STUDIES ON THE EFFECT OF ZINC IN COMBINATION WITH LIME ON THE GROWTH, YIELD AND ABSORPTION OF NUTRIENTS BY RICE

BY

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C E R T I F I C A T E

Certified that the thesis is a record of research work done independently by Kum. K.A. Mariam under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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C O N T E N T S

INTRODUCTION

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Rice is the staple food of the teaming millions of South East Asia whose numbers are increasing at an alarming rate. It, thus being the basis of nutrition for a large section of the human race, bears a large influence on their life and economic condition. Inspite of a large acreage under rice in India, grain production falls below our estimated requirements. Thus the problem of stepping up rice production in every conceivable way is one of supreme importance to our country.

Considerable emphasis has been given to the stepping up of rice production in our agricultural programmes. New, fertilizer responsive, high-yielding varieties of rice have been introduced and appreciable yield increases have been obtained. But the cultivation of such varieties with the application of only the major fertiliser elements has led to nutritional imbalances in the soil resulting in micronutrient deficiencies. During the 1960's visible symptoms of deficiency of one or the other micronutrients began to be manifested in field crops in many of our States and since the last decade, micronutrient imputs to field crops are becoming necessary to maintain crop yields at satisfactory levels.

Zinc was first definitely shown to be one of the essential micronutrients for plant growth by Sommer and Lipman (1926). Experience accumulated during the past few years indicate that of the various micronutrients essential for plant growth, the deficiency of zinc is more wide-spread in rice. The work done in India clearly reveals that the application of zinc to rice has gained considerable attention after it was shown that the 'Khaira' disease of paddy is due to the deficiency of zinc (Nene, 1965).

Zinc plays an important role in crop production. It performs many important physiological functions in plants. It is now recognised to be an essential component of several plant enzymes - carbonic anhydrase, ribonuclease and peroxidase, dehydrogenase and proteinases. It catalyses the process of oxidation in plant cells and is vital for the transformation of carbohydrates. It also regulates the consumption of sugars, increases the source of energy for the production of chlorophyll, aids in the formation of auxines and promotes the absorption of water.

Nene and Sharma (1969) have described the deficiency symptom of zinc in paddy and suggested methods of zinc application. It is possible that certain kinds of yellowing noticed in rice in Kerala soils may be due to the deficiency of zinc. Rice plants growing under conditions of zinc deficiency are severely stunted and the leaf size is considerably reduced. The older leaves show a rusty brown, discoloration which is preceeded by chlorosis of the leaves. This discoloration is seen in narrow patches on the leaves and actually results from the coalescence of minute necrotic spots. Such leaves finally dry out and die.

Fertility investigations carried out in Kerala in recent years (Praseedom, 1970; Varghese, 1971; Valsaji, 1972) have shown that in many Kerala soils the levels of zinc may be marginal. In such soils the indiscriminate use of NPK fertilizers may result in acute zinc deficiency. As a matter of fact, zinc deficiency has been noted in some regions of the State and the application of zinc has resulted in the recovery of the crops involved.

More than ninety per cent of soils of Kerala are acidic in reaction. Hence liming has become an indispensable and wide-spread practice in the acid rice soils of the State. But the application of lime, if it results in appreciable increase in the pH, may induce micronutrient deficiencies especially that of zinc. Hence this study was undertaken with a view to finding out how far the application of zinc in combination with lime will affect in the plant growth and yield characteristics of rice.

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REVIEW OF LITERATURE

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The role of zinc in the nutrition of plants has been well recognised in recent years. Maze (1919) furnished the first convincing evidence of the essentiality of zinc for higher plants. However, its essential nature was not generally accepted until Sommer and Lipman (1926) and Sommer (1928) showed that zinc is indispensable for plant growth. It is, therefore, necessary that the soil contain a significant level of zinc for the proper growth of plants.

Distribution of zinc in the soil

The zinc content of soils varies widely from place to place. Nair and Mehta (1959) found that the total zinc content of Gujarat soils varied from 2 to 95 ppm and the available zinc content from 0.5 to 6.1 ppm.

According to Lal et al (1960) the total zinc content in the alluvial, black and laterite soils of India are in the range of 34 to 60 ppm, 69 to 76 ppm and 24 to 30 ppm respectively.

Bandyopadhya and Adhikari (1968) have reported that the total zinc content of the rice soils of West Bengal varied between 30.8 ppm and 76.8 ppm. They have also reported that the exchangeable zinc ranged from 0.51 to 6.2 ppm in these soils.

Gupta and Singh (1972) found that the total zinc content of the surface soils of Indore district ranged from 40 to 131 ppm.

In Tamil Nadu, Balasundaram *et al* (1970) noted that their soils contain on an average 8.2 ppm of total zinc.

According to Praseedom (1970) the total zinc content of the typical soils of Kerala vary from 3.5 to 100 ppm. In the alluvial soils of Kerala the total zinc content varied from 50.0 to 92.5 ppm with an average of 40.4 ppm. Valsaji (1962) noted that the total zinc content varied from 12.6 to 100 ppm in the surface samples of Amaravila series and from 25.4 to 119.2 ppm in the Marukil series of Trivandrum district. In the peat soils of Kerala, Gopinath (1973) noted that total zinc varied from 12.5 to 41.6 ppm in the surface layers and from 10.8 to 42.5 ppm in the sub-surface layers.

Available zinc is usually determined by the Ammonium acetate-Dithizone extraction method as suggested by Shaw and Dean (1952). Prasad and Sinha (1969) noted that the dithizone extractable zinc ranged from 0.5 to 6.7 ppm with an average of 2.2 ppm in the alluvial soils of Bihar.

Tripathi *et al* (1969) reported that the available zinc content ranged from 0.9 to 8.8 ppm (5 to 15 per cent of total zinc) in the soils of Uttar Pradesh.

Grewal *et al* (1969) obtained an available zinc content of 0.24 to 1 ppm in some soils of Punjab by extracting the available zinc with neutral Normal Ammonium acetate solution plus 0.01% Dithizone in Carbon tetrachloride.

Agarwala *et al* (1970) reported that the available zinc content ranged from 0.02 to 1.82 ppm in the eastern regions of Uttar Pradesh.

Praseedom (1971) has reported that the available zinc content of the different soils of Kerala varies from 0.25 to 8 ppm. In the alluvial soils of this state Varghese (1971) noted that the available zinc content varied from 1.2 to 6.5 ppm. Valsaji (1972) observed that the available zinc content varied from 1.2 to 4.8 ppm in the Amaravila series and from 1.2 to 5.5 ppm in the Marukil series of Trivandrum district. In a study of the *kari* soils of Kerala, Gopinath (1973) noted that the available zinc content varied from 0.8 to 1.6 ppm with an average of 1.4 ppm in the surface layers and from 0.7 to 1.8 ppm with an average of 1.4 ppm in the sub-surface layers.

Soil reaction and zinc availability

Thorne (1957) found that zinc deficiencies occurred generally in the range of pH 6.0 to 8.0 under conditions of minimum zinc availability.

Nair and Mehta (1959), however, observed a significant positive correlation between the pH and the 0.1 N HCl soluble zinc content of Gujarat soils.

Chatterjee and Dass (1964) reported that there was more Ammonium acetate extractable zinc in soils of pH below 6.0 and that its content decreased as the pH rose above 7.0.

Bandyopadhya and Adhikari (1968) obtained a significant negative correlation between pH and extractable zinc in the rice soils of West Bengal.

Eswarappa et al (1969) reported a significant positive correlation between pH and the available zinc content in tropical soils.

Tisdale and Nelson (1970) have indicated that the greatest uptake of zinc, both native and applied, occurs at the lowest pH values. As a general rule, most pH induced zinc deficiencies occur within the range of pH 6.0 to 8.0.

Phosphate fertilization and zinc availability

West (1938) reported that zinc deficiency symptoms of citrus occurred on superphosphate treated plots in Australia, apparently being induced by the phosphate ion.

Boawn et al (1954) found that the application of phosphate fertilizers for rice had no effect on the uptake of zinc from either applied or native zinc present in the soil. Burleson and Page (1967) found that when phosphate was added first, zinc increased total P in the lower and upper roots and decreased total phosphate in the tops; when zinc was applied first, phosphate increased total zinc in the tops.

Garv et al (1968) suggested that in soyabean high phosphate levels decreased zinc concentrations in leaves most, and in roots least.

Brown et al (1971) reported that phosphorus increased zinc deficiency in maize.

Rajagopal and Mehta (1971) found that phosphate application reduced the concentration of zinc by 34.3 per cent but it had no effect on the total uptake of zinc by plants. They also reported that there was a beneficial effect on the uptake of most of the elements with the combined application of zinc and phosphate.

From an experiment to study the response of maize to different levels of phosphorus and zinc, different methods of zinc application and their effect on the contents, and the uptake and inter-relationships of these nutrients, Patel and Mehta (1973) observed that zinc application increased the zinc content and its uptake by the crop while it depressed the uptake of phosphorus. Increase in the rate of P application decreased the zinc concentration in plants.

Boawn and Rasmussen (1972) reported that zinc was not directly toxic to plants but that it upset P metabolism resulting in the stunting symptoms of P deficiency.

<u>Organic matter and zinc availability</u>

Himes and Barber (1957) reported that organic matter reacted with divalent metallic ions in a manner similar to chelation.

Nair and Mehta (1959) observed a significant correlation between organic matter and acid soluble zinc.

De Remer and Smith (1964) have reported that decomposing plant residues may immobilize zinc in an unavailable form.

Randhawa and Broadbent (1965) have suggested a definite indication of the binding of the monovalent form of zinc on the very acidic exchange sites on humic acid, weakly acidic sites retaining zinc in the divalent form.

Sharma and Motiramani (1969) obtained a positive correlation for zinc with organic carbon in soils.

Tripathi *et al* (1969) obtained a non-significant relationship between organic matter and available zinc in Uttar Pradesh soils. Balakrishnan (1970) and Praseedom (1970) also observed a non-significant positive correlations between organic matter and available zinc in Kerala soils.

Deb and Sharma (1973) reported that organic matter content showed significant positive relationship with available zinc as determined by three extractants in pearl-millet maize soils, whereas such relationship was found non-significant in rice soils.

Retention of zinc in soils

Zinc is adsorbed in small amounts on the colloidis in most soils. Elgabaly and Jenny (1943) investigated the adsorption and fixation of zinc on montmorillonite clays.

Tiwari and Misra (1964) suggested that the retention of zinc tended to increase with the depth of soil and about half of the adsorbed zinc remained in the fixed form which could not be desorbed by 0.1 N HCl.

According to Basu et al (1964) the adsorption of Mn^{++}, Cu^{++} and Zn^{++} for H^+ of humic acid takes place in the order Zn > Mn > Cu.

Misra and Tiwari (1966) found that zinc retention in soil is affected by $CaCO_3$, soluble carbonates and the pH of the soil.

Sharpless et al (1969) reported that approximately 75 per cent of the zinc added was accounted for in the exchangeable form within the first minute. They also reported that the rate of conversion from exchangeable to acid extractable form varied widely among soils.

Zinc and plant growth

As regards the requirement of rice for zinc Tokuoka and Gyo (1939) reported that adding 1 ppm in culture solution increased the yield of rice while 5 ppm produced toxic effect.

Karunakar (1952) observed an increase of 20 to 28 per cent in rice yield consequent on the spraying of zinc salts.

Lal and Subharao (1953) discussed the role of zinc in crop production and reported that zinc deficiency symptoms appeared in rice when zinc concentration in the solution was less than 0.2 ppm and growth was optimum at 0.5 ppm.

Nair and Mehta (1958) analysed the mature leaves of different plant species and reported that the average zinc content was 36.6 ppm in fruit crops, 36.0 ppm in cash crops and 18.5 ppm in grasses.

According to Naik and Asana (1961) zinc deficiency resulted in reduced rate of protein synthesis and increased accumulation of non-protein intermediates on cotton plants.

Ishizuka and Tanaka (1962) reported that the deficient and excess critical levels of zinc in the shoots of rice was 15 ppm and 600 ppm respectively where the yield of rice was maintained constant.

Rao (1962) noted that the major portion of zinc required by rice was at the milk stage.

Narayan and Vasudevan (1962) found that Zn as a spray in ragi and maize increased the number of grains per ear head which was due to the increase in the number of fertile spikelets per ear.

By conducting replicated field trials for studying responses to soil application of zinc in acid tea soils for three years, Kanwar and Joshi (1964) found a significant response to this element.

Nagarajan and Vadivelu (1964) observed that soil application of $ZnSO_4.7H_2O$ distinctly improved grain yield under field conditions in rice.

Singh and Jain (1964) reported that for rice, soil application of 2.33 kg/ha of zinc increased tillering and the production of dry weight, and that when applied as spray at higher levels appreciable increases in grain yield were obtained.

Niranjan and Srivastava (1965) reported that the application of zinc led to an increase in the amount of total leaf chlorophyll.

Pillai (1965) studied the response of rice to the application of Zn, Cu and Mn and found that the effect of Zn was more beneficial than that of Mn and Cu.

Roy and Dhua (1967) reported good response to paddy by the application of zinc sulphate (upto 10 lb/acre) on a sandy loam. Lower rates significantly increased the yields and increasing rates (especially as sprays) progressively depressed the yields.

Shukla and Morris (1967) reported that $ZnSO_4 \cdot 7H_2O$ was more effective than ZnO or chelate for corn.

Reddy (1968) reported that foliar application of Zn, as well as Zn and Cu chelates to 3 week old rice seedlings had pronounced effects on the distribution of rhizosphere microflora and the proportion of certain soil fungi.

Samboornaraman <u>et al</u> (1968) reported that soil or spray application of zinc was more effective in increasing the height, number of tillers and dry weight of wheat grain.

Mortvedt and Giordano (1969) reported that chelated zinc was the most effective source of this element, and that the efficiency of granular $ZnSO_4 7H_2O$ was not affected when it was banded with fertilizer granules.

Singh and Vyas (1970) reported that the yield of grain sorghum increased by 13.9 per cent in the presence of zinc.

Padhi (1971) suggested that the application of Cu, Mn, Zn and B increased the grain yield of rice crop in certain regions but not universally, and that the response depended largely on several soil factors such as its reaction, texture, organic matter content, microbial activity and availability of micronutrients.

Sharma et al (1972) reported that zinc amendments in soil improved growth, prevented the onset of zinc deficiency symptoms and increased tissue concentration of zinc and dry weight and grain yield of wheat.

Gangwar and Mann (1972) suggested that zinc application generally increased the dry matter, significantly under flooding condition and marginally under irrigation to field capacity.

Bokde (1973) reported that zinc sulphate sprays at 10 lb/acre increased paddy yields from 10 to 28 per cent over control at Coimbatore.

Mehta et al (1973) observed positive and significant response to zinc application at either 5 or 10 ppm levels in wheat.

Singh and Tripathi (1974) reported that the application of N enhanced the uptake of both indigenous as well as applied Zn, the effect being more pronounced when nitrogen was applied along with Zn. Phosphorus fertilization depressed Zn uptake. Potassium application without phosphorus depressed the zinc uptake substantially while with phosphorus its application increased the uptake by 7.1 to 8.5 per cent.

Symptoms of zinc deficiency

Viets et al (1954) reported that plants suffering from zinc deficiency showed poor growth and generally had interveinal chlorosis and necrosis of lower leaves.

Lloyd et al (1957) reported that the typical symptoms of Zn deficiency in most field crops is chlorosis of the lower leaves.

Thorne (1957) pointed out that lack of zinc results in distinctive plant symptoms associated with retardation of normal plant growth and lack of chlorophyll.

Naik and Asana (1961) suggested that typical chlorotic pattern of zinc deficient leaves appeared after fifty days in rice and that the Zn content of deficient leaves after 28 and 52 days was 17 and 12 ppm respectively.

Karim and Vlamis (1962) reported that the deficiency of zinc affected root development, prevented maturation and failed to produce seed in rice.

Nene and Srivastava (1967) showed that in rice the 'Khaira' disease was caused by zinc deficiency and that it could be easily identified in field by the discoloration on the older leaves.

Nene and Sharma (1969) reported that in rice zinc deficiency first shows itself as yellowing at the base of the leaves which is quickly followed by the appearance of very fine reddish brown specks that join each other and form patches.

Krishnamoorthy et al (1971) suggested that zinc deficiency in rice was cured by soil application of $ZnSO_4$ upto 100 kg/ha with responses upto 25 per cent in some cases.

Shirotori (1974) reported that under paddy field conditions transplanted upland rice seedlings showed greater resistance to Zn deficiency.

Wells et al (1974) studying the effect of zinc and other micronutrients on rice growing on alkaline silt loam soil showed that only zinc was of value for preventing seedling chlorosis and increasing yield. They have also reported that the use of zinc fertilizer for rice growing in such soils, coupled with delayed flooding and timely draining, largely eliminated seedling chlorosis.

Liming and plant growth

The concept of liming acid soils to induce the availability of plant nutrients is an accepted procedure. Application of lime to many soils produced striking increases in plant growth.

Albrecht and Smith (1952) indicated that the principal effect of liming acid soil was the supply of calcium as nutrient for plants.

Florell (1956) obtained evidence to show that calcium favoured the formation of increased protein content of mitochondria. In view of the role of mitochondria in aerobic respiration and hence salt uptake a direct relationship between calcium and uptake of ions in general was indicated.

Degochi et al (1958) reported that heavy basal liming improved tillering and decreased yield.

Gupta (1958) reported that the beneficial effects of liming was a maximum at earlier stages of growth and a minimum at the flowering stage.

According to Gutierrez and Gonzalez (1965) liming resulted in increased fixation of P and slight increases in the solubility of potassium and sodium.

Borlan and Militescu (1966) suggested that liming increased the mobility of nitrogen and phosphorus and decreased that of potassium and boron.

Devilliers and Lakerm (1966) noted that the previous application of lime stimulated the uptake of phosphorus by corn except at the first harvest when the detrimental effect of lime on zinc uptake curtailed growth.

Mandal et al (1966) suggested that liming, not only supplied adequate amounts of Ca to the plants but also induced larger uptake of Ca and P from the soils and fertilizers.

Tembhare and Rai (1967) reported that available Mn decreased with increasing amounts of $CaCO_3$ and that the relationship was statistically significant.

In a greenhouse experiment Brown et al (1968) observed that the application of lime depressed the growth of sugarbeet.

Borthakur and Mazumder (1968) reported that liming, generally decreased the total nitrogen of the soils under waterlogged conditions, but increased it under low moisture level when compared with the corresponding unlimed treatments. Nitrogen uptake by paddy seedlings was significantly correlated with the mineral nitrogen content of soils only under limed waterlogged situations.

Loneragan et al (1968) have reported that on laterite gravelly sand the calcium concentration of the tops of 21 species of annuals was reasonably well correlated with published figures for the C.E.C. of roots. Dicotyledonous plants tended to have high calcium concentration and C.E.C. values, whereas monocots had low values.

According to Sekiya (1968) prolonged calcium deficiency affects adversely the development of tiller buds.

Smith (1968) reported that the initial application of dolomite at the rate of 3 tons/acre reduced the movement and availability of the nutrient metals in soils.

Kabeerathumma (1969) reported a notable increase in the uptake of the major nutrients by rice with increasing dose of lime in Kuttanad soils.

Mahapatra (1969) suggested that liming reduced all fractions of native and added inorganic P except Ca-P fractions.

Consequently the extractable P was also reduced in air-dry and waterlogged soils.

Rana and Sherman (1971) suggested that air-drying alone did not improve the productivity of a hydrol humic latosol and a ferruginous latosol and that liming in some form was essential for Ca nutrition and plant growth.

Lime interactions in soils

In an investigation to study the effect of the free lime status of soils on the various soil characteristics and on the uptake of P, Mn and Ca by jowar and paddy, Shor et al (1970) noted that the presence of free lime in the soil increased the dry matter production upto a certain limit. It had a significant effect on the uptake of P and Mn in both test crops. The uptake of calcium by plant was observed to be directly proportional to the lime content of the soil.

Glyde and Kamprath (1970) reported that liming increased the growth of corn in a mineral soil when the aluminium saturation was greater than 70 per cent.

Mate et al (1971) suggested that liming increased soil pH, decreased hydrolytic acidity and increased exchangeable calcium and base saturation; but it did not significantly affect organic matter, available P and K and insoluble Fe and Al compounds.

Morelli et al (1971) reported that liming decreased the salt and exchangeable and titrable acidity and influenced the pH upto 100 cm in depth.

Umesh et al (1971) suggested that liming to a pH of 5.6 and above reduced the availability of Mn and Zn in the soil. They also reported that the dry matter yield of forage increased significantly with successive increases in lime upto pH 6.6 and with each increment of fertilization.

Solankey et al (1972) observed that the availability of N, K and Mg increased with the dose of lime added except at the highest dose (300 and 400 mg $CaCO_3$/100 g of soil). They found that the amount of available Fe, Mo, Cu and Zn decreased with an increase in the amount of added $CaCO_3$. On an average the dose of lime required to raise the pH of the soil to 6.2 - 6.3 resulted in the maximum availability of macronutrients and optimum availability of micronutrients in the soil.

Matt et al (1972) suggested that Zn levels in the tops and roots of alfalfa, and the Mg content of tops declined due to liming, whereas Ca and Mo levels in both plant parts increased. He also reported that liming brought about favourable effects in plant growth. This was related to changes in soil properties effected by lime application. Reduction of aluminium and manganese toxicities were the major factors responsible for the increased yields and the decreased growth period required to reach the harvest stage.

Asit et al (1973) observed a decrease in ammonium fixation due to liming.

Bhumbla and Poonia (1973) reported that the availability of Ca from added $CaCO_3$ decreased gradually in all crops in response to ESP.

Helyar and Anderson (1974) reported that addition of $CaCO_3$ caused decreases in soil solution concentration of Al, Mn, Na, K, Mg, NO_3 and H_2PO_4 and increases in the concentration of SO_4'' and Ca. The plant growth responses were explained as effects of aluminium toxicity at low pH and P deficiency at higher pH values.

Krishnasamy and Raj (1974) reported that the calcium content as well as the uptake of calcium, were enhanced by the application of lime along with fertilisers and organic matter to rice, variety IR 8.

Zinc availability and liming

Zinc deficiencies are commonly observed on calcareous soils and the liming of acid soils has also produced zinc deficient plants. Results of several studies have shown that zinc is adsorbed by the carbonates of calcium and magnesium. It is most strongly adsorbed by magnesite ($Mg\ CO_3$) to an intermediate degree by dolomite and least of all by calcite ($CaCO_3$).

Jurinak and Bauer (1956) reported that Zn was adsorbed on the crystal surfaces of dolomite and magnesite by replacing Mg in the lattice.

Nair and Mehta (1959) indicated that in a number of instances the availability of zinc decreased as the lime content increased.

Brown and Jurinak (1964) observed that Dithizone extractable zinc in the soil decreased somewhat as a result of liming.

Tiwari and Misra (1964) reported that with higher doses of $CaCO_3$ the retention of applied zinc increased gradually in all soils due to the physical adsorption of ions at the colloidal surfaces and formation of some basic zinc carbonates.

Laker (1967) reported that lime reduced the uptake of applied zinc from the top soil by almost 50 per cent. In the sub-soil lime had a much smaller effect on pH and did not decrease zinc uptake.

Navrot et al (1967) studied the zinc fixation and the availability of native and added zinc in two calcareous soils - a rendzina and a loess. They observed that zinc fixation was very rapid and almost complete in both soils.

Pauli and Mosser (1968) found that $CaCO_3$ decreased water extractable zinc as well as its translocation.

From an experiment conducted in Finland, Sauchelli (1969) found that the adsorption of zinc decreased as the Zn concentration increased on unlimed soil whereas on heavily limed soils adsorption increased to a constant level.

Melton et al (1970) found that liming induced zinc deficiency in pea beans.

Aydeniz (1970) reported that the Zn content of corn plants increased with increasing rate of Zn and decreased with increasing rate of $CaCO_3$ application.

Meuer et al (1972) suggested that zinc deficiencies in Zea maise occurred at soil pH values of 6.3 or greater and independently of the rate of P application.

Safaya et al (1974) suggested that zinc deficiency may occur in calcareous soil. Zinc availability is a minimum when the soil pH is in the range of 5.5 to 7.5.

MATERIALS AND METHODS

MATERIALS AND METHODS

A pot culture experiment was designed to study the effect of zinc and lime application, alone and in-combination, on the growth, yield and composition of a high yielding variety of rice, Annapurna. The details of the experiment are given below:

1. The soil

The soil used was collected from the kayal land attached to the Agricultural College Farm, Vellayani. The mechanical and chemical composition of the soil are given in table (I).

Table I

The mechanical and chemical composition of soil
(On oven dry basis)

Coarse sand	-	37.8%
Fine sand	-	13.6%
Silt	-	9.2%
Clay	-	34.2%
pH	-	4.3
Moisture	-	1.72%
Loss on ignition	-	1.52%
Total N	-	0.11%
Total P_2O_5	-	0.02%
Total K_2O	-	0.36%

Total CaO	-	0.18%
Total MgO	-	0.13%
Lime requirement	-	2000 kg/ha
Available Zn	-	4.2 ppm

2. Zinc

The zinc was supplied in the form of zinc sulphate, $ZnSO_4 \cdot 7H_2O$ (E.Merck).

Levels of zinc	Zn_0	$ZnSO_4 \cdot 7H_2O$	at 0 kg/ha
	Zn_1		10 ..
	Zn_2		20 ..
	Zn_3		40 ..

3. Lime

The lime used was carbide ash containing 43.0 per cent CaO distributed in Kerala under the trade name 'Geolime'.

Levels of lime	L_0	lime at 0 kg/ha
	L_1	250 ..
	L_2	500 ..
	L_3	1000 ..

Experimental design

A Randomized block Design with three replications was used for the experiment. The different treatment combinations were as follows:-

1.	$L_0\ Zn_0$	9.	$L_2\ Zn_0$
2.	$L_0\ Zn_1$	10.	$L_2\ Zn_1$
3.	$L_0\ Zn_2$	11.	$L_2\ Zn_2$
4.	$L_0\ Zn_3$	12.	$L_2\ Zn_3$
5.	$L_1\ Zn_0$	13.	$L_3\ Zn_0$
6.	$L_1\ Zn_1$	14.	$L_3\ Zn_1$
7.	$L_1\ Zn_2$	15.	$L_3\ Zn_2$
8.	$L_1\ Zn_3$	16.	$L_3\ Zn_3$

5. Experimental procedure

Earthenware pots of uniform size, viz., 10" x 15" were used for the experiment. Ten kg of the ground, air-dried soil was weighed into each pot and mixed well with the lime at the specified rates. Sufficient water was then added to each pot to bring about effective mixing of the soil with lime and also puddling.

Half the dose of nitrogen and full dose of P_2O_5 and K_2O were also added to each pot in the form of urea, superphosphate and muriate of potash respectively.

After mixing the soil well with lime and the NPK fertilizers, zinc sulphate was added to each pot at the specified rates in aqueous solution. Twenty day old seedlings of rice, variety Annapurna, were then planted at the rate of 3 plants per pot on 26-6-1974.

Controlled irrigation was given to the pots at a uniform rate and optimum moisture levels were maintained throughout the cropping period.

The remaining half of nitrogen was applied on the 20th day after planting.

The pots were kept free of weeds. The plants were sprayed with endrin twice as a prophylactic measure against stem borer attack.

A few grams of soil were removed from each pot on the 20th day and after harvest for pH determination in the composite samples corresponding to each treatment.

The crop was harvested on 17-9-1974 (103 days).

The grain and straw from each pot were placed in separate paper bags and dried in an air oven at 70°C. The yields of grain and straw were recorded separately. The straw was ground in an electric grinding mill. The ground straw and the grain were stored in plastic containers for chemical analysis.

6. Observations

The following observations were noted regarding the growth and yield characteristics.

1. Number of tillers per plant one month after planting
2. Number of productive tillers as on the 70th day after planting
3. Height of the plant as on the 35th day after planting
4. Length of panicle
5. Number of grains/panicle
6. Yield of grain/pot
7. Yield of straw/pot
8. Grain-straw ratio and
9. Weight of 1000 grains

7. Laboratory studies

Standard analytical procedures were followed for the chemical analysis of the grain and straw.

Nitrogen was estimated by the Micro-Kjeldahl method as given by Jackson (1967).

For the estimation of P, K, Ca, Mg and Zn triple acid digestion as suggested by Piper (1950) was followed.

Phosphorus was estimated by the Vanadophosphomolybdate method using a Klett Summerson photoelectric colorimeter. Potassium was estimated using an EEL flame photometer.

Calcium and magnesium were determined by the versenate titration method as described by Jackson (1967).

Zinc was determined colorimetrically as dithizonates using the method described by Black (1965).

Grain and straw were analysed for all constituents other than zinc in all the replications and the means calculated. Zinc was estimated only in the composite straw samples.

RESULTS

RESULTS

The experimental results relating to the influence of different levels of zinc and lime on the growth, yield and composition of rice are given below:

A. Growth

The data relating to the effect of zinc and lime application on the growth characters such as the number of tillers, number of productive tillers and height of the plant are presented in table II.

1. Number of tillers

It may be noted from table II that the application of zinc has slightly suppressed the number of tillers per plant. Thus the number of tillers per plant is 14.1 for zero zinc application which has decreased to 13.4 for an application of zinc sulphate at 10 kg/ha and to 12.8 and 13.2 for applications of 20 and 40 kg/ha respectively. The effect, however, has not been statistically significant. Lime, on the other hand, has helped to increase the number of tillers per plant. The application of lime has increased the number of tillers per plant from 12.5 for no lime treatment to a maximum of 14.2 for an application of lime at

Table II Influence of different levels of zinc and lime on the growth characters of rice, variety - Annapurna.

Levels of lime kg/ha	Levels of zinc kg/ha	Growth characters: Number of tillers/ plant	Number of productive tillers	Height of plant (cm)
	0	13.0	11.6	54.3
	10	11.7	11.3	54.3
0	20	12.7	11.6	46.9
	40	12.7	12.3	51.0
	Mean	12.5	11.7	51.6
	0	14.0	12.0	52.6
	10	15.3	14.6	49.6
250	20	12.7	11.0	53.8
	40	11.0	9.3	53.0
	Mean	13.2	11.7	52.2
	0	14.7	13.3	51.8
	10	12.7	11.0	52.7
500	20	12.7	11.6	53.8
	40	14.3	11.6	53.6
	Mean	13.8	11.9	52.9
	0	14.7	13.0	49.2
	10	14.0	13.0	53.8
1000	20	13.3	12.0	55.1
	40	14.7	13.0	55.0
	Mean	14.2	12.8	53.3
	0	14.1	12.5	51.9
	10	13.4	12.5	52.6
All levels	20	12.8	11.6	52.4
	40	13.2	11.6	53.2
C.D. for comparison between levels of zinc/ lime at 0.05 level		0.90	N.S.	1.1
C.D. for comparison between combinations of zinc and lime at 0.05 level		1.90	N.S	2.2

1000 kg/ha. The effect of lime on the number of tillers is also found to be significant at the 5 per cent level.

2. Productive tillers

The effect of zinc and lime on the number of productive tillers per plant has not been statistically significant. However, the trend was for zinc to decrease the number of productive tillers and for lime to increase it. Thus for an application of zinc sulphate at 0 and 10 kg/ha the number of productive tillers was found to be 12.5 per plant, which decreased to 11.6 at the higher rates of applications of zinc sulphate at 20 and 40 kg/ha. As for lime, the number of productive tillers per plant has increased from 11.7 for applications of 0 and 250 kg/ha to 11.9 for an application of 500 kg/ha and 12.8 at 1000 kg/ha.

3. Height of plant

The height of plant has steadily increased with increased application of zinc from 51.9 cm for 0 zinc application to 53.2 cm for zinc sulphate at 40 kg/ha through 52.6 cm and 52.4 cm for applications of zinc sulphate at 10 and 20 kg/ha respectively. But this effect also has not been statistically significant. Lime has generally helped to increase the height of plants and the effect was found to be significant statistically. The maximum height (53.3 cm) was obtained for a lime treatment of 1000 kg/ha as compared to 51.6 cm for the no lime treatment. The interaction between lime and zinc was also found to be significant.

B. Yield

The results relating to the effect of different levels of zinc and lime on the yield characters, such as length of panicle, weight of grain, weight of straw, grain-straw ratio, the number of grains/panicle and the weight of 1000 grains are presented in tables III and IV.

(a) Length of panicle

The application of zinc has resulted in slightly increased length for panicles, although the effect has not been statistically significant. The mean length of panicles for zinc applications of 0 and 10 kg/ha of zinc sulphate is 21.8 and 22.1 cm respectively which has increased to 22.4 and 22.3 cm respectively for applications of zinc sulphate at 20 and 40 kg/ha. Application of lime has also helped to increase the length of panicles and the effect has been statistically significant at the 5 per cent level. The mean length of panicles has increased from 21.7 cm to 22.7 cm when lime was applied at 0 and 1000 kg/ha respectively.

Table III. Influence of different levels of zinc and lime on the yield characters of rice

Levels of lime kg/ha.	Levels of zinc kg/ha	Yield characters	
		Length of panicle (cm)	Number of grains per panicle
0	0	20.6	92.6
	10	21.6	109.3
	20	22.7	110.0
	40	21.7	104.6
	Mean	21.7	104.1
250	0	21.9	104.0
	10	22.0	111.0
	20	21.9	110.3
	40	22.2	101.6
	Mean	22.0	106.7
500	0	22.2	101.3
	10	22.1	103.0
	20	22.2	99.0
	40	22.9	106.6
	Mean	22.3	102.4
1000	0	22.8	113.6
	10	22.8	116.3
	20	22.8	120.0
	40	22.5	117.3
	Mean	22.7	116.8
All levels	0	21.8	102.9
	10	22.1	109.9
	20	22.4	109.8
	40	22.3	107.5
C.D. for comparison between levels of zinc/lime at 0.05 level		0.5	6.5
C.D. for comparison between combinations of zinc and lime at 0.05 level		1.0	13.1

(2) Number of grains/panicle

Both zinc and lime have helped to increase the number of grains per panicle and this effect was also found to be statistically significant. The mean number of grains per panicle for the zero zinc treatment was 102.9 which increased to 109.9 when zinc sulphate was applied at 10 kg/ha. Higher rates of zinc application had a slightly depressing effect on the number of grains/panicle, but the differences were not significant. The highest number of grains/panicle viz., 116.8 was obtained for a lime application of 1000 kg/ha which was much above the figure of 104.1 for the no lime treatment.

(3) Weight of grains/pot

The application of zinc and lime has not resulted in any significant effect on the yield of grain. The effect of zinc on the weight of grain/pot has been inconsistent, whereas lime has shown a tendency to increase the yield. Thus the weight of grain per pot has increased from 40.2 g for the no lime treatment to 42.1 g for lime at 500 kg/ha and 42.9 g for lime at 1000 kg/ha.

(4) Weight of straw

The effect of zinc and lime on the yield of straw is similar to their effect on grain and is found to be

Table IV. Influence of different levels of zinc and lime on yield characters of rice, variety Annapurna

Levels of lime kg/ha	Levels of zinc kg/ha	Yield characters			
		Weight of grain g/pot	Weight of straw g/pot	Grain-straw ratio	Weight of 1000 grains (g)
	0	45.7	40.1	1.13	24.9
	10	38.6	52.3	0.74	23.5
0	20	33.7	33.6	1.00	23.3
	40	42.7	47.7	0.89	24.3
	Mean	40.2	43.4	0.94	24.0
	0	43.3	39.7	1.09	24.7
	10	45.8	46.0	0.99	23.7
250	20	34.1	40.0	0.85	24.0
	40	26.9	32.0	0.84	24.2
	Mean	37.5	39.4	0.94	24.2
	0	41.4	40.9	1.01	24.0
	10	43.7	45.3	0.96	24.7
500	20	41.3	47.3	0.87	24.5
	40	41.8	39.7	1.05	25.0
	Mean	42.1	43.2	0.97	24.6
	0	39.5	40.0	0.98	23.6
	10	39.7	41.3	0.96	23.4
1000	20	40.8	42.0	0.99	23.9
	40	51.7	40.0	1.29	23.8
	Mean	42.9	40.8	1.05	23.4
	0	42.5	40.1	1.05	24.3
	10	42.0	46.2	0.91	23.8
All levels	20	37.5	40.7	0.93	23.9
	40	40.8	39.9	1.02	24.3
C.D. for comparison between levels of zinc/lime at 0.05 level		N.S.	N.S.	N.S.	N.S.
C.D. for comparison between combinations of zinc and lime at 0.05 level		N.S.	N.S.	N.S.	N.S.

inconsistent and statistically insignificant.

(5) Grain-straw ratio

Zinc and lime have not given any statistically significant effect on the grain-straw ratio. However, zinc appears to have slightly decreased the ratio of grain to straw. Lime, on the other hand, has a beneficial effect on this ratio. The grain-straw ratio of 0.94 for lime applications of zero and 250 kg/ha has increased to 0.97 for a lime application of 500 kg/ha and to 1.05 for lime at 1000 kg/ha.

(6) Thousand grain weight

The influence of zinc and lime on the thousand grain weight also has not been statistically significant. Both at 0 and 40 kg zinc sulphate per hectare the weight of 1000 grains is found to be the same viz., 24.3 g. At the intermediate levels of zinc application the thousand grain weight is found to be slightly less, viz., 23.8 and 23.9 g. Lime, on the other hand, has influenced the thousand grain weight to a greater extent. From 24.0 g for 0 lime application the thousand grain weight has increased to 24.2 g for a lime application of 250 kg/ha and to 24.6 g for an application of 500 kg/ha. At 1000 kg/ha, however, the thousand grain weight is a minimum viz., 23.4 g.

C. Composition of grain and straw

The data pertaining to the composition of grain and straw for the various treatments of zinc and lime are presented in tables V and VI.

Grain

(1) Nitrogen

The nitrogen content of grain is influenced significantly by the application of zinc and lime. As the level of zinc sulphate application increases from 0 to 10, 20 and 40 kg/ha the nitrogen content of the grain increases steadily from 1.54 per cent to 1.58 per cent, 1.60 and 1.67 per cent respectively. Lime, on the other hand, has a slightly depressing effect on the nitrogen content of the grain. As the level of lime application is increased from 250 kg/ha to 500 kg/ha and 1000 kg/ha the nitrogen content of the grain is decreased from 1.69 per cent to 1.54 per cent and 1.47 per cent respectively.

(2) Phosphorus

The effect of zinc and lme on the phosphorus content of grain is also found to be significant. With the increasing levels of zinc applied, there is a slight decrease

Table V. Influence of different levels of zinc and lime on the composition of rice-grain

Levels of lime kg/ha	Levels of zinc kg/ha	N	P_2O_5	K_2O	CaO	MgO
		Per cent				
0	0	1.56	0.33	0.20	0.13	0.06
	10	1.69	0.37	0.22	0.11	0.09
	20	1.66	0.34	0.22	0.11	0.09
	40	1.71	0.31	0.22	0.14	0.07
	Mean	1.65	0.34	0.22	0.12	0.07
250	0	1.67	0.36	0.20	0.18	0.07
	10	1.71	0.35	0.23	0.14	0.08
	20	1.66	0.37	0.21	0.13	0.07
	40	1.73	0.39	0.23	0.12	0.09
	Mean	1.69	0.37	0.22	0.14	0.08
500	0	1.55	0.39	0.19	0.12	0.09
	10	1.49	0.41	0.21	0.18	0.07
	20	1.53	0.39	0.20	0.12	0.08
	40	1.61	0.43	0.23	0.12	0.09
	Mean	1.54	0.41	0.21	0.13	0.08
1000	0	1.39	0.45	0.23	0.12	0.10
	10	1.43	0.41	0.28	0.19	0.05
	20	1.56	0.35	0.20	0.12	0.08
	40	1.53	0.32	0.18	0.13	0.08
	Mean	1.47	0.38	0.22	0.14	0.08
All levels	0	1.54	0.38	0.21	0.14	0.08
	10	1.58	0.39	0.23	0.15	0.07
	20	1.60	0.36	0.22	0.12	0.08
	40	1.67	0.36	0.22	0.13	0.08
C.D. for comparison between levels of zinc/lime at 0.05 level		0.07	0.03	N.S.	N.S.	N.S.
C.D. for comparison between combinations of zinc and lime at 0.05 level		0.15	0.07	N.S.	N.S.	0.02

in the P_2O_5 content of the grain. But with increased applications of lime the tendency is for the phosphorus content of the grain also to increase. As the lime applied is increased from zero to 250 and 500 kg/ha the P_2O_5 content of the grain increases from 0.34 per cent to 0.37 per cent and 0.41 per cent respectively. But at 1000 kg/ha the P_2O_5 content of the grain is again lowered to 0.38 per cent. The interaction between lime and zinc is also found to be significant at the 5 per cent level.

(3) Potassium

The level of potassium in the grain is not significantly influenced by the applications of zinc and lime. For the different levels of zinc and lime, the K_2O content of the grain remains fairly steady at 0.21 to 0.23 per cent.

(4) Calcium and magnesium

The calcium and magnesium levels of the grain are also little affected by the applications of zinc and lime. The CaO content of the grain remains fairly steady in the range of 0.12 to 0.15 per cent for the various treatments. Similarly the MgO content also remains appreciably constant in the range of 0.07 - 0.08 per cent, irrespective of the treatment.

Straw

(1) Nitrogen

The nitrogen content of straw is found to be influenced significantly by the various treatments. As in the case of grain this constituent shows a tendency to decrease with increasing levels of lime applied. For zero application of lime the nitrogen content of straw is found to be 1.34 per cent which decreases to 1.25 per cent, 1.21 per cent and 1.23 per cent for lime applications of 250, 500 and 1000 kg/ha respectively . Unlike in the case of grain the effect of zinc on the nitrogen content of the straw is found to be inconsistent.

(2) Phosphorus

The effect of zinc and lime application on the phosphorus content of straw is found to be non-significant. However, the applications of lime tend to increase the level of phosphorus in the straw over that of the control treatment.

(3) Potassium

The potassium content of the straw is influenced significantly by applications of zinc and lime. The variation in this content is in the range of 1.4 to 1.6 per cent for the different treatments, but the variations do not follow

Table VI. Influence of different levels of zinc and lime on composition of rice-straw

Levels of lime kg/ha	Levels of zinc kg/ha	N	P_2O_5	K_2O	CaO	MgO	Zn ppm
		Per cent					
	0	1.22	0.14	1.67	0.52	0.35	52.4
	10	1.63	0.14	1.38	0.50	0.42	48.0
0	20	1.23	0.10	1.62	0.45	0.34	59.0
	40	1.29	0.11	1.43	0.65	0.33	63.7
	Mean	1.34	0.12	1.52	0.53	0.36	55.2
	0	1.22	0.10	1.67	0.65	0.42	46.0
	10	1.28	0.13	1.87	0.59	0.37	49.0
250	20	1.22	0.14	1.37	0.67	0.39	55.3
	40	1.29	0.18	1.56	0.74	0.28	51.8
	Mean	1.25	0.14	1.62	0.66	0.36	50.5
	0	1.22	0.22	1.28	0.56	0.41	51.8
	10	1.05	0.11	1.33	0.64	0.33	53.5
500	20	1.29	0.16	1.29	0.67	0.43	39.7
	40	1.29	0.18	1.53	0.54	0.33	52.3
	Mean	1.21	0.17	1.36	0.60	0.37	49.3
	0	1.34	0.12	1.51	0.57	0.35	40.8
	10	1.17	0.17	1.47	0.95	0.45	41.8
1000	20	1.17	0.15	1.44	0.47	0.31	43.8
	40	1.23	0.14	1.81	0.76	0.42	45.5
	Mean	1.23	0.15	1.56	0.69	0.38	42.9
	0	1.25	0.15	1.53	0.57	0.38	47.8
All levels	10	1.28	0.14	1.51	0.67	0.39	48.1
	20	1.23	0.14	1.43	0.57	0.37	49.3
	40	1.28	0.15	1.58	0.68	0.34	53.3
C.D. for comparison between levels of zinc/lime at 0.05 level		N.S.	N.S.	0.19	N.S.	N.S.	
C.D. for comparison between combinations of zinc and lime at 0.05 level		0.22	N.S.	0.37	N.S.	N.S.	

any regular pattern.

(4) Calcium

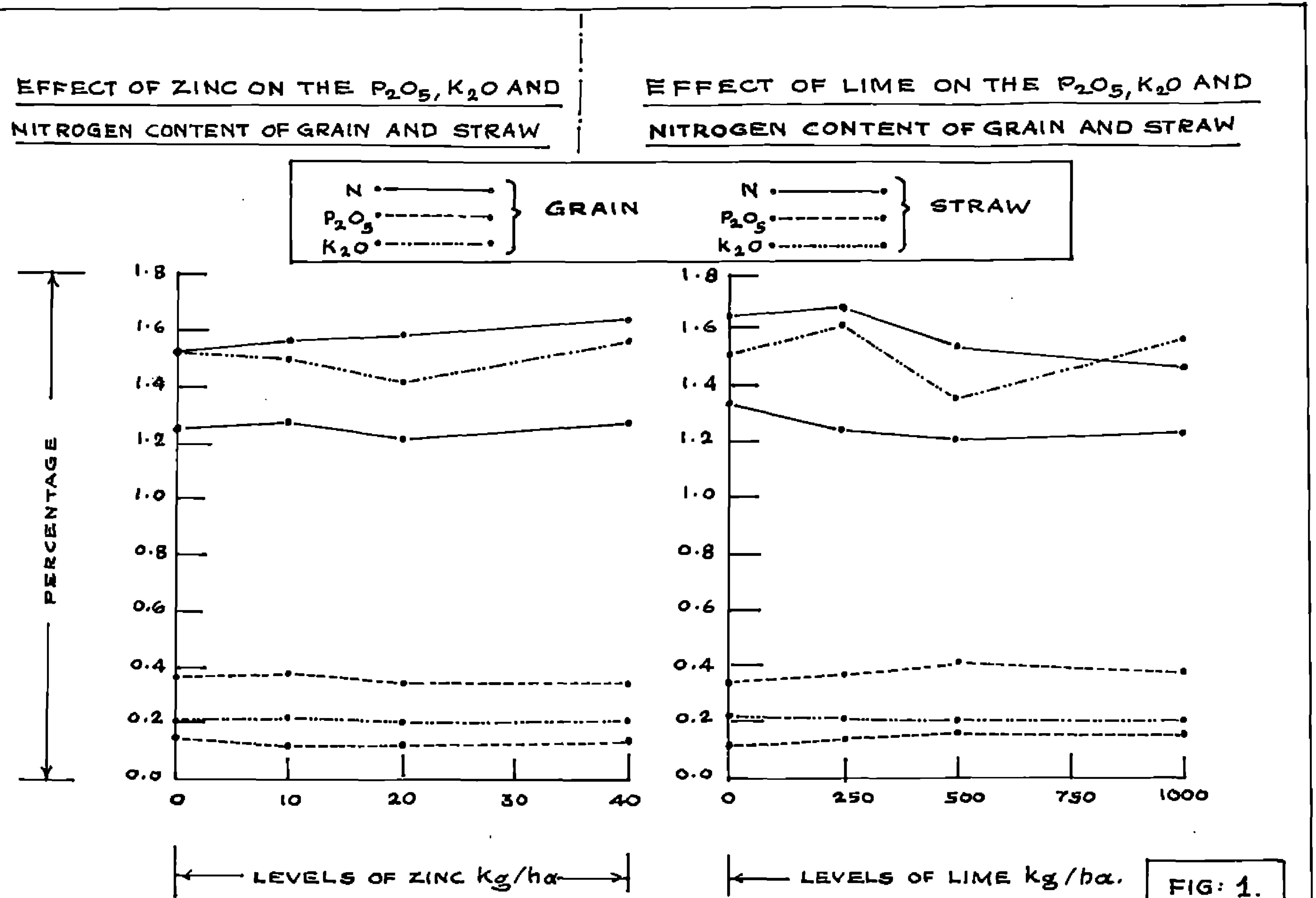
The effect of zinc and lime on the CaO content of straw is not found to be significant, although the level of this constituent tends to increase with application of lime. For the no lime treatment the CaO content of straw is 0.53 per cent which increases to 0.66 per cent and 0.60 per cent and 0.69 per cent respectively for lime applications of 250, 500 and 1000 kg/ha. Zinc applications, nevertheless, had no consistent effect on the calcium content of straw.

(5) Magnesium

The level of MgO in the grain is little affected by treatments with zinc and lime. For the various levels of zinc the MgO content varies irregularly between 0.34 and 0.38 per cent and for the different treatments with lime it remains fairly steady between the mean values of 0.36 to 0.38 per cent.

(6) Zinc

The zinc content of straw increased with increased applications of zinc. As the levels of applications of zinc sulphate increased from 0 to 10, 20 and 40 kg/ha, Zn content of straw increased from 47.8 to 48.1, 49.3 and 53.3 ppm respectively. Lime on the other hand, had an antagonistic



EFFECT OF ZINC ON THE P_2O_5, K_2O AND NITROGEN CONTENT OF GRAIN AND STRAW
EFFECT OF LIME ON THE P_2O_5, K_2O AND NITROGEN CONTENT OF GRAIN AND STRAW
N
P_2O_5
K_2O
GRAIN
N
P_2O_5
K_2O
STRAW
PERCENTAGE
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
0
250
500
750
1000
LEVELS OF ZINC kg/ha
LEVELS OF LIME kg/ha

FIG: 1.

effect on the absorption of zinc. Thus as the level of lime application is increased from 0 to 250, 500 and 1000 kg/ha the level of Zn decreased from 55.2 to 50.5, 49.3 and 42.9 ppm respectively in the straw.

Uptake of nutrients

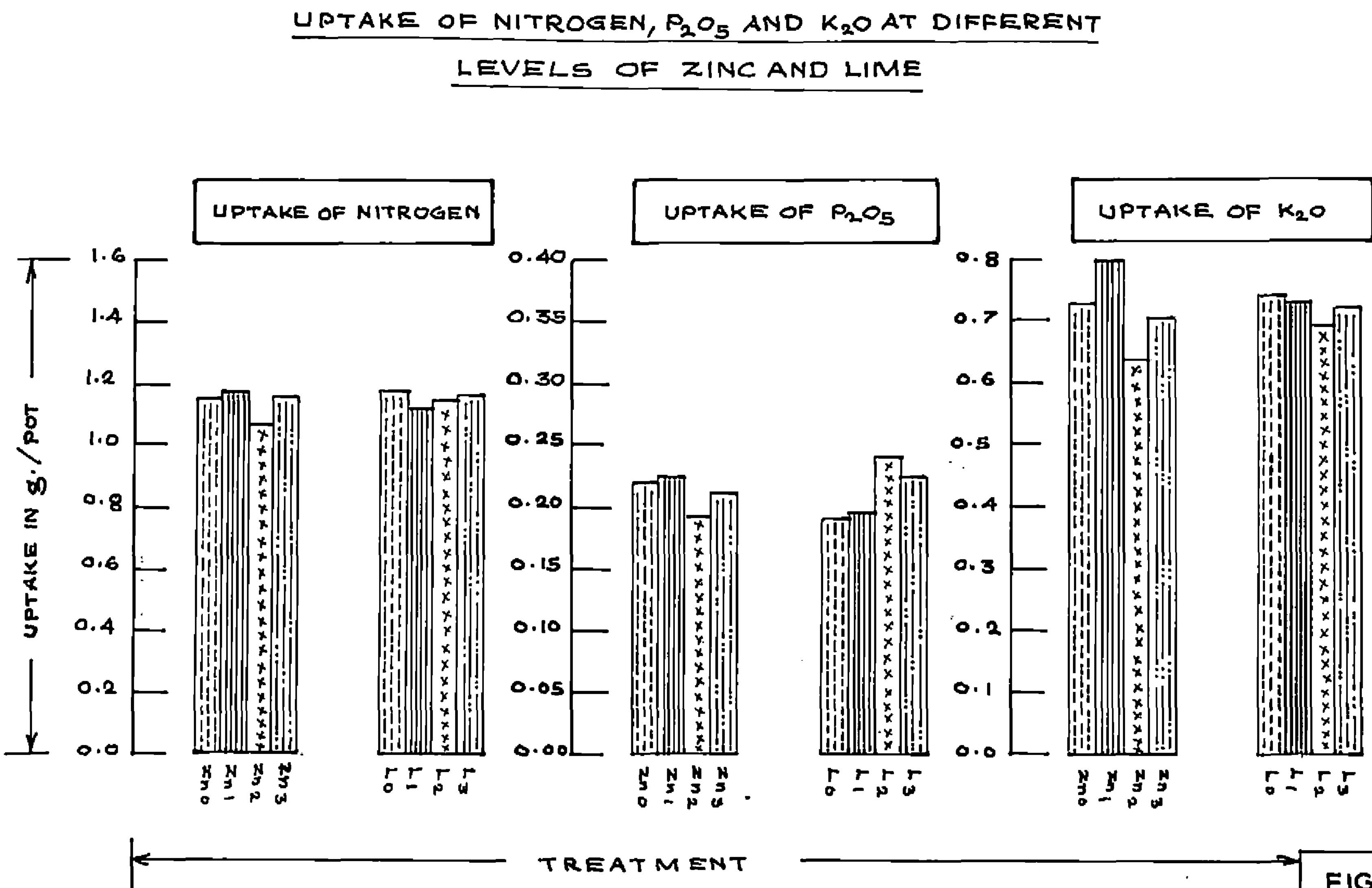
The total quantities of the various nutrients removed from one pot by the grain and straw are given in table VII. There is significant variation only in the case of nitrogen and phosphorus removed whereas in the case of the other nutrients the effect of treatment on the total quantities removed per pot is found to be nonsignificant.

D. Variations in soil pH

The variation in the soil pH during the course of the experiment is given in table VIII. The treatment with lime has raised the pH of the air-dried soil from 4.3 to the level of 4.6 to 4.7 in the course of 20 days. But this value has again fallen to 4.3 - 4.4 by the time of harvest. The pH of the soil, before air-drying is found to be slightly higher than the pH after air-drying. The zinc, apparently, has not influenced the soil reaction.

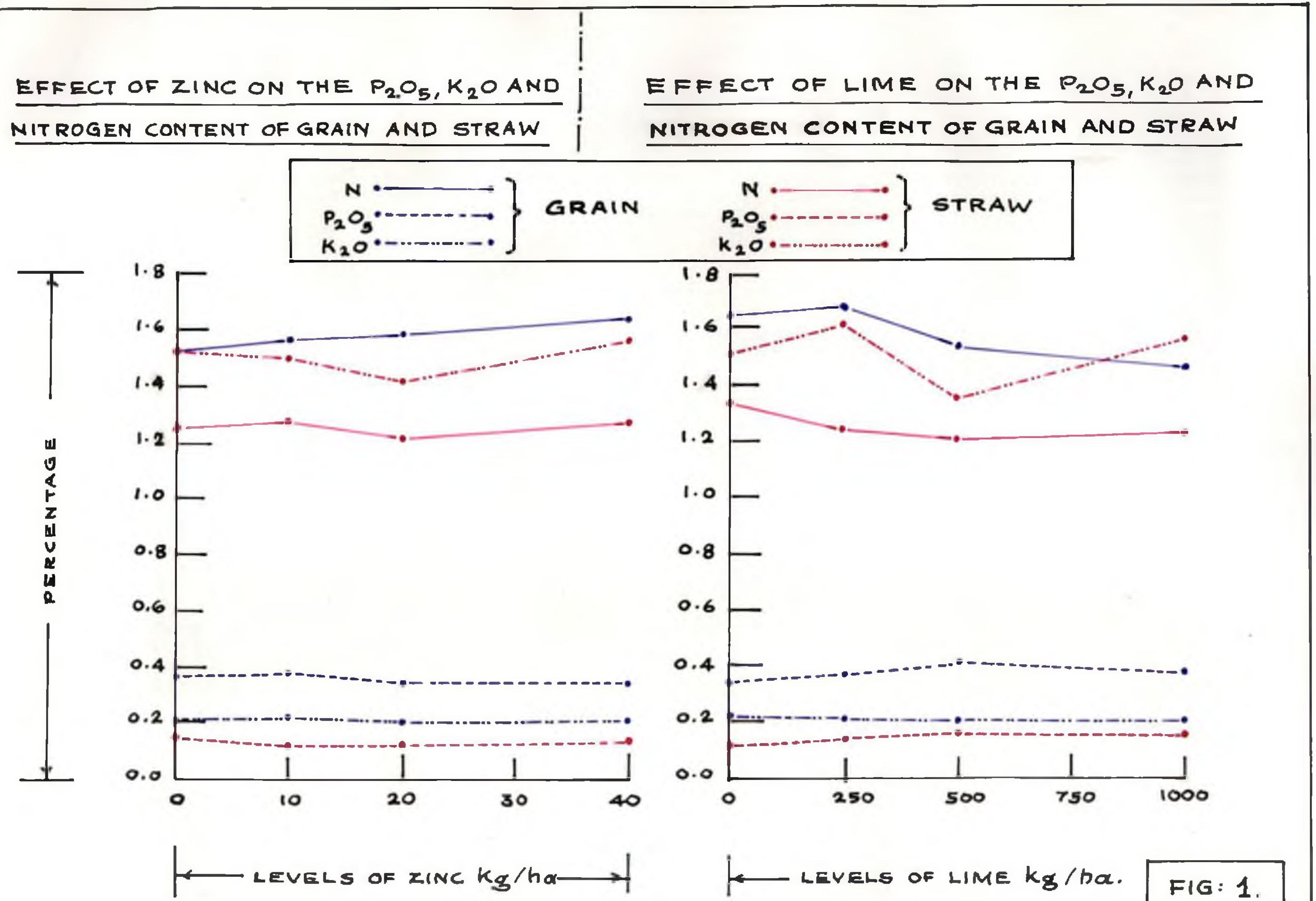
Table VII. Influence of different levels of zinc and lime on the uptake of nutrients by rice

Levels of lime kg/ha	Levels of zinc kg/ha	Uptake of nutrients (g/pot)				
		N	P_2O_5	K_2O	CaO	MgO
0	0	1.16	0.19	0.80	0.28	0.17
	10	1.18	0.21	0.77	0.32	0.25
	20	0.97	0.14	0.62	0.18	0.14
	40	1.31	0.18	0.74	0.37	0.18
	Mean	1.15	0.18	0.73	0.29	0.19
250	0	1.20	0.20	0.79	0.33	0.20
	10	1.37	0.21	0.95	0.37	0.20
	20	0.99	0.18	0.60	0.32	0.18
	40	0.86	0.15	0.55	0.25	0.11
	Mean	1.10	0.19	0.72	0.32	0.17
500	0	1.12	0.25	0.59	0.29	0.10
	10	1.04	0.22	0.77	0.37	0.18
	20	1.20	0.24	0.68	0.37	0.23
	40	1.15	0.25	0.70	0.28	0.17
	Mean	1.13	0.24	0.69	0.33	0.17
1000	0	1.11	0.23	0.73	0.28	0.18
	10	1.05	0.23	0.69	0.46	0.20
	20	1.12	0.19	0.66	0.25	0.16
	40	1.28	0.25	0.81	0.37	0.20
	Mean	1.14	0.22	0.72	0.34	0.18
All levels	0	1.15	0.22	0.73	0.29	0.16
	10	1.16	0.22	0.80	0.38	0.21
	20	1.07	0.19	0.64	0.28	0.18
	40	1.15	0.21	0.70	0.31	0.17
C.D. for comparison between levels of zinc/lime at 0.05 level		N.S.	0.03	N.S.	N.S.	N.S
C.D. for comparison between combinations of zinc and lime at 0.05 level		0.29	0.07	N.S.	N.S.	N.S



UPTAKE OF NITROGEN, P_2O_5 AND K_2O AT DIFFERENT LEVELS OF ZINC AND LIME
UPTAKE OF NITROGEN
UPTAKE OF P_2O_5
UPTAKE OF K_2O
UPTAKE IN g./POT
TREATMENT
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Zn0 Zn1 Zn2 Zn3
L0 L1 L2 L3

FIG: 2



EFFECT OF ZINC ON THE P2O5, K2O AND NITROGEN CONTENT OF GRAIN AND STRAW
EFFECT OF LIME ON THE P2O5, K2O AND NITROGEN CONTENT OF GRAIN AND STRAW
N
P2O5
K2O
GRAIN
N
P2O5
K2O
STRAW
PERCENTAGE
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
0
250
500
750
1000
LEVELS OF ZINC kg/ha
LEVELS OF LIME kg/ha.

FIG: 1.

UPTAKE OF NITROGEN, P_2O_5 AND K_2O AT DIFFERENT LEVELS OF ZINC AND LIME

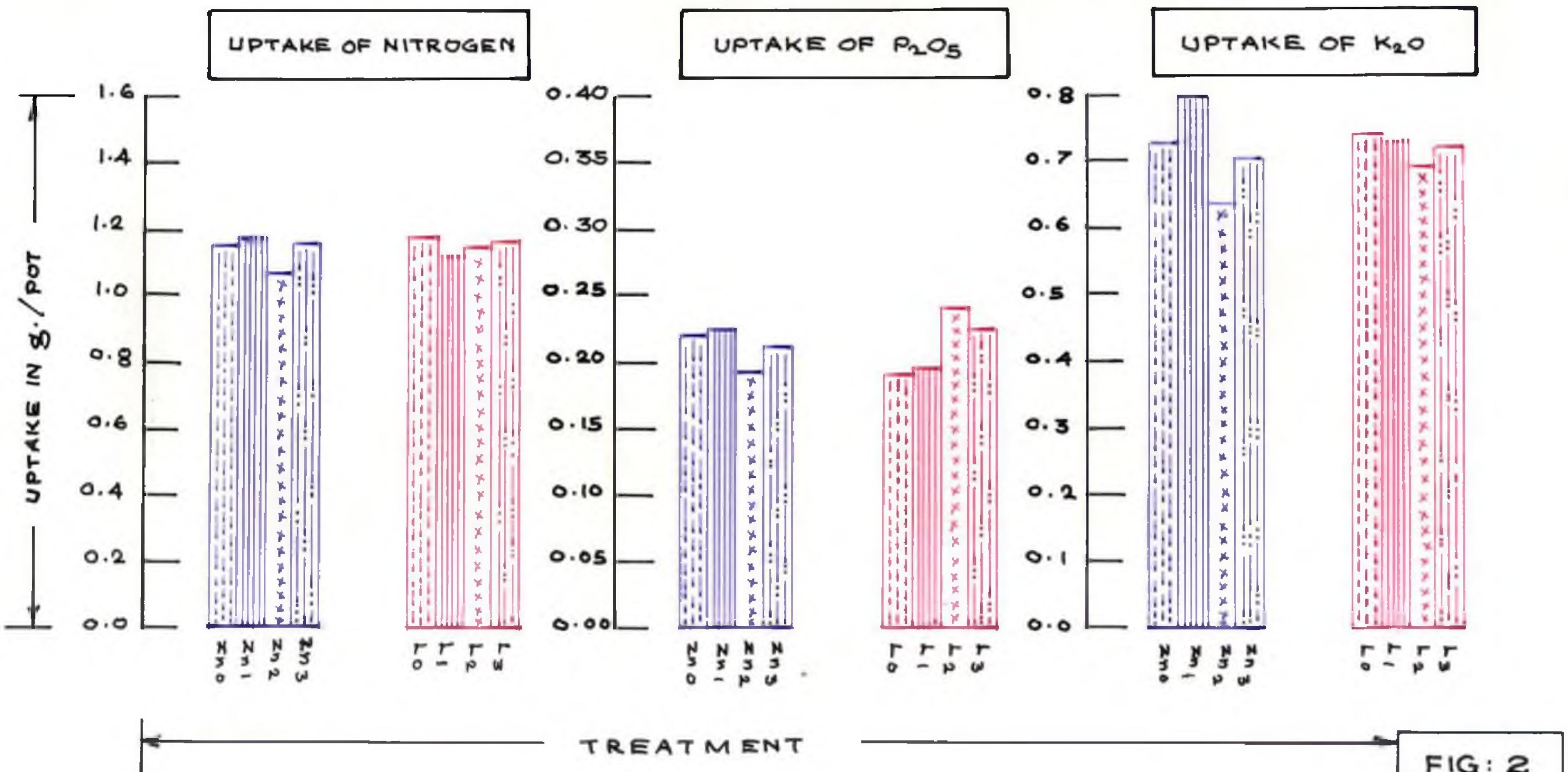


FIG: 2

UPTAKE OF CaO AND MgO AT DIFFERENT LEVELS OF ZINC AND LIME

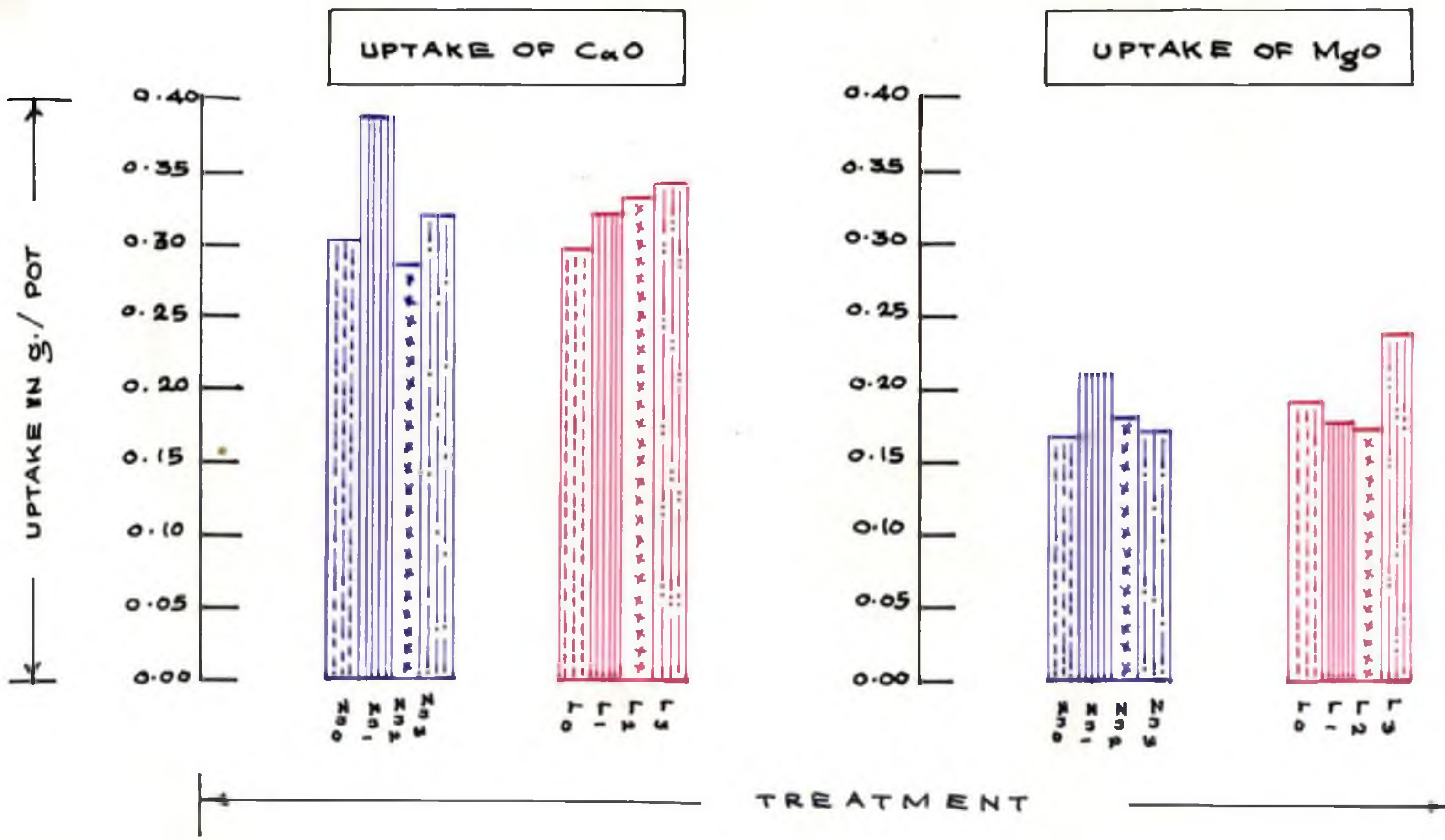


FIG: 3

Table VIII. Variation in the pH of the soil (Original pH of air dried soil 4.3)

Levels of lime kg/ha	Levels of zinc kg/ha	Date of collection of soil			
		20th day after planting		After harvest	
		pH immediately after collection	pH after air drying	pH immediately after collection	pH after air drying
	0	5.2	4.7	4.3	4.2
	10	4.9	4.4	4.1	4.2
0	20	5.5	4.6	4.2	4.0
	40	5.1	4.6	4.4	4.3
	Mean	5.2	4.6	4.3	4.2
	0	5.4	4.5	4.4	4.3
	10	5.7	4.8	4.3	4.4
250	20	5.2	4.4	4.2	4.1
	40	5.2	4.9	4.4	4.4
	Mean	5.6	4.7	4.3	4.3
	0	5.3	4.5	4.5	4.3
	10	5.4	4.7	4.3	4.2
500	20	5.6	4.7	4.4	4.4
	40	5.4	4.5	4.4	4.1
	Mean	5.4	4.6	4.4	4.3
	0	5.7	4.8	4.7	4.5
	10	5.0	4.6	4.5	4.3
	20	5.1	4.7	4.4	4.2
1000	40	5.5	4.8	4.5	4.4
	Mean	5.3	4.7	4.5	4.4
	0	5.4	4.6	4.5	4.3
All levels	10	5.3	4.6	4.3	4.3
	20	5.4	4.6	4.3	4.2
	40	5.5	4.7	4.4	4.3

DISCUSSION

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The present study has revealed some of the beneficial effects of zinc application to rice even under conditions of apparent sufficiency.

Zinc has served to increase the height of plants, the length of panicles and the number of grains/panicle. Although these beneficial effects have not been reflected in a corresponding increase in the yield of grain and straw its beneficial effect on the nitrogen content of the grain has been noteworthy. An increase in the nitrogen content of grain means an increase in its protein content and therefore also a higher nutritive value.

The fact that zinc has not increased the yield of grain statistically is not surprising, because this element was not possibly a limiting factor in the soil used in the present study. The soil already contained an available zinc content of 4.2 ppm which is much above the threshold value of 0.5 ppm suggested by Brown et al (1962). Nevertheless this soil was used in this study because there are reports from different parts of India that even soils which are apparently well supplied with zinc may also respond to applications of zinc for various reasons. The zinc nutrition of the rice plant is a complex phenomenon which is conditioned by several environmental factors. For instance, an increase in the soil pH consequent on the application of lime may result in a deficiency of this element. Similarly the indiscriminate use of phosphatic fertilisers may result in reduced availability of Zn due to the formation of insoluble zinc phosphate. Again, too much of exchangeable aluminium, iron or manganese in the soil can also result in restricted availability of this micronutrient element. The submerged acid rice soils of Kerala as represented by the soil used in this study are prone to all these adverse conditions and hence one cannot be sure of the plant availability of extractable zinc in the soil.

As most of the soils in Kerala are acidic in reaction, liming has become a regular cultural practice in the State. In the present case liming has not effected any appreciable increase in the soil reaction. This is what is generally observed in many experiments on liming and may be due to the fact that much of the added lime is leached into the lower horizons of the soil or lost in seepage. However, lime helps to correct many adverse soil environmental factors and thereby improve the plant performance. Lime enhances microbial activity which results in accelerated decomposition of the soil organic matter which, in turn, results in the increased availability of many nutrients. Lime itself is a source of nutrient calcium in highly acid and deficient soils. Further, lime helps to reduce toxic concentrations of iron, aluminium, manganese etc. and also to increase the availability of native and added phosphorus. It must be one or more of these beneficial effects which has been reflected in many of the improved growth and yield characters noted in the present study.

Liming has significantly increased the number of tillers, height of plants and length of panicles, although some inconsistencies have been noted at certain levels of application. The number of productive tillers, the number of grains per panicle, the grain-straw ratio, the thousand grain weight and the P_2O_5 content are also increased by lime application, though not significantly. The yield of grain has not been significantly increased by lime applications, but the trend has been for the yield to improve as a result of liming.

It is to be noted that the application of lime at the rates used in this study has not raised the pH to such a level as to result in a deficiency of zinc. The availability of zinc is known to be suppressed as the soil reaction is raised from the extremely acid range to a pH of about 6.0. But in the present case the increase in pH obtained as a result of liming even at the rate of 1000 kg/ha was not very appreciable. Hence it is to be concluded that there is very little danger to zinc availability consequent on the liming of our soils at the rates ordinarily recommended in the State, viz., 500 kg/ha.

The interaction between zinc and other elements is so complex that it is often difficult to foretell when a deficiency of this element may, or may not, occur. Phosphorus-zinc interaction or P- induced zinc deficiency is said to occur in soils containing high levels of available P or with application of high doses of P to the soil. (Mehta 1974). But at the same time Millikan (1963) and some other Russian workers feel that zinc is essential for P utilization. The work done by Ambler and Brown (1969), on the other hand, indicates that an optimum balance between Fe, Zn and P is essential for proper growth of plants. As pointed out by Warnock (1970) Mn may also be invariably related to the mobility of Zn inspite of the antagonism between Fe and Mn. The possibility of Zn - Cu antagonism has also been indicated by some workers like Gilbey et al (1970). All this points to the delicate nature of the balance between the various micronutrient elements in the soil. Moderate amounts of lime may help the availability of Zn to crops by suppressing higher concentration of Fe and Mn, although indiscriminate use of lime may result in the deficiency of zinc.

Zinc application should be an indispensable cultural practice in deficiency areas, but in other places it may be applied if deficiency symptoms are noted. According to Nene and Sharma (1964) rice plants exposed to zinc deficiency remain short and a reddish brown discoloration appears in the older leaves. The leaves first show yellow colour at the base and this is quickly followed by the appearance of very fine reddish brown specks which join each other and form patches. The disease appears in the nursery or in the field after transplanting within 45 days of seeding. Zinc may be applied in the form of foliar sprays or by soil application. Foliar sprays may give better results in some cases whereas soil application may be better in other instances. In emergency cases and for paddy foliar sprays are to be recommended.

With the growing use of NPK fertilisers for increased crop production using high yielding varieties of cereals micronutrient deficiencies are bound to arise in the future. The results of the present study are only indicative and not conclusive. A detailed systematic survey of the soils of Kerala for their micronutrient status, followed by pot culture studies and field trials on an extensive scale, is necessary to arrive at more definite conclusions regarding the response of rice to micronutrient elements including zinc.

SUMMARY AND CONCLUSIONS

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A pot culture experiment was carried out to assess the effect of different levels of zinc and lime on the growth, yield and chemical composition of rice, variety Annapurna. The soil used was collected from the kaval land attached to the College Farm, Vellayani. The levels of zinc and lime applied in the study were 0, 10, 20 and 40 kg/ha of zinc sulphate and 0, 250, 500 and 1000 kg/ha of 'Geolime' respectively. A Randomised Block Design with 16 treatment combinations and 3 replications were used in the experiment. The results obtained are summarised below.

(1) The height of plant was increased by zinc application but the effect was not significant. Calcium produced significant positive effect on this growth character.

(2) The number of tillers per plant increased significantly with applications of lime. Zinc tended to reduce the number of tillers, but the effect was not significant.

(3) The number of productive tillers decreased with applications of zinc and increased with applications of lime, but both these results were not significant.

(4) The length of panicles was increased by both zinc and lime applications. In the case of zinc its effect was not significant but for calcium it was significant.

(5) The number of grains per panicle increased with increased applications of zinc and lime, but the results were significant only in the case of lime.

(6) Zinc had no effect on the yield of grain but lime tended to increase grain yields. The yield of straw was practically unaffected by the applications of zinc and lime.

(7) Grain-straw ratio and the thousand grain weight were not affected significantly by zinc application. But the application of lime tended to improve both these characters.

(8) The nitrogen content of grain was increased significantly by zinc but it had no effect on the nitrogen content of straw.

(9) The nitrogen content of grain was reduced significantly by applications of lime.

(10) Zinc tended to decrease, and lime tended to increase, the P_2O_5 content of both grain and straw. But this effect was significant only in the case of grain.

(11) The K_2O contents of the grain and straw were little influenced by the treatments and tended to remain fairly steady.

(12) The CaO and MgO contents of both grain and straw were practically unaffected by the applications of zinc and lime. However, there was a trend for CaO and MgO to increase in the plant material with increased applications of lime.

(13) The zinc content of the plant material increased with increased rate of zinc applications but lime showed an antagonistic effect on the absorption of zinc.

(14) The application of lime increased the pH of soil slightly but zinc produced no such effect.

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APPENDICES

APPENDIX I

Statistical analysis of data on the growth characteristics of rice

Source	Df	Height of plant M.S.	No. of tillers per plant M.S.	No. of productive tillers M.S.
Total	47			
Replication	2	4.26	1.34	1.39
Treatments	15	16.03**	4.35**	4.39
Zinc	3	2.56	3.36	3.36
Lime	3	6.53*	5.80*	2.41
Zinc x Lime	9	23.57**	4.22**	5.39
Error	30	1.67	1.31	4.51

*Significant at 5% level

**Significant at 1% level

APPENDIX II

Statistical analysis of the data on yield characteristics of rice

Source	Df	Length of panicle M.S.	Number of grains per panicle M.S.
Total	47		
Replication	2	0.92	18.25
Treatment	15	1.01*	159.72*
Zinc	3	0.03	129.80
Lime	3	1.68*	489.53**
Zinc x Lime	9	1.11*	59.77
Error	30	0.43	61.58

*Significant at 5% level

**Significant at 1% level

APPENDIX III

Statistical analysis of the data on yield characteristics of rice

Source	Df	Yield of grain M.S.	Yield of straw M.S.	Grain-straw ratio M.S.	Weight of 1000 grains M.S
Total	47				
Replication	2	23.02	210.64	0.061	0.25
Treatment	15	96.75	77.86	0.044	0.87
Zinc	3	60.17	107.69	0.058	0.85
Lime	3	68.28	48.81	0.032	1.45
Zinc x Lime	9	118.43	77.38	0.042	0.68
Error	30	78.77	64.82	0.043	1.14

APPENDIX IV

Statistical analysis of the data on the chemical composition of rice-grain

Source	Df	Per cent nitrogen M.S.	Per cent P_2O_5 M.S.	Per cent K_2O M.S.	Per cent CaO M.S.	Per cent MgO M.S.
Total	47					
Replication	2	0.035**	0.005	0.004**	0.002	0.0018**
Treatment	15	0.051**	0.005**	0.002	0.002	0.0005**
Zinc	3	0.030*	0.002	0.001	0.003	0.0003
Lime	3	0.113**	0.010**	0.001	0.001	0.0001
Zinc x Lime	9	0.037**	0.004*	0.002	0.002	0.0007**
Error	30	0.008	0.002	0.001	0.001	0.0002

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

APPENDIX V

Statistical analysis of the data on chemical composition of rice-straw

Source	Df	Per cent nitrogen M.S.	Per cent P_2O_5 M.S.	Per cent K_2O M.S.	Per cent CaO M.S.	Per cent MgO M.S.
Total	47					
Replication	2	0.100	0.0400	0.019	0.005	0.057*
Treatment	15	0.043*	0.0033	0.118*	0.047	0.007
Zinc	3	0.003	0.0003	0.089	0.040	0.006
Lime	3	0.043	0.0066	0.160**	0.060	0.001
Zinc x Lime	9	0.057**	0.0036	0.115*	0.045	0.001
Error	30	0.017	0.0020	0.050	0.042	0.011

*Significant at 5% level

**Significant at 1% level

APPENDIX VI

Statistical analysis of the data on the uptake of nutrients by rice

Source	Df	Nitrogen g/pot M.S.	P_2O_5 g/pot M.S.	K_2O g/pot M.S.	CaO g/pot M.S.	MgO g/pot M.S.
Total	47					
Replication	2	0.115*	0.0051	0.075**	0.002	0.001
Treatment	15	0.078*	0.0031	0.031	0.013	0.003
Zinc	3	0.062	0.0036	0.047	0.020	0.004
Lime	3	0.0042	0.0081*	0.010	0.003	0.001
Zinc x Lime	9	0.096*	0.0012	0.033	0.013	0.004
Error	30	0.032	0.0022	0.021	0.010	0.004

*Significant at 5% level

**Significant at 1% level