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Studies On Potassium Magnesium Interaction In Coconut (*Cocos nucifera*)

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ABSTRACT

The widespread deficiency of magnesium in coconut acts as a limiting factor to increased production. Two ongoing experiments on potassium-magnesium (K-Mg) interaction in coconut conducted in lateritic gravels (ultisols), in the wet and intermediate agroclimatic zones of Sri Lanka showed significant yield responses (P=0.01) to differential K treatments, in the wet zone, but not in the intermediate zone. Differential Mg treatments, however, did not give rise to yield responses. Leaf and nut water analysis showed significant changes in the concentrations of Na, K and Cl (P=0.001), with a distinct inverse relationship between Na and K when K was applied. Differential Mg applications showed a significant effect only for leaf Mg (P=0.001), in the fourth year of the experiment, in the wet zone. Results indicate the usefulness of nut water analysis as an additional diagnostic tool, for Na, K and Cl.

INTRODUCTION

In the plantation agriculture in Sri Lanka, coconut (*Cocos nucifera* L.) occupies the highest area of nearly 420,000 ha. The estate sector (8 ha or more) comprises 104,000 ha (24.7%) of the area while the balance, 316,000 ha (75.3%) is categorized as small holdings.

Coconut is a very important commodity in Sri Lanka. It is used traditionally as a component in food, and about 70% of the production is consumed locally. About 9% of the total expenditure on food of an average household is spent on coconut, the principal source of edible oil and fat. Coconut provides about 22% of the total intake of calories of an average consumer in Sri Lanka second to rice. These data amply demonstrate the importance of coconut.

In order to meet the high domestic consumption and also maintain the export market, increased production can be achieved with regular and increased fertilization.

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Potassium is the most important nutrient for the production of nuts and copra, the latter used in oil extraction. Although the importance of K nutrition has been experimentally shown (Loganathan and Balakrishnamurthi, 1979; Salgado, 1950) widespread occurrence of Mg deficiency in the lateritic and the sandy soils has been a limiting factor in coconut production. It is necessary therefore to study the limitations in the use of high levels of K obviously due to K-Mg interactions and their antagonistic effects. This paper describes results of two experiments conducted to elucidate this aspect in coconut nutrition with a view to determine levels of Mg in the soil and leaf for more effective K usage.

MATERIALS AND METHODS

Two experiments were conducted on adult tall coconut (variety typica) of age about 55 years, in 7 and 14 hectare blocks, at Sirikandura Estate, Dodanduwa (Southern Province) and at Heemmeliyagara Estate, Hiruwalpola (North Western Province), from October 1984.

Sirikandura Estate (SE) falls in the wet zone receiving an annual rainfall of 1875 to 2500 mm. while Heemmeliyagara Estate (HE) is in the intermediate zone receiving an annual rainfall of 1000 to 1875 mm. The rainfall is bimodal, with peaks in April/June and October/November. The soils in both experimental sites are Red Yellow Podzolic with soft and hard laterite (Ultisols).

The chemical characteristics of the soils are given in Table 1.

Design and treatments

The experimental design consisted of a 4 X 4 factorial arrangement for the two nutrients K and Mg in three blocks, each consisting of 16 plots of eight effective palms separated by a single row of guard trees. The planting density is 158 palms/ha.

Fertilizer applications were made annually starting in 1984, as follows:

Muriate of Potash (60% K2O) kg/palm/yr		Kieserite (24% MgO) kg/palm/yr	
K1	0.0	Mg1	0.0
K2	1.2	Mg2	0.6
K3	2.4	Mg3	1.2
K4	3.6	Mg4	1.8

Basal applications of urea and rock phosphate, each at the rate of 0.7 kg/palm/yr, equivalent to 0.32 kg N and 0.19 kg P_2O_5, were made in all treatments.

At SE, only the first three levels of treatment were imposed. The fertilizer was applied on the surface of a circular area with a radius of 1.75 m, around the base of the palm, and incorporated into the soil using a fork.

Soil and leaf sampling

Four palms were chosen randomly from each plot. In these palms, the 14th leaf from the top, the 1st being the fully opened leaf with its leaflets separated, was selected and six leaflets were taken from the mid region and composited to form a sample, oven-dried at 85 °C and ground for analysis.

Soil samples were collected from the manure circle. Two borings were made at 1 m from the base on either side of the palms and samples were collected from two depths, 0-25 cm, and 25-50 cm and composited separately.

Nut water analysis

Nut water or 'coconut water' is the colourless liquid found within the hard white kernel (the solid endosperm), both of which are enclosed by the hard shell. From each plot, eight nuts representing each of the palms, selected at random, were sampled and the nut water from them was mixed well, filtered and aliquots were taken for analysis.

Chemical analysis

For soil analysis a 1 M CH_3 $COONH_4$ extractant was used for the extraction of exchangeable Na, K, Ca and Mg and determined by atomic absorption, Na and K in the emission and Ca and Mg in the absorption modes. Cl was read off the Chlor-O-Counter after extraction in 1:1 soil water ratio.

For leaves, N was determined in 0.1-g samples digested in Se/H_2SO_4 mixture, and P, Na, K, Ca and Mg, in 0.5 g samples digested in a $HNO_3/HCLO_4$ mixture. N and P were estimated colorimetrically on a Technicon Auto Analyzer and Na, K, Ca and Mg, as for soils, by atomic absorption. Cl was determined in 2.0-g samples, ashed in a muffle furnace at 450° C, extracted with water and read off the Chlor-O-Counter.

Nut water was analysed by diluting 20 times for Na and K, and 100 times for Ca and Mg and read off the Atomic Absorption Spectrophotometer (Somasiri *et al*.., 1986). Cl was estimated on the Chlor-O-Counter, using 0.1 ml of nut water (Periathamby, personal communication).

Yield

Commencing January 1985, ripe nuts were harvested from the two mature bunches bimonthly and the total number of nuts recorded. Weights of the husked nuts were obtained from samples of 32 nuts representing each treatment. The yield of copra was determined using the 'copra index factor' (Mathes, 1985 - personal communication).

RESULTS AND DISCUSSION

Soils and leaf analysis - Pretreatment data

The pretreatment soil analytical data in Table 1 show the exchangeable cations in the manure circle higher than in the centres of squares. This is due to the residual fertility in the manure circle, while the centre of squares reflects the inherent fertility.

Table 1 - *Soil analysis - October 1984*

Parameters	*Sirikandura Estate*		*Heemmeliyagara Estate*	
	Depth		*Depth*	
	0-25 cm	*25-50 cm*	*0-25 cm*	*25-50cm*
Chemical parameters of pretreatment samples in the fertilized circle				
pH	4.2	3.8	5.5	5.1
E.C (mmhos/cm)	51.39	55.25	46.88	52.26
Exch. Na (meq%)	0.08	0.06	0.08	0.10
Exch. K (meq%)	0.26	0.16	0.30	0.44
Exch. Ca (meq%)	1.27	0.59	1.56	1.04
Exch. Mg (meq%)	0.20	0.16	0.57	0.38
Avail. Cl (mg/kg)	27.62	27.30	24.01	30.08
Outside the fertilized circle, in the centre of square formed by four palms				
pH	4.0	3.9	5.0	5.0
E.C (mmhos/cm	33.39	21.75	36.08	16.34
Exch. Na(meq%)	0.03	0.03	0.07	0.08
Exch. K (meq%)	0.08	0.04	0.13	0.10
Exch. Ca (meq%)	1.06	0.31	0.73	0.65
Exch. Mg (meq%)	0.20	0.16	0.42	0.40
Avail. Cl (mg/kg)	18.94	20.40	16.06	14.33

The mean exchangeable K level in the manure circles of the two sites at the first depth was 0.28 meq%. Earlier experiments in lateritic soils in the wet zone have shown that in spite of such high K levels in the soil, the palms responded to muriate of potash (Loganathan and Balakrishnamurti, 1979). In the sub-soil (25-50 cm) the exchangeable K was much lower at SE than at HE, 0.16 and 0.44 meq%, respectively, which is probably due to leaching losses resulting from higher rainfall in the wet zone.

Information available on exchangeable Mg is scanty. Ollagnier *et al.*, (1983) considered an exchangeable Mg level of 0.46 meq% as high. The critical values for exchangeable K, and Mg in the Philippines are 0.45, and 2.9 meq%, respectively (Santiago, 1978). Margate *et al.* (1979) did not observe a K-Mg antagonism in a long-term KCl fertilizer study on a clay loam soil in the Philippines in spite of high application of KCl (8 kg/palm/year), with soil levels of 0.45 meq% K and 5.3 meq% Mg. On this basis, the soils in SE are not rich.

The data in Table 2 show the average concentrations of nutrients in the 14th leaf. With the exception of K in both locations and Mg at SE, the levels of the other nutrients fall within the sufficiency ranges as described by Loganathan and Atputharaja (1986).

Table 2 *Pretreatment leaf nutrient concentrations (14th leaf) on the Sirikandura and Heemeliyagara Estates*

Nutrients (% in dry weight)

	N	P	K	Ca	Mg	Cl
Sirikandura	2.02	0.15	1.09	0.38	0.16	0.30
Heemmeliyagara	1.98	0.15	1.10	0.50	0.30	0.34
Sufficiency ranges	1.9-2.1	0.11-0.13	1.2-1.5	0.35-0.55	0.25-0.30	0.30-0.40

Sirikandura Estate Analysis of leaf samples collected in May 1988 (Table 3) showed that the concentrations of both N and P had remained unaltered by the differential treatments.

Applications of K showed significant quadratic responses in leaf K and Mg, a significant linear increase in Cl and decrease in Na and Ca.

Increasing rates of Mg applied showed a highly significant linear increase for Mg only in 1988, the fourth year of the experiment.

At SE leaf K reached the value of 1.49% from the premanurial 1.09% at the highest level, K3 (2.4 kg/palm/year), a significant improvement in K nutrition. Increasing applications of Mg caused significant increases in leaf Mg, from the premanurial 0.16%, to 0.22% at the Mg3 level (1.2 kg/palm/year) still below the critical concentration of 0.25%.

Hemmeliyagara Estate As at SE, both N and P remained unaffected by the differential K-Mg treatments (Table 4).

Increasing rates of K applied showed significant linear increase in leaf K and decreases in leaf Na and Mg. Cl showed a linear response.

From the pretreatment 1.10% level, leaf K increased to only 1.12% at K4, still below the critical level of 1.2%. Unlike at SE, increasing rates of Mg caused no changes in any nutrient levels.

Table 3. *Leaf nutrient concentrations after four years of differential K and Mg applications, at Sirikandura Estate - May 1988*

	Concentration of nutrients (% in 14th leaf)						
Treatment	*N*	*P*	*Na*	*K*	*Ca*	*Mg*	*Cl*
K1	2.27	0.156	0.30	0.63	0.50	0.27	0.37
K2	2.38	0.158	0.25	1.18	0.41	0.15	0.49
K3	2.36	0.156	0.21	1.49	0.40	0.15	0.56
Mg1	2.32	0.157	0.26	1.14	0.43	0.15	0.49
Mg2	2.34	0.158	0.25	1.09	0.45	0.20	0.45
Mg3	2.35	0.157	0.24	1.07	0.43	0.22	0.47
Sign level							
K l	-	-	***	***	**	***	***
K q	-	-	-	**	-	**	-
Mg l	-	-	-	-	-	***	-
CV%	3.55	2.81	11.89	7.76	9.24	9.41	9.20

*P=0.05, ** P=0.01; *** P=0.001 l=linear response, q=quadratic response

Table 4. *Leaf nutrient concentrations due to differential applications of K and Mg at Heemmeliyagara Estate -January 1988*

	Concentration of nutrients (% in 14th leaf)						
Treatment	*N*	*P*	*Na*	*K*	*Ca*	*Mg*	*Cl*
K1	2.14	0.128	0.15	0.83	0.56	0.35	0.35
K2	2.13	0.129	0.12	0.99	0.51	0.32	0.46
K3	2.13	0.130	0.11	1.04	0.45	0.29	0.49
K4	2.11	0.130	0.10	0.12	0.50	0.27	0.52
Mg1	2.13	0.131	0.12	0.98	0.52	0.30	0.46
Mg2	2.11	0.129	0.13	1.00	0.52	0.31	0.46
Mg3	2.16	0.129	0.11	1.00	0.50	0.32	0.43
Mg4	2.11	0.128	0.12	1.00	0.50	0.32	0.48
Sign. level							
K l	-	-	***	***	*	***	***
K q	-	-	-	-	*	-	-
CV%	6.21	21.77	12.89	14.95	14.95	11.75	22.70

*P=0.05; **P=0.01; ***P=0.001 l=linear response, q=quadratic response.

Nut water analysis

Sirikandura Estate Analysis of the nut water collected in March 1988 (Table 5) showed responses to increasing rates of K and Mg. K application caused highly significant positive responses, both linear and quadratic, in the uptake of K and Cl, and a negative response for Na. Mg application only caused a significant linear increase in Cl, which is unusual and difficult to explain.

Heemmeliyagara Estate As at SE, negative linear and quadratic responses of Na to increasing K applications were observed (Table 6). K and Mg showed significant responses, both linear and quadratic, to increasing rates of K. Increased application of Mg caused a linear increase in K, which was unexpected, in view of the fact that usually these two nutrients show antagonistic effects.

In Sri Lanka, chemical analysis of nut water has been successfully used in the study of P and K nutrition of coconut (Salgado, 1955; 1966). In other countries this approach has also been used with some measure of success (Lockhard *et al.*., 1969, Southern, 1956).

Present indications are that nut water analysis can be used as an additional tool in the interpretation of field experiment data for Na, K, Mg and Cl. Both Ca and Mg have functionally limited roles to perform, both in the liquid and in the solid endosperm, and therefore their concentration will be low and so too the changes.

Yield

Sirikandura Estate Analysis of the second year's data (1986) showed a significant response in terms of copra production at ($P = 0.01$) to increasing K applications. For the years 1987 and 1988, these responses were highly significant at $P = 0.001$ (Table 7). Nut yields also significantly increased during these two years as a result of K application (Table 8).

There has been an overall decrease in yield of copra, despite the increased application of K. The drop in the `no fertilizer' plots has been drastic, 32.4% between 1986 and 1988. During the same period, at the K1 and K 2 levels, the decreases have been 17.2% and 14.6%, respectively. Fertilizer application has to some extent arrested the decline. The fall in production can be attributed to adverse weather conditions, to the insufficient state of nutrition of the palms and to the low soil nutrient status. Table 9 gives the rainfall and yield data for the `no fertilizer' plots at both sites. At SE, rainfall was high, except for 1986. The lower rainfall in 1986 was compensated for by a better distribution and therefore yields were not adversely affected in 1987.

From the nutritional aspects, it was observed that with all K application levels the K demand of the trees has been satisfied, and it is yet to be seen whether better yields will be obtained when the Mg concentrations reach the sufficiency level. It is only after K deficiency has been corrected that Mg manuring was found to have a positive effect on production (Brunin, 1970; Coomans, 1977).

Table 5 *Nut water nutrient concentrations after four years of differential application of K and Mg at Sirikandura Estate-March 1988*

	Nutrient ($mg\ l^{-1}$)				
Treatment	Na	K	Ca	Mg	Cl
K1	270	1634	186	101	1870
K2	139	2375	171	105	2095
K3	91	2627	180	99	2102
Mg1	179	2195	185	100	2073
Mg2	167	2238	179	101	2038
Mg3	154	2202	174	105	1956
Sign. level					
K l	***	***	-	-	***
K q	***	***	-	-	**
Mg l	-	-	-	-	**
CV%	15.73	4.49	13.73	10.72	3.61

*P= 0.05; ** P= 0.01; *** P=0.01 l= linear response, q = quadratic response

Table 6 *Nut water nutrient concentrations after four years of differential application of K and Mg at Heemmeliyagara Estate - March 1988.*

	Nutrient (mg l-1)				
Treatment	Na	K	Ca	Mg	Cl
K1	140	1918	283	156	1959
K2	80	2128	278	138	1997
K3	71	2201	282	130	2012
K4	64	2196	301	142	2062
Mg1	96	1985	292	143	1983
Mg2	85	2120	303	143	2037
Mg3	90	2141	276	140	2027
Mg4	84	2197	272	141	1984
Sign. level					
K l	***	***	-	**	-
K q	*	*	-	***	-
Mg l	-	**	-	-	-
CV%	41.44	7.55	14.92	9.74	5.48

*P=0.05; **P=0.01; ***P=0.001 l=linear response, q=quadratic response.

Table 7. *Weight of copra in different years following the start of differential annual applications of K and Mg at Sirikandura Estate, with 158 palms per ha.*

Treatment	*Copra (kg/ha)*	*%*	*Difference (kg/ha)*
	Yield 1986		
K1	1668*	100	-
K2	1882	113	214
K3	1985	119	317
	Yield 1987		
K1	1442**	100	-
K2	1798	125	356
K3	1843	129	401
	Yield 1988		
K1	1127***	100	-
K2	1559	138	432
K3	1696	150	569

*P=0.05; ** P=0.01; *** P=0.001.

Table 8. *Nut yield in different years following the start of differential annual applications of K and Mg at Sirikandura Estate, with 158 palms per ha.*

Treatment	*Nuts/ha*	*%*	*Difference*
	Yield 1986		
K1	8091 NS	100	-
K2	8447	104	356
K3	8815	109	724
	Yield 1987		
K1	7433**	100	-
K2	8545	115	1112
K3	8888	120	1455
	Yield 1988		
K1	5728***	100	-
K2	7290	127	1562
K3	7773	136	2045

NS = Not Significant; * P=0.05; ** P=0.01; *** P=0.001

Soil analysis data for the years 1987 and 1988 at the Mg3 application level yielded 0.73 and 0.63 meq% Mg, respectively. These fairly high exchangeable Mg levels in the soil can be expected to raise the Mg concentrations in the leaves enough to have a bearing on future production.

Heemmeliyagara Estate Statistical analysis of the yield data for the years 1986, 1987 and 1988, in terms of nuts and copra, showed neither a significant response to the main treatments K and Mg nor to any interaction between them.

A combination of factors contributed to the lack of yield response, such as `no fertilizer' plots performing much better than the others at the commencement of the studies (Table 9), and delayed application of fertilizers due to prolonged drought periods, compounded by the drought effect itself.

Table 9. *Yield and rainfall data and corresponding nut and copra yield in the' no fertilizer' treatments at the two estates.*

Year	*Ranfall*	*No. of wet days*	*Nuts/ha*	*Copra (kg/ha)*
Heemmeliyagara Estate				
1984	1815	87	-	-
1985	1262	55	11179	2074
1986	885	44	9263	1501
1987	1134	59	5649	751
1988	807	42	5267	898
Sirikandura Estate				
1984	2240	133	-	-
1985	2724	164	9381	1936
1986	1990	174	8907	1783
1987	2676	149	8117	1541
1988	2505	137	6590	1249

Changes in the concentrations of Na and Cl were observed in both leaf and nut water, resulting from differential fertilizer treatments. Both elements have some functions in the nutrition of coconut, particularly Cl, but discussion of such functions is beyond the scope of this paper.

CONCLUSIONS

Significant yield responses were obtained for the experiment at SE, albeit with an overall decrease in yield due to weather and nutritional factors. The experiment at HE failed to display any yield responses as a result of drought.

With respect of leaf and nut water analysis, in both experiments responses to the main treatments K and Mg, were noticeable, with varying trends. Changes in the leaf composition was more pronounced at SE than at HE.

Nut water analysis shows promise as an additional tool for interpretation of field experimental data.

The presentation covers a four-year period. Statistical studies on when to conclude long-term fertilizer trials on coconut yield consider an eight- to ten-year period as sufficient to understand the full response (Mathes, 1980). Both experiments are still in progress.

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