NUTRITIONAL AND PHYSIOLOGICAL STUDIES ON COCONUT WATER

PART 1: FURTHER ASPECTS OF THE NUTRIENT CONTENT OF NUT WATER IN RELATION TO SOIL NUTRIENTS

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INTRODUCTION

Nutrient analysis of Plant Tissues (Plant Analysis) as a method of assessing the nutritional requirements of plants has received considerable attention and study during the last two decades. Ulrich (9) and Smith (8) have comprehensively discussed the varied aspects of this technique. In the last decade no less than three Colloquia on plant analysis and fertilizer problems have been held. In a paper presented at the first of these Colloquia held in Paris under the auspices of the IRHO, Salgado (5) pointed out the possibilities of using coconut water as a plant tissue, the nutrient contents of which could be used as a method of assessing nutrient needs of the coconut palms growing under different soil conditions and manurial treatments.

In this context, the recent findings (Salgado 1955) on the nutrient content of coconut water in relation to available soil nutrients evoke considerable interest among research workers on coconut, because compared with other organs of the coconut palms (such as leaflets, petioles, or husks etc.), "nut water forms a material which can be easily sampled for purposes of analysis, and has the unique advantage that sampling errors can be kept at a minimum".

While disclaiming any credit for conclusive evidence as such, Salgado discussed therein some valuable though tentative trends in the potash content of nut water *vis a vis* available potash in the soil and nut yields and thereby opened up a promising field for further study. The main conclusions are summarised below:—

"Drought markedly affects nut size and the volume of nut water and also, by the reduced uptake of nutrients by the palm, the actual potash content of nut water".

"The potash content of 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".

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

"The yield data show a negative interaction of N on K. This is shown in the yield curve 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".

The very same data on which the above tentative conclusions have been based, and further data collected subsequently as a routine measure by the Soil Chemist's Division of this Institute, were re-examined in 1956 (Harland and Abeywardena), and further interesting trends were observed—in fact some apparently conflicting with the corresponding earlier tentative findings (Salgado 1955). However, as the data available at the time were insufficient to clarify the supposed conflicting features, steps were taken to collect further data on the nutrient contents of nut water in individual palms in a uniformly manured block of about 300 palms at Bandirippuwa Estate. From a study of these data, we have been able to shed more light on the inter-relations between available nutrients in the soil, the yield of palms, and the nutrient content of nut water. In this paper we are recording the results of our analysis with an apology for the long delay in presenting these for publication.

In 1956 Salgado, Nethsinghe and Nalliah (7) developed a rapid routine method for the determination of phosphates in coconut water, and the nut water technique developed by Salgado was applied to corresponding studies on the phosphate status of soils and response to phosphate manuring as assessed by the content of phosphoric acid content of nut water.

Pursuant to the work of Prevot et al (4) on foliar analysis of coconut palms at the I.R.H.O. for assessing manuring needs, further work on rationalising the use of nut water for diagnostic purposes as applied to potash and phosphate manuring of coconut palms, have been projected by utilising the data of the long-term manurial experiments both at Bandirippuwa and at Ratmalagara for determining "critical levels" of nutrients in relation to yield responses to manuring and their interpretations.*

Further work in hand is mainly directed towards an elucidation of the fundamental bases on which the interpretation of nut water and foliar analysis data *vis a vis* yields should be determined on the lines of modern concepts of plant physiology so as to give a scientific and fundamental understanding of the physiological mechanism and relationships involved.

These studies involve a deeper understanding of the translocation of nutrients taken up by the root system and transported to the leaves, and from the leaves to the developing bunches of nuts, as also any possible reversible translocations of mobile nutrients from one plant organ to the other. Such studies would form a sound basis of fundamental crop physiology on the results of which manuring for optimum crop responses could be worked out with some measure of exactness.

MATERIAL AND METHODS

The effect on the potash content of nut water (K_2O gms./litre) of the addition of nitrogen, phosphates, and potash into the soil and the inter-relationships between nut yields, available nutrients in soil and K_2O content of nut water have been examined from the data of the 54 plots of the $3 \times 3 \times 3$ NPK experiment at Bandirippuwa Estate.

* Field experiments must remain the final testing ground to check the usefulness of laboratory methods and are essential for obtaining accurate yield data and for measuring fertilizer responses to correlate with laboratory data on plants and soils, Wallace (10, p. 21).

The relationships between nut yields of individual palms and nut water nutrients etc. have been examined from data collected from a block of 300 palms maintained under a uniform system of management and manuring also at Bandirippuwa Estate.

The N.P.K. experiment falls into two periods and the analysis is carried out separately for the two periods. The periods being (1) Pre-stepping period when the responses to NPK have been tested at levels:—N_0 = nil; N_1 = 0.5 lbs. N per palm; N_2 = 1.0 lb. N per palm; P_0 = nil; P_1 = 1 lb. P_2O_5 per palm; P_2 = 2 lbs. P_2O_5 per palm; K_0 = nil; K_1 = 0.75 lbs. K_2O per palm; K_2 = 1.50 lbs. K_2O per palm (applied biennially) and (2) Post-stepping period when the K levels have been stepped up by one level i.e. K_0 = 0.75 lb. K_2O per palm; K_1 = 1.50 lbs. K_2O per palm and K_2 = 2.25 lbs. K_2O per palm and the levels of N and P remain the same as before.

RESULTS

1. Effect of N.P.K. added to the soil on the K_2O content of nut water and the yield of copra

The effect of the addition of N, P and K into the soil, on the yield as well as the K_2O content in nut water are shown by the results of the analysis of variance of the mean K_2O content (gms./litre) per plot and also the general trends summarised below.

Pre-stepping up period (K at levels 0, 1 *and* 2)

(*a*) *Significant responses* (Analysis of Variance)

Yields of Copra

(i) Significant positive response to K.
(ii) A significant N × K positive interaction.
(iii) Significant seasonal variation.

K_2O in nut water (gms./litre)

(i) Significant positive response to K.
(ii) Significant negative response to N.
(iii) Significant negative response to P.
(iv) Significant seasonal variation of K_2O does not interact with N, P and K (in soil) or their interactions.

(*b*) *General Trends*

(i) *Main Effects:*

N	N_0	N_1	N_2
Yield (lbs. copra/324 palms)	7912	8344	7764
K_2O (gms./litre)	1.61	1.53	1.41

P	P_0	P_1	P_2
Yield	8134	7879	8007
K_2O	1.58	1.48	1.49

K	K_0	K_1	K_2
Yield	6545	8419	9057
K_2O	1.03	1.56	1.96

(ii) *Interactions*:

$N \times K$	N_0	N_1	N_2
K_0	2229 1.10	2258 1.03	2058* 0.95**
K_1	2814 1.63	3028 1.65	2576* 1.38**
K_2	2869 2.09	3058 1.92	3130* 1.89**

$P \times K$	P_0	P_1	P_2
K_0	2254 1.56	2162 1.50	2169* 1.60**
K_1	2882 1.56	2772 1.50	2764* 1.60**
K_2	2998 2.05	2945 1.92	3114* 1.93**

$N \times P$	N_0	N_1	N_2
P_0	2662 1.68	2843 1.51	2629* 1.53**
P_1	2632 1.68	2654 1.47	2593* 1.30**
P_2	2618 1.47	2847 1.62	2542* 1.38**

Post-stepping up period (*K at levels* 1, 2 *and* 3)

(*a*) *Significant Responses* (Analysis of Variance)
Yield of copra

(i) Significant positive response to K.
(ii) Significant N $\times$ K positive interaction.
(iii) Highly suggestive positive response to P.
(iv) Significant seasonal variation.

* Yield (lbs. copra per 108 palms).
** K_2O (gms/litre).

K_2O in nut water (gms./litre)

(i) Significant positive response to K.

(ii) Significant negative response to P.

(iii) Significant negative response to N.

(iv) Significant seasonal variation of K_2O does not interact with N, P or K (in soil) or their interactions.

(*b*) *General Trends*

(i) *Main effects:*

N	N_0	N_1	N_2
Yield (lbs. copra/324 palms)	10203	10597	10155
K_2O (gms./litre)	1.61	1.58	1.48

P	P_0	P_1	P_2
Yield	10032	10417	10506
K_2O	1.68	1.52	1.48

K	K_1	K_2	K_3
Yield	9089	10663	11203
K_2O	1.13	1.61	1.94

(ii) *Interactions:*

$N \times K$	N_0	N_1	N_2
K_1	3093	3108	2888*
	1.13	1.14	1.12**
K_2	3489	3742	3432*
	1.68	1.69	1.47**
K_3	3821	3747	3835*
	2.05	1.92	1.86**

*Yield (lbs. copra per 108 palms).
**K_2O (gms/litre).

$P \times K$	P_0	P_1	P_2
K_1	2975 1.24	3048 1.11	3066* 1.03**
K_2	3527 2.11	2866 1.86	3810* 1.84**
K_3	3527 2.11	2866 1.86	3810* 1.84**

$N \times K$	N_0	N_1	N_2
P_0	3236 1.68	3522 1.72	3274* 1.65**
P_1	3550 1.66	3425 1.48	5442* 1.40**
P_2	3417 1.49	3650 1.56	3439* 1.39**

The above analysis shows clearly that the K_2O content in nut water reflects the available potash content of the soil—a point on which over-whelming evidence has been provided earlier (Salgado 5).

The effect of N in soil on the K_2O content in nut water is noteworthy. Our analysis shows that for the same level of K in soil, the K_2O content in nut water is *significantly depressed by higher levels of N*. This is one of the main points which, due to the limited data available at the time, could not be clearly understood (Salgado 5). Therein it was stated that "at the higher level of N, there has been a progressive decline in yield and yield data show a negative interaction of N on K". The same yield data re-examined by us do show a significant interaction. But this interaction, suggests that the yield response to K is better in the presence of N, hence calling for a revision of the earlier argument that there has been an "interference in the uptake of K by N". It is also to be noted that as far as the effect on K_2O content is concerned, there is no significant N × K interaction, showing that the depression of K_2O content due to N added to the soil, is of the same order at all levels of K.

The effect of P added to the soil, although not significant, also shows a depressing effect on the K_2O content in nut water; and there is again no significant P × K interaction. Therefore while the K_2O content in nut water rises at higher levels of K in the soil, N and P in soil lower the K_2O content and quite independently of K and probably of each other.

A useful point that needs emphasis as a result of the present analysis, is that the effect of soil N, P, K or their interactions on K_2O content of nut water does not interact with seasons, suggesting that whatever pattern exists with regard to the K_2O content of nut water relative to the soil, it is repeatedly

*Yield (lbs. copra per 108 palms).
**K_2O (gms/litre).

so over the seasons. *From a practical (i.e. diagnostic) point of view, this is a very HELPFUL situation, in that an analysis of the K_2O content in any season should give us the same result as far as the relationships with N, P or K in the soil are concerned, although the absolute levels may vary.*

Another point (in fact the second of the two major points) on which the previous study (Salgado '55) proposed to provide statistical testimony, and which we now have to revise, was that the potash content of nut water is positively correlated with yields. This conclusion was based and reasonably so on two findings viz. (i) "At Bandirippuwa Estate, where the only response that is highly significant is due to Potash, the yields rise almost linearly and the curves for the potash contents of nut water are almost parallel", and (2) in the analysis of covariance of copra yield and K_2O content of nut water, the correlation coefficient (given by the ratio of the sums of products to the geometric mean of the sums of squares in the error row) was positive and significant.

An isolated view restricted to these two results, necessarily leads one to the above conclusion that the K_2O content in nut water is positively correlated with yields. However, on a re-examination of the overall trends, Harland and Abeywardena (1956) observed that while the K_2O content rose with an increase of K in the soil, there were indications that N and P whenever they helped to increase yields gave rise to a reduction in the K_2O content. For example, in the pre-stepping up period when N was the primary limiting factor as far as yield was concerned, there was a significant depression of K_2O content with N added to the soil—the depressing effect of P being less marked; and in the post-stepping period, when P response reversed its earlier depressing trend to give rise to a positive response in yield, the K_2O content showed a significant depression at higher levels of P and the depressing effect of N became less emphasized.

The data of the 3 × 3 × 3 NPK experiment (Bandirippuwa), however did not provide us with sufficient data to clarify the above situation satisfactorily nor could we reasonably reconcile ourselves to an acceptance of a positive correlation between yield and K_2O content in nut water in the face of trends observed by Harland and Abeywardena (1956). With a view to clarify the above, we examined the data in respect of the nut water analyses of individual palms in a block of (nearly) 300 palms maintained under a uniform system of management and manuring by the Botanist's Division, and the results are discussed later in this paper.

2. Effect of N, P, K added to the soil on the P_2O_5 content of nut water

A study of the effect of the addition of N, P and K into the soil on the P_2O_5 content in nut water is a new feature of the present analysis. The results of the analysis of variance of the P_2O_5 content (mgms. per litre), per plot of the 3 × 3 × 3 NPK experiment at Bandirippuwa Estate and the general trends are summarised below:

(*a*) *Significant Responses*

(i) Significant negative response to N.

(ii) Significant positive response to P.

(iii) Significant negative response to K.

(iv) P × K interaction is significant.

(v) Significant seasonal variation of P_2O_5 does not interact with N, P or K (in soil) or their interactions.

(b) *General Trends*

(i) *Main effects:*

N	N_0	N_1	N_2	(in soil)
P_2O_5 (mgms./litre)	204	196	196	(in nut water)
P	P_0	P_1	P_2	(in soil)
P_2O_5 (mgms./litre)	187	200	208	(in nut water)
K	K_0	K_1	K_2	(in soil)
P_2O_5 (mgms./litre)	203	199	193	(in nut water)

(ii) *Interactions:*

$N \times P$	N_0	N_1	N_2
P_0	194	183	185
P_1	199	199	201
P_2	218	205	211

$N \times K$	N_0	N_1	N_2
K_0	209	195	205
K_1	205	197	194
K_2	197	195	188

$P \times K$	P_0	P_1	P_2
K_1	182	207	220
K_2	194	196	207
K_3	186	197	197

The above analysis indicates that while a high phosphate content in the soil is reflected by a high P_2O_5 content in nut water and vice versa, high nitrogen and potash in the soil significantly depress the P_2O_5 content in nut water and independently of each other. This is similar to the trends observed in respect of K_2O in nut water where there was a positive response to K in soil and negative responses to both N and P. However while there were no soil nutrient interactions on the K_2O content, in the case of P_2O_5 content there is a significant (soil) $P \times K$ interaction, suggesting that the positive response of P_2O_5 content to P added to the soil, is marked at the lower level of K (i.e. K_1) and slight at the higher levels of K (i.e. K_2 and K_3). Also as in the case of the K_2O content, P_2O_5 in nut water in relation to soil nutrients follows the same pattern in every season.

3. Inter-relationships between coconut yields, nut characters, and the K_2O—content of nut water under similar soil conditions

The inter-relationships between nut yields, volume of water per nut, copra per nut (i.e. weight of husked nut which is a constant multiple of the copra content) and the K_2O (gms. per litre) of nut water, have been examined from data collected from 271 palms of a uniformly managed block.

For the purposes of the present study, it was thought sufficient to get only the broad trends through (linear) correlation coefficients (Table 1).

TABLE 1

Correlation coefficients between K_2O in nut water and yield characters

Relationships between X *and*	Y	*Correlation coefficient* γxy
Yield	K_2O	-0.3611
Vol. of water per nut	K_2O	+0.4629
Copra/nut	K_2O	+0.3341
Average yield	Vol. of water/nut	-0.2476
Average yield	Copra per nut	-0.2560
Vol. of water per nut	Copra per nut	+0.5140

Generally, it is observed that while the yield is negatively correlated with K_2O content, the volume of water per nut and the copra content per nut are positively correlated with K_2O. The yield on the other hand is negatively correlated with both the volume of water per nut and the copra per nut; and the volume of water per nut and the copra per nut are positively correlated.

However as all these factors are inter-related, partial correlation coefficients (Table 2) give a better picture of the extent of the real relationships.

TABLE 2

Partial correlation coefficents between K_2O content and yield characters (one factor constant)

Relationships between X	Y	*Constant factor* (z)	*Partial* $\gamma xy.z$
Yield	K_2O	Vol. of water/nut	-0.2870
Yield	K_2O	Copra per nut	-0.3025
Vol. of water per nut	K_2O	Copra per nut	+0.3602
Copra per nut	K_2O	Vol. of water per nut	+0.1265
Yield	Vol. of water per nut	Copra per nut	-0.1399
Vol. of water per nut	K_2O	yield	+0.4134
Copra per nut	K_2O	yield	+0.2681
Vol. of water per nut	Copra per nut	yield	+0.4811

The correlation coefficients between any two factors at a constant level of a third factor as given in Table 2 are self-explanatory. But our immediate interest being the possible influence of any one factor (in its own right) on the K_2O content of nut water, the partial coefficients between each factor and K_2O content keeping the other two factors constant, have been calculated (Table 3).

TABLE 3

Partial correlation coefficients between K_2O and yield characters (2 factors constant)

Relationship between X	Y	*Constant factors* (z_1 *and* z_2)	*Partial* $xy.\ z_1 z_2$
Yield	K_2O	Vol. of water per nut and copra per nut	-0.2729
Vol. of water	K_2O	Yield and Copra/nut	+0.3975
Copra per nut	K_2O	Yield and vol. of water per nut	+0.0867

These coefficient indicate that high yielding palms record a lower content of K_2O while palms which have a higher volume of water per nut record a higher K_2O content. However, the copra per nut of a palm has no influence on the K_2O content.

Similar results were obtained from a multiple regression analysis of K_2O content as the dependent variate (y) and the yield, volume of water per nut and copra per nut as the independent variates (x_1, x_2 and x_3). The yield makes a significant negative contribution to the K_2O content, the volume of water per nut a significant position contribution and the copra per nut has no significant bearing on the K_2O content. As far as the two significant factors are concerned, the volume of water per nut has a greater control over the K_2O content than the yield.

4. Inter-relationships between coconut yields, nut characters, and the P_2O_5 content of nut water under similar soil conditions

As in the case of K_2O, the inter-relationships between yield, volume of water per nut, copra per nut and the P_2O_5 content (mgm./litre) of nut water, have been examined and the following correlations (Table 4) were obtained.

TABLE 4

Correlation coefficients between P_2O_5 content and yield characters

Correlation between X	Y	*Correlation coefficient* γxy
Yield	P_2O_5	-0.1152
Vol. of water per nut	P_2O_5	-0.0091
Copra per nut	P_2O_5	+0.0147
K_2O	P_2O_5	+0.2197

The corresponding partial coefficient are given below:—

Correlation between X	Y	*Constant factors* z_1 *and* z_2	*Partial correlation* $Vxy. z_1z_2$
Yield	P_2O_5	Vol. of water per nut and copra per nut	-0.1246
Vol. of water per nut	P_2O_5	Yield and copra per nut	-0.0383
Copra per nut	P_2O_5	Yield and vol. of water per nut	+0.0084

It is interesting to note that under identical soil conditions while the K_2O content is negatively correlated with yield, positively correlated with volume of water per nut and independent of copra per nut, the P_2O_5 content in nut water on the other hand is independent of either the volume of water per nut or the copra per nut—the correlations coefficients being not significant. There is however a highly suggestive negative correlation between yield and P_2O_5 content ($r = -0.1246$) though not so marked as in the case of K_2O content. But this correlation is apparently incidental to the positive correlation between K_2O and P_2O_5 content as confirmed by the non-significant partial coefficient of -0.0733 between P_2O_5 content and yield keeping K_2O constant. Therefore it may be concluded that the P_2O_5 content in nut water is completely independent of either the yield or the volume of water per nut or the copra per nut.

The significant negative correlation between the yield capacity of a palm and the K_2O content and also the fact that the P_2O_5 content is independent of the yield capacity of the palms is further confirmed by certain nut water analyses carried out in the $3 \times 3 \times 3$ NPK experiment. The nut water of the six best palms and the six poorest palms of each of the 54 plots of this experiment were bulked separately and analysed for their K_2O and P_2O_5 contents. The data obtained were examined statistically. For each of the plots, when the poor palms gave a higher K_2O value as compared with the good palms, a + sign was given and when the reverse a – sign. Thus a series of 54 plus and minus signs were obtained. —a predominance of plus signs denoting a higher K_2O content in poor palms. A similar series of plus and minus signs was obtained for the P_2O_5 content. The results were as follows:—

	No. of palms with		*Significance*
	Poor>Good + *signs*	*Poor<Good* – *signs*	
K_2O contents	43	11	Highly significant
P_2O_5 contents	29	25	Not significant

A statistical test of the incidence of + and – signs (based on the Binomial distribution) shows that good palms record a lower K_2O content as compared with poor palms and as far as P_2O_5 content is concerned, it is independent of the yield capacity of palms.

The general trends discussed already were based on linear correlations. It would however be appreciated that curvilinearity might be present with some factors; for instance the copra per nut is curvilinearly related to yield (Table 5) in that as the nut yields decrease, the copra per nut increases up to a point and as the yield decreases further, the copra per nut again decreases. For the guidance of future studies, we are giving (Table 5) the mean K_2O and P_2O_5 contents and the mean nut characters for each yield class, to indicate possible curvilinear trends, which may be taken cognizance of in future studies.

TABLE 5

The mean nutrient contents in nut water and the mean yield characters in different yield groups

	Yield class nuts/year						
	<40	40-50	50-60	60-70	70-80	80-90	90 *and above*
K_2O in nut water (gms./litre) ..	1.830	1.764	1.597	1.494	1.519	1.464	1.179
P_2O_5 in nut water (gms./litre) ..	192	182	200	181	175	174	174
Vol. of water per nut (c.c.) ..	135	145	146	127	121	113	86
Copra/nut (wt. of husked nut) ..	1.442	1.557	1.559	1.510	1.449	1.383	1.264
Average yield (nuts/year) ..	29.8	44.4	55.0	64.9	74.9	84.3	102.0

DISCUSSION

There is considerable evidence that the K_2O and P_2O_5 contents of nut water reflect to some degree or other, the available potash and phosphate levels of the soil; such parallel trends, however, seem to be subject to a general restriction that for a particular soil potash level, the presence of a high level of N or P (in the soil) depresses the K_2O content in nut water and for a particular soil phosphate level, the presence of a high level of N or K (in the soil) also depresses the P_2O_5 content in nut water. In the case of P_2O_5 there is a further interesting interaction ($P \times K$), suggesting that the depressing effect of K on P_2O_5 content is more marked at higher levels of P. The depressing effect of N on P_2O_5 though not significant is also more marked at higher levels of P.

Given an identical soil nutrient complex, the K_2O content of nut water is low for high yielding palms, high for palms with a larger volume of water per nut and unaffected by the copra content per nut. On the other hand, the P_2O_5 content of nut water is unaffected by either the yield of palms or the volume of water per nut or the copra content per nut.

A palm having a higher K_2O content in the nut water will to a certain extent record a high P_2O_5 content. But the fact that the K_2O content is controlled by yield as well as the volume of water per nut, and the P_2O_5 content is independent of these factors, indicate that the positive correlation between K_2O and P_2O_5 contents is conditioned by some other factors to a certain extent independent of the volume of water per nut or the yield. An explanation for this positive correlation between K_2O and P_2O_5 may be given by uptake i.e. a palm that enjoys a better uptake takes in more K_2O as well as more P_2O_5 and vice versa, giving rise to a positive correlation.

The negative correlation between K_2O and yield may be explained by the higher potash content stored in the kernel and or a higher demand for K in nut production. The absence of a correlation between P_2O_5 and yield may be explained by the low P_2O_5 content in the kernal, and or the fact that P may not be required for nut producton. Any way the fact that the P_2O_5 content is independent of yield or the volume of water per nut as is the case with K_2O, still remains a curious feature. An alternative explanation may be that under Bandirippuwa Estate soil conditions supposed to contain a high reserve of phosphates, most of the relationships get masked, because at its worst there is sufficient uptake of P to keep the P_2O_5 in the plant tissues at a high level. In this context it will be interesting to examine some nut water data of individual palms in a soil with high potash and low phosphates as at Ratmalagara Estate. Under such conditions can we expect a reversal of the situation viz. P_2O_5 to be controlled to a marked degree by the yield characters and the K_2O relatively less affected?

At this stage it would be relevant to reconcile the apparently conflicting issue arising from the positive correlation between yield and K_2O observed in the earlier study (Salgado 1955) and the negative correlation observed in the present study. The latter finding based on individual palms that high yielding palms show a low K_2O content is irrevocable. On the other hand the positive correlation between K_2O and yield observed earlier can be explained by the fact that the yield therein refers to plot yields. With the relative large sized plots used in coconut experiments, and assuming a random distribution of high yielding and low yielding palms, between—plot yield variations may be controlled appreciably by variations of the soil conditions (say) soil moisture or texture favouring uptake. So that the interpretation of the positive correlation between K_2O and yield in the $3 \times 3 \times 3$ NPK experiment will be that plots which gave a high yield (due to such favourable soil conditions) also showed a high K_2O content, thus creating no conflicting issue with the inherent negative correlation between yield and K_2O content observed in this study.

In the face of the present findings, there is a need for more data in respect of the nut water nutrient contents of individual palms in a few more areas, and over a number of seasons; and it may be possible to work out certain critical values for diagnostic purposes in relation to the manurial needs of the coconut palm. The fact that within the same soil nutrient levels, the nut water nutrients are controlled by the yield characters should not cause undue alarm, because such interactions may be eliminated by averaging out a representative selection of low, medium and high yielding palms. With more data objectively collected, such statistical issues can be satisfactorily solved.

We have not attempted in the course of this paper to offer any physiological explanation to these observations. It is hoped to put forward a possible theory in due course, when data obtained from further work that is projected is available in due course based on similar work on individual palms from the plots at Ratmalagara Estate. The main difference between the soils at Bandirippuwa and Ratmalagara are: (*a*) Bandirippuwa soils being poorer in potash and high in phosphate and (*b*) Ratmalagara soil being rich in potash and low in phosphate.

It may be postulated here that while potash is a very mobile nutrient in the process of translocation within the plant and between the soil and the plant, phosphate is a slowly mobile nutrient. It may also be possible that besides the relative immobility of translocation of P as between different plant organs, (e.g. from root to leaves and leaves to nut), the fact that the phosphate concentration in the soil solution is always low and would be a static concentration and at maximum supply for production in the Bandirippuwa soil, it may be possible that studies at Ratmalagara where the soil phosphate levels are very low and is the limiting factor to high yields as shown by the $3 \times 3 \times 3$ manurial experiment on bearing palms, as well as the $3 \times 3 \times 3$ NPK experiment on young palms from the seedlings stage (1), there may be a different pattern of responses and interactions to P at Ratmalagara on its content in nut water.

SUMMARY

The chemical analysis of nut water offers a very convenient and promising approach to the elucidation of problems regarding the manurial needs of the coconut palm.

While the K_2O and P_2O_5 contents of nut water reflect the available soil potash and phosphates, (1) for a particular soil potash level, N and P in soil tend to depress the K_2O content of nut water and for a particular soil phosphate level, N and K in soil tend to depress the P_2O_5 content; (2) for a particular N, P and K combination in soil, the K_2O and P_2O_5 contents of nut water is high for a soil tupe which is conducive to a higher uptake such as soil moisture or soil texture etc. and vice versa; (3) for a particular soil nutrient complex and identical conditions of uptake, the K_2O content of nut water is negatively associated with the yield of palms and positively with the volume of water per nut, whereas the P_2O_5 content is independent of these yields characters and (4) whatever nut water nutrient pattern there is in relation to the soil nutrients in a particular situation, it is repeatably so in any season.

With a study of further data collected objectively, it may be possible to work some critical values useful for diagnostic purposes in relation to the manurial needs of the coconut palm.

ACKNOWLEDGEMENTS

We are deeply indebted to Dr. S.C. Harland of the University of Manchester (formerly Interim Director, Coconut Research Institute) whose re-examination of earlier data and suggestions thereform, prompted us to collect further data with a view to seeking clarifications recorded in this paper. Our thanks are also due to Messrs. Rienzil de Almeida and G. Karunasena of the Division of Biometrics of this Institute for the statistical work and the preparation of the typescripts and to the Technical Assistants and Field Assistants of the Soil Chemistry Division for carrying out the analysis of the nut water.

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