THE INFLUENCE OF CALCIUM AND MAGNESIUM IN INCREASING THE EFFICIENCY OF FERTILISERS FOR RICE

and

CALCIUM AND MAGNESIUM STATUS OF SOME TYPICAL RICE SOILS OF KERALA

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This is to certify that the thesis herewith submitted contains the results of bonafide research work carried by Shri Thomas Varghese under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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INTRODUCTION

It is common knowledge that crop yields in India are very low compared to the yields obtained in most other countries. In fact, in the case of many crops, our yields are the lowest in the world. It is, therefore, not surprising that we have to depend on large imports of food from other countries to meet the mounting demands of our ever increasing population. There are several causes for the low crop yields in India. The root cause undoubtedly is that our soils have been severely drained of their supply of essential plant foods by centuries of injudicious cultivation without adequate manuring. It is quite obvious that unless this enormous loss of nutrients is made good and soil fertility built up we can never hope to increase our yields or substantially reduce our massive import of food.

One of the quickest and surest ways of increasing crop yields in India is by the extended use of commercial fertilizers. This is a widely recognised fact and statistics show that the consumption of fertilizers in India is steadily increasing from year to year. It is estimated that the requirements of fertilizers in the last year of the Third Five Year Plan will be of the order of 1,500,000 million tons of nitrogen, 750,000 tons of phosphoric acid and 200,000 tons of potash. There is little doubt that fertilizers will play an important role in increased agricultural production in India and in the achievement of self-sufficiency in food which is an accepted aim of our national policy.

Farmers in this country do not always obtain satisfactory response to fertilizer application. This is a common experience in the case of the rice soils of Kerala State and there is evidence to show that the response even to balanced NPK fertilization is often disappointing. This may be due to several causes as response to fertilizers is a complicated phenomenon. It must be noted, however, that when lime is applied in conjunction with fertilizers there is a much better response. The obvious conclusion is that apart from its other benefits lime helps in increasing the availability of mineral nutrients in the added fertilizers. Magnesium acts in much the same way as calcium in this respect. Kerala is perhaps the most fertilizer minded State in India and the annual investment on fertilizers is even now appreciable. Consequently, the efficient utilisation of added fertilizers is a matter of paramount importance.

The great majority of the rice soils of Kerala are acid in reaction. They are also low in lime due to the drastic leaching that they are subjected to. Though these are well known facts liming is seldom practised in this State. Work carried out in other countries has shown that the efficiency of added fertilizers could be significantly increased by the application of lime. Thus there appears to be great scope for increasing our rice yields by the application of lime in conjunction with balanced NPK fertilization. But this needs to be confirmed by experimental work as the evidence now available is very meagre. The present work was, therefore, undertaken to fill this gap and had two main objectives, viz.,

(i) To determine the influence of lime and magnesium in increasing the efficiency of fertilizers in the rice soils of Kerala.

(ii) To assess the lime and magnesium status of typical rice soils in the State.

REVIEW OF LITERATURE

A. THE INFLUENCE OF CALCIUM ON SOIL REACTION, NUTRIENT AVAILABILITY AND PLANT GROWTH.

Numerous workers have studied the influence of calcium compounds on soil reaction, nutrient availability and plant growth using different techniques, such as, laboratory studies, pot experiments and field trials. A comprehensive review has been made by Truog (1938) of the earlier work carried out on this subject. An attempt is made here to review only the work done on the effect of calcium on soil reaction, nutrient availability and yield of crops.

Effect of calcium on soil reaction

The Virginia farmer Edmund Ruffin (1794-1865) was probably the first to recognise the general prevalence of soil acidity and he conducted several field experiments with lime.

Later Truog (1918) suggested that the reason why calcium sulphate did not prove beneficial in acid soils was that the plant needed calcium, mainly to neutralise the acids formed within the plant and not so much as a plant nutrient.

Albrecht (1932) has emphasised the important role of calcium in plant growth and distinguished between its effects on acid reaction and its direct nutritive effects. According to Schmitt, Peech and Bradfield (1950), the beneficial effect of liming or diluting the soil with sand may be attributed to a decrease in the concentration of aluminium and manganese in the soil solution.

Hutchings (1936) found that calcium not only decreased the acidity of the soil complex but also aided the plant in making more tissue and in absorbing larger quantities of other nutrients. Sauchelli (1950) stated that most crops could tolerate considerable soil acidity but not any serious calcium deficiency. Aslander (1952) concluded that it was a lack of nutrients and not an acid reaction that made most acid soils unproductive.

Effect of calcium on nutrient availability

Davis and Brewer (1940) found that liming enabled Australian winter peas and common vetch to utilise larger quantities of phosphorus supplied by applications of superphosphate. Lime alone produced an increase in the percentage content of only calcium, while lime applied with superphosphate resulted in an increased content of calcium, phosphorus and nitrogen.

Dunn (1943) has shown that soil phosphorus became increasingly available with additions of lime upto slightly above the neutral point. Chemical analysis of the forage from a green house experiment indicated that the supply of available calcium readily increased in proportion to the amount of lime applied. It was, therefore, concluded that liming of acid soils to pH values of about 6 to 7 was most favourable to the growth of plants, as it tended to increase the supply of calcium and the availability of soil phosphorus for plant nutrition.

Beater (1945) observed changes in soil pH consequent on the additions of calcium carbonate. The effect on the pH values appeared to depend on the physical conditions of the soil and the native calcium already absorbed. When maize followed by sugarcane was grown on the soils prelimed to varying pH values, it was found that preliming resulted in a 20 percent increase in the concentration of nitrogen and calcium in the dry plant material.

Smith and Hester (1948) found that the liming of an acid Putnam silt loam very low in calcium failed to increase the calcium content of soy beans, but produced a significant increase in the nitrogen and phosphorus content. Robertson, Neller and Bartlett (1954) showed that liming the soils relatively low in residual phosphorus, increased the availability of applied phosphorus upto a pH of about 6 to 6.5 when the sexqui-oxide content was high, but had no effect when the sexqui-oxides were low.

The influence of lime on potassium availability has been studied by many of the earlier workers. Ehrenberg (1919) attributed the decreased uptake of potassium and low yields on limed soils to an "antagonistic" effect between calcium and potassium. He formulated what has since been known as the "lime potash law" which means that when the calcium concentration is relatively high, plants may not be able to absorb the required potassium at an adequate rate. Mac Intire and co-workers (1927) conducted extensive investigations on the effect of lime and calcium salts on the solubility of soil potassium, using lysimeters. They reported that neutral salts of calcium could liberate potassium to the leachings of an acid soil. This did not however result from applications of calcium and magnesium oxides. Aqueous extractions actually indicated decreases in soluble potassium by liming.

Jenny and Shade (1934) disputed such findings of increased retention of potassium by soils upon liming. They found that additions of calcium hydroxide, calcium carbonate and a variety of neutral, alkaline and acid calcium salts to permutite, bentonite, Putnam clay and soils, invariably transformed some exchangeable potassium to the soluble form. They considered this result to be consistent with the principles of cation exchange.

York and Rogers (1947) concluded that it would be extremely difficult to make generalisations regarding the overall influence of lime on the available supply of potassium in the soil because it was dependent upon the nature of soil and many other factors.

Effect of calcium on plant growth and crop yields

Contradictory observations have been reported in literature regarding the role of lime in increasing crop production.

Peech, Bradfield and Richard (1948) concluded that the yield responses of crops to applications of lime on acid soils were complex and involved many contributing factors, such as, calcium deficiency and the toxicity of hydrogen ions, aluminium, iron and manganese, the relative significance of which will vary with different crops and soils. Reed and Cummings (1948) in their experiments to study the effect of soluble sources of calcium on plant growth observed that pea nuts required a higher degree of calcium in the soil area, in which the pod was formed. Their data indicated that soluble sources of calcium may be preferred by certain crops. The general use of soluble sources of calcium is, however, of very limited value on acid soils of high exchange capacity.

Mitsui (1954) reported that Japanese farmers laid great emphasis on the application of lime to rice fields, though, it is one of the most acid tolerant crops. Subramonium and Varadarajan (1957) investigated the effect of lime on rice in Coorg. There was a progressive increase in crop yield with increase in rainfall upto 90 inches, but with further increases there was a steady decrease in yield.

According to Pierre _et al_ (1935) liming resulted in depression in crop yields. Experiments conducted by Mandal _et al_ (1955) showed that the rice crop did not respond to liming.

Neischlag _et al_ (1956) observed that liming increased the yield of crops. Sethi and Ramiah (1952) have reported that the rice crop in the slightly acid soil of Pattambi responded to liming. The results of experiments conducted by Ananthakrishnan _et al_ (1952) and Ahamed Bavappa and Hanumantha Rao (1956) showed substantial increases in the yield of rice in response to liming.

According to Coleman (1955) on most Missouri soils, lime will not only increase crop yields, but will enhance their feeding value as well. On Putnam silt loam at Columbia, lime applied to soy beans increased the protein produced per acre by 131 percent. In a similar experiment with lespedeza, the protein yield per acre was increased 113 percent by using lime and phosphate.

Lawton and Davis (1956) observed that the dry weight of field beans was markedly increased by lime applications upto

12 tons of calcium carbonate per acre. The growth of corn, however, was depressed when more than 3 tons of calcium carbonate per acre were applied. Liming had little or no effect on the yield of Sudan grass.

B. INFLUENCE OF MAGNESIUM ON SOIL REACTION, NUTRIENT AVAILABILITY AND PLANT GROWTH.

The specific functions of magnesium within the plant and on soil properties are not yet fully established. Even in his time, Justus Von Liebig (1803-1873) enquired into the necessity of applying magnesium fertilisers, when he found this element to be a constant component of plant ash. The discovery by Wilstatter (1909) that magnesium is one of the components of chlorophyll drew attention to its importance as a plant nutrient. Several investigators, have subsequently demonstrated the functions of magnesium as nutrient element and their work has been reviewed by Zimmerman (1947).

Effect of magnesium on soil reaction

From the investigations of Domontovich, Pryanishnikov (1930) has assumed the existence of an antagonism between magnesium and hydrogen ions. In the presence of magnesium salts, plants are believed to tolerate higher concentrations of hydrogen ions and consequently the application of magnesium salts will have a favourable effect on acid soils.

Trenel and Schonberg (1959) reported that benefit from magnesium is obtained only if aluminium ions have been removed from the soil solution by liming with materials, such as, dolomitic limestone.

In a field experiment on sandy and loam soils Schmitt

(1960) found that neutralisation was better achieved and higher yields of root crops and cereals were obtained from nitrogen, phosphorus and potassium treatments when liming was carried out with dolomitic limestone rather than with calcium oxide, magnesium oxide or calcium carbonate.

Effect of magnesium on the availability of other nutrients

Loew (1903) stated that magnesium by acting as a "carrier" of phosphates is closely related to phospholipid formation and to the synthesis of nucleo-proteins. Truog (1947) and his associates investigated the relationship of the supply of available magnesium to the phosphorus content of pea seeds by means of field and nutrient culture tests in which the supplies of available magnesium and phosphorus were varied. Consistent increases in the phosphorus content occurred with increasing supply of available magnesium. The phosphorus content of seeds increased much more by the extra magnesium than by the extra phosphorus. These authors suggested that greater attention should be given to supplies of available magnesium in order that the phosphorus present in the soil might be used more effectively.

Truog et al (1947) in another study noticed that by increasing concentrations of magnesium the nitrogen content of peas went up slightly. There was only very negligible increase in the potassium content with additions of this element in an available form.

Dewan and Hunter (1949) in a comparison of the effects of magnesium, calcium and sodium salts concluded that magnesium applications to soils markedly increased the percentage of magnesium in soy beans and sudan grass but failed to increase significantly the percentage of phosphorus in soy bean plants harvested as pod formation began.

Enzmann (1956) in a trial with barley reported that after the supplementary application of phosphorus, the magnesium content was as a rule lower than that without any such addition. On the other hand, the supplementary application of magnesium sulphate in many cases tended to increase the absorption of phosphorus by the plant, from the fertiliser or alternatively it led to an increased absorption of this element from the soil. On a slightly sandy, humus loam with neutral reaction a better absorption of phosphorus from the fertiliser has been reported. A close correlation was observed between the magnesium and potassium absorbed by plants.

Albrecht (1937) showed that when no magnesium was added to the nutrient medium biological fixation of nitrogen was insignificant unless extra calcium was available. When magnesium was added, however, fixation increased. He suggested that nodule bacteria were acclimated to plants that were accustomed to a high level of soil fertility in the form of calcium, magnesium and other mineral nutrients. Magnesium also had an indirect effect in that it appeared to promote the release of calcium which was absorbed by the plant with resulting increase in nitrogen fixation. Graham (1928) showed in addition that magnesium increased fixation of nitrogen by soy bean plants by stimulating bacterial activity to a much greater degree than equivalent quantities of calcium compounds.

Effect of magnesium on plant growth and yield of crops.

Tests carried out by Popp (1922), with magnesium and non-magnesium potash salts, did not help to establish the effect of magnesium. On peaty soils, the application of magnesium fertilisers frequently showed favourable results, while on sandy soils it appeared to be less effective. On acid soils, magnesium fertilisers contributed to an increase in yield, winter rye showed better results with magnesium than with non-magnesium salts.

Russel and Garner (1941) found in their investigations on potatoes at Rothamsted that magnesium sulphate was effective only when it liberated potash salts by base exchange.

Nieschlag (1959) in trials with magnesium fertilisers on light soils observed that dolomitic limestone was superior to ordinary limestone in increasing yields in cereal - root crop rotation.

In field trials conducted by Jacobson and associates (1960) on a reclaimed moor sand, 200 kg. per hectare of super was applied with fertilisers containing ammonium, potassium, magnesium, copper, manganese, zinc and molybdenum. Where rates of super were heavy magnesium deficiency symptoms were widespread. After one year, magnesium was applied, with different rates of super, potassium chloride and with nitrogen in the form of calcium nitrate or ammonium sulphate. Ammonium and potassium intensified magnesium deficiency in oats. Applications of magnesium sulphate at the rate of 500 kg. per hectare increased the yield appreciably, especially when used with

Cooper et al (1947) observed that crops containing a relatively large quantity of magnesium such as potatoes, cotton, tobacco, buck wheat and some vegetables often gave a marked response to applications of magnesium in mixed fertilisers as indicated by their yields.

C. THE INFLUENCE OF CALCIUM AND MAGNESIUM ON CATION EQUILLIBRIA IN PLANTS

Van Itallie (1938) showed that although the content of calcium, magnesium and potassium varied greatly, in relation to both the nature of the soil and the number of crops harvested, the sum of their equivalents per 100 gm. of the dry matter for any one harvest was virtually constant for all soils. He also observed that calcium did not cause any great variation in the composition of the plant and therefore did not play an important part in ion replacement. Magnesium, on the other hand, had a greater influence on the composition of plants because from an equal application of calcium and magnesium, more magnesium than calcium was taken up.

Beeson and Barrentine (1944) reported that the phosphorus concentration of tomatoes was significantly and positively correlated with magnesium supply, whereas neither the potassium nor calcium supplies were significant in their correlation with phosphorus concentration in the leaflets. In general, there was positive correlation between the concentration of the cations in the plants and their supply, while there was negative correlation between calcium and potassium, and between calcium and magnesium.

PART I

THE INFLUENCE OF CALCIUM AND MAGNESIUM IN INCREASING THE EFFICIENCY OF FERTILISERS FOR RICE.

Bear and Toth (1948) after 8 years of study on 20 important agricultural soils of New Jersey with alfalfa came to the conclusion that for proper nutrition of crops, 65 percent of the exchange complex of the soil should be occupied by calcium, 10 percent by magnesium, 5 percent by potassium and 20 percent by hydrogen. The plants tended to take up more potassium than required, unless the calcium content of the soil was maintained at a relatively high level.

Hunter (1949) in a factorial pot-trial, studied the effect of variations in the exchangeable calcium-magnesium ratio, the level of available phosphorus in the soil, and the method of soil preparation, upon the growth and composition of alfalfa. The percentage of phosphorus in the plants increased significantly, as the calcium content or the calcium-magnesium ratio decreased. When calcium was present in large proportions increasing levels of magnesium had little influence on the uptake of phosphorus. There was no direct relationship between the amounts of magnesium and phosphorus absorbed. With increasing calcium-magnesium ratios, the increase in the magnesium content of alfalfa was several times as great as the increase in the phosphorus content.

Prince (1951) reported that the leaves of plants showed a much greater increase in magnesium, following the application of magnesium materials, as compared to the edible portions Calcium was the dominant cation in the leaves and potassium in the edible portions. The calcium and potassium content of the leaves of potatoes tended to decrease, as the content of magnesium increased. The amounts of magnesium removed from the soil, were relatively small being of the order of 15 to 20 pounds of magnesium oxide, per acre. More than half the applied magnesium could not be accounted for in the harvested crops or in the exchange complex of the soil. This indicated that the annual application of magnesium to deficient soils, should supply 30 to 40 pounds of magnesium oxide per acre.

Koshy (1960) observed an increased uptake of calcium and a decreased absorption of potassium in magnesium deficient soil, in the presence of high levels of applied calcium and magnesium.

MATERIALS AND METHODS

A. POT CULTURE EXPERIMENT

The influence of calcium and magnesium on the growth characteristics of rice was studied in a pot culture experiment of, $2^3 \times 4$, factorial randomised block design. The eight treatments were as follows.

Treatment	1	-	F_o	C_o	M_o
"	2	-	F_o	C_1	M_o
"	3	-	F_o	C_o	M_1
"	4	-	F_o	C_1	M_1
"	5	-	F_1	C_o	M_o
"	6	-	F_1	C_1	M_o
"	7	-	F_1	C_o	M_1
"	8	-	F_1	C_1	M_1

F_o - No fertiliser. Only a basal dressing of organic manures, at the rate of 5000 pounds per acre.

F_1 - Nitrogen, phosphorus and potassium at the rate of 40 pounds each per acre.

C_o - No calcium.

C_1 - Calcium at the rate of 1000pounds of pure calcium oxide per acre.

M_o - No magnesium.

M_1 - Magnesium at the rate of 1000pounds of pure magnesium oxide per acre.

Table 1. -- Chemical character of the soil used for pot experiment.

1.	Moisture	per cent	2.130
2.	Loss on ignition	"	1.653
3.	Total nitrogen	"	0.021
4.	Total P_2O_5	"	0.139
5.	Total K_2O	"	0.067
6.	Total CaO	"	0.032
7.	Total MgO	"	0.047
8.	Total sesqui oxides	"	21.200
9.	Available P_2O_5	"	0.0003
10.	Available K_2O	"	0.0012
11.	Exchangeable Ca.	me/100g.	1.50
12.	Exchangeable Mg.	"	1.86
	Soil pH		6.00

The soil used was Vellayani sandy clay loam. The chemical characteristics of this soil are given in Table 1. The rice variety used was PTB.12 of 125 days' duration. The fertilisers used were urea, superphosphate and muriate of potash. The basal dressing was given as cattle manure and glyricidia leaves. Calcium and magnesium were applied in the form of carbonates.

In the actual procedure, the soil was mixed with cattle manure and glyricidia leaves and then applied in equal amounts to the 32 pots. Each pot held forty pounds of dry soil. Three rice seedlings were planted in each pot and after five days, when they were well established, the different fertiliser treatments were given as per schedule. The pots were watered daily with well water. The crop was harvested on 1-12-1962. The harvested plants from each pot were placed in separate polythene bags and dried in an air oven at 70°C. The weights of straw and grains were noted separately. The dried plant material was then powdered well in an electric grinding mill and stored in glass containers for chemical analysis.

B. LABORATORY INVESTIGATIONS

Soil Studies

Soil samples were drawn from the pots at regular intervals to determine the changes in pH and in the available phosphorus and potassium. The pH measurements were made with photovolt pH meter using a 1.2.5 soil-water suspension. Available phosphorus and potassium were determined by quick soil test methods as indicated later.

Plant performance studies

The following observations were made to determine the effect of different treatments on plant performance.

1. Number of tillers per plant.
2. Length of earhead.
3. Number of grains per earhead.
4. Weight of filled grains per pot.
5. Ratio of number of filled grain to chaff.

These observations were analysed statistically to find out whether there was any significant difference due to the various treatments.

Chemical analysis of plant material

The plant material from each pot was analysed for nitrogen, phosphorus, potassium, calcium and magnesium. The methods followed are briefly indicated below.

Nitrogen was determined by Kjeldahl method and the protein content was calculated by multiplying this value by the factor, 6.25.

Phosphorus, potassium, calcium and magnesium

A weighed quantity of the oven-dry plant material was dry ashed and digested with 1.1 hydrochloric acid 1 ml. of nitric acid was added to oxidise ferrous salts and evaporated to dryness and then ignited to dehydrate the silica. The residue was extracted with 1 1 hydrochloric acid, filtered using whatman No.44 filter paper, and the filtrate made upto 250 ml. This extract was used for the following determinations.

In aliquots of this extract phosphorus, potassium, calcium and magnesium were determined using standard methods. Phosphorus was precipitated as ammonium phosphomolybdate and estimated volumetrically. Potassium was precipitated using sodium cobalti nitrite and determined gravimetrically. Calcium was estimated volumetrically after precipitating as calcium oxalate and magnesium was estimated gravimetrically as pyrophosphate.

R E S U L T S

A. SOIL STUDIES

The results of soil studies are presented in Tables 2 and 3. The data in these tables, indicate the variation in the pH and available phosphorus and potassium in the soil due to different treatments, over a period of three to six weeks.

Changes in soil reaction

The pH values of the soil were influenced significantly by the different treatments of calcium and magnesium. The initial pH of the soil was 6. At the end of three weeks, the pH value increased from 6.38 to a maximum of 6.65. At the end of six weeks, the pH had further increased to a maximum of 6.70. It was also observed that the change in soil reaction was influenced more markedly by the combined application of calcium and magnesium than by their individual application.

Changes in available phosphorus

It may be noted from Table 3 that the available phosphorus was maximum for the treatment in which calcium and magnesium were applied together with the fertilisers. The next highest value was obtained for the fertiliser plus calcium treatment. Similar results were obtained

Table 2. -- Effect of calcium and magnesium treatments on soil reaction.

Treatment	Initial pH	pH after 3 weeks	pH after 6 weeks
1	6.0	6.38	6.38
2	6.0	6.38	6.50
3	6 0	6.50	6 53
4	6.0	6.45	6.53
5	6.0	6.38	6.37
6	6.0	6.58	6.58
7	6.0	6.53	6.63
8	6.0	6 65	6 70

Table. 3 -- Effect of calcium and magnesium treatments on available phosphorus and potassium.

Treatment	Available phosphorus		Available potassium	
	Initial level %	After 4 weeks %	Initial level %	After 4 weeks %
1	0.0003	0.0006	0.0012	0.0032
2	0.0003	0.0007	0.0012	0.0053
3	0.0003	0.0010	0.0012	0.0046
4	0.0003	0.0011	0.0012	0.0038
5	0.0003	0.0021	0.0012	0.0053
6	0.0003	0.0025	0.0012	0.0063
7	0.0003	0.0026	0.0012	0.0058
8	0.0003	0.0026	0.0012	0.0056

from treatments in which no fertilisers were used.

Changes in available potassium

Reference to Table 3 shows that the availability of potassium increased to a maximum, in both the fertilised and unfertilised pots, by the application of calcium. The next highest value for available potassium was obtained with magnesium, while the combination of calcium and magnesium gave the lowest value.

B. PLANT PERFORMANCE STUDIES

Yield of filled grains was maximum for the treatment in which calcium and magnesium were used along with fertilisers. Here the increase in yield was 98 per cent more than the control pot. The next highest yield was obtained by the treatment in which fertilisers were applied in conjunction with calcium. In this case, the increase in yield was 95 per cent ove the control. In unfertilised pots also calcium and magnesium combination gave the highest yield. Individual applications of calcium and magnesium gave almost similar results.

Statistical analysis show that the effect of treatment is highly significant at 0.05 and 0.01 levels Separate analysis of the treatments, show that the effects of fertiliser, calcium and magnesium are significant at the above levels.

Table 4. -- Effect of calcium and magnesium on yield of rice.

Treatment	Weight of filled grains. g. per pot	Weight of straw g. per pot
1	10.4	21.2
2	11.6	23.7
3	11.8	22.5
4	14.8	23.3
5	17.3	34.1
6	20.3	36.4
7	19.0	35.6
8	20.6	35.8

Treatment effect is significant at 0.05 and 0.01 levels. Effects of fertiliser, calcium and magnesium are also significant at 0.05 and 0.01 levels.

Table 5. -- Effect of calcium and magnesium on plant performance.

Treatment	Number of tillers per plant	Length of earhead cms	Number of grains per earhead	Ratio of number of grain to chaff
1	11	19.7	76	1.60
2	10	20.3	88	3.40
3	10	20.2	84	3.55
4	12	21.4	98	3 62
5	17	21.5	98	2.63
6	18	21.5	98	3.05
7	17	21.1	93	3.40
8	19	21.7	103	3.60

Study of the tillering characteristics indicated that application of fertilisers produced a definite increase in the number of tillers per plant. The maximum number of tillers was observed in treatments in which calcium and magnesium compounds were applied together There was not much variation among the different treatments, as regards the length of earhead The number of grains per earhead was similar for treatments 4, 5 and 6. But the maximum count was obtained for the treatment 8. The total number of grains and chaff was determined and the ratio calculated. The ratio was highest for treatments 3, 4 and 8. It was evident that magnesium applied alone or in combination with calcium had the beneficial effect, in reducing the proportion of chaff to grain in the earheads.

C. CHEMICAL COMPOSITION OF GRAIN (Tables 6--9)

Nitrogen content of grain was maximum in the treatment in which calcium and magnesium were applied along with the fertilisers. Calcium had a greater effect than magnesium, in increasing the nitrogen and protein content of grain. It was evident, that the application of calcium or magnesium is beneficial in increasing the protein content and thereby the nutritive value of rice.

The phosphorus content was highest in grain, in the treatment in which fertilisers were used along with magnesium Similar result was obtained in treatments in

Table 6. -- Effect of calcium and magnesium on the chemical composition of grain.

Treatment	Nitrogen %	Protein %	P_2O_5 %	K_2O %	CaO %	MgO %
1	1.23	7 68	0.344	0.132	0.044	0.046
2	1.26	7.90	0.394	0.126	0.092	0.054
3	1.25	7.81	0.415	0.137	0.048	0.078
4	1.31	8.18	0.398	0.135	0.066	0.062
5	1.37	8.56	0.533	0.304	0.088	0.048
6	1.40	8.75	0.620	0.234	0.121	0.062
7	1.39	8.68	0.621	0.253	0.084	0.089
8	1.42	8.87	0.606	0.236	0.106	0.073

Table 7. -- Effect of calcium and magnesium on the chemical composition of straw.

Treatment	Nitrogen %	P_2O_5 %	K_2O %	CaO %	MgO %
1	0.060	0.039	0.030	0.032	0.027
2	0.073	0.044	0.039	0.051	0.041
3	0.070	0.047	0.041	0.037	0.064
4	0.070	0.085	0.036	0.048	0.047
5	0.086	0.091	0.067	0.063	0.029
6	0.094	0.103	0.059	0.082	0.045
7	0.089	0.114	0.063	0.064	0.068
8	0.094	0.110	0.061	0.071	0.049

Table 8 -- Effect of calcium and magnesium on nutrient recovery by rice.

Treatment	N mg./pot	P_2O_5 mg./pot	K_2O mg./pot	CaO mg./pot	MgO mg /pot
1	141	44.1	20.1	11.4	10.5
2	164	56.1	23.9	22.8	15.9
3	163	59.6	25.4	13.9	23.5
4	210	78.7	28 4	20.9	20.1
5	266	123.0	75 4	36.7	18.2
6	318	163.4	68.9	54 4	23.9
7	296	158.6	69.4	38.7	41.1
8	324	164.4	70.5	47.3	32.6

which no fertiliser was used. The effect of calcium in increasing the phosphorus content of grain was less than that of magnesium.

The potassium content of grain tended to decrease when calcium was applied either alone or in combination with fertilisers and magnesium. The depressing effect of magnesium on potassium uptake was not as high as that of calcium.

The calcium content of grain was increased with applications of calcium. The magnesium content of grain was a maximum where magnesium was applied along with the fertilisers. Comparatively greater absorption of magnesium was observed from pots where both calcium and magnesium were applied.

Relation between the contents of calcium, magnesium and potassium

The content of these three cations in the plant material was found to be dependent one another. Magnesium was found to be the dominant cation in grain, and calcium in straw. An increase, in the percentage of one cation was found to be associated with a decrease in the percentages of the other two. It was also observed that the sum of these cations expressed as milli-equivalents per 100 gm of plant material, was almost equal, for the different treatments.

Table 9. -- Effect of calcium and magnesium on the cation content of rice.

Treatment	K me./100g.	Ca me./100g.	Mg me./100g.	Total cations
1	2.1	1.9	3.1	7.1
2	2.1	3.7	4.0	9.8
3	2.2	2.2	5.9	10.3
4	2.2	2 9	4.6	11 7
5	4.7	3 8	3.3	11.8
6	3.7	5 1	4.9	13 7
7	3.9	3.7	6.6	14.2
8	3.7	4.5	5.1	13.3

DISCUSSION

The results of the present study provide useful information regarding the influence of calcium and magnesium in increasing the efficiency of fertilisers in respect to the rice crop.

The beneficial effects of the application of calcium and magnesium in correcting soil acidity and increasing the growth and yield of rice are revealed from the data obtained There was a significant increase in pH in soils treated with both calcium and magnesium. Schmitt (1960) has pointed out the superiority of magnesium-bearing liming materials over other forms of lime. Careful studies by Arnon and Johnson (1942) with nutrient solutions and sand cultures have shown that many plant species can make normal growth at pH values as low as those encountered in most acid soils and, therefore, the hydrogen-ion concentration cannot be considered as the cause of poor crop yields in these soils. On the other hand, there is much evidence in favour of the view that toxic concentrations of certain cations such as iron, aluminium and manganese would largely account for the low fertility of acid soils and for the poor growth of plants on them. Liming tends to reduce the toxic concentrations of these cations in the soil solution thereby facilitating satisfactory growth of plants.

Better growth of plants at higher pH may be due to the greater availability of nutrients from the added fertiliser and the soil. According to Arnon and Johnson (1942) the availability of most plant nutrients will be a maximum in the pH range 6.0 to 7.0 This has been revealed in the present study also.

The yield data obtained show that the application of calcium or magnesium along with fertiliser helps to increase the yield of grain. This seems to be partly due to their direct nutrient effects and partly to their influence in correcting soil acidity and increasing the availability of other nutrients. The effect of fertiliser on yield was highly significant indicating clearly that crop yields can be considerably increased by a judicious application of fertilisers. The data also show that fertiliser efficiency can be further increased by the application of calcium or magnesium in conjunction with the fertilisers. Maximum yields were obtained from the treatments involving the combined use of calcium and magnesium.

The yield figures obtained in these studies correlated positively with the level of nutrients in the plant material. A higher protein content was noted in grains obtained from pots which received both calcium and magnesium, which shows that there was greater nitrogen availability from these pots. Beater (1945) and Albrecht (1937) have obtained similar results The increase in the phosphorus content of plants from magnesium treated pots was very significant. This critical role of magnesium in the utilisation of soil phosphorus deserves much consideration. Truog <u>et al</u> (1947) reported that there was an increase in the level of phosphorus in peas with increasing concentrations of magnesium and thought that this result confirmed the theory that magnesium functions as a "carrier" for phosphorus. These authors attribute the failure in many experiments, to produce crops of higher phosphorus content through phosphorus fertilisation, to a lack of available magnesium. This would explain the superiority of dolomite as a liming material over other forms of lime which supply only calcium to the soil. When the influence of calcium and magnesium on the potash content of plants was considered, it was noted, that these cations have an antagonistic effect both in the plant and in the soil. Although the data obtained from this study are not quite illustrative of the hypothesis of cation equilibria', they suggest that there should be a balance between the contents of these cations to ensure maximum fertiliser efficiency.

When considered independently, the effect of calcium appeared to be superior to that of magnesium in certain respects, like the yield of grain, and the content of protein. But magnesium proved to be more effective in increasing the ratio of grain to chaff and also in the better utilisation of phosphorus by plants.

SUMMARY AND CONCLUSIONS

A pot experiment to study the influence of calcium and magnesium in increasing the efficiency of fertilisers applied to rice was carried out Samples of soil and plant material were analysed for their nutrient contents.

The chief findings were as follows

1. Significant increase in soil pH was observed consequent on the addition of calcium and magnesium compounds. The available P_2O_5 was also increased correspondingly. Calcium tended to increase the available K_2O in the soil.

2. Significant growth and yield responses to application of fertilisers (40 40 40) along with calcium and magnesium were obtained. The effect of calcium was more than the effect of magnesium in increasing the yield. It was, further, noted that the combined application of calcium and magnesium was superior to individual applications in increasing the growth and yield.

3. Magnesium application increased the ratio of grain to chaff. The P_2O_5 content in grain was also a maximum for these treatments.

4. Calcium increased the protein content of grain,

thus improving its nutritive value.

5. The chemical composition of the plant material indicates the existence of a cation equilibrium in the rice plant.

The results of the present study underline the importance of including calcium and magnesium in any manurial schedule for rice in Kerala.

PART II

CALCIUM AND MAGNESIUM STATUS OF SOME TYPICAL RICE SOILS OF KERALA

INTRODUCTION

The results of the investigation reported in Part I of this thesis clearly show that calcium and magnesium increase significantly the efficiency of added fertilizers and thereby help in obtaining higher crop yields in the rice soils of Kerala. These soils cover an area of 19.24 lakh acres and rice is by far the most important crop in the State. Consequently, precise information regarding the calcium and magnesium status of these rice soils is absolutely essential for the formulation of sound fertilizer schedules.

Soil surveys have been carried out during the past 25 years of most of the important rice growing tracts in Kerala. These were essentially fertility surveys and were undertaken with the main objective of determining the nutrient status of the rice soils with respect to nitrogen, phosphorus, potassium and calcium. In the case of a few of these tracts, the level of magnesium was also determined. The results have been summarised by Raychaudhuri (1953). The data reveal that there is a widespread and serious deficiency in calcium in the rice soils of Kerala. The deficiency is particularly grave in sandy soils of the type found in Vaikom and Shertallai taluks (1935) and in laterite soils like those in Kunnathunad taluk (1948). In alluvial soils the content of lime is slightly better and ranges from 0.1 to 0.3%. As pointed out in Part I the low level of calcium in these soils is largely due to the heavy rainfall and drastic leaching that they are subjected to.

Very little data are available in regard to the magnesium status of our rice soils. In the Trichur and Thalapalli taluks, 67% of the soils were found to contain less than 0.2% MgO (1938). In Mukundapuram taluk, 96% of the soils examined fall below the safety limit (1942). These results are indicative of the nature and extent of the deficiency in magnesium that may exist in other areas also.

Field experiments carried out in recent years unmistakably show that many of the rice soils in Kerala respond well to application of calcium and magnesium compounds. Magnesium appears to be almost as important as calcium for these soils which are invariably acid in reaction.

In the light of the above findings, the need for further studies to assess the calcium and magnesium status of the rice soils of Kerala is obvious This was the main objective of the investigation reported herein. Incidently, the interrelationships between calcium, magnesium and other essential cations required for plant growth were also studied.

MATERIALS AND METHODS

Fifteen soil samples representing the main rice growing tracts of the State were used in this study The soils were analysed for total and available nutrients, following standard methods indicated below.

1. Moisture

Moisture was determined by drying a known weight of the soil in an air-oven at 105 - 110°C for six hours and noting the difference in weight.

2. Loss on ignition

A known weight of the soil was ignited until all the organic matter was oxidised and the loss in weight was expressed as loss on ignition, on moisture free basis.

3. Nitrogen

Total nitrogen was determined by Kjeldahl method using sulphuric-salycilic acid mixture.

4. Total phosphorus

Total phosphorus was determined volumetrically in 1 1 hydrochloric acid extract after precipitation as ammonium phosphomolybdate.

5. Total potassium

Potassium was precipitated as potassium sodium cobaltinitrite and determined gravimetrically.

6. Calcium

Calcium was precipitated in the hydrochloric acid extract as the oxalate and estimated volumetrically

7. Magnesium

Magnesium was precipitated in the hydrochloric acid extract as magnesium ammonium phosphate and determined as pyrophosphate.

8. Available phosphorus

The available phosphorus was determined by extracting the soil with Dickman and Bray's solution No.1 and estimating the phosphorus colourimetrically.

9 Available potassium

This was determined by extracting the soil with Morgan's reagent and estimating the potassium turbidimetrically.

10. Exchangeable calcium

Determined by extracting the soil with ammonium acetate buffered to pH 7.0 and estimating the calcium in the extract volumetrically.

11 Exchangeable magnesium

In the filtrate from exchangeable calcium estimation, magnesium was determined gravimetrically.

12. pH

The hydrogen-ion concentration of the soil sample was determined using a photovolt pH meter in a 1 2.5 soil-water suspension.

R E S U L T S

Calcium and magnesium status of soils

Of the fifteen soils examined, eight samples showed a total calcium content below 0.1 percent. The total calcium varied from 0.032 percent in Ambalavayal soil to a maximum of 0.384 percent in Thottappally *kari* soil, with an average of 0.133 percent. Comparatively higher amounts of calcium were present in all the samples from the *kari* areas. The level of calcium was very low in soils from Chalakudi, Vellayani and Ambalavayal. The magnesium content of soils varied from 0.047 percent in Vellayani soil to a maximum of 0.171 percent in Alathur soil, with an average of 0.093 percent. Eleven soil samples contained less than 0.1 percent MgO. Exchangeable calcium content was found to be dependent upon the total calcium content, ranging from 0.9 me. per 100 g in Chalakudi soil to a maximum of 10 me. per 100 g in Thottappally *kari* soil Exchangeable magnesium was noted in Kumarakom *kari* soil Except in the case of soils from Ambalavayal, Alathur, Chalakudi, Kumarakom and Vellayani the ratio of calcium to magnesium was greater than one.

The chemical composition of the soils showed that these soils are fairly rich in total nitrogen, phosphorus and potassium. It may however be noted, that the level of

Table 1 -- Chemical composition of rice soils of Kerala.

No	Locality	Moisture %	Loss on ignition %	Total N %	Total P_2O_5 %	Total K_2O %	Total CaO %	Total MgO %	Available P_2O_5 %	Available K_2O %	pH
1	Ambalavayal	3 68	5 38	0 22	0 14	0 19	0 032	0 063	0 0013	0 0081	5 2
2.	Calicut	4 53	8 34	0 11	0 20	0 06	0.141	0.098	0 0014	0 0010	6.0
3	Kanjikode	1 43	5 01	0 18	0.09	0.13	0.096	0.081	0.0002	0 0019	5.2
4	Alathur	2 21	6 81	0 19	0.06	0.10	0 072	0.171	0.0006	0 0021	5.3
5	Trichur	3.49	2 89	0 13	0 07	0 12	0 120	0.081	0.0003	0.0010	5 6
6	Chalakudi	4.87	3 15	0.14	0.12	0 04	0.050	0.140	0 0007	0 0027	5 8
7.	Kallamassery	5.40	1.98	0.09	0 03	0.11	0.150	0.070	0.0008	0 0031	6 3
8	Mundar	9.31	29 69	0.98	0.39	0.43	0.378	0.080	0.0006	0 0143	5 0
9.	Kumarakom	8 66	16 32	0 72	0 03	0 39	0 160	0 120	0 0001	0 0113	5 3
10	Monkompu	7.21	14.15	0 62	0 23	0 17	0.144	0.072	0.0002	0.0077	5 6
11	Thottappally	8 71	23 77	0.89	0 08	0 21	0 384	0.110	0 0006	0 0108	4 5
12	Kayamkulam	0 87	2 14	0 01	0 08	0 14	0 076	0 054	0 0023	0.0019	5 2
13	Kottarakkara	3 41	6.97	0 13	0 18	0.43	0 073	0 060	0 0001	0 0083	5 1
14	Karamana	1 48	3 82	0 04	0 12	0.13	0 080	0 150	0 0013	0 0016	5.2
15	Vellayani	2 13	1 65	0 02	0 14	0 07	0 032	0 047	0.0003	0.0012	6 0
	Average			0 23	0 13	0.18	0 133	0 093	0 0006	0 0050	5 38

Table 2. -- Calcium and magnesium status of rice soils of Kerala.

No	Locality	Total CaO %	Exchangeable Ca. me./100g.	Total MgO %	Exchangeable Mg. me./100g
1.	Ambalavayal	0.032	1.0	0.063	4.5
2.	Calicut	0.141	2.8	0.098	4.1
3.	Kanjikode	0.096	3.5	0.081	4.8
4.	Alathur	0.072	2.0	0.171	4.6
5.	Trichur	0.120	2 0	0.081	3.9
6	Chalakudi	0.050	0.9	0.140	6.1
7.	Kallamassery	0.150	3.6	0.070	3.1
8	Mundar	0.378	6 5	0.080	4.7
9.	Kumarakom	0.160	5.0	0.120	8.6
10.	Monkompu	0.144	3.5	0.072	4.4
11.	Thottappally	0.384	10.0	0.110	8.2
12.	Kayamkulam	0.076	1.0	0.054	2.4
13.	Kottarakkara	0.073	1.2	0.060	2.3
14.	Karamana	0.080	1.5	0.071	0.2
15.	Vellayani	0.032	1.5	0.047	1.8
	Average	0.133	3.7	0.093	4.2

Table 3. -- Inter-relationship between exchangeable calcium and magnesium and available phosphorus and potassium.

No.	Locality	Exchangeable Ca. me./100g.	Available P_2O_5 %	Available K_2O %	Exchangeable Mg. me./100g
1	Chalakudi	0.9	0.0007	0.0027	6.1
2.	Ambalavayal	1.0	0.0013	0.0081	4.5
3.	Kayamkulam	1.0	0.0023	0.0019	2.4
4	Kottarakkara	1.2	0.0001	0.0083	2.3
5.	Karamana	1.5	0.0013	0.0016	0.2
6.	Vellayani	1.5	0.0003	0.0012	1.8
7.	Alathur	2.0	0.0006	0.0021	4.6
8.	Trichur	2 0	0.0003	0.0010	3.9
9.	Calicut	2.8	0.0014	0.0010	4.1
10.	Kanjikode	3.5	0.0002	0.0019	4.8
11.	Monkompu	3.5	0.0002	0.0077	4.4
12.	Kalamassery	3.6	0.0008	0.0031	3.1
13.	Kumarakom	5.0	0.0001	0.0113	8.6
14.	Mundar	6.5	0.0006	0.0143	4.7
15.	Thottappally	10.0	0.0006	0.0108	8.2
	Average	3.7	0.0006	0.0050	4.2

available phosphorus and potassium is very low in most of these soils. The low content of exchangeable calcium and magnesium in these soils appeared to be correlated with the low availability of phosphorus and potassium.

the absence in these soils of factors which cause reversion of the phosphates. In all other soils the available phosphorus content is very low, probably because of high acidity and the presence of iron and aluminium compounds. The low potassium content of these soils is probably the result of severe leaching brought about by heavy precipitation.

The pH values of all the soils were below 6.0 This rather high acidity might be responsible for the low availability of phosphorus and potassium in these soils.

DISCUSSION

Most of the soils examined contained a very low percentage of calcium and magnesium. This may be due to the low content of these elements in the parent material and also to severe leaching which they are subjected to. Further more, our rice soils receive very little of these elements through fertiliser application.

The data also show that most of our rice soils are fairly well supplied with nitrogen phosphorus and potassium. Kari soils contain a high level of nitrogen obviously because of their high organic matter content. These soils are waterlogged for most part of the year and hence only one crop is cultivated annually. They are fairly rich in total phosphorus and potassium but the availability of these nutrients is rather poor, which may be mainly due to their high acidity. The total calcium and magnesium contents of the kari soils were also found to be higher than those of the other soils. The higher CaO content might be attributed to the presence of lime shells in these soils. The high MgO content is probably due to the intrusion of sea water, which is a common feature in this area.

A significant observation made during the course of this study is the high level of available phosphorus in the coastal sandy soil from Kayamkulam. This may be due to

SUMMARY AND CONCLUSIONS

A detailed study of the calcium and magnesium status of some typical rice soils of Kerala was carried out. The chief findings were as follows

1. The calcium and magnesium contents, total as well as available, of all the soils examined were very low.

2. The pH of all the soils was below 6.0 which might be responsible for the low availability of phosphorus and potassium in these soils.

3. The level of total nitrogen, phosphorus and potassium was satisfactory in all the soils. The nitrogen content of the *kari* soils was high. The available phosphorus and potassium was very low in all the soils.

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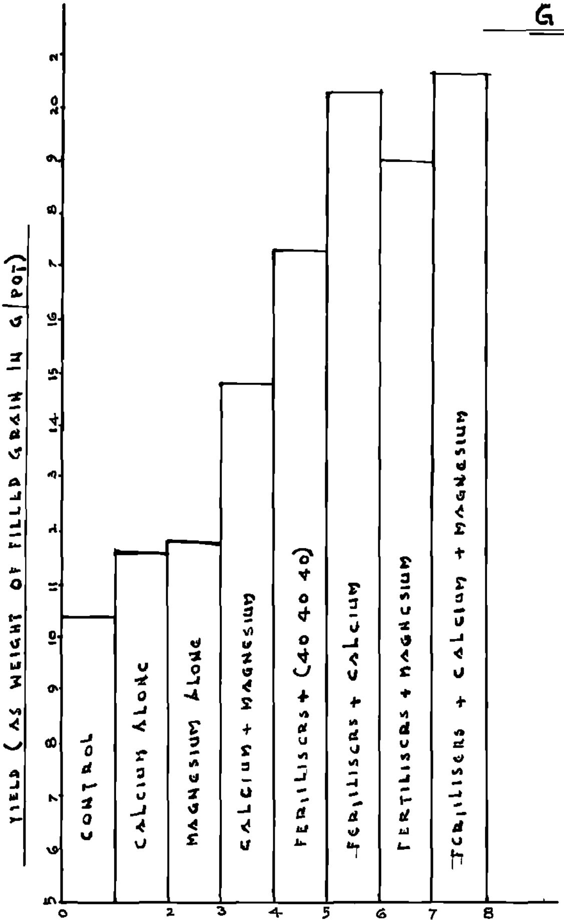
* Original not seen.

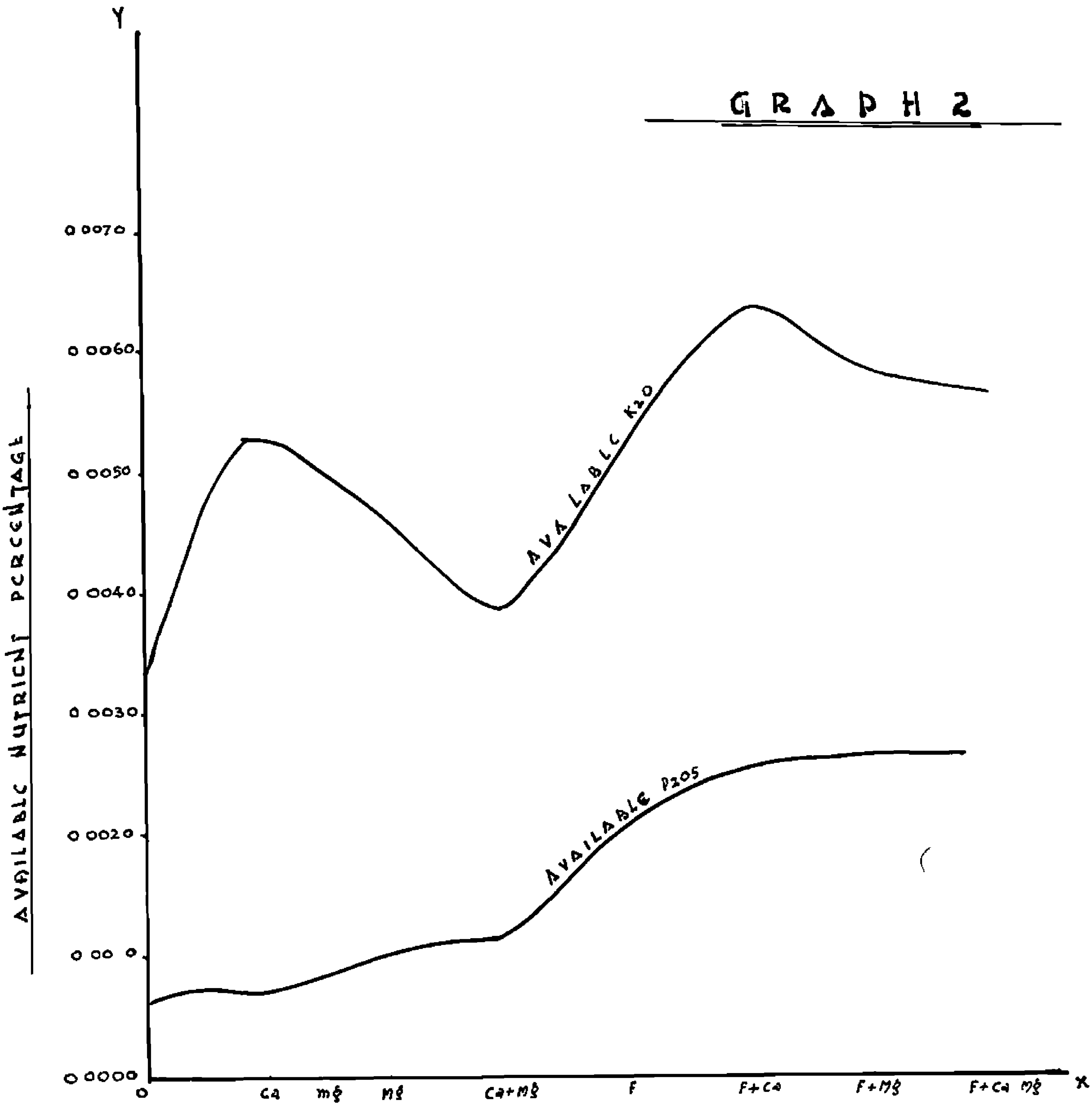
<u>GRAPH I</u>



TREATMENTS

EFFECT OF CALCIUM AND MAGNESIUM
ON YIELD OF RICE

GRAPH 2



CALCIUM AND MAGNESIUM TREATMENTS

EFFECT OF CALCIUM AND MAGNESIUM ON AVAILABLE PHOSPHORUS AND POTASSIUM

PLATE 1. APPEARANCE OF PLANTS SIX WEEKS AFTER PLANTING.

Pot No.1 - Control
" No.2 - Calcium alone
" No.3 - Magnesium alone
" No.4 - Calcium plus magnesium
" No.5 - Fertiliser (N.P.K - 40.40:40)
" No.6 - Fertiliser plus calcium
" No.7 - Fertiliser plus magnesium
" No.8 - Fertiliser plus calcium and magnesium.

PLATE II. APPEARANCE OF PLANTS AT THE TIME OF HARVEST.

Pot No. 1	-	Control	(yield 10.4 g./pot)
" No. 2	-	Calcium alone	(" 11.6 g./pot)
" No. 3	-	Magnesium alone	(" 11.8 g./pot)
" No. 4	-	Calcium plus magnesium	(" 14.8 g./pot)
" No. 5	-	Fertiliser (40 40.40)	(" 17.3 g./pot)
" No. 6	-	Fertiliser plus calcium	(" 20.3 g./pot)
" No. 7	-	Fertiliser plus magnesium	(" 19.0 g./pot)
" No. 8	-	Fertiliser plus calcium and magnesium	(" 20.6 g./pot)