique of Dennet** was not successful;

(b) *Determination of Other Nutrient Elements : Ca, Mg, Na & P.*

For determination of elements other than potash (Ca, Mg, Na & P) it was necessary to remove the sugars and other organic matter, such as the degradation products of fermentation, in case of samples that were not fresh. In fact for these determinations it is essential that fresh samples should be used as nutrients such as Ca & P may be absorbed by the yeast cells and other organisms which cause fermentation and remain in colloidal suspension or as a white deposit on standing.*

To avoid fermentation, various antiseptics were tried such as toluene and chloroform but were not satisfactory and the following techniques adopted :

Calcium. — To 350 c.c. of coconut water 50 c.c. concentrated nitric acid was added and made up to 500 c.c. in a volumetric flask. This was found not only to ~~present~~ prevent fermentation, but also serve as an oxidising agent for removing the sugars etc.

100 c.c. of this solution was evaporated on a vitreosil dish and repeated with the further addition of small amounts of conc. nitric acid to ensure complete oxidation of sugars. When all sugar was oxi...ed the residue was extracted with hot water, transferred to pyrex beak..., heated to boiling on a sand bath, filtered and the residue washed w... a few c.c. of Hydrochloric acid (50 % conc.).

* It was found that coconut water ferments very quickly ; that mannitol was a byproduct, which in old samples appeared as a white deposit (W.R.N. Nathanael, private communication, also vide (14).

** DENNET J.H. : " The Cobaltinitrite method for the estimation of Potash with Particular reference to Soils."

Calcium was determined in the filtrate by oxalate-permanganate volumetric method and magnesium in the filtrate from the calcium oxalate.

Sodium. — 25 c.c. of nut water (to which nitric acid had been added to prevent fermentation as before) was evaporated to dryness, ashed and residue extracted with hot water, filtered and made up to 100 c.c., 45 c.c. of this solution was evaporated to dryness, extracted in 1 c.c. of water and sodium determined by the Uranyl Zinc acetate method. The method was tested by addition of standard amounts of NaCl to fresh nut water and 99 % recovery obtained.

Spectrographic methods. — The possibilities of using quick spectrographic methods, in particular Flame Photometry, that may expedite routine analysis deserve study (Mitchell 13 ; Lundergardh 12). It is possible that where Flame photometric techniques are used, the coconut water as such could be used direct without any preliminary treatment, such as ashing and acid extraction required to prepare an extract with materials such as leaves.

If this could be done, it would serve as a very rapid method of routine diagnostic and practical value.

Field Experiments

The work reported in this paper as applied to the potash content of nut water has been based on work carried out on the following statistically designed manurial experiments :

(i) 3 × 3 × 3 replicated N.P.K. factorial experiment, where N, P & K are at three levels (N_0 — nil ; N_1 — 0.5 lbs N per palm ; N_2 — 1.0 lbs per palm ; P_0 — nil ; P_1 — 1 lb P_2O_5 per palm ; P_2 — 2 lbs/palm ; K_0 — nil ; K_1 — 0.75 lbs K_2O/palm ; K_2 — 1.50 lb per palm biennially). Full details of this experiment have been published (1, 19, 22).

This manurial experiment has been in existence since 1935 November when the first differential applications of manures were carried out.

Determinations of potash in nut water of the plots of this experiment were commenced as from the second year after manuring (M II — 1937) until the sixth year (M VI — 1945). Potash determinations were made on mixed water samples from 100 nuts taken from the 16 plots (18 palms each) at each pick (6 picks a year, comprising the following treatment combinations forming the 2 replications of the 3 × 3 × 3 design :

K_0 : (No potash)

N	P	K
0	0	0
0	2	0
2	0	0
2	2	0

K_2 — 1.5 lbs K_2O per palm

N	P	K
0	0	2
0	2	2
2	0	2
2	2	2

Subsequently, in view of the fact that the data of the 16 plots selected in this manner are not amenable to rigid statistical analysis, nut water samples from all the 54 plots comprising the 2 Replications of the 3 × 3 × 3 layout, were analysed as from the first pick of the 12th year after the first manuring M XII (1) (i.e. 6th November 1946) and continued for each pick up to the 14th year (M. XIV).

These data are summarised in Table I to VIII.

In November 1951 during the 9th biennial application of manure, the potash levels were stepped up by converting K_0 to K_1 (0.75 lbs K_2O/palm), K_1 to K_2 (1.50 lbs K_2O/palm) and K_2 to K_3 (2.25 lbs K_2O/palm) in order to see the nature of the responses obtained to potash applications at higher levels, and in particular the possibility of high order interactions.

This higher rate of K manuring was repeated in November 1953 and as from the first pick of the nineteenth year after the first manuring

TABLE I

3 × 3 × 3 N.P.K. MANURIAL EXPERIMENT (BANDIRIPPUWA)
VOLUME OF WATER PER NUT : c. c.

(Means of 8 plots)

K_0 PLOTS (No potash)

YEAR	PICK	1	2	3	4	5	6	TOTAL FOR THE YEAR	MEAN/PICK	RAINFALL (PREVIOUS YEAR)
M II 37..........	—	165	168	122	139	116	96	806	134	93.26 Inches (1936)
M III 38..........	—	112	140	113	93	93	112	663	111	87.41 „ (1937)
M IV 39..........	—	113	71	65	74	78	84	485	81	47.81 „ (1938)
M V 40..........	—	134	119	108	125	113	63	662	110	70.07 „ (1939)
M VI 41..........	—	102	125	105	119	113	72	636	106	81.92 „ (1940)
MEAN.........		125	125	103	110	103	85	650	108	

K_2 PLOTS (1.5 lbs $K_2$0/palm)

YEAR	PICK	1	2	3	4	5	6	TOTAL FOR THE YEAR	MEAN/PICK	RAINFALL (PREVIOUS YEAR)
M II 37..........	—	185	171	149	132	138	124	899	150	93.27 „ (1936)
M III 38..........	—	118	127	152	242	101	108	848	141	87.41 „ (1937)
M IV 39..........	—	134	109	84	83	80	83	573	96	47.81 „ (1938)
M V 40..........	—	145	135	268	128	146	125	947	158	70.07 „ (1939)
M VI 41..........	—	245	126	142	193	134	128	968	161	81.92 „ (1940)
MEAN.........		165	134	159	156	120	114	847	141	

3 × 3 × 3 N.P.K. MANURIAL EXPERIMENT (BANDIRIPPUWA)
POTASH (K_2O GRAMS) PER LITRE

YEAR	PICK	1	2	3	4	5	6	TOTAL FOR YEAR	MEAN PER PICK
K_0 (No Potash)									
M II 37.......	—	1.84	1.77	1.48	1.67	1.76	1.38	9.90	1.65
M III 38.......	—	1.47	1.60	1.24	1.41	1.31	1.40	8.43	1.41
M IV 39.......	—	1.28	1.08	0.87	0.92	1.17	1.15	6.47	1.07
M V 40.......	—	1.38	1.41	1.11	1.10	1.16	0.77	6.93	1.15
M VI 41.......	—	1.15	1.23	1.06	1.15	1.19	0.92	6.70	1.12
MEAN		1.42	1.42	1.15	1.25	1.32	1.12	7.68	1.28
K_1 (1.5 lbs. K_2O/palm)									
M II 37.......	—	2.26	2.26	1.99	2.20	2.27	1.83	12.21	2.13
M III 38.......	—	1.99	2.16	1.84	2.06	2.02	2.04	12.11	2.02
M IV 39.......	—	1.84	1.83	1.50	1.52	1.83	1.83	10.35	1.73
M V 40.......	—	2.14	2.16	1.86	1.87	1.85	1.61	11.49	1.92
M VI 41.......	—	2.02	2.18	2.01	2.02	2.00	1.60	11.83	1.97
MEAN		2.05	2.12	1.84	1.93	1.99	1.78	11.72	1.95

TABLE III

3 × 3 × 3 N.P.K. MANURIAL EXPERIMENT (BANDIRIPPUWA)

POTASH (GRAMS K_2O) PER 1000 NUTS

YEAR	PICK	1	2	3	4	5	6	TOTAL FOR YEAR	MEAN PER PICK
K_0 PLOTS (No Potash)									
M II 37.......	—	285	298	180	232	205	134	1334	222
M III 38.......	—	165	224	140	130	122	158	939	157
M IV 39.......	—	146	78	57	69	91	96	537	90
M V 40.......	—	186	166	119	137	131	50	789	132
M VI 41.......	—	117	154	112	138	134	70	725	121
MEAN		180	184	122	141	137	102	865	144
K_2 PLOTS (1.5 lbs. K_2O/palm)									
M II 37.......	—	419	388	263	306	282	196	1854	309
M III 38.......	—	235	325	224	208	219	276	1487	248
M IV 39.......	—	245	154	127	122	155	168	971	162
M V 40.......	—	312	285	239	273	233	121	1463	244
M VI 41.......	—	249	310	290	270	256	141	1516	253
MEAN		292	292	229	236	229	180	1458	243

TABLE IV

3 × 3 × 3 N.P.K. MANURIAL EXPERIMENT (BANDIRIPPUWA)

(A) GRAMS K_2O PER PLOT

K_0 PLOTS

YEAR	PICK	1	2	3	4	5	6	TOTAL FOR YEAR	MEAN PER PICK
M II 37.......	—	153	206	187	275	199	85	1105	184
M III 38.......	—	87	120	92	109	97	67	572	95
M IV 39.......	—	98	58	46	51	44	33	330	55
M V 40.......	—	62	114	135	123	90	26	550	92
M VI 41.......	—	39	38	67	134	118	39	435	73
MEAN....		88	107	105	138	110	50	598	100

(B) K_2 PLOTS — GRAMS K_2O PER PLOT

YEAR	PICK	1	2	3	4	5	6	TOTAL FOR YEAR	MEAN PER PICK
M II 37.......	—	205	265	288	390	302	144	1594	266
M III 38.......	—	155	194	152	193	189	134	1017	170
M IV 39.......	—	176	114	105	94	86	71	646	107
M V 40.......	—	123	237	301	288	184	70	1203	201
M VI 41.......	—	95	106	176	275	270	97	1019	170
MEAN....		151	183	204	248	206	103	1096	183

TABLE V

3 × 3 × 3 N.P.K. MANURIAL EXPERIMENT (BANDIRIPPUWA) EFFECT OF PHOSPHORIC ACID ON POTASSIUM UPTAKE

(Grams K_2O. Totals of 4 Plots for six Pick)

YEAR	M II '37	M III '38	M IV '39	M V '40	M VI '41
K_0 P_0	1157	665	400	646	527
K_0 P_2	895	476	259	452	341
Depression Due to P_2	262	188	141	194	186
% Depression on K_0 P_0	23 %	28 %	35 %	30 %	36 %
K_2 P_0	1570	1081	698	1341	1076
K_2 P_2	1410	944	590	1063	958
Depression Due to P_2	160	144	108	277	118
% Depression on K_0 P_0	10 %	13 %	15 %	21 %	11 %

K_2 — 1.50 lbs. K_2O per palm once in 2 years.
P_2 — 2.00 lbs. Phosphoric Acid once in 2 years.

(M XIX (1)), potash determinations were again carried out as from January 1954.

The data of 3 picks available are summarised in Table IX.

(ii) 3 × 2 × 2 (K X P X C — manurial × cultivation) experiment at Ratmalagara Estate, Madampe (Three levels of K : 0, 1, 2 lbs K_2O/palm 2 of P. : 0 & 1 lb P_2O_5/palm ; C — no cultivation (O) versus ploughing).

This manurial experiment based on a design published by Yates (28 page 58) (where interactions PC & KPC are partially confounded with block differences in each replication) has been in existence from June 1943.

Nut water analysis (K) were commencéd as from January 1953, and are being continued to date. The data are summarised in Table X.

It should be noted that in this soil there is no response to potash — the soil being rich in potash. (vide 1 page 20-21 ; and Salgado (20, page 5).

(iii) 3 × 3 × 3 N.P.K. manurial experiment (non replicated) at Marandawila Group consisting of 27 plots only, where combinations of N, P & K at two levels (O & unit rates — N — 0.5 lbs/palm ; P — 1 lb P_2O_5/palm ; K — 1 lb K_2O/palm, are applied *biennially* in three methods ; viz : nil, circular trenches round palms (C) and Broadcast (B) — a " PLACEMENT " experiment.

This experiment has been in existence since June 1949 and analysis of nut water have been carried out since June 1951. These are summarised in Table XI.

The corresponding crop data for the different main effects of the 3 manurial experiments are given in Tables VII, VIII, XII, XIII. The crop data for *each pick* have not been statistically analysed, except for the data of 3 × 3 × 3 N.P.K. experiment at Bandirippuwa for 1946 already published (Salgado 21, page 298) and only the mean treatment effects for the year (i.e. total of 6 picks) are given.

Discussion

A discussion of the data presented in Tables I to XIV based on the potash content of nut water samples from the three manurial experiments

TABLE VI

POTASH CONTENT OF COCONUT WATER (Gms K_2O/litre)
NPK 3 × 3 × 3 MANURIAL EXPERIMENT (Bandirippuwa)

Means of 18 plots

DATE OF PICK	DATE OF SAMPLING	K_0	K_1	K_2	N_0	N_1	N_2	P_0	P_1	P_2
MXII (1) : 16.12.46	20. 1.47	1.06	1.56	1.95	1.65	1.53	1.40	1.57	1.48	1.53
MXII (2) : 7. 2.47	10. 3.47	1.08	1.64	2.07	1.70	1.58	1.51	1.63	1.56	1.59
MXII (3) : 8. 4.47	9. 4.47	0.99	1.47	1.82	1.52	1.40	1.37	1.49	1.38	1.40
MXII (4) : 9. 6.47	21. 7.47	0.92	1.51	1.90	1.52	1.48	1.33	1.51	1.39	1.43
MXII (5) : 18. 8.47	9. 9.47	1.06	1.59	1.98	1.60	1.63	1.41	1.60	1.55	1.49
MXII (6) : 10.10.47	10.10.47	1.04	1.59	2.05	1.67	1.56	1.44	1.65	1.53	1.49
Mean of 6 picks		1.03	1.56	1.96	1.61	1.53	1.41	1.58	1.48	1.49

DATE OF PICK	DATE OF SAMPLING	K_0	K_1	K_2	N_0	N_1	N_2	P_0	P_1	P_2
MXIII (1) : 10.12.47	20. 1.48	0.91	1.52	1.99	1.58	1.54	1.30	1.56	1.42	1.34
MXIII (2) : 5. 2.48	9. 3.48	0.95	1.55	2.01	1.61	1.53	1.38	1.59	1.43	1.50
MXIII (3) : 6. 4.48	8. 5.48	0.67	1.18	1.70	1.27	1.21	1.07	1.26	1.13	1.16
MXIII (4) : 8. 6.48	13. 7.48	0.84	1.15	1.66	1.33	1.22	1.10	1.25	1.17	1.23
MXIII (5) : 3. 8.48	7. 9.48	0.80	1.16	1.68	1.36	1.25	1.03	1.21	1.25	1.18
MXIII (6) : 9.10.48	9.11.48	0.68	1.03	1.51	1.15	1.12	0.95	1.05	1.06	1.11
Mean of 6 picks		0.81	1.27	1.76	1.38	1.31	1.14	1.32	1.24	1.25

TABLE VII

3 × 3 × 3 NPK MANURIAL EXPERIMENT (Bandirippuwa)
MAIN EFFECTS: LBS COPRA PER ACRE/ANNUM

(Mean of 18 plots)

	K_0	K_1	K_2	N_0	N_1	N_2	P_0	P_1	P_2	PREVIOUS YEAR
MXII : 1946-47...	1333	1715	1845	1612	1700	1582	1657	1605	1631	96-85
MXIII: 1947-48...	1383	1833	1965	1710	1743	1719	1731	1716	1725	59-93
MXIV : 1948-49...	891	1292	1437	1185	1282	1153	1205	1230	1185	73-35

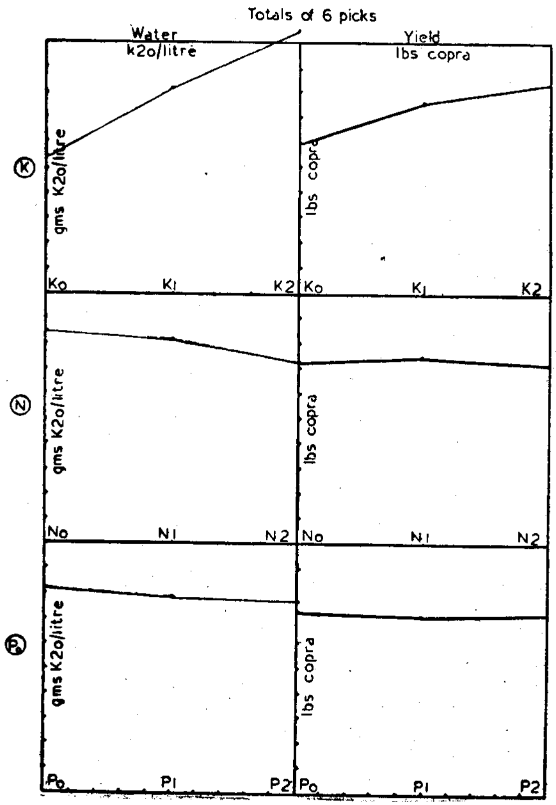
and the corresponding yield data reveal interesting possibilities, both as to the value of the method in assessing the potash needs of coconut soils and the fertiliser interactions on yield.

The statistical analysis of the data of the 3 × 3 × 3 N.P.K. Experiment are not included in this paper nor are the two-way tables showing the yield data corresponding to the 27 treatment combinations recorded.

DIAGRAM I

Influence of Manuring on

POTASH CONTENT OF COCONUT WATER



The complete statistical analysis of the yield data of the 3 × 3 × 3 N.P.K. experiment at Bandirippuwa for the first 14 years data are published in the Annual Report for 1949 (1) and the subsequent data in the corresponding Annual Reports.

In calculating the relation between the potash content of nut water and yield of copra from the data of this experiment the method of statistical analysis that should be adopted would be (1) by calculating the regression coefficients of the yield on the potash content of the nut water in an analysis of covariance of these two variates and (2) by dividing the treatment mean squares in the analysis of variance of the potash contents of the coconut water into the linear response and curvature.

Calculations on these lines have not been completed on all the data summarised in the Tables. However, for the data already published (Oleagineux 1953, 8, 5, 297-298) regression coefficients of the yield on the potash content of the nut water have been calculated by the methods of covariance analysis for the six picks of one year (1946-47 and are given overleaf).

ANALYSIS OF COVARIANCE : NPK BANDIRIPPUA ESTATE ***

Source	DF	ξx^2	ξxy	ξy^2	r
(1) Total	323	70.1098	+ 1083.70	226919	+ 0.2717
(2) Aggregate of 6 picks	53	64.4706	+ 1179.76	82060	+ 0.5129
Blocks	5	0.4907	+ 1.61	45731	+ 0.0107
N	2	2.4906	+ 20.63	890	+ 0.4380
P	2	0.5115	+ 0.04	36	+ 0.0093
K	2	49.2887	+ 1026.19	22306	+ 0.9792
N × K	4	1.0394	+ 21.97	2778	
N × P	4	2.3416	+ 18.03	385	
P × K	4	0.5320	— 5.70	471	
Error (a)	30	7.7761	+ 96.99	9463	+ 0.3575
(3) Seasons	5	1.5794	— 130.11	120860	
(4) Seasons × Blocks	25	0.4452	— 1.83	3016	
(5) » × N	10	0.3096	+ 0.75	853	
(6) » × P	10	0.1441	+ 4.23	1393	
(7) » × K	10	0.2364	— 3.34	3250	
(8) » × N × K	20	0.2070	+ 15.18	2245	
(9) » × N × P	20	0.1322	+ 10.68	1750	
(10) » × P × K	20	0.2717	+ 3.20	1471	
Error (b)	150	2.3136	+ 5.18	10021	+ 0.0340

Coefficient of Correlation K_2O *per litre — copra yield* = + 0.9576

X = K_2O per litre.
y = lbs copra per plot.

(i) *Seasonal Effects :*

In Tables I to V, as well as the subsequent data for the years 1946 to 1948 (Table VI), the seasonal effects on (a) the volume of nut water and (b) the concentration of potash — gms. K_2O/litre are clearly shown.

The main climatic factor in influencing both these variates is rainfall and its anticlimax drought. Drought markedly effects nut size and the volume of nut water, and also by the reduced uptake of nutrients by the palm, the actual potash content of the water.

Similarly rainfall and drought effect yield of nuts and copra weights. This is clearly shown in the statistical analysis of the yield data of the 3 × 3 × 3 N.P.K. experiment at Bandirippuwa for the first 14 years already published (1, p. 22), where it is shown that (a) the variance due to seasons

*** It is necessary to transform the K_2O percentages to the scale worked out by Clark Leonard (5) for chemical percentages — a statistical detail often ignored in the analysis.

TABLE VIII

3 × 3 × 3. N. P. K. EXPERIMENT—MAIN EFFECTS

YIELD EXPRESSED AS LBS. PER ACRE														
YEAR	1936 M I	1937 M II	1938 M III	1939 M IV	1940 M V	1941 M VI	1942 M VII	1943 M VIII	1944 M IX	1945 M X	1946 M XI	1947 M XII	1948 M XIII	1949 M XIV	14 Years Mean
N_0	1,713	2,209	1,646	1,391	1,859	1,486	1,720	1,890	1,708	1,609	1,427	1,612	1,710	1,185	1,655
N_1	1,821	2,297	1,769	1,472	1,975	1,612	1,880	2,003	1,794	1,673	1,490	1,700	1,743	1,282	1,751
N_2	1,781	2,402	1,729	1,385	1,969	1,549	1,805	1,909	1,711	1,628	1,400	1,582	1,719	1,153	1,694
P_0	1,814	2,328	1,695	1,431	1,974	1,546	1,831	1,974	1,801	1,659	1,456	1,657	1,731	1,205	1,722
P_1	1,719	2,292	1,716	1,433	1,889	1,562	1,740	1,901	1,694	1,616	1,420	1,605	1,716	1,230	1,681
P_0	1,782	2,288	1,733	1,385	1,940	1,539	1,834	1,927	1,719	1,635	1,440	1,631	1,725	1,185	1,697
K_0	1,740	2,249	1,629	1,351	1,752	1,418	1,528	1,697	1,430	1,387	1,185	1,333	1,383	891	1,497
K_1	1,815	2,332	1,733	1,408	2,005	1,584	1,879	2,000	1,800	1,715	1,498	1,715	1,833	1,292	1,757
K_2	1,759	2,347	1,782	1,490	2,043	1,644	1,998	2,105	1,983	1,808	1,633	1,845	1,965	1,437	1,846
General Mean	1,772	2,303	1,715	1,416	1,934	1,549	1,862	1,934	1,738	1,637	1,439	1,631	1,724	1,207	1,700
Significant Dif. P. 05.	180	143	131	89	163	120	143	141	140	112	98	140	132	132	
Standard error	89	70	61	44	80	59	70	73	57	55	48	69	64	60	65

TABLE IX

3 × 3 × 3 N. P. K. EXPERIMENT (BANDIRIPPUWA) M XIX

POTASH CONTENT IN NUT WATER — MEAN OF 18 PLOTS (Grms/Litre)

(A) Potash Response

DATE OF PICK	Date of Sampling	K_1 (0.75 lbs K_2O/Palm)			K_2 (1.50 lbs K_2O/Palm)			K_3 (2.25 lbs K_2O/Palm)		
		Volume 100 nuts	Total K_2O 100 nuts	K_2O/Litre	Volume 100 nuts	Total K_2O 100 nuts	K_2O/Litre	Volume 100 nuts	Total K_2O 100 nuts	K_2O/Litre
MXIX - 1 17.12.53. .	26.1.54	10515	10.20	0.97	13378	20.67	1.55	13830	26.74	1.93
MXIX - 2 17. 2.54. .	27.3.54	10715	10.51	0.98	12809	19.34	1.51	13160	25.47	1.94
MXIX - 3 2. 4.54. .	7.5.54	11124	11.18	1.00	13926	21.61	1.55	14243	26.96	1.89

(B) Nitrogen Response

DATE OF PICK	Date of Sampling	N_0 (No nitrogen)			N_1 (0.5 lbs N/Palm)			N_2 (1.0 lbs N/Palm)		
		Volume 100 nuts	Total K_2O 100 nuts	K_2O/Litre	Volume 100 nuts	Total K_2O 100 nuts	K_2O/Litre	Volume 100 nuts	Total K_2O 100 nuts	K_2O/Litre
MXIX - 1 17.12.53. .	26.1.54	13032	20.78	1.59	12530	19.43	1.55	12161	17.40	1.43
MXIX - 2 17. 2.54. .	27.3.54	12762	20.06	1.57	11949	18.03	1.51	11973	17.23	1.44
MXIX - 3 2. 4.54. .	7.5.54	14021	22.62	1.61	12810	19.36	1.51	12468	17.77	1.43

(C) Phosphoric Response

DATE OF PICK	Date of Sampling	P_0 (No (Phosphoric)			P_1 (1.0 lbs P_2O/Palm)			P_2 (2.0 lbs P_2O/Palm)		
		Volume 100 nuts	Total K_2O 100 nuts	K_2O/Litre	Volume 100 nuts	Total K_2O 100 nuts	K_2O/Litre	Volume 100 nuts	Total K_2O 100 nuts	K_2O/Litre
MXIX - 1 17.12.53. .	26.1.54	12461	20.34	1.63	12470	19.42	1.43	12792	17.85	1.36
MXIX - 2 17. 2.54. .	27.3.54	11830	19.51	1.65	12647	18.46	1.46	12207	17.36	1.42
MXIX - 3 2. 4.54. .	7.5.54	12993	21.55	1.66	13316	19.80	1.49	12989	18.40	1.42

TABLE X

3 × 2 × 2 (K × P × C) MANURIAL EXPERIMENT

Ratmalagara Estate

POTASH CONTENT OF NUT WATER (Grms/Litre)

MVII			
PICK	K_0	K_1	K_2
M VII 3..	2.17	2.30	2.34
— 4..	2.57	2.70	2.78
— 5..	2.47	2.60	2.67
— 6..	2.35	2.61	2.72
Mean (4 picks)..	2.39	2.55	2.63

MVIII			
PICK No.	K_0	K_1	K_2
M VIII 1.	2.42	2.63	2.72
— 2.	2.35	2.37	2.54
— 3.	2.31	2.48	2.55
— 4.	2.46	2.58	2.70
— 5.	2.22	2.27	2.45
— 6.	2.22	2.45	2.54
Mean.	2.33	2.46	2.58

M IX			
PICK No.	K_0	K_1	K_2
MX 1....	2.27	2.45	2.54
— 2....	2.11	2.30	2.45
— 3....	2.11	2.33	2.47
— 4....	2.39	2.55	2.60
— 5....	2.20	2.46	2.56
— 6....	2.13	2.47	2.60
Mean	2.20	2.43	2.54

PICK No.	K_0	K_1	K_2
M X 1...	2.37	2.72	2.77
— 2...	2 16	2.47	2.57
— 3...	2.06	2.34	2.44
— 4...	2.29	2.50	2.54
— 5...	1.91	2.18	2.30
— 6...	2.06	2.44	2.53
Mean	2.14	2.44	2.53

accounts for more than a third of the total variance ; (b) a very high season × K interaction which is highly significant (P. 01) — in fact the only season × manurial treatment interaction that is significant.

(ii) *Correlation Between Potash Content in nut Water and Yield Response :*

The potash content of the nut water rises with the potash application and presumably with the available potash content (the native available potash in the soil and potash added as manure), and may provide an index (a)... of the potash status of the soil, and (b) of the expected yields. Some typical data are shown graphically in Diagram I.

(iii) *Potash Content of Soil and Potash Content of nut Water in Relation to Response to Potash Manuring :*

A comparison of the data of the three manurial experiments is particularly revealing.

There is a high correlation between the yield and the potash content of the nut water.

At Bandirippuwa where the only response that is highly significant is due to potash, vide (Table VIII) the yields rise almost linearly and the curves for the potash contents of nut water are almost parallel,

TABLE XI

°/₀ 3 × 3 × 3 (NPK X METHODS OF APPLICATION) MANURIAL EXPERIMENT

Marandawila Group

POTASH CONTENT IN COCONUT WATER (Gms K_2O/litre) (MEAN OF 9 PLOTS)

PLOT No.	K_O (No potash)			K_C (Potash 1 lb K_2O in circular trenches)			K_B (Potash 1 lb K_2O Broadcast and ploughed)		
	Volume c. c. (100 nuts)	Potash gms K_2O	K_2O per litre	Volume c. c. (100 nuts)	Potash gms K_2O	K_2O per litre	Volume c. c. (100 nuts)	Potash gms K_2O	K_2O per litre
MII (1)	12138	22.79	1.88	12376	27.35	2.21	12969	29.05	2.24
II (2)	10065	18.77	1.88	10948	23.18	2.12	11004	26.60	2.20
II (3)	11080	20.88	1.88	11269	24.13	2.14	11960	26.63	2.23
II (4)	9128	16.13	1.77	9107	17.96	1.97	9584	19.72	2.06
II (5)	6064	8.46	1.39	6156	9.74	1.58	6770	11.57	1.71
II (6)	9443	16.21	1.72	9068	17.18	1.90	9252	17.77	1.92
MEAN	9653	17.21	1.75	9821	19.92	1.99	10257	21.89	2.06
	K_O			K_C			K_B		
MIII (1)	10157	17.60	1.73	9468	18.68	1.97	10248	21.29	2.08
III (2)	10833	18.03	1.57	11708	21.06	1.80	13507	25.12	1.86
III (3)	13943	27.68	1.99	15947	34.16	2.14	15642	35.66	2.28
III (4)	13517	25.51	1.89	13940	30.74	2.21	14613	30.12	2.06
III (5)	14076	21.94	1.56	14898	29.99	2.01	15410	32.16	2.09
III (6)	15252	26.82	1.76	15680	34.27	2.19	16442	36.47	2.22
MEAN	12963	22.76	1.75	13607	28.15	2.05	14310	30.14	2.10
MIV (1)	12036	23.26	1.93	13022	31.39	2.41	13992	33.87	2.42
IV (2)	12001	21.97	1.83	12222	26.57	2.17	13369	29.78	2.23
IV (3)	12004	23.51	1.82	13182	28.99	2.20	14196	31.44	2.21
IR (4)	9610	16.92	1.76	10749	21.86	2.03	11511	24.26	2.11
IV (5)	9277	14.54	1.57	9081	17.93	1.97	8793	16.99	1.93
IV (6)	10406	17.85	1.72	9771	20.41	2.09	10630	22.21	2.09
MEAN	11039	19.68	1.77	11338	24.53	2.15	12082	26.43	2.17

TABLE XII

3 × 2 × 2 (K X P X C) MANURIAL X CULTIVATION EXPERIMENT (RATMALAGARA ESTATE)

Main effects

Lbs. Copra per acre per annum

TREATMENTS	MII 1944-45	MIII 1945-46	MIV 1946-47	MV 1947-48	MVI 1948-49	MVII 1949-50	MVIII 1950-51	MIX 1951-52	MX 1952-53
K_0	1771	1691	1415	1841	1438	1342	1631	1978	1663
K_1	1935	1674	1393	1842	1466	1327	1677	1957	1684
K_2	1893	1738	1492	1975	1589	1449	1760	2161	1813
Significant Difference P.O5	194	152	181	215	161	173	—	—	—

TABLE XIII

3 × 3 × 3 (N.P.K. × METHODS OF APPLICATION) MANURIAL EXPERIMENT (Marandawila Group)

Main Effects. ***

Lbs. Copra per acre per annum

Treatment	MI 1949-50	MII 1950-51	MIII 1951-52	MIV 1952-53
Ko	1583	1514	1482	1401
Kc	1659	1936*	1472	1528
Kb	1669	1930*	1638	1570
* Significant at P.O5	252	83	217	14

K = no potash.

Kc = 1 lb K per palm applied in circular trenches.

Kb = 1 lb K per palm broadcast and ploughed.

*** Yields data adjusted by the method of covariance by use of premanurial records.

For every addition of 0.75 lbs K_2O/palm as potash manure there is a corresponding increase of about 0.5 gms K_2O per litre in the nut water.

No such significant differences in yield or potash are found at Ratmalagara, in spite of the fact that the rates of application of potash are higher (1 lb and 2 lbs K_2O/palm).

Soil analysis have shown that while the available potash (EXCHANGEABLE POTASH) is low in the Bandirippuwa soil (.02 M.E. per 100 gms soil), the soil at Ratmalagara is comparatively high in this constituent varying from 0.20 to 0.26 ME (vide 1 page 20), i.e. nearly ten times that of the potash deficient soil.

Table XIV giving the data of potash values for nut water samples obtained from six estate Blocks of Mudukatuwa Estate and Keenakelle Estate (Marawila) are of particular significance.

TABLE XIV

POTASH CONTENT OF NUT WATER
MUDUKATUWA ESTATE (Marawila)

K_2O gms. per Litre

BLOCK No	Date of Sampling 8 - 4 - 53	Date of Sampling 24 - 6 - 53	Date of Sampling 26 - 8 - 53	Date of Sampling 30 - 10 - 53	Date of Sampling 18 - 12 - 53
1........	2.612 2.610	2.431 2.456	2.655 2.688	2.588 2.522	2.73 2.73
2........	2.242 2.187	1.966 1.966	2.240 2.157	2.257 2.157	2.40 2.41
3........	2.075 2.046	2.174 2.215	2.082 2.016	2.190 2.157	2.37 2.39
4........	2.285 2.185	2.331 2.481	1.958 1.999	2.198 2.091	2.49 2.48
5........	2.220 2.221	2.713 2.638	2.174 2.497	2.174 1.974	2.85 2.85
6........	2.192 2.132	2.041 2.215	1.850 1.800	2.298 1.983	2.17 2.20

KEENAKELLE ESTATE (Marawila)

K_2O gms. per Litre

BLOCK No	Date of Sampling 16 - 7 - 53	Date of Sampling 22 - 9 - 53	Date of Sampling 14 - 11 - 53
1................	1.452 1.435	1.991 1.933	1.867 1.825
2................	2.115 2.190	1.950 1.925	1.750 1.742
3................	2.273 2.198	1.767 1.634	1.891 1.858
4................	1.734 1.742	1.717 1.568	1.941 1.925

These samples were obtained in duplicate from the nut heaps of six blocks (or '*Fields*') of the former and 4 Blocks of the latter, comprising 400 acres, and would represent such samples as would be obtained in a routine potash survey of soil of coconut estates in Ceylon.

These two estates represent two of the highest yielding coconut estates in Ceylon on a rich deep soil, the Marawila '*Chocolate loams*'. The unique fertility of these soils are indicated by the record values for potash e.g. 2.73 gms K_2O/litre for Block No. 1.

It should be mentioned that the seasonal fluctuations in potash contents which are not consistent for the different blocks, are probably due to (a) the small sample of 100 nuts selected for water sampling out of a heap of about 20,000 nuts ; (b) delays between picking and husking of nuts for curing. This period is normally one month and if delayed beyond six weeks, germination occurs, particularly during the wet season and the potash content decreases.

Soil potash availability and nut water potash

There arises difficulties where we adopt chemical procedures of " soil analysis " for estimating the fertility status of soils when we confine our attention almost exclusively to efforts to measure the nutrient supply in terms of surface soils — the so called 9 inches of *top soil.* We thereby measure merely the *Intensity Factor* of soil fertility and disregard the *Capacity Factor.* The actual *Capacity Factor* should be a function of the *Intensity Factor,* in terms of the weight of nutrients available per unit weight of soil, which will depend on the texture, water table and or the volume weight of soil which will express the depth to which the root system of the palms can penetrate.

It is the *Capacity Factor* which will be measured by the nutrient content of the nut water, and in this case potash. For example the Marawila soils are light sandy loams, whose available contents would not be very high on the basis of say ME per 100 gms. soil ; but as these soils are very deep and sometimes up to 30 to 40 feet of soil where the roots penetrate,.there is an extensive area for the root system to scour for plant food, so that, although the percentage content of available potash is small the nett quantity available is considerable.

We know that on these soils, unlike shallow soils with impermeable subsoils such as laterites and lateritic gravels, coconut roots penetrate to great depths. It is unfortunate that Sampson (18) has classified coconut roots into " feeding roots " and " water roots ". Such a classification does not appear to be correct on physiological grounds.

There are untapped reserves of most nutrients beneath the surface soil, which adequate cultivation and drainage to provide the necessary aeration for root development, can help to exploit (23). Such nutrients which soil analysis cannot evaluate, nut water analysis can be expected to throw some light on.

Manurial Interactions — Crop physiology and nut water potash.

By the statistical method of subsidivision of treatment responses in the analysis of variance of potash contents of nut water with the linear response and curvature, and by the methods of regression analysis, it would reveal small but significant regressions of nut water K on N and P as well as corresponding regressions based on yield.

Table VIII and Diagram II show that at the higher level of N (1 lb N per palm), there has been a progressive decline in yield and yield data show such a negative interaction of N on K. This is shown in the yield curves and also correspondingly reflected in parallel curves for nut water potash — a physiological explanation being that this indicates an interference in the uptake of K by N. Such interactions have been observed for most potash loving crops such as potatoes as shown by Knowles, Watkins and Cowie (10).

Similar interactions of P on K are indicated in the data of Table V.

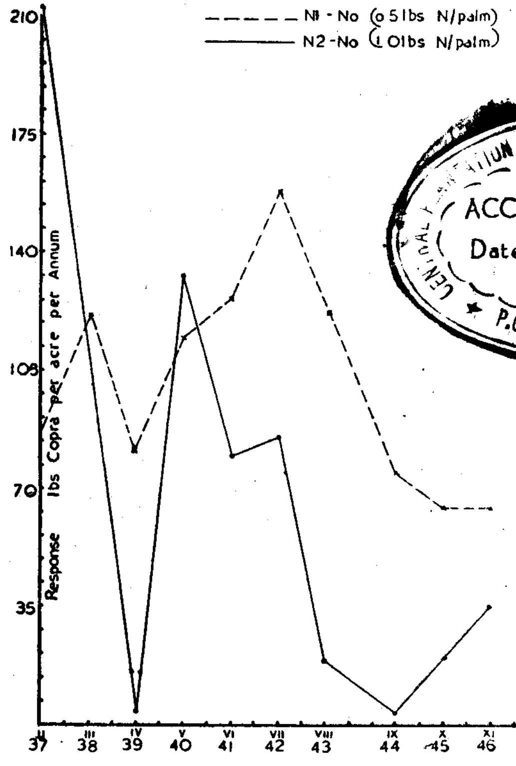
The physiology of nut water as shown by recent studies by Katherine Wilson and Cutler (27) in America is particularly interesting. It is not proposed to speculate further on this aspect here except to mention that nut water forms a unique physiological material, analogous to plant sap in providing the ideal indicator of the physiological status of the palm and of the soil conditions in which it is grown.

DIAGRAM II

N. P. K. — Experiment

RESPONSE TO NITROGEN MANURING

Lbs Copra Per Acre



Calcium, Magnesium, Sodium, Phosphate

As mentioned before, the analytical details in determining Ca, Mg, Na and P are complicated by the fact that it is necessary to destroy the organic matter (mostly sugars about 4%).

A few determinations have been made on the nut water samples of the 3 × 3 × 3 N.P.K. Experiment (Bandirippuwa) and are briefly discussed below :

Ca : In the results shown below it will be seen that there is hardly any change in the calcium content of the nut water under the conditions of differential manuring and that different levels of N, P & K do not appear to influence the level of Ca relative to that of P.

According to Ehrenberg's Kalk-kali Gesetz*, Ca inhibits the absorption of K by plants and in the case of potash loving crops such as the coconut palm it can be expected that there would be an antagonism between K and Ca, above a certain critical level of Ca.

On the basis of an average value of 1.5 gms K_2O/litre and 0.40 gms CaO/litre in nut water, concentration of potash in Milli-equivalents (M.E.) per litre would be 31.91 for K and 14.29 for Ca, with a K/Ca ratio of 2.23.

* EHRENBERG, P. (1919) : (Das Kalk-kali Gesetz. Landwirtsch. Jahrb. 34, 1-159).

CALCIUM CONTENT COCONUT OF WATER (gms CaO/Litre)

BLOCK I		BLOCK II		BLOCK III		BLOCK IV		BLOCK V		BLOCK VI	
Plot No.	CaO per litre	Plot No.	CaO per litre	Plot No.	CaO per litre	Plot No.	CaO per litre	Plot No.	CaO per litre	Plot No.	CaO per litre
1	0.42	10	0.37	19	—	28	0.37	37	0.36	46	0.43
2	0.42	11	0.37	20	0.37	29	0.38	38	—	47	—
3	0.40	12	0.41	21	—	30	—	39	—	48	0.49
4	0.38	13	0.37	22	0.36	31	0.39	40	—	49	—
5	—	14	0.36	23	0.39	32	—	41	—	50	—
6	—	15	0.35	24	0.40	33	—	42	0.41	51	—
7	—	16	—	25	0.40	34	—	43	0.40	52	—
8	0.37	17	—	26	0.41	35	—	44	—	53	—
9	0.34	18	—	27	0.39	36	0.40	45	—	54	—

The soil of this manurial experiment is acid, ranging from pH 5.1 to 5.3, and with low exchangeable Calcium reserves (1.06 ME per 100 gms soil). The only differential addition of Calcium is from the ground mineral phosphates (Saphos), equivalent to 1.6 lbs CaO per palm for P_1 and double that for P_2 applied biennially. It should also be mentioned that application of lime is not carried out as a part of coconut manuring.

It would also be of interest to note that K/Ca ratio for leaflets of the Coconut palm (young palms 3 years old) varied from 3.3 to 3.8 and also showed considerable seasonal variation (unpublished data by writer).

Mg : No detailed estimations have been made of Mg but the amounts are much smaller than Ca.

P : Except for a few casual samples, determinations of P have not been made on a scale sufficient to correlate with yield responses.

In view of the recent work of Katherine Wilson and Cutler (27) on the distribution of acid phosphatases and inorganic phosphate concentrations during development of the fruit of *Cocos nucifera,* work on P levels of nut water in relation to manuring should be of particular interest.

Na : Sodium has been popularly considered to be an important nutrient element for coconuts, the assumption being that as coconuts thrive on the coastral littoral close to the sea, sodium is the key to its successful growth. It is not possible to discuss the fallacies of this argument but to state that the coconut palm does equally well thrive inland in Ceylon, almost 30 to 40 miles from the coast and yet further away from the sea. Whether this fact is due to the presence in both locations of another common element like magnesium which the palm may require is a matter for further study.

While sodium may have indirect effects by releasing other nutrients such as potash from the soil, there is no evidence to prove the essentiality of sodium in the nutrition of the coconut palm.. A few sodium determinations on nut water samples of the 3 × 3 × 3 N.P.K. Experiment (Bandirippuwa) have been carried out, but are insufficient for discussion here. Its concentration is of the order of 0.68 gms/Na_2O/litre, equivalent to 4.8 ME/litre.

On this basis the average relative molecular proportions of K, Ca and Na are 63 : 27 : 10.

" .. if the investigator works out a satisfactory technic that takes into account the selection of the samples and the physiological stage of development of the given variety of a crop under the prevailing weather conditions, plant analysis can be of great value in predicting the fertiliser needs of plants, particularly for perennial crops " (26).

CONCLUSION

This paper provides data some of which cannot be considered conclusive but which throws new light on the fertilizer requirements of the coconut palm. It opens up an interesting field for further study.

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