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THE INTERACTION BETWEEN POTASSIUM AND MAGNESIUM IN RED YELLOW PODZOLIC SOILS WITH LATERITE AND ITS EFFECT ON NUTRITION OF COCONUT PALMS *(Cocos nucifera, L.)*

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ABSTRACT

The interaction between plant available potassium and magnesium in highly leached red yellow podzolic soils with laterite in Southern coastal area of Sri Lanka and its effect on coconut palm was studied in a 3x2 KxMg factorial experiment that consisted of 3 levels of potassium and 2 levels of magnesium fertilizer application to coconut palms in plots. Five years after continuation of treatment application, soil samples were taken from top soils (0-20 cm) and sub soils (20-40 cm) at monthly intervals for 10 months and analyzed for exchangeable potassium and magnesium (1M ammonium acetate extraction at pH 7.0) and water soluble potassium and magnesium (1:10 soil/water ratio). Leaf samples taken from the 14^{th} frond at bimonthly intervals were analyzed for potassium and magnesium.

The results showed that the application of potassium fertilizer decreased the quantity of both exchangeable and water extractable magnesium and magnesium fertilizer decreased the quantity of exchangeable potassium in soils. The mutual decreasing effect on the exchangeable fraction of each nutrient is attributed to low cation exchange capacity and base saturation of the soils. The close association of the coconut leaf nutrient contents with soil nutrient status implies that poor chemical characteristics of red yellow podzolic soils bring about imbalance of potassium and magnesium nutrition in coconut palms.

INTRODUCTION

Potassium has long been recognized as the most widely needed element for coconuts (Lyne, 1915; Georgi and Teil, 1932; Salgado, 1946;

Fre'mond et al., 1966; Loganathan and Balakrishnamurti, 1975). A fertilizer experiment carried out at Veyangoda, Sri Lanka showed that there was a 209% yield increase of coconut palms treated with 1.82 kg of muriate of potash per palm annually over those that did not receive any potassium fertilizer (Loganathan and Balakrishnamurti, 1979). Based on long term yield data of a number of NPK factorial experiments, the Coconut Research Institute of Sri Lanka has recommended a general NPK fertilizer mixture for adult coconut palms which comprised of 8 parts of urea, (46% N), 6 parts of imported rock phosphate (27.5% P_2O_5) and 16 parts of muriate of potash (60% K_2O) by weight. The composition of the above mixture is 12% N, 6% P_2O_5 and 32% K_2O which indicates that the potassium concentration is comparatively high (Anon, 1986).

It has been observed that application of high levels of potassium fertilizer induces magnesium deficiency in coconut palms particularly on red yellow podzolic soils with laterite in the sub soil (Jeganathan, 1990). Also it has been a general observation that application of NPK coconut fertilizer mixtures without application of dolomite induces magnesium deficiency in palms on most of the soils.

As a preventive measure against occurrence of magnesium deficiency of coconut palms, it is recommended to apply 1 kg of dolomite per palm annually along with NPK fertilizers. But when Mg deficiency symptoms appear in palms 1 kg of kieserite per palm has to be applied biannually until the disorder is corrected (Mahindapala and Pinto, 1991). Nevertheless the planters experience is that it takes a long time to correct magnesium deficiency even by application of kieserite along with NPK fertilizer mixtures particularly in palms on red yellow podzolic soils with laterite in the wet zone which are highly leached. The nature of the interaction of potassium and magnesium applied to the soil through muriate of potash and kieserite over one year period and its effect on the nutrition of the coconut palm is discussed in this paper.

MATERIALS AND METHODS

Experimental site

Soils and coconut leaf were sampled from an ongoing experiment conducted at Sirikandura Estate, Ratgama from 1985. In this experiment, coconut palms had been annually treated for five years with three levels of muriate of potash and two levels of magnesium in the 3 x 2 factorial arrangement by the time of sampling. The treatment levels were as follows.

Muriate of potash	(60% K_2O) (kg/palm/y)	Kieserite (24% MgO) (kg/palm/y)	
K_0	0.0	Mg_0	0.0
K_1	1.2	Mg_1	1.2
K_2	2.4		

A basal dose at the rate of 0.8 kg of urea (46% N) and 0.6 kg of saphos phosphate (27.5% P_2O_5) per palm had also been applied for five years to each plot. Each treatment plot consisted of eight palms and treatments were arranged in randomized block design with three replicates. Each treatment plot was separated from the other by a single row of coconut. The last treatment application was done on 20 May, 1990.

The experimental site was situated in the agro ecological region of WL_2 receiving annual rainfall of more than 2500 mm and was located on a terrain of 5-8% slope. The soils of the site belong to the great soil group of red yellow podzolic with laterite which is classified as plinthudults according to the 7th approximation (1967). The soils are well drained and moderately deep. The soil contains about 40-50% lateritic gravels beyond the depth of 60-90 cm.

Some important characteristics of the soils are given below.

Particle size of 2 mm fraction	
sand	75%
silt	15%
clay	10%
pH (1:5 soil/water)	5.12
organic matter	2.1%
CEC	6.12 meq/100 g
Base saturation	30%

Soil and leaf sampling

Soils were sampled from the manured area of four randomly chosen palms in each treatment plot by making borings at 0.9 m distance from the base of either side of the palm and they were composited to obtain a representative sample for the plot. Samples were taken from two depths 0-25 and 25-50 cm from each plot. Soil sampling was carried out at monthly intervals for the period of May 1990 to February 1991. The samples were taken during the second week of each month.

The 1st sampling commenced in May 1990, five days before treatment application and afterwards the sampling was continued at monthly intervals up to February 1991. Coconut leaf samples were taken from the palms of the same plots that were taken for soil sampling but at bimonthly intervals for the period of May 1990 to March 1991. Six leaflets were sampled from the 14th frond counted from the top, the 1st being the fully opened leaf with its leaflets separated. Six leaflets were cut from the mid region of the 14th frond and composited the samples of the four palms to form one representative sample per plot.

Determination of soil moisture

Fifty grammes of field moist soils of each sample was placed in a pre-weighed aluminum can immediately after being sampled, and dried in an oven at 105^{0}C for 24 h and reweighed. The percentage moisture was calculated to the oven-dried basis using the weight difference.

CHEMICAL ANALYSIS OF SAMPLES

Exchangeable potassium and magnesium

Five grams of 2 mm sieved air dry soils were shaken with 25 ml of 1 M ammonium acetate (pH 7.0) for 30 min in a 50 ml centrifuge tube after which it was centrifuged at 3000 r.p.m. for 10 min. The supernatant was decanted into a 50 ml volumetric flask and the residue was re-shaken with a fresh 25 ml portion of 1 M ammonium acetate. The second fraction was also centrifuged and added to the volumetric flask which was then made up to 50 ml with 1 M ammonium acetate (Thomas, 1982). The extract was analyzed for potassium and magnesium by the atomic absorption spectrophotometer.

Water soluble potassium and magnesium

Five grams of 2 mm sieved air dry soils were shaken with 50 ml of distilled water in a centrifuge tube for five minutes and then centrifuged at 3000 r.p.m. for 10 minutes. The supernatant was filtered with Whatman No. 42 filter paper (Olsen and Sommers 1982). The extract was analyzed for potassium and magnesium by theatomic absorption spectrophotometer.

Leaf analysis

Leaf samples were washed with distilled water and dried at 70^{0}C for 3 days and ground to pass through 1 mm sieve. For determination of total potassium and magnesium, 0.5 g of the samples were weighed into 75 ml digestion tubes, 5 ml of conc. HNO_3 and 1 ml conc. $HClO_4$ were added and heated on a digestion block at 70^{0}C for 1 h and at 250^{0}C for further 2h. The residues in the tubes were dissolved in 5% HCl and the volume was made up to 50 ml. The resulting solutions were analyzed for potassium and magnesium by the atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

The rainfall distribution over the period of May 1990 to February 1991 shows two distinct rainy periods i.e. from May to July 1990 and from October to December, 1990. During January and February 1991 there has been more than 100 mm of rainfall per month (Figure 1a). Comparison of number of wet days (Figure 1b) and the monthly rainfall (Figure 1a) shows that rains in June (31 mm/day), October (21 mm/day) and December (24 mm/day) were more intensive than that in other months. Considerable leaching and/or run off of applied nutrient can be expected to occur to a greater extent during those months than the rest of the period. The moisture content of the top soils and the sub soils at the time of the sampling ranged from 7.9% to 5.7% during July to October and it ranged from 10.5% to 15.5% during the rest of the period (Figures 1c and 1d).

The exchangeable potassium content (determined by 1M ammonium acetate extraction) of the top soil (0-20 cm) in the manured area (i.e. manure circle) of the palms showed a rapid increase immediately after treatment application and thereafter an overall decreasing trend (Figures 2a). It did not considerably decrease over the period of August to October during which soil moisture content was low but it rapidly decreased over the period of October to January during which soil moisture content was high (Figure 1c). The rapid decrease of exchangeable K during more wet period could be due to the efficient uptake of potassium by the coconut palm, leaching and fixation which are taking place to a lesser extent when the soils are less wet. The increase of exchangeable K in the sub soils of both K_1 & K_2 treatments during June-July period implies that K distributed well throughout the soil profile up to 40 cm depth within a short duration following treatment application (Figure 2c). It shows the high mobility of K in soil during the wet period. In the sub soils also the same trend of decrease in exchangeable K

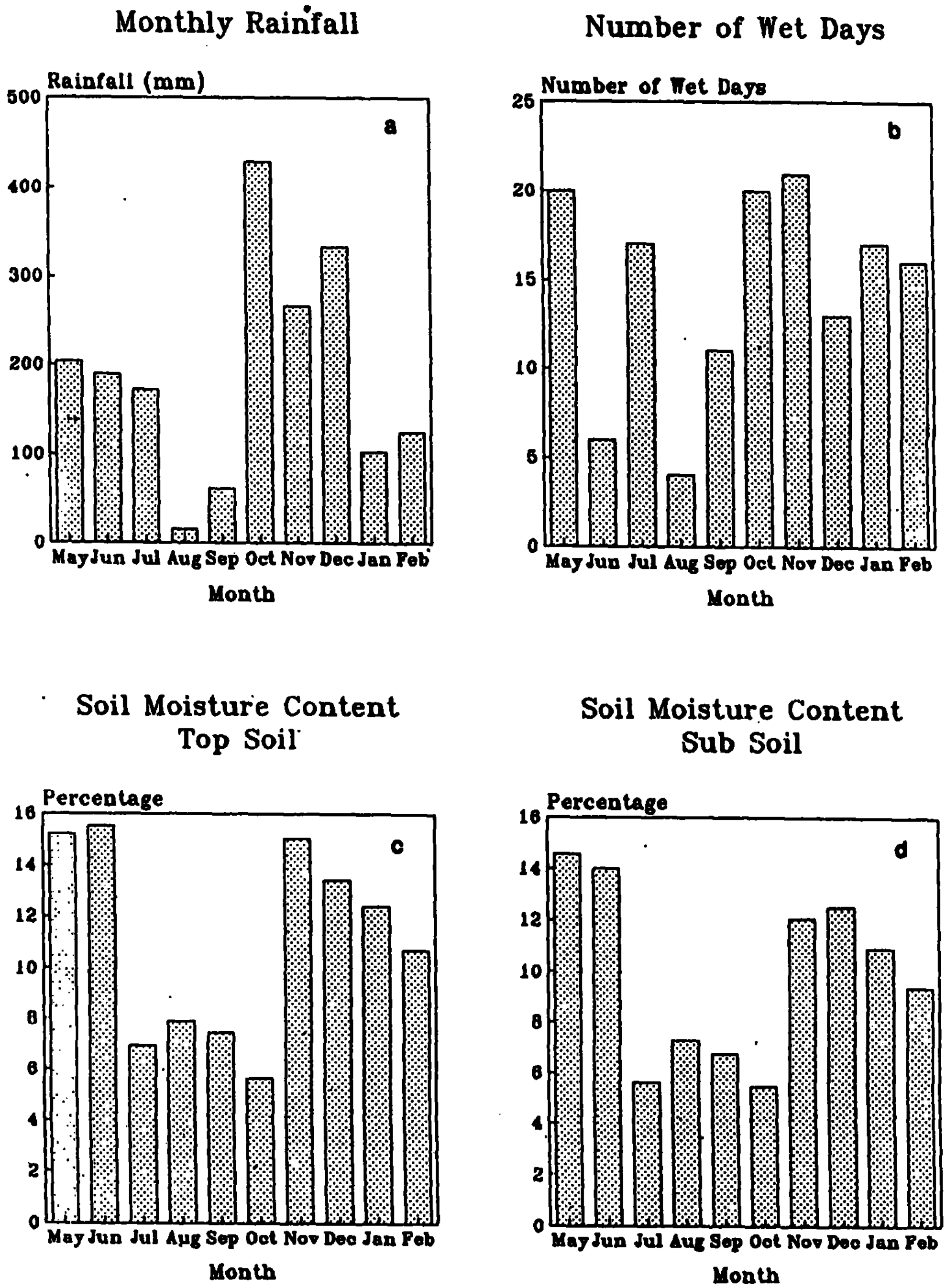


Figure 1 Monthly rainfall, number of wet days, soils moisture content in top soil and the sub soil from May 1990 to February 1991.

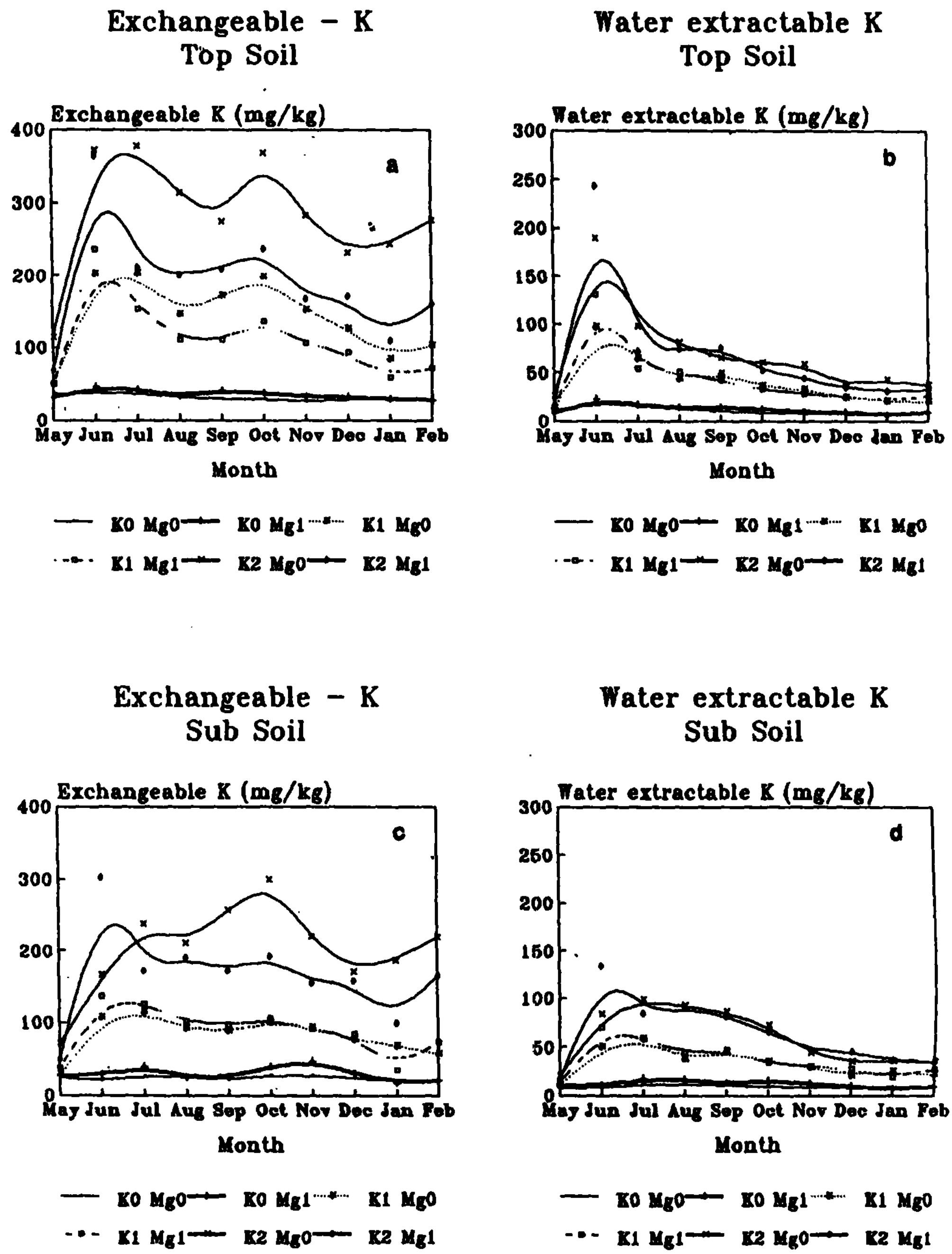


Figure 2 Monthly variation of exchangeable K and water extractable K of soils in different treatments from May 1990 to February 1991.

was observed from October 1990 to January 1991. It implies that the reactions taking place in the sub soils during that period is much similar to those in top soils. The quantity of exchangeable potassium in both the top and sub soils also followed the same pattern as that of treatments; $K_2>K_1>K_0$ throughout the observation period.

The changes that occurred in exchangeable K contents of K_1 & K_2 treatments in the presence of Mg_1 treatment were quite interesting. At the end of the 1st two months (June to July) after fertilizer applioation in which soils were quite wet, the distribution of exchangeable K in the top soil layer was in the order of $K_2Mg_0>K_2Mg_1>K_1Mg_0>K_1Mg_1>K_0Mg_0 = K_0Mg_1$ (Figure 2a). The differences were significant at 0.1% level. The difference of exchangeable K between K_2Mg_0 and K_2Mg_1 remained greater than 100 mg/kg throughout the observation period. Similarly the difference of exchangeable K between K_1Mg_0 and K_1Mg_1 remained greater than 43 mg/kg. Calculation showed that exchangeable K was 40% low in K_2Mg_1 treatment compared to K_2Mg_0 treatment and it was 30% low in K_1Mg_1 treatment compared to K_1Mg_0 treatment. But there was no significant effect on exchangeable K of K_0 treatments (no muriate of potash application) by Mg treatments.

The differences in the rate of increase of exchangeable K in the sub soil between Mg_0 and Mg_1 treatments during 1st two months are noteworthy as the results clearly show that in the presence of Mg fertilizer treatments exchangeable K rapidly moves down from top soils to the sub soils (Figure 2b). It is quite contrasting to what happened in the top soil (Figure 2a). The reason could be high concentration of Mg in top soils of K_2Mg_1 treatment (Figure 3a). The downward movement of K was rather slow in soils that received K_2Mg_0 treatment as the Mg concentration of the top soil is much lower compared to K_2Mg_1 treatment (Figure 3a). Thus exchangeable K gradually accumulated in the sub soils of K_2Mg_0 treatment up to October and then dropped probably due to uptake by the palm. But in K_2Mg_1 treatment, initial rapid increase of exchangeable K from May to June followed by a rapid drop from June to July which could be due to further leaching of K from sub soil as a result of accumulation of exchangeable Mg in the sub soil during the latter period (Figure 3c). But exchangeable K in the sub soils of K_1 treatment which remained less than 100 mg/kg was not significantly affected by high Mg concentration in the soil (Figure 2c). It also shows that displacement of K by Mg takes place when K level is above a certain value.

The water soluble K fraction of both K_1 and K_2 treatments was in the order $K_2>K_1>K_0$ and also increased sharply from May to June following fer-

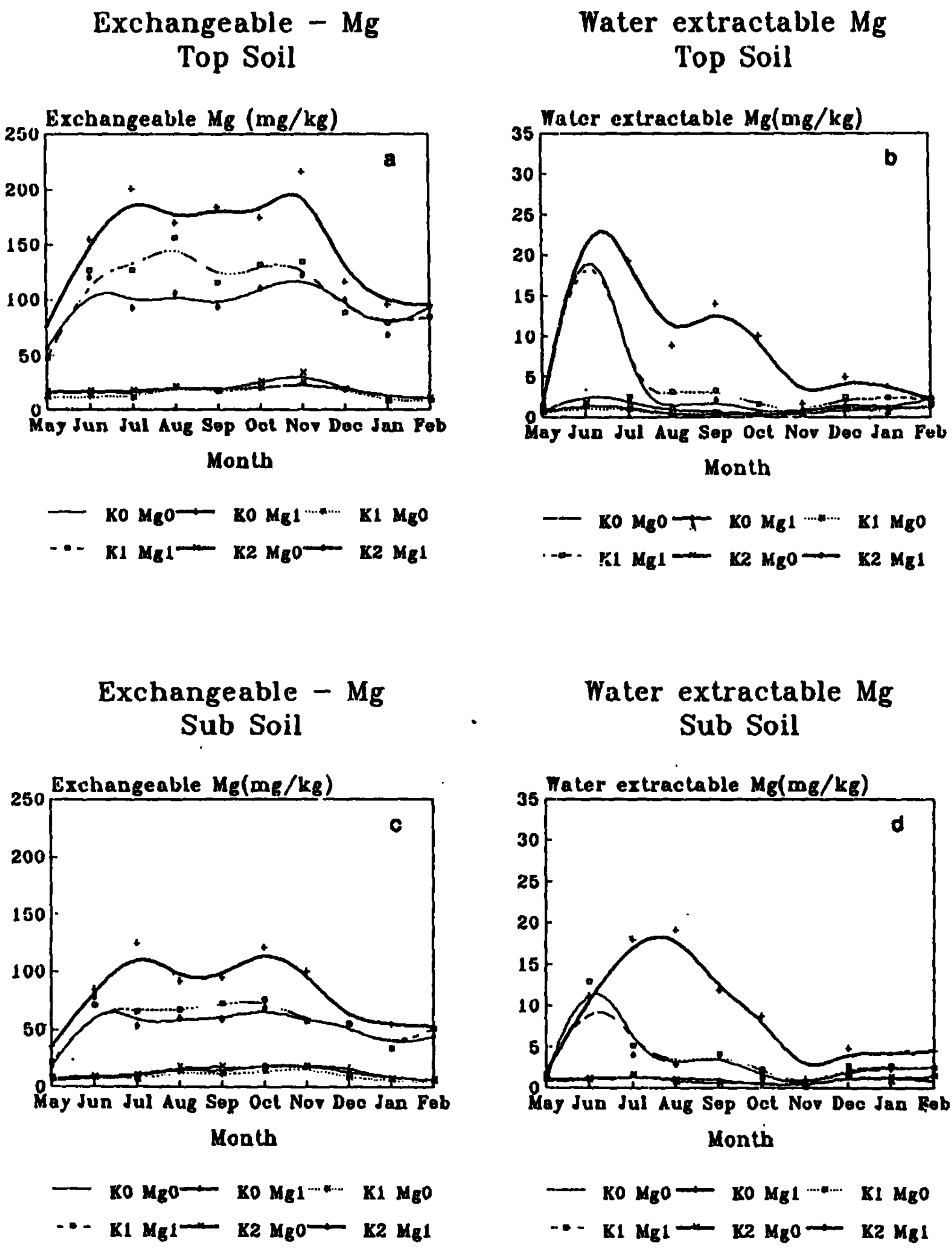


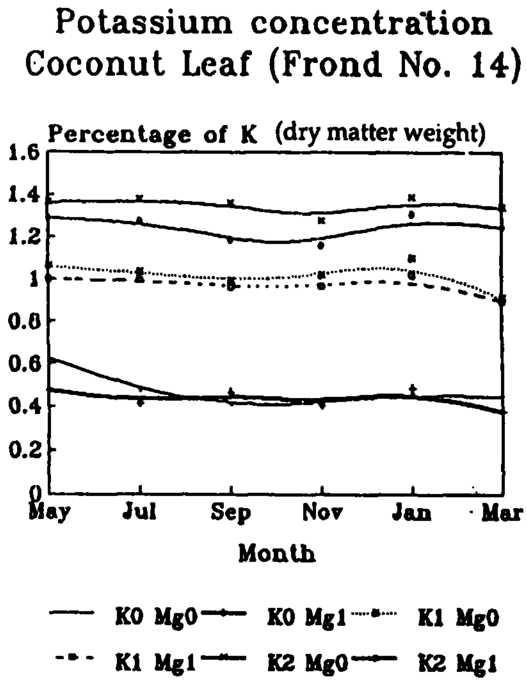
Figure 3 Monthly variation of exchangeable Mg and water extractable Mg of soils in different treatments from May 1990 to February 1991.

tilizer application (Figure 2b). In the top soils, the water soluble K of K_1 and K_2 treatments sharply dropped from June to July and gradually dropped at a slow rate from August to December and at a much slower rate from January to February of the following year. The pattern of decrease of water soluble K in the top soils was rather different from that of exchangeable K and it was not dependent on the Mg treatments (Figure 2b). The water soluble K of sub soils also increased in less than a month period following fertilizer application (June) which shows that free K^+ have rapidly moved down the soils. It is also seen from Figure 2d that free K^+ of K_2Mg_1 moved faster than K_2Mg_0 during the initial two months (up to July) but thereafter the decreasing pattern was the same. In the sub soils also, the water soluble K was in the order of $K_2>K_1>K_0$ and it was not dependent on Mg treatments.

The observed gradual decrease of water soluble K with time could be mostly due to reaching the equilibrium state of the reaction between water soluble K and exchangeable K (Tisdale and Nelson, 1996)

Water soluble K is readily taken up by plants and in consequence exchangeable K rapidly diffuses to soil solution to enrich the depleted solution with K. The observation that water soluble K remained high in proportion to treatment level of K (K_2,K_1 and K_0) suggests that plant availability of K in the descending order should be $K_2>K_1>K_0$. It is also important to note that since water soluble K fraction was unaffected by Mg treatments, the uptake of K by coconut palm could not be affected by Mg level in the soils. This interpretation can be justified to a certain extent by the leaf K concentrations given in Figure 4a in which percentages of K of K_2Mg_0 and K_2Mg_1 and K_1Mg_0 and K_1Mg_1 are quite close.

The exchangeable Mg (determined by 1M ammonium acetate extraction) of treated soils also followed the general pattern of $Mg_1>Mg_0$ through out the observation period. There was no significant variation of exchangeable Mg among Mg_0 treatments in both top and sub soils. But in Mg_1 treatments, it followed the pattern $K_0Mg_1>K_1Mg_1$ throughout the observation period. It also followed the order of $K_1Mg_1>K_2Mg_1$ from June to November in both top and sub soils (Figure 3a and 3b). It clearly shows that first level of K fertilizer (K_1 = 1.2 kg of muriate of potash) application imposed a drastic decreasing effect on exchangeable Mg in soils and the effect was seen to a lesser extent with further increase in K application level. It is also important to note that within two months period after kieserite application, Mg has moved down to sub soils which indicated that kieserite is very active in increasing the Mg concentration in soils (Figure 3c). It is also evident from the



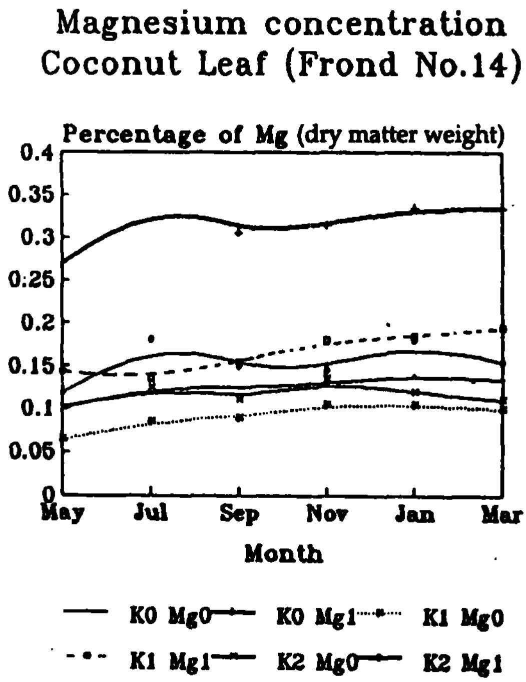


Figure 4 Bi-monthly variation of potassium and magnesium concentration of coconut leaf of treatment palms.

above observation that the rate of mobilization of Mg in red yellow podzolic soils is quite high during rainy periods.

The water soluble fraction of Mg also greatly increased following Mg treatment application but it remained much higher in K_0Mg_1 treatment than K_1Mg_1 and K_2Mg_2 in both top soils and sub soils throughout the observation period. The pattern of variation of water soluble Mg with time was much similar for both top and sub soils. An important observation is that except in K_0Mg_1 treatment, the water extractable Mg remained lower than 5 mg/kg from July onward.

The water extractable quantity of K and Mg can be considered only as an approximate measure of the soil solution concentration of each ion. However, water extractable quantity of ions can contain a fraction of sparingly soluble salts and exchangeable quantities which come into solution due to re-equilibration process during the extraction (Gregory, 1988). The concentration of ions in the soil solution is controlled by the buffer capacity of individual soils which is known as the action of regulation of soil solution nutrient concentration by the solid phase nutrients. The results of the present study show that water extractable K content (Figure 2b & 2d) is very high (40-150 mg/kg) compared to water extractable Mg (Figure 3b & 3c) which ranged from 2 to 20 mg/kg. Thus, in the soils used for the present study, the K^+ was the predominant ion in the soil solution. The Mg^{2+} concentration was greatly suppressed by K^+ when it was present in the soil solution in high concentration. It follows that it is difficult to maintain high concentration of Mg^{2+} in the soil solution in the presence of K^+, which can affect the Mg nutrient status in the coconut palm. Sinclair (1981) reported that Mg concentration in the soil solution could be related to the crop uptake of Mg better than exchangeable Mg. The present study also shows that leaf Mg concentration of coconut palm was very high in K_0Mg_1 treatment in which water soluble Mg of soil was much higher than all other treatments (Figure 4b). Despite application of kieserite (Mg_1 treatment), the leaf Mg levels remained very low in K_1 and K_2 treated plots. By leaf Mg concentration also, it was clearly seen that the first level of K application (K_1) has drastically hindered the Mg uptake by the palm and further increase of K application (K_2) has had no significant effect on further reducing Mg uptake. Thus the values of exchangeable and water extractable Mg of soils clearly explains that the uptake of Mg by coconut palms grown on red yellow podzolic soils with laterite is low in the presence of high K fertilizer application.

The overall results show that there was a mutual displacement of K by Mg and Mg by K from the soil exchange complex. This phenomena could be attributed to the limitations in the cation exchange capacity (6.12 meq/100g) and base saturation (30%) in the red yellow podzolic soils. These soils cannot accommodate high quantity of both K and Mg in the exchange complex.

The soil solution concentration is dominated by K^+ following K and Mg fertilizer application to these soils and Mg^{2+} concentration in the soil solution is suppressed when K^+ concentration in the soil solution is high. The K nutrient status of the coconut palms could be raised above the critical nutrient level of 1.2% (by dry matter content of leaflets in 14th frond) by application level of K_2 irrespective of Mg treatments. But, the Mg nutrient status of the coconut palms could not be raised above the critical level of 0.25% (by dry matter content of leaflets in the 14th frond) by application level of Mg_1 in the presence of K_1 and K_2 treatments. Only Mg treatment in the absence of K fertilizer treatments (K_0Mg_1) could raise the Mg nutrient status of the coconut palm above the critical level but K nutrition in the palm was very poor in the same treatment. The results also showed a decreasing trend in leaf K with high Mg treatments.

.The maintenance of proper, K and Mg nutrient status in coconut palms on red yellow podzolic soils with laterites presents difficulties due to KxMg interaction (Jeganathan, 1990). The present study showed that the problem was very much associated with soil characteristics. It also showed that increase of the quantity of application of each fertilizer ingredient was not the appropriate solution. Although the currently recommended K fertilizer application rate of 1.6 kg of muriate of potash per palm per·year could be sufficient to maintain the proper K nutrient status of the palm, it may bring on magnesium deficiency particularly in plantations on lateritic soils. In such cases attempts for increasing CEC of those soils by frequent incorporation of organic matter in addition to inorganic fertilizers would be more helpful in balancing K and Mg nutrition in palms grown on such problem soils.

CONCLUSION

The results showed that application of potassium fertilizer to the coconut palm would drastically affect the magnesium status of the palm on lateritic soils despite Mg fertilizer application. In the presence of K fertilizer even the application of kieserite at the rate of 1.2 kg per palm is not sufficient to raise the magnesium status of the palm to the sufficiency range.

It is very difficult to balance K and Mg nutrition of coconut palms grown on highly leached red yellow podzolic soils with laterite just by application of inorganic fertilizers due to their poor soil characteristics such as low cation exchange capacity and base saturation. The problem can be overcome by improving cation exchange capacity of such soils by increasing the humus content of the soils by organic matter incorporation.

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