COCOS (2000-2002), 14, 69-86
Printed in Sri Lanka

EFFECT OF THE METHODS OF APPLYING POTASSIUM AND MAGNESIUM FERTILIZERS ON THEIR INTERACTION IN THE SOIL AND UPTAKE BY COCONUT (*Cocos nucifera, L.*)

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ABSTRACT

An experiment was carried out with the objective of evaluating the interaction between potassium and magnesium on coconut nutrition in respect to different methods of potassium and magnesium fertilizer application such as spatial separation, time separation and mixed application of the two fertilizers in a loamy sand soil (ferralic arenosols, FAO - UNESCO classification, (1994). The experiment was on CRIC 60 palms grown in the agro-climatic region IL_3. Soil samples were taken from the top soil (0 - 20 cm) and subsoil (20 - 40 cm) at three month intervals for the investigation of exchangeable potassium and magnesium. Concentration of potassium and magnesium in the ground water was obtained from analysis of ground water samples collected in the field. Leaf samples were taken from the 14^{th} leaf at four month intervals and analyzed for potassium and magnesium.

The application of potassium fertilizer decreased the quantity of exchangeable magnesium and application of magnesium fertilizer decreased the quantity of exchangeable potassium in the soil. The exchangeable potassium and magnesium content in the soil across the seasons reveal that the interaction between potassium and magnesium can be minimized by different methods of application.

The application of magnesium fertilizer did not increase the concentration of magnesium in the 14^{th} leaf of the palms during the first year of the experiment. However, placement of kieserite and potassium with spatial separation and time separation seemed promising in correcting the leaf magnesium concentration of the palms compared to mixed placement at the end of the two-year period.

BACKGROUND AND OBJECTIVES

Application of N, P, K and Mg fertilizers is generally considered important for increasing coconut production. Coconut palms require a relatively large quantity of K for nut production and growth. (Loganathan and Balakrishnamoorthy 1975). Hovland and Caldwell (1960) has reported ionic antagonism between potassium and magnesium. According to Jeganathan (1990), K fertilizer application in high quantities resulted in decrease of Mg content in tissues of the coconut palm. Somasiri (1997) showed that application of K and Mg fertilizers simultaneously to lateritic gravelly soils resulted in displacement of exchangeable Mg from soils and hence reducing the Mg uptake efficiency of the coconut palm. The present study evaluates the effect of spatial on the behavior of these nutrients separation, time separation and mixed application of K and Mg fertilizers on the behavior of these nutrients in soil and on the uptake efficiency of Mg by the coconut palm.

MATERIALS AND METHODS

The study was conducted on 40 year old CRIC 60 plantation on a deep loamy sand soil at Pallama located in the agro-climatic region IL_3. Fertilizer was applied within the manure circle, with a radius of 2m from the base of the palm. The experiment consisted of four treatments arranged in a randomized complete block design with five replicates. There were at six palms per plot. The treatments per palm per year were as follows: T_1 : 1.6kg of Muriate of Potash (MOP), applied in the entire manure circle (MC); T_2 1.6kg of MOP and 1 kg of Kieserite, applied in entire (MC); $T_{3a:}$ 1.6 kg of MOP in 1/2 of the MC, and T_{3b} ; 1 kg of Kieserite in the other 1/2 of the MC; T_4; 1.6 kg of MOP in the entire manure circle, followed by 1 kg of Kieserite in the entire manure circle six months later. Each palm also received 800g of urea and 600g of Saphos Phosphate per annum which was applied in the entire manure circle.

Soil and leaf sampling

Soil samples were taken from each manure circle at two points located 0.9m away from the base of the palm of the palm to provide one sample. Samples were taken by boring upto two depths of 0-20 cm and 20-40 cm and composited to provide one sample per plot for each depth. Soil sampling was carried out at bimonthly intervals throughout the experimental period and the initial samples were obtained before the application of fertilizers. Leaf samples were taken from the 14^{th} frond of three randomly selected palms of each plot and composited.

Chemical analysis of the samples

Soil analysis for exchangeable bases:

The exchangeable bases of the soil were extracted with 1 M ammonium acetate solution (pH 7.0) (Thomas 1982) and analyzed for potassium, calcium, magnesium and sodium by the atomic absorption spectrophotometer

Leaf analysis:

Leaf samples were washed with distilled water, dried at 70° C for 3 days and ground to pass through 1mm sieve. For determination of total, potassium, calcium and magnesium, 0.5g of each sample was digested with 4ml conc. HNO_3 and 1ml of conc. $HClO_4$ in a 75ml digestion tube on a block digester at 70°C for 1h and at 250°C for further 2h. The residues in the tubes were dissolved in 5% HCl, made up to 50 ml and the solutions were analyzed for potassium, calcium and magnesium by the atomic absorption spectrophotometer.

Ground water analysis:

When the site was water logged after prolonged intensive rainfall during September 1999 to January 2000, the ground water samples were collected at 20 cm depth from the manure circle of each palm in December 1999. Samples were centrifuged at 2000 rpm for 2 minutes, filtered and analyzed directly using the atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

Prior to application of treatments, exchangeable K and Mg concentrations of the soil were in the range of 0.14 - 0.22 and 0.87 - 1.10 meq / 100g soil, respectively (Tables 1 and 2). At these concentrations of exchangeable K and Mg of the soil in the manure circle, the coconut palms had K status in

Table 1: Levels of exchangeable K in the topsoil (0-20 cm) with different treatments

Treatments	**Exchangeable potassium - meq/100g soil**							
	July 99	**Oct 99**	**Jan 00**	**April 00**	**July 00**	**Oct 00**	**Jan 01**	**April 01**
T1 (MOP only)	0.16	0.36	0.28	0.15	0.06	0.34	0.32	0.26
T2 (MOP+Kieserite)	0.15	0.36	0.12	0.07	0.08	0.37	0.20	0.13
T3a (half circle Kieserite)	0.14	0.16	0.06	0.07	0.05	0.18	0.10	0.08
T3b (half circle MOP)	0.14	0.55	0.32	0.14	0.10	0.58	0.40	0.31
T4 (MOP + six months later Kieserite)	0.22	0.48	0.22	0.12	0.08	0.41	0.33	0.18
Significance	**ns**	**	**	**ns**	**ns**	**	**	**
LSD	-	**0.2958**	**0.0523**	-	-	**0.1925**	**0.1342**	**0.1214**

ns – Not significant
*- Significant at 5%
**- Significant at 1%

MOP - Muriate of Potash (K fertilizer)
Kieserite - Mg fertilizer

Table 2: Levels of exchangeable Mg in the topsoil (0-20 cm) with different treatments

Treatments	**Exchangable magnesium - meq/100g soil**							
	July 99	**Oct 99**	**Jan 00**	**April 00**	**July 00**	**Oct 00**	**Jan 01**	**April 01**
T1 (MOP)	1.1	0.76	0.86	0.59	0.65	0.45	0.51	0.67
T2 (MOP+Kieserite)	1.05	0.83	0.88	0.61	0.67	0.90	1.01	0.73
T3a (half circle Kieserite)	0.87	1.12	1.01	0.66	0.71	1.40	1.14	0.96
T3b (half circle MOP)	0.87	0.70	0.87	0.51	0.65	0.47	0.66	0.55
T4 (MOP + six months later Kieserite)	0.96	0.80	0.86	0.77	0.73	0.69	0.97	0.94
Significance	**ns**	**	*	*	**ns**	**	**	**ns**
LSD	-	**0.2581**	-	**0.1741**	-	**0.3589**	**0.3436**	-

ns – Not significant
*- Significant at 5%
**- Significant at 1%

MOP - Muriate of Potash (K fertilizer)
Kieserite - Mg fertilizer

the sufficiency range and Mg status in the deficiency range as reflected by the leaf content of these nutrients (Tables 3 and 4). The sufficiency ranges of K and Mg are 1.2 - 1.5% and 0.25 - 0.35 as the % of the dry matter in the leaf of the 14^{th} frond. The foregoing data and observations indicate that the exchangeable magnesium concentration of the soils in the manure circle at the time of commencement of the experiment, was not adequate to maintain the Mg status of the palms at sufficiency level. All the palms were showing visible Mg deficiency symptoms. The treatments of the present experiment were designed to compare the efficiency of the three methods of kieserite application, viz. 1kg kieserite with 1.6kg of muriate of potash simultaneously (T_2), with spatial separation (T_{3a} & T_{3b}) and with time separation (T_4), in correcting Mg deficiency. By applying magnesium treatments of 1kg of kieserite with spatial separation (T_{3a}) and time separation (T_4) from K fertilizer, it was expected to minimize interactions between exchangeable K and exchangeable Mg.

Table 3: Potassium content as % of dry matter in the 14 th leaf of the coconut palms

	Before application	6 months AA1	12 months AA1	6 months AA2	9 months AA2	12 months AA2
		(Percentage dry matter basis)				
T_1	1.436	1.490	1.409	1.582	1.409	1.52
T_2	1.461	1.492	1.414	1.423	1.312	1.59
T_3	1.572	1.652	1.498	1.352	1.517	1.55
T_4	1.344	1.501	1.370	1.371	1.404	1.52

AA1 - After first application
AA2 - After second application

Table 4: Magnesium content as % of dry matter in the 14 th leaf of the coconut palms

	Before application	6 months AA1	12 months AA1	6 months AA2	9 months AA2	12 months AA2
	(percentage dry matter basis)					
T_1	0.181	0.181	0.139	0.138	0.147	0.19
T_2	0.177	0.198	0.165	0.166	0.173	0.26
T_3	0.177	0.194	0.152	0.162	0.190	0.29
T_4	0.183	0.189	0.166	0.167	0.169	0.28

AA1 - After first application
AA2 - After second application

Analysis of soils taken three months after application of treatments revealed that exchangeable K of all soils which received muriate of potash increased compared to the initial stage (Table 1). The increase was higher in treatments that received K in half circles (0.41 meq / 100g soils) than treatments which received K in the entire manure circle (0.20 meq/100g soils). Coconut palms require high amounts of K due to higher removal of this element (879g K/palm/year) as reported by Somasiri *et al.* (2000). Therefore the increased exchangeable soil K may be an advantage for the palms to realize its full production potential.

The exchangeable K of the top soil layer (0-20cm) showed a sharp decreasing trend from October 1999 to January 2000 in all the treatments. The decrease could be due to two reasons; uptake by the palm and leaching with rainwater. The rainfall recorded during October 1999 to January 2000 was 1100 mm (Figure 1) and as a result the ground water table was raised to the surface and slowly dropped to 1m level by January 2000. This happened because the site was located in a river flood plain where soils were imperfectly drained. The concentration of K and Mg in the ground water was found to be 50 - 55 ppm and 9 - 12 ppm, respectively, irrespective of the location and the depth (0-20 cm) of the samples taken.

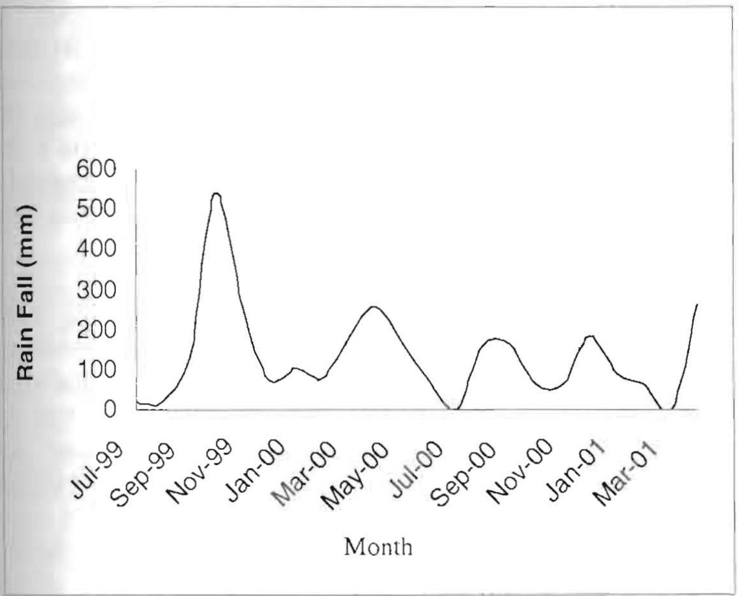

Figure 1: Rainfall at the experimental site between July '99 and April '01

It follows that diffusion of both K and Mg from soil colloid to the ground water has taken place or dissolution of K and Mg fertilizers occurred with rising of water table and K and Mg would have evenly distributed in the water table over the entire area. It would have resulted in the drop of soil exchangeable K concentration in the topsoil as seen in exchangeable K values in January 2000. The drop of exchangeable K in January 2000 seemed to be enhanced due to the application of kieserite as indicated by the sharp drop of exchangeable K in treatments T_2 and T_{3a} compared to T_1 and T_{3b} drops from 0.55 to 0.32.

The rate of reduction in exchangeable K was higher (66%) in T_2, that received K and Mg together as against T_1, that received only K (22%), between October 1999 to January 2000. This clearly shows the effect of Mg on exchangeable soil K. (Table 1). However, in treatments T_{3b} and T_4, exchangeable K concentrations in October 1999 were as high as 0.55 and 0.48 meq/100 g soils respectively. After the rainfall of 800mm in November and December, the K values of T_{3b} and T_4 dropped by 42% respectively which indicates that concentrations as high as 0.48 - 0.55 me/100g of exchangeable K would not persist in this loamy sand soil when subjected to intensive rainfall and leaching.

Even in the absence of kieserite application the decreasing trend of exchangeable K continued further from January 2000 for all the treatments. The soil analysis during April 2000 did not show significant differences among the treatments for exchangeable K. This is in agreement with the findings of Giritharan *et al.* (2000) that retention of applied K fertilizers in the manure circle persists only for a short period of 6 months. The treatment T_{3b} that did not receive Mg and received only K also showed a decline from January 2000.

Although kieserite application to T_2 and T_{3a} was effected in July 1999, exchangeable Mg of T_2 showed a decline instead of an increase. However, exchangeable Mg of T_{3a} showed 29% increase compared to the initial value recorded. The main difference between the two treatments was that the application of 1kg kieserite, in T_2 was mixed with 1kg muriate of potash, and not so in T_{3a}. The decrease of exchangeable Mg of T_2 indicates that the Mg has not been effectively adsorbed to the soil exchange complex due to the interaction between K and Mg. This interaction has also been demonstrated in treatments T_1, T_{3b} and T_4 where exchangeable Mg showed a decline compared to the initial value. Kieserite was not applied to these treatments in July 1999. A decrease in exchangeable Mg was observed in all treatments that received K, which indicates that the applied K has replaced the Mg that already existed in the exchangeable complex. The average reduction in exchangeable Mg in treatments that received potassium was found to be 20% within the first three months period after application. The findings of Hogg 1962, that displacement of Mg following application of K in sandy soils was as high as 59.5% within the first three weeks of application of KCl, supports the above finding. All treatments except T_{3a} showed an increase in exchangeable Mg in January 2000. This increase of Mg is concurrent with the drop in exchangeable K during the same period. (Tables 1&2) The average increase of exchangeable Mg in treatments T_1, T_{3b} and T_4 was 12.5%. These observations indicate that when K^+ is present in high concentration in the soil solution, it displaces Mg^{2+} from exchange sites whereas when K^+ concentration drops Mg^{2+} in the soil solution displaces the K^+ from exchangeable sites. Apparently this phenomenon occurs over a period of six months. Findings of Hovland and Caldwell (1960) that potassium competes with magnesium for exchangeable sites is clearly evident from the above results.

The exchangeable K values of all treatments that received K dropped to around 0.10 meq/100g soil seven months after application and there was no significant difference in exchangeable K between treatments by April 01. Similar trend was observed for exchangeable Mg values in treatments that received only K, and K and Mg together, one year after application, with drop in the values from 1.10 to 0.65 and 1.05 to 0.67 meq / 100g of soil, respectively (Table 2). However, the exchangeable Mg in T_{3a} and T_4 dropped upto 0.71meq/100g soils and 0.73 meq/100g soils respectively at the end of the first year. The treatment (T_2) that received K and Mg together showed a 36% decrease for exchangeable Mg against the initial exchangeable Mg level. Whereas the treatment T_{3b} and T_4 showed 14% and 28% decrease of exchangeable Mg respectively.

Treatments were re-imposed in July 2000. The exchangeable K and Mg showed similar trends as in the previous year. But the rate of decline in exchangeable K and Mg from the time of second application was lower than that of the first year. This may be attributed to the relatively lower intensity of rainfall (571mm) during the period between September 2000 to January 2001.

However, such effects were not sufficient to make an impact on the Mg status of the palm during a short period such as 12 months. But at the end of the second year, the treatment with spatial separation (T_3) and time separation (T_4) and mixed application recorded higher values for the leaf Mg status than in the treatment that did not receive magnesium (Table 4). The visual Mg symptoms of yellowing of mature fronds remained same in the T1 treatment where as it disappeared in all other treatments.

The effect on the sub-soil layer at 20 - 40 cm depth:

The effect of K fertilizer on each K in soil layer at 20 - 40 cm depth (sub soil layer) was observed to be significant at $p < 0.05$. It showed an increase in the range of 0.12 - 0.18 meq/100 g soil in full manure circle applications and

0.24 meq/100 g soil in 1/2 circle applications. (Table 5). Though treatment of mixed K and Mg (T_2) showed an increase of 0.12 meq/10 soil for exchangeable K in the sub soil layer, it was lower compare treatments with only K such as T_1 and T_4 showing increases of 0.17 0.18 meq/100 g soils respectively. The increase in sub soil exchangeab was relatively higher (0.24 meq / 100g soil) in treatment (T_{3b}) that receive in the half circle.

Exchangeable K in the sub soil layer showed a similar pattern of declin in the topsoil layer with seasonal rainfall (Table 5). The observed incre in exchangeable K of the sub soil layer remained only for a period of ne seven months and showed a sharp decline thereafter.

In contrast to K, sub soil layer did not show a significant increas exchangeable Mg even in treatments that received Mg. The penetration into the subsoil layer shows its high mobility in soils compared to Mg. treatment effects on exchangeable Mg in the sub soil layer was r significant throughout the experimental period and remained low, except one instance in October 2000 (Table 6).

Table 5: Levels of soil exchangeable K in the sub-soil (20-40 cm) with different treatments

Treatments	Soil exchangeable Potassium - meq/100g soil							
	July 99	Oct 99	Jan 00	April 00	July 00	Oct 00	Jan 01	Apr 01
T1 (MOP)	0.12	0.29	0.12	0.10	0.06	0.25	0.20	0.19
T2 (MOP+ Kieserite)	0.09	0.21	0.11	0.06	0.05	0.22	0.14	0.12
T3a (half circle Kieserite)	0.11	0.15	0.12	0.10	0.05	0.12	0.05	0.06
T3b (half circle MOP)	0.10	0.34	0.14	0.10	0.07	0.37	0.31	0.28
T4 (MOP + six months later Kieserite)	0.10	0.28	0.20	0.12	0.10	0.26	0.26	0.19
Significance	ns	*	**	ns	ns	**	**	**
LSD	-	0.1282	0.1081	-	-	0.0708	0.1228	0.0897

ns - Non significant
* - Significant at 5%
** - Significant at 1%

MOP - Muriate of Potash (K fertilizer)
Kieserite - Mg fertilizer

Table 6: Levels of exchangeable Mg in the sub-soil (20-40 cm) with different treatments

Treatments	Soil exchangeable Magnesium - meq/100g soil							
	July 99	Oct 99	Jan 00	April 00	July 00	Oct 00	Jan 01	April 01
T_1 (MOP)	0.47	0.34	0.35	0.27	0.26	0.34	0.24	0.34
T_2 (MOP+ Kieserite)	0.38	0.32	0.34	0.26	0.36	0.27	0.32	0.34
T_{3a} (half circle Kieserite)	0.37	0.30	0.31	0.21	0.37	0.52	0.49	0.42
T_{3b} (half circle MOP)	0.40	0.42	0.42	0.29	0.32	0.18	0.16	0.27
T_4 (MOP + six months later Kieserite)	0.46	0.38	0.33	0.35	0.34	0.37	0.46	0.45
Significance	**ns**	**ns**	**ns**	**ns**	**ns**	**	**ns**	**ns**
LSD						**0.1814**		

ns – Non significant
*- Significant at 5%
**- Significant at 1%

MOP - Muriate of Potash (K fertilizer)
Kieserite - Mg fertilizer

Leaf K and Mg concentration:

Leaf analysis revealed that all palms, which received K and Mg, showed an increase of leaf K and Mg six months after application and declined thereafter during the first year of the experiment. But the palms that did not receive Mg (treatment T_1) showed a sharp decrease in the leaf Mg levels (0.181% - 0.139%) compared to other treatment palms at the end of first year. (Tables 3 and 4).

The leaf analysis six months after second treatment application (second year) showed an increase from 0.152% to 0.162 % for leaf Mg in T_3 palms whereas the levels of leaf Mg in other treatment palms remained the same. This shows the beneficial effect of spatial separation of K and Mg fertilizers in the efficiency of uptake. The leaf analysis of the palms 9 months and 12 months after application of fertilizers in the second year showed an increasing trend for leaf magnesium in all treatments. The increase could be due to the higher exchangeable Mg levels existed in the top soils of T2, T2a and T4 treatments than the control particularly during October 2000 to January 2001 (Table 2). It is also important to note that all treatments that received Mg have shown leaf values in the sufficiency range (0.25% - 0.35%) regardless of the method of application. The highest percentage increase in the concentration of leaf magnesium over the two year period was observed in T_3 (spatial separation) palms followed by T_4 (time separation) and T_2 (mixed application) with the values of 81.3%, 64.7%, and 52.9% respectively. Whereas the treatment palms that did not receive Mg showed deficiency for leaf Mg.

The ratio between K and Mg in the leaf was in the range of 7.34 to 8.88 prior to application of treatments. The sufficiency range for leaf K and Mg lie between 1.2 % - 1.5 % and 0.25 % - 0.35 % respectively on dry matter basis. Considering the above range the K and Mg ratio in the leaf would fall in the range of 3.4 to 6.0 to maintain a healthy balance between the two elements. The treatment that did not receive fertilizer Mg exhibited a K/Mg ratio in the range of 7.93 to 11.46 and resulted in a value of 8.00 at the end of the two-year period. (Table 7)

In contrast the treatments that received Mg showed K/Mg ratio in the range of 9.86 to 5.34. At the end of the two year period, the Mg treatments resulted in decreasing the K/Mg ratio to the range of 6.12 to 5.34. A favorable K and Mg balance among the treatments was found in T_3 (spatial separation) and T_4 (time separation). However K/Mg ratio of 6.12 in treatment T_2 was also not far out.

Table 7: The ratio between K and Mg in the 14 th leaf of the adult coconut palms

	Before application	6 months AA1	12 months AA1	6 months AA2	9 months AA2	12 months AA2
		(Percentage dry matter basis)				
T_1	7.93	8.23	10.14	11.46	9.59	8.00
T_2	8.25	7.53	8.57	8.57	7.58	6.12
T_3	8.88	8.52	9.86	8.35	7.98	5.34
T_4	7.34	7.94	8.25	8.21	8.31	5.43

AA1 - After first application
AA2 - After second application

CONCLUSION

The results show that fertilizer potassium has an interaction on exchangeable Mg in the soil. The exchangeable K and Mg values of soil across the seasons suggest that interaction of the above elements in the soil can be minimized by different methods of application. The increase in exchangeable Mg achieved by spatial separation with placement of fertilizers compared to mixed placement remained for duration of 6-8 months. The results revealed that Mg deficiency (level of Mg in leaf < 0.25%) of coconut palms cannot be corrected within a period of one year with the application of Mg fertilizer kieserite at the rate of 1kg/palm using spatial and time separation. However, placement of kieserite and potassium with spatial separation and time separation seemed to be promising in increasing the leaf magnesium level of the coconut palm in the long run compared to mixed placements. It was not possible to simultaneously increase both exchangeable K and Mg concentrations in soils at the site beyond a level due to limitations in the soil cation exchange capacity (1.68 meq/100 g soil).

REFERENCES

FAO - UNESCO. (1974), Soil Map of the world. Paris: UNESCO. Vol 1. Legend.

Giritharan.D, Somasiri L.L.W, Perera B.S.V.J Studies on seasonal fluctuation of exchangeable cations in a loamy sand soil of a coconut plantation. *Agrieast* Vol 2 pp 49-55

Hogg, D. E. (1962), N.Z. J. Soil Sci., 5, 64.

Hovland, D. and Caldwell, A.E. (1960), Soil Sci., 89,92.

Jeganathan, M. (1990) Studies on potassium-magnesium interaction in coconut (*Cocos nucifera; L.*). *Plant and Soil.* 124: 265-271.

Loganathan, P., Balakrishnamoorthy, T.S. (1975) Response of coconut (*Cocos nucifera;* L) to N, P and K application from the time of field planting on a lateritic gravel soil in Sri Lanka. *Ceylon Cocon. Q* 26: 89-98

Somasiri, L.L.W. (1997) The interaction between potassium and Magnesium in red yellow podzolic soils with laterite and its effect on nutrition of coconut palms (*Cocos nucifera* L.) *Cocos,* 18-32.

Somasiri, L.L.W., Wijebandara, D.M.D.I Sabaratnam, S. Panditharatne, D.P and Perera, U.S.S. (2000). Removel of plant nutrients form soils by nuts of the coconut plam. Proceedings of the Sri Lanka Association for the Advancement of Science 56 (1) 77.

Thomas , G.W. (1982). Exchangeable cations. In: Page, A.L. Miller and Keeney, D.R., Methods of soil analysis Part - 2 Chemical and microbiological properties, Agronomy No 9, Madison, Winsconsin, USA 159-164.