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INTER-RELATIONSHIPS AMONG ROOT CEC, YIELD AND MONO- AND DIVALENT CATIONS IN COCONUT (*COCOS NUCIFERA* L.)

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SUMMARY

A study was conducted on different yield groups of coconut palm (West Coast Tall) to investigate the relationships among root CEC, yield and mono- and divalent cations. The results showed that correlation between root CEC and yield was negative but not significant. The foliar content of (K + Na) decreased with increase in root CEC while (Ca + Mg) increased with increase in root CEC. The uptake of cations by the palm was found to be governed by their ratios in soil. Highly significant correlations were obtained between K/Na, K/(Ca + Mg) and K/Mg in soil and their corresponding ratios in the leaf. Among the nutrients studied, potassium content of soil as well as that of leaf correlated positively with yield. The critical level of K, 0.8 to 1.0 per cent, was found to hold good in coconut. The interaction between leaf nutrients showed that the leaf potassium level was affected by the combined level of (Na + Ca + Mg). The impact of this interaction on critical levels of Na, Ca and Mg is discussed. Based on this, a level of 43.8 to 47.3 me per 100 g (or 0.75 to 0.82 per cent) was suggested as 'satisfactory level' for (Na + Ca + Mg) together. The negative correlation of root CEC and positive correlation of both soil and leaf potassium with yield, indicate the role of potassium in increasing the yield of coconut.

INTRODUCTION

The long pre-bearing period and the time taken to attain stability in bearing (about 10–12 years) is a bottleneck in the breeding and selection of coconut as progenies are evaluated on the basis of yield of nuts or copra. Selection indices, enabling efficient screening of prospective high yielders at the nursery stage itself are, therefore, of utmost importance. The possibility of using cation-exchange capacity of roots for this purpose has been reported for sugar cane [3].

It is one of the objectives of this study to find out whether any relationship does exist between root CEC and yield in coconut.

Cation-exchange capacity of roots has also been used to explain the differential uptake of mono- and divalent cations [6], although contraversy still exists among soil scientists and plant nutritionists over the validity of this, mainly because of the wide variations due to factors like root sections used for its measurement [5], soil nitrogen levels [11], *etc*. If a relationship exists in coconut, the mineral nutrition of the palm may then be directly affected by the root cation-exchange capacity.

It is well known that the foliar critical levels of the nutrients are highly variable from variety to variety, location to location, due to difference in age, time of sampling of the leaf, interaction between nutrients etc. and as such, these levels fixed for one agro-climatic location may not be applicable in another. An attempt is also made here in this report to assess the interactions between mono- and divalent nutrients and their influence on yield and critical levels.

MATERIALS AND METHODS

Four to six palms (var. West Coast Tall) from each yield group (Table 1) were selected at random from red sandy loam strip of this Institute for the study. The total number of palms studied was 59. The mean annual yield per palm for the last five years ranged from less than 5 to 142 nuts per year and the age of palms was within 34–45 years. Each palm was receiving an annual fertilizer dose of 0.50 kg N, 0.14 kg P and 1.00 kg K. The average annual rainfall in the area is about 3500 mm. The soil is acidic in reaction (pH 5.5) and CEC is very low, 4 me per 100 g soil.

Preliminary studies with coconut seedlings [12] revealed that the first 5-cm portion of the tip of the lateral roots was suitable for CEC measurement. Considering the predominance of this type of roots in coconut, the same procedure of root sampling was adopted in the present study. Freshly grown 10 roots were taken from each palm and CEC measured by potentiometric titration [4] and expressed as me per 100 g dried root.

The leaf numbered 14th starting from the first fully opened one [2] was chosen for the analysis of cations *viz*. Na, K, Ca and Mg. After digesting the dried and powdered leaf with nitric-perchloric-sulphuric acid mixture, suitable aliquots were taken for the determination of Na and K by flame photometry and Ca and Mg by Versene complexio-metric titration [9]. Values were expressed as per cent or me per 100 g oven dried leaf.

Soil samples were taken from individual palm basins at a distance of 150 cm from the bole to a depth of 50 cm. Analyses of the soils were made for available K, Na, Ca, and Mg after extraction with neutral 1 *N* ammonium acetate using the same methods stated above and values were expressed as me/100 g air dry soil. Simple correlations were worked out between different factors taking individual values. Nutrient ratios were worked out on milliequivalent basis. The sampling of soil, leaf and roots was done in September simultaneously.

TABLE 1

Available nutrient status in the soil basins (me/100 g)

Yield groups	Mean yield* (nuts/year)	K	Na	Ca	Mg
<5	4.2	0.369	0.039	0.400	0.331
6–15	10.8	0.080	0.043	0.650	0.300
16–25	21.8	0.098	0.034	0.692	0.400
26–35	30.9	0.131	0.039	0.469	0.175
36–45	40.0	0.081	0.027	0.500	0.258
46–55	49.5	0.123	0.035	0.555	0.220
56–65	61.9	0.126	0.032	0.515	0.325
66–75	69.8	0.398	0.043	0.917	0.533
76–85	78.3	0.184	0.038	0.688	0.329
86–95	89.8	0.128	0.033	1.369	0.413
96–105	99.0	0.267	0.028	0.650	0.246
106–115	111.4	0.324	0.040	1.094	0.431
116–42	134.3	0.470	0.037	1.104	0.486
Coefficient of variation (%)	–	60.780	13.610	38.310	29.780

* Average of 5 years

TABLE 2

Correlation between root CEC and yield and leaf mono- and divalent cations

Y	Correlation coefficients (r values)
Yield	−0.03
Leaf K	−0.25*
Leaf Na	−0.04
Leaf (K + Na)	−0.33**
Leaf Ca	+0.16
Leaf Mg	+0.22
Leaf (Ca + Mg)	+0.23*

X is root CEC in all cases

* Significant at 5% level

** Significant at 1% level

RESULTS

The relationships of root CEC with yield and mono- and divalent cations of leaf are shown in Table 2. The cation-exchange capacity of roots varied from 12.1 to 23.0 me/100 g, with a mean of 16.1 me/100 g. The coefficient of variation was low, being 16 per cent. The correlation coefficient between root CEC and yield was found to be negative but not significant. However, with foliar mono- and divalent cations significant correlations were obtained. Of importance, leaf (K + Na) correlated negatively, while (Ca + Mg) correlated positively with root CEC.

The data regarding the available soil nutrients are given in Table 1. Variation in soil K status was larger than that of Na, Ca or Mg. Positive and significant correlations were obtained between yield and soil available K, Ca and Mg while among the foliar nutrients, only K gave positive correlation with yield though not significant (Table 3). Of all the individual nutrients and different ratios among them, soil K/Na gave the highest correlation with yield (r = 0.48**).

TABLE 3

Correlation between yield and nutrient concentrations in soil and leaf

X	Correlation coefficients (r)
Soil K	+0.45***
Soil Na	−0.01
Soil Ca	+0.39**
Soil Mg	+0.23*
Soil K/Na	+0.48***
Soil Ca/Mg	+0.30**
Soil Na/(Ca + Mg)	−0.41**
Soil Na/Ca	−0.29*
Leaf K	+0.17
Leaf Ca	−0.14
Leaf Mg	−0.10
Leaf (Ca + Mg)	−0.11

Y is yield in all cases. Nutrient ratios were worked out on milliequivalent basis

* Significant at 5% level

** Significant at 1% level

*** Significant at 0.1% level

Even though soil Ca and Mg correlated positively with yield, the foliar levels of these nutrients correlated negatively but none of them was significant.

As regards the relationship between soil and leaf nutrients, significant positive correlation was obtained only in the case of potassium (Table 4). It was also seen that the soil Ca, Mg, and Na correlated negatively with their corresponding concentrations in leaf, though not significant. Among the ratios, K/Na gave the highest correlation here again. Soil K/(Ca + Mg) and K/Mg ratios were also highly significantly correlated with the corresponding ratios in the leaf.

TABLE 4

Correlation between soil and leaf cations (r values)

Soil K	*vs*	Leaf K	= +0.328**
Soil Na	*vs*	Leaf Na	= −0.204
Soil Ca	*vs*	Leaf Ca	= −0.008
Soil Mg	*vs*	Leaf Mg	= −0.158
Soil $\frac{K}{Na}$	*vs*	Leaf $\frac{K}{Na}$	= +0.847***
Soil $\frac{K}{Ca}$	*vs*	Leaf $\frac{K}{Ca}$	= +0.196
Soil $\frac{Ca}{Mg}$	*vs*	Leaf $\frac{Ca}{Mg}$	= +0.209
Soil $\frac{K}{Mg}$	*vs*	Leaf $\frac{K}{Mg}$	= 0.334**
Soil $\frac{K}{(Ca+Mg)}$	*vs*	Leaf $\frac{K}{(Ca+Mg)}$	= +0.631***

* Significant at 5% level
** Significant at 1% level
*** Significant at 0.1% level

Interactions between leaf nutrients are furnished in Table 5. It was found that leaf K decreased the levels of other three cations in the order Na $<$ Mg $<$ Ca, as evident from the magnitude of the negative correlation coefficient between them. Leaf Na was found to increase with Ca and to a lesser extent with Mg also. The relationship between foliar levels of K and (Na + Ca + Mg) together is shown in Fig. 1. Maximum level of (Na + Ca + Mg) was obtained at a potassium level of 12.5 me/100 g (or 0.49 per cent) after

TABLE 5

Interactions between leaf nutrients (r values)

	Na	(Na+K)	Ca	Mg	(Ca+Mg)	(Na+Ca+Mg)
K	−0.60***	—	−0.29*	−0.44***	−0.46***	−0.70***
Na		—	+0.77***	+0.12	+0.13	—
(Na+K)			−0.31*	−0.46***	−0.49***	—
Ca				+0.34**	—	—
Mg					—	—
(Ca+Mg)						—
(Na+Ca+Mg)						

* Significant at 5% level
** Significant at 1% level
*** Significant at 0.1% level

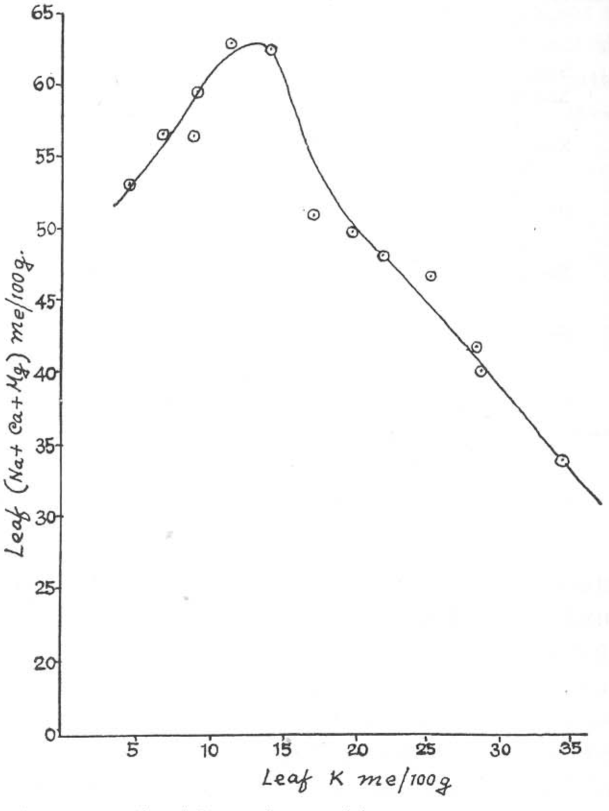

Fig. 1. Foliar (Na + Ca + Mg) level in relation to K

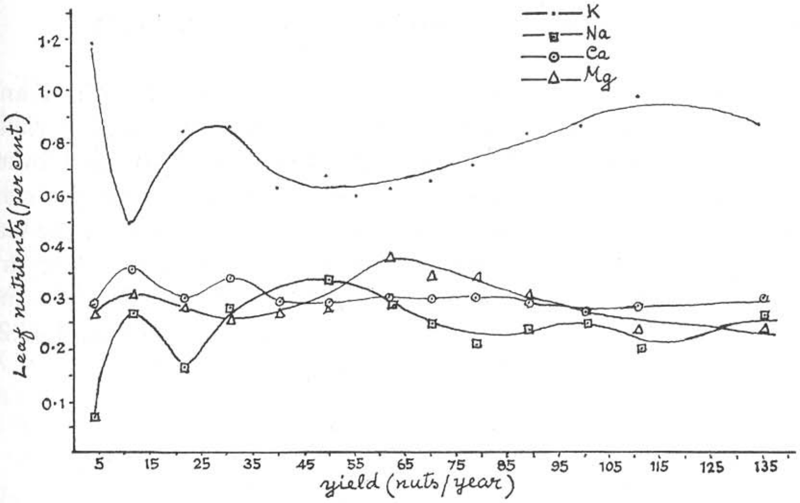

Fig. 2. Leaf concentrations of K, Na, Ca and Mg with respect to nut yield.

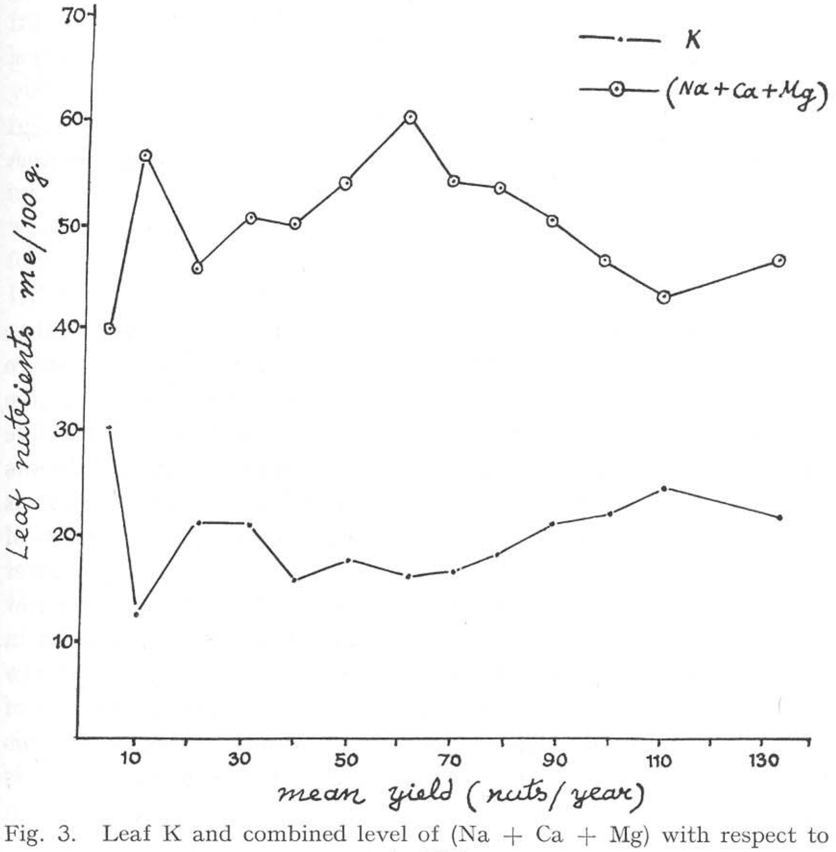

Fig. 3. Leaf K and combined level of (Na + Ca + Mg) with respect to nut yield.

which there was only decrease. When the values of both K and (Na + Ca + Mg) were plotted on milliequivalent basis against yield, both curves appeared to be almost symmetrical to each other (Fig. 3). Similar curves were obtained when plotted on per cent basis also. The total mono- and divalent cation content in the leaf was found to be practically constant (about 70.0 me/100 g dry matter). In the highest yield group of palms the levels of K and (Na + Ca + Mg) were 22.33 me/100 g (or 0.87 per cent) and 47.27 me/100 g (or 0.82 per cent) respectively.

TABLE 6

Effect of root CEC on leaf mono- and divalent cations

*Root CEC (me/100 g dry roots)	Contents in leaves (% of dry weight)	
	(K + Na)	(Ca + Mg)
13.2	1.13	0.57
15.0	1.09	0.58
16.9	0.94	0.60
19.0	0.78	0.68

* Means of different groups of palms classed according to their root CEC. Each figure is a mean of more than 10 values.

DISCUSSION

The uptake pattern of mono- and divalent cations, was found to be governed by the CEC of roots (Table 6). Significant positive correlation with leaf divalent cations (Ca + Mg), and negative correlation with monovalents (K + Na) indicate that the principle of Donnan equilibrium operates at the root surface. Since at the roots having high exchange capacity, more dilution of bulk solution is possible and in the Donnan distribution equation, the activity of divalent cations is inserted as the square root ($K/\sqrt{Ca}$), greater adsorption of divalents can occur, while at the roots having low CEC the reverse case happens. The reflection of this condition in leaf indicate that root CEC may be one of the reasons for the differential absorption of cations. The low correlation coefficient of root CEC with yield suggests that the possibility of employing this property in the West Coast Tall variety as a selection index is rather very remote.

The uptake of Ca, Mg and Na were found to be not related to their individual concentrations in the soil as evident from the negative correlation between leaf and soil Ca, Mg and Na. Thus, ratios *viz* K/Na and K/(Ca + Mg) in soil were better estimates of availability. In view of the fact that the correlation between root CEC and yield is negative, it can be said that for higher yields monovalents are preferred. However, only potassium and not sodium had any effect on increasing the yield. This indicates that K/Na ratio in the soil is the most deciding factor for higher yields in coconut.

The interaction between leaf mono- and divalent cations presented a different picture. Joint interaction of more than one cation *viz* Na, Ca and Mg against another, potassium, has not so far been reported in coconut (Fig. 1). This observation has a direct impact on the concept of critical levels in coconut. As could be inferred from Fig. 3, the palm always tended to maintain an equilibrium level in the leaf of mono-and divalent cations irrespective of the yield (about 70.0 me/100 g). It can be further deduced from the results that potassium is the primary factor deciding the yield. Apart from this correlation study, the beneficial effect of K on increasing yield in coconut has been repeatedly proved by so many workers [8 13 15] by field experiments, while no such relation was found in the case of Ca and Mg [10 15]. Critical level of K adopted by I.R.H.O. in coconut [7] (0.8 to 1.0 per cent) was found to be in close agreement with the results of the present study also. The same authors also reported critical levels of Ca as 0.5 per cent and that of Mg as 0.3 per cent. The behaviour of the three cations together *viz* (Na + Ca + Mg) against K or *vice versa* poses a problem in establishing critical levels individually for the former three cations mainly because the totality of these nutrients is governing the level of K and also, the concentrations of these nutrients in the leaf is negatively correlated with yield. According to Bould and Hewitt [1] the modern trend is to use leaf analysis as a guide to the nutritional status of the plant which involves: (1) the determination of threshold levels of nutrients below which plants show visual symptoms of deficiency and (2) the establishment of nutrient levels associated with optimum growth or yield. Richards and Bevege [14] opined that distinction needs to be made when considering plant analysis *viz* between its purely *diagnostic* use and its use for *pre-*

dictive purpose. If it is so, it can be argued that the nutrient in question should have some degree of association with yield. It is self-evident in this argument that a study of the nutrient and its relation with yield is a pre-requisite for establishing critical levels. In other words, when foliar analysis is put to prediction purpose the establishment of critical levels is advantageous only in the case of nutrients that are positively related to yield. If one goes by this argument, it follows that establishing critical levels for Na, Ca and Mg in coconut is not a realistic approach in as much as their prediction values are concerned. This is very much evident from Fig. 2. Taking into account the joint interaction of (Na + Ca + Mg) with K and their negative relation with yield it is suggested here that a foliar level of 43.8 to 47.3 me per 100 g (or 0.75 to 0.82 per cent) for (Na + Ca + Mg) together is 'satisfactory' in coconut. This level corresponds to the critical level of 0.8 to 1.0 per cent K. Above this level of potassium when no other element is limiting, the yield is likely to go down when the sum of these three cations decrease below the 'satisfactory level' (Fig. 3). Implicit in the concept of 'satisfactory level' is the assumption that adjustment in the concentrations of these three nutrients in the leaf is made between themselves against the level of K. In other words, fluctuation in the concentration of one causes adjustment in the other in order to maintain the combined level corresponding to concentration of K in the leaf.

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