INVESTIGATIONS ON THE CAUSES OF POOR PRODUCTIVITY OF THE RICE SOILS OF "PAZHAMCHIRA ELA" IN CHIRAYINKIL TALUK

BY

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THESIS
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DECLARATION

I hereby declare that this thesis entitled "Investigations on the causes of poor productivity of rice soils of "Pazhamchira ela" in Chirayinkil Taluk" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title at any other University or Society.

(GIRIJA. V)

Vellayani,
29th December, 1986

CERTIFICATE

Certified that this thesis entitled "Investigations on the causes of poor productivity of rice soils of Pazham-chira ela in Chirayinkil Taluk" is a record of research done by Smt. V. Girija 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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INTRODUCTION

More than ninety percent of the rice soils of Kerala are acidic in reaction and their pH ranges between 3 and 5.5. The degree of soil acidity, depletion of exchangeable bases, nutrient status and plant available nutrients show extreme variations depending upon the geological position, hydrology and the vagaries of tropical climate. Soil reaction is perhaps the most important single characteristic of a soil which affects the plant growth and productivity both directly and indirectly.

Most of these soils respond to application of lime. The general recommendation of lime may vary with pH of the soil and its texture. Balanced application of NPK fertilizers seldom achieve economical increase in grain yield in certain categories of soils. The chief causes for this lack of response to application of balanced fertilizers are mostly associated with some intrigueing soil phenomena prevalent in such localities, not withstanding soil acidity alone.

Cropping problems associated with laterite and allied soils are generally attributed to low pH, low base saturation, low available P and high P fixing capacity and toxic levels of Fe and Al (Ponnamperuma 1960, Mandal 1971, IRRI 1970, Patnaik 1971) and those of acid sulphate soils are due to low pH, high salt content, Fe and Al toxicity and associated phosphate deficiency (Kobayashi *et al* 1953, Hesse 1963, Kanapathy 1971 b, Ikehashi and Ponnamperuma 1978).

In fact, Rice culture in Kerala is beset with many complicated localised soil fertility problems. Such a location specific problem was discussed at length in the monthly T & V workshops as early as 1983 and later in the first Regional Workshop of NARP (Southern Region) held at Vellayani. It was suggested that the low productivity of Pazhamchira "Ela" (Group of paddy fields) of Chirayinkil taluk, Trivandrum district, be investigated upon a priority basis.

Pazhamchira "ela" otherwise known as Melkadakkavur ela comprises 85 hectares of wet land, of which fifty hectares are reported to be problematic. The area was under rice cultivation since last sixty years. A low average yield of about 450 kilograms per hectare and frequent crop failures since last seven years have been reported by the farmers of the locality and at present the farmers have started abandoning rice cultivation in these lands, by switching over to coconut by raising mounds.

Incidently this "Ela" as well as a number of pockets of paddy lands lying along a straight course from Murukkumpuzha through Chirayinkil, Kadakkavur and other nearby places are situated right upon the well known "Varkala Formation" extending from Cape Comorin to Gujarat. This formation is characterised by a lower layer of lignite and partially decomposed organic debris. These paddy fields, located about 2.6 km from the coast are low lying, with impaired drainage during monsoons and have no organised irrigation or drainage systems. Poor drainage coupled with unavailability of good quality irrigation water, capillary rise of toxic salts, production of H_2S and probable formation of sulphuric acid can normally be expected under such conditions which are characteristic of acid sulphate and acid saline soils. During times of water scarcity the crop shows bronzing in small as well as large patches and then dry up. At times the entire crop in the "Ela" dries up showing typical symptoms of complex nature. The capillary rise of salt from below is evidenced by the appearance of white encrustations on the soil surface during such times.

Some exploratory studies conducted on these soils revealed that the soils are predominantly acidic with high potential acidity and the entire "ela" has restricted drainage.

the general standing crop exhibiting
toxicity symptoms

Several liming experiments conducted in Kerala rice soils indicate that fractional doses based on lime requirement at the rate of $\frac{1}{4}$ to $\frac{1}{2}$ lime requirement give economical increase in yield in moderately acid soils and highly acidic soils respectively. Since the high grade fully burnt lime shell which is the commonest liming material in Kerala is forbiddingly costly, it is high time to think about using low cost industrial calcic and magnesic bye products and other low grade but effective liming materials including silicates.

The information now available in respect of the characters and causes of poor productivity of Pazhamchira "ela" and other similar paddy areas situated nearby is very meagre.

The present investigation and field trial in the farmers field was taken up with the following objectives:-

1. To study the conditions presently prevailing in the area.
2. To conduct a field experiment in cultivators field for trying out the effect of different liming materials at $\frac{1}{4}$ and $\frac{1}{2}$ L.R, keeping the fertilizer doses as per Package of Practices and to correlate their

response with grain yield with a view to arriving at an economical lime recommendation.

3. To carry out chemical investigations of the soil and also the analysis of rice plants including grains, growing in the experimental plots, so as to elucidate causes contributing to low productivity.

4. To suggest better fertilizer, lime and water management practices for the optimum grain production with minimum inputs, and finally to deter the farmer from abandoning rice culture.

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REVIEW OF LITERATURE

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REVIEW OF LITERATURE

Vast areas in the tropics have acid soils. The acidity and low fertility status observed in most of the red laterite and lateritic soils are caused by continuous leaching of the bases and the resultant accumulation of relatively insoluble residues, composed largely of oxides of iron, aluminium and silica. Acid sulphate soils as described by Park and Park (1969) are typical low productivity soil characterised by poor drainage, extremely low pH and the presence of large quantities of sulphates and soluble iron and aluminium. These soils have somewhere within 50 cm depth a pH below 3.5 for Entisols or 4 for inceptisols that is directly or indirectly caused by sulphuric acid formed by oxidation of pyrites (FeS_2) or rarely of other reduced sulphur compounds (van Breeman and Pons 1978).

In India, acid sulphate soils have been reported to occur in the west coast of Kerala locally known as Kari, Kayal, Karapadom, Kole, Pokkali and swamp soils depending upon their location and occur mainly in the districts of Alleppey, Kottayam, Ernakulam, Trichur, Palghat and Cannanore (Subramoney and Sukumaran 1973). Liming is a key management practice for improving these soils. In general laterite and allied soils and the acid sulphate soils have a low production potential which is associated with several inherent soil problems. The nature of these problems and their amelioration for increased rice production are briefly reviewed in the following pages.

2.1. Properties of acid rice soils

2.1.1. Physical

Droupathi Devi (1963) in her studies of the physical and chemical properties of Kerala soils found a negative correlation for clay with coarse sand and fine sand. Bandyopadhya and Adhikari (1968) recorded close association between the rise and fall of water table and salinity in wet land rice soil profile. Ghildyal (1969) reported that yield component were increased significantly by increasing bulk density from 1.4 to 1.8 g cm^{-3} in low lands.

According to Kawaguchi and Kyuma (1969), Tanaka and Yoshida (1970) and also van Breeman (1976) within the limits of diagnostic criteria, acid sulphate soils vary widely in physical and chemical properties. In surface soil the bulk density varies from 1 to 1.5 g cm^{-3}. Organic carbon varies between 1.5 to 18%. The texture generally is clayey and rarely loamy and sandy. Cation exchange capacity is low ranging from 10 to 25 me/100 g due to low pH.

Brinkman and Pons (1973) list a score; a characteristic that may be helpful in identification of acid sulphate soils. Bronzing in rice grown in coastal plain soils often indicates acid sulphate soil. Puddling hastens the mineralization of soil organic matter. Plants grown in puddled fields are more vigorous and greener in appearance than unpuddled ones. Plants on granulated unpuddled soils begin to show nitrogen deficiency symptoms during the tillering stage, while plants on puddled soil maintain dark green colour (Sanchez, 1973). Richmond et al (1975) observed that development of cracks on soil surface promoting penetration of oxygen increased soil consistency and improved bearing capacity of the soil.

Kawaguchi and Kyuma (1977) found that 40 percent of the tropical low land soils they studied had atleast 45 percent clay and such soils are not easily managed and tend to be poorly aerated especially during monsoon seasons. Kyuma (1981) suggested that physical properties of rice soils are relatively unimportant in producing yields of 4 to 5 tonnes of rice per hectare so long as adequate water is available for the rice crop.

2.1.2. Chemical

Thenabadu and Ferndo (1966) made a description of the rice soils and their distribution in two low land valleys of Hawaii. Soil pH of surface horizon ranged between 4.5 and 5.5 and the sub surface horizon ranged between 5 and 5.5. Cation exchange capacity varied from 4.5 to 7.5 meq/100 g. Base saturation was between 20 and 25 percent. Bronzing was an important soil problem in this region.

Dolman and Baol (1967) while studying histosols found that they are extremely low in pH values, high in carbon nitrogen ratio and contains logs and stumps in the profile. All the profiles studied contained a mixture of organic and mineral component both of which contribute to the cation exchange capacity and acidity. Alexander and Durairaj (1968) on studying Kerala soils reported that loss on ignition, organic carbon, total nitrogen and cation exchange capacity of acid soils are negatively correlated with soil pH.

Koshy (1970) found that carbon nitrogen ratio ranged from 12.17 in a submerged rice soil to 23.67 in _Kari_ soils of Kerala. Adityachaudhury and Saha (1973) in their studies on distribution of organic matter and total nitrogen found that top layer contained higher quantities of both. Ghosh et al (1973) in their studies on _Kari_ soils of Kerala reported that these soils are clay loam in texture and that the bulk density and particle density varied from 1.24 to 1.46 and 2.52 to 2.56 g cm^{-3} respectively.

Sudjadi et al (1973) reported surface efflorescences of water soluble aluminium sulphates such as sodium alum ($Na\ Al\ (So4)_2\ 12\ H_2O$) tamarugite ($Na\ Al\ (So4)_2\ 6\ H_2O$) and Pickeringite ($Mg\ Al2\ (So4)_4\ 22\ H_2O$) form under strongly evaporative conditions where pyrite oxidises at shallow depth.

Abdul Hameed (1975) studied the morphological chemical and physico-chemical characteristics of the <u>Kole</u> soils and found that the surface soils had pH values between 3.3 to 6.1, EC from 0.27 to 2.39 mmhos cm^{-1} and organic carbon 1.97% to 5.59% and total nitrogen 0.31% to 0.58%.

Menon (1975) described the soil profile of the <u>kayal</u> lands of <u>Kuttanad</u> and found a general trend of decrease in pH with increase in depth. Electrical conductivity steadily increased with depth. Levels of available P was low but K was adequate. Aluminium existed mostly in lower layers and hydrogen ion concentration showed an increase with depth of the soil. Yadav (1976) reported that peaty or mineral surface horizon of young acid sulphate soils from India, Malaya, Vietnam and Thailand normally have a pH in the 3-4 range.

van Breeman (1976) reported that when potentially acid soils are exposed to the air in moist conditions, strong acidification often occurs within a few weeks. Within a few months the pH falls below 3 or 4 and pyrite content in the order of 3 to 6 percent may be halved within 2 or 3 months.

2.2. Soil acidity

Pillay and Subramonian (1931) attributed the infertility of kari soils of Kerala to their low pH and high content of iron and aluminium sulphate. An acid soil stronger than pH 4.0 harmed higher plants directly (Arnon and Johnson 1942) and rice was no exception (Okuda 1952). Subramoney (1958) traced the low productivity and frequent crop failures in kari soils to the production of free sulphuric acid by biological oxidation of sulphur compounds present in them. The resulting acidity encouraged the solubilisation of iron in toxic concentrations. Manua et al (1965) reported that there exist a significant correlation between pH and lime requirement.

Laterite soils had moderate to high acidity which posed serious problems in major rice growing areas (Ponnamperuma 1960; Patnaik 1971). Despite high acidity and its associated adverse effects on plant growth moderately acid sulphate soils are often used for rice growing. IRRI (1968) reported that in acid ferralitic soils the spontaneous increase in pH upon flooding was rapid enough to overcome the harmful effects due to low pH.

2.2.1. Toxic effects of iron, aluminium, manganese and hydrogen sulphide

IRON

Rice leaves containing more than 300 ppm iron often showed symptoms of bronzing according to Tanaka et al (1966). Bronzing disease of paddy due to iron toxicity in red laterite soils of Orissa was reported by Sahu (1968). IRRI (1971) reported bronzing as a wide spread physiological disorder of rice in laterite soils of India, Ceylon, Thailand, Malayesia and Cambodia. Strongly acid soils with adequate amounts of organic matter and reactive iron oxide can build up toxic concentration of ferrous iron (Tanaka and Yoshida 1970). The concentration of water soluble iron which at submergence rarely exceeds 0.1 ppm may rise to 60 ppm within a few weeks after flooding and then declines and reaches a plateau (Ponnamperuma 1972). The soluble iron concentrations are enhanced by the presence of salts. Thus according to him iron toxicity is common in submerged ultisols, oxisols and acid sulphate soils in the tropics.

Ponnamperuma et al (1973) considered the main disorder in acid sulphate soil to be acidity. According to subramoney and Gopalaswami (1973) the acid sulphate soils of rice growing area in Kerala are acidic. Pyrites are found in these soils. Oxidation on drying and hydrolysis of the sulphur compounds present in the subsoil release sulphuric acid. As a result of the break down of clay minerals in acid conditions, free aluminium and iron are released in the profile. The subsoils in most of these soils have sulphur and sulphur compounds.

According to Ponnamperuma (1977) the pH of acid soils increases upon flooding and when the soil dries it decreases. Aluminium toxicity and phosphorus deficiency occur in strongly acid soils especially in acid sulphate soils. Flooding a soil depresses the electrical conductivity of the soil solution of saline soils because of the dilution of soluble salts.

According to van Breeman and Pons (1978) iron toxicity is common in the young acid sulphate soils (sulphaquepts). Iron toxicity is rare in more deeply developed acid sulphate soils (sulphic Tropaquepts) which do not produce high levels of Fe^{2+} upon flooding.

An extremely low pH below 4.0 may decrease the physiological activity of the rice plant and thus weaken the root functions by which rice tolerates high iron-concentration in the soil solution (Tanaka and Tadano 1969 a). They conducted a pot culture experiment and showed that a potassium deficient plant had high iron content and exhibited severe symptoms of iron toxicity. Iron toxicity may occur in soils low in phosphorus or in silica-supplying power. The iron excluding power of a healthy rice plant is 87 percent (Tadano and Yoshida 1978). Alam (1981) reported that in the presence of ferric iron higher levels of aluminium increased the content of aluminium in all plant parts in barely.

Aluminium

A number of scientists who have worked in acid soils have indicated that calcium deficiency is a lesser problem to plant growth in acid soils compared to the toxicity due to aluminium. Chatterjee (1949) showed that aluminium present on the surface of clays may be liberated by neutral salts (inorganic fertilizers) in amounts toxic to crop plants.

Cate and Sukhai (1964) reported that young seedlings of rice suffered from 0.5 to 2 ppm dissolved aluminium while

3 to 4 weeks old plants suffered from > 25 ppm aluminium. Coleman and Thomas (1967) reported that the reactive aluminium in acid soil may be contributed by the positively charged hydroxy aluminium polymers of various sizes and degree of hydration. Ota (1968) reported that bronzing of paddy was due to high aluminium content and calcium deficiency.

Sumner (1970) conducted pot experiments with sudan grass in some acid sandy soils from Natal and found toxic amounts of exchangeable Al in the subsoils as the cause of low crop yield. Erico et al (1979) and Farina et al (1980) also obtained similar results.

Helias and Coppenet (1970) assessed exchangeable aluminium in soils of Britany and reported that in horizons of uncultivated soils with a pH of 5.5. contained 1 to 5 me of exchangeable aluminium per 100 g soil, exceeding the amount of total exchangeable bases.

Black (1973) noted that poor crop growth in acid soils was directly correlated with aluminium saturation of the soils and that pH had no direct effect in plant growth except at values below 4.2. Wright (1937) considered internal precipitation of phosphorus in plants by aluminium to play an important role in the poor development of certain plants grown in acid soils. The corrective action of application of superphosphate in acid soils was attributed largely to the internal precipitation of aluminium by phosphorus with sufficient P remaining for metabolic activities of the plant.

Thawornwong and Diest (1974) reported that the concentration of 2 ppm aluminium was lethal, only to young rice seedlings and that plants which had passed the seedling stage were not affected. Instances of seedling injury due to very high aluminium concentration have been observed in some of the typical acid sulphate soils of kari region of Kerala. Sanchez (1976) has stated that hydrogen ions produced by organic matter decomposition were unstable in mineral soils because they reacted with layer silicate clays releasing exchangeable Al and silicic acids.

Karthikakutty Amma et al (1979) found that IN KCl exchangeable aluminium in rice soils of Kerala ranged from 85-3700 ppm and water soluble from 1 to 16 ppm.

Bloom et al (1979) found that concentration of aluminium in soil solution is a function of pH. Exchangeable aluminium in soils form an important source of soil acidity. Das et al (1976) obtained similar results. Exchangeable aluminium status was reported as a suitable criteria for determination of lime requirement by Reeva and Somner (1970 b) and also by Cochrane et al 1980).

Farina et al (1980) found that yield and aluminium content of the tissues were exponentially related irrespective of the levels of P applied. Strong Al - P and Al - Mg antagonism were noticed at both high and low pH values. They further postulated that many of the anamalous results ascribed to such factors as micronutrient or phosphorus unavailability could be explained on the basis of the observed antagonistic effect.

Blamey et al (1983) have also reported that aluminium in solution markedly reduced root elongation as well as absorption and translocation of nutrients to the plant tops. Alice Abraham (1984) in a solution culture experiment observed that with increase in the aluminium concentration, the root elongation was adversely affected. Shortening and branching of roots and onset of anatomical modifications were more couspicuous from the 40 ppm level of aluminium in the nutrient solution. A high aluminium level affects cell division and hampers uptake of P, Ca and K. Singh and Aleoshin (1983) reported that one of the possibilities of liberation of aluminium ions in KCl extract appears to be the dissolution of surface of the acidic clay minerals of the soil. They also observed that organic matter acts as a protector of aluminium ions, oxidation of which leads to considerable increase in its concentration. Alice Abraham (1984) investigated the release of soluble aluminium in soils under submerged conditions and its effect on rice. The study has revealed that the majority of rice soils contain appreciable level of exchangeable aluminium capable of producing aluminium toxicity conditions of varying degree. The usual practice of flooding the soil after treatment with lime though reduces the severity of the problem, does not completely eliminate it in the highly acidic kari soils. The rice crop under such conditions can produce only a lower yield of grain and straw having a comparatively lower nutrient content.

Because aluminium concentrations are harmful even before they cause visible toxicity symptoms (intraveinal orange - yellow discolouration of the tips of older leaves followed by brown mottling) and because the aluminium content in the plant do not necessarily reflect aluminium toxicity, the disorder is easily overlooked. Aluminium is probably harmful in most acid sulphate soils just after flooding, and aluminium toxicity may persist in soils showing little or no increase in pH after flooding (van Breeman and Pons 1978).

Manganese

Moormann (1963) in his investigations on acid sulphate soils showed that the excess manganese concentration and its increased solubility cause toxicity to rice plant. Kanwar (1976) reported that total Mn in Indian soils vary from 92 - 11500 ppm, but the majority of Indian soils contain 300 - 1600 ppm of Mn. For an acid soil the amount of exchangeable Mn plus water soluble Mn was 2.8 to 15.6% of the total. Studies conducted by Aiyer et al (1975) and Rajagopal et al (1977) showed that the available Mn content of Kerala State ranged from 0.2 to 220 ppm. Exchangeable Mn was not found to be deficient in the districts of Alleppey, Kottayam, Quilon and Cannanore.

H_2S.

Subramoney (1965) observed that symptoms of physiological disease in paddy known locally as 'Kuttipachil', in Kerala had symptoms similar to those seen in H_2S injury. Tanaka and Yoshida (1970) reported that plants affected by akiochi are susceptible to Helminthosporium leaf spot and infection with this fungus can be taken as an indication of "ackiochi". IRRI (1973) reports that harmful concentration of hydrogen sulphide may be present in acid sulphate soils and in acid soils low in active iron during the first few weeks after flooding but not later as generally supposed.

2.2.2. Nutrient status, stress and uptake from acid soils

According to Albercht and Smith (1952) soil acidity is only a condition of nutrient deficiency predominantly of calcium. But Santos and Doss (1966) are of opinion that low yield of rice in acid soils were not due to Calcium deficiency but due to decreased availability of P and toxic levels of aluminium and iron.

Rodrige (1962) working on Ceylon soils found considerable loss of nitrogen by denitrification in submerged soils. Moorman (1962) observed that the acid soils with considerably high content of sulphate showed extreme variability in soil reaction. Ray Chaudhury and Mukherjee (1941) and Chandler (1971) reported that acidity coupled with high content of sesquioxides will favour maximum phosphorus fixation.

In five West Bengal acid soils with pH varying from 4.3 to 6.3 Kar and Chakravarthy (1969) showed that 30 to 50 percent of the added soluble phosphate was found to get fixed during the crop growth and analysis of soil showed appreciable increase in aluminium phosphate, iron phosphate and to a lesser degree occluded aluminium phosphate.

Tanaka et al (1958) studied the nutrient absorption by rice plants. They found that growth and yield were optimal with 5 to 10 ppm P_2O_5 and 20 ppm K_2O. Low phosphorus level below 5 ppm produced stunted growth, poor tillering reduced earhead formation and consequently low grain yield. The leaves were bluish green in colour and the stem base developed a purple streak.

According to Park et al (1973) Phosphorus deficiency is the most important disorder in acid sulphate soils. In moderately acid sulphate soils of pH 4.2 to 4.5 low phosphorus is the main growth limiting factor (Motomura et al 1975). On such soils P alone can double rice yield.

Tripathi and Pande (1971) found convincing evidence that at low soil pH, uptake of nutrients particularly phosphorus, calcium, manganese and potassium was reduced because of excess soluble aluminium. Results obtained by Goswami et al (1976) support this view. Reported ills of acid sulphate soils include low pH per Se; toxicity from aluminium, iron, hydrogen sulphide and carbondioxide; salt injury, toxicity of organic acids at low pH and deficiencies of phosphorus and micronutrients and a low general nutrient status (Ponnamperuma et al 1973, Bloomfield and Coulter 1973).

Ponnamperuma (1978) suggests that a pH of about 6.6 and Eh of 0.3 to 0.14 along with specific conductance of about 2 mmhos cm^{-1} at $25^{o}C$ are most favourable for nutrient uptake by the rice plant. He states that under such conditions the availability of N, P, K, Ca, Mg, Fe, Mn and Si is high; the supply of copper, zinc and molybdenum is adequate and injurious concentration of aluminium, manganese, iron, carbondioxide and organic acids are absent.

Kabeerathumma and Patnaik (1978) studied the effect of submergence on the availability of toxic and deficient nutrients in acid sulphate soils of Kerala. It was noted that flooding resulted in an increase in soil pH and the extent of increase was determined by certain inherent characters of soil. The exchangeable iron content increased and reached a peak value after 30 days and then decreased. The overall effect of submergence was towards an increased availability of calcium and potassium.

2.3. Effect of different types of soil amendments on the amelioration of soil problems.

Silicates

Although silicon is not normally classified as an essential element for plant growth it appears necessary for good rice yield. In Japan and Korea significant quantities of silicates containing fertilizers are used. The silicon enhances resistance to lodging, to pests such as stem borers and to disease such as blast. Slag that contains calcium silicate is used as a silicon source; rates of 1.5 to 2 t/ha are applied.

Subramoney (1965) has suggested the use of magnesium silicate in acid sulphate soils of Kerala to prevent the production of hydrogen sulphide and other toxic factors. Reeve and Sumner (1970 b) showed that response to calcium sulphate and calcium silicate in oxisols in Natal was due to the elimination of aluminium toxicity and consequent improvement in phosphorus uptake by plants rather than to any improvement on the rate of P supplied to soils. For the liming of strongly acidic top soils (pH 3.6 to 4.2) slow acting wollastonite (calcium silicate) is considered more suitable than calcium-carbonate at the rate of 3 to 6 t ha^{-1} (Park et al 1971).

Vijayakumar (1977) conducted a field experiment and a pot culture experiment to study the effect of magnesium silicate and lime individually and in combination on the growth, yield and composition of rice, in Vellayani. He observed that in the pot culture experiment and in field experiment also, 600 kg ha^{-1} of magnesium silicate increased the number of spiklets, number of filled grains and thousand grain weight. The yield of grain and straw showed a tendency to decrease with increasing levels of magnesium silicate though not significantly.

Karunakara Panicker (1980) studied the utility of magnesium silicate for rice in Kuttanad soils. Steatite was applied in uniformly limed soils at the rate of 100 kg, 200 kg, 300 kg and 400 kg per hectare. The yield of grain and straw showed increase with statistical significance at 400 kg per hectare. There was a decrease in the NPK and Ca content of grain and straw, while Mg and Si content increased with increasing levels of steatite. The uptake of NPK and Ca was not linear with the varying levels of treatment but magnesium and silica uptake was linear with increase in the levels of treatment.

Bhushakthi

To evaluate the effect of calcium, magnesium and silica containing soil amendment viz., Bhushakthi on the yield of rice, a trial was conducted at Rice Research Station, Moncompu. The results indicated that the material had no effect on the yield and yield attributes of rice under soil conditions in the Moncompu farm (Anon. 1981).

Lime

Application of lime might help in correcting soil acidity, improving microbial activity, bringing about favourable physiochemical changes and also prevent the release of toxic nutrients like iron and aluminium. The literature refering to the application of lime is very vast and hence only very relevant aspects are reviewed here. Ponnamperuma (1960) found that physiological disorder arising out of excess iron and manganese can be corrected by application of lime and he got strikingly increasing yield of paddy due to liming of acid laterite soils of Ceylon. Subramony and Nambiar (1969) reported a high response to liming in acid sulphate soils of Kerala and they suggest that liming is a key management practice for improvement of such acid soils. Park et al (1971) studied the effect of lime on growth of rice and changes in pH, Eh ~~and~~ ferrous ~~ion~~ and aluminium in acid sulphate soils of Korea. They recommended the use of silicate fertilizers and organic matter especially rice straw, split application of red earth or mud with a high clay content, to improve these soils.

Baumgartner et al (1974) reported that liming increased dry matter yield and total yield and total nitrogen content of the plant irrespective of the rates of liming. Ameliorative measures like application of lime and repeated flushing with fresh water often improved the acid sulphate soils and produced good yield in the ensueing season. But very often problem reappears on drying of the soil after harvest. For such soils Kuruvila and Patnaik (1973) proposed the use of ameliorants particularly magnesium carbonate and magnesium silicate where the resultant sulphates formed by interaction were more soluble than calcium sulphate formed when lime alone was added.

2.3.1. Effect on physico-chemical characteristics of soil

The beneficial effect of lime for crop productivity has long been recognised (Russel 1937) and the effects of altered pH on plant nutrition have been discussed for many years (Pearson and Adanis 1967). It was noted that soil tilth was sometimes improved by corrective lime application and this result was attributed by Baver (1956) to indirect effect of liming.

Oldershan and Gardener (1949) reported that liming improves the soil texture causing the soil to behave like a heavy soil. Bekhari et al (1957) found that liming increases the porosity of the soil and decreases soil disperson and resistance to ploughing.

Allaway (1957) reported that toxic effect of iron and aluminium can be corrected by application of lime. Increase in pH of laterite and associated soils due to application of lime was reported by several investigators like Mitsui (1955), Mandal et al (1966), Patnaik et al (1968), Singh et al (1970), Prasad et al (1971), Padmaja and Varghese (1972) and Hanes (1973).

Mandal (1971) classified the rice crop as the least responsive to application of lime. Lack of response to lime application on growth and yield of rice was also reported in several instances (IRRI 1968, Leite et al (1970) and Khanvilkar et al (1978). Keogh et al (1968) found a significant decrease in grain yield due to limestone application.

Beater (1945) recorded changes of soil pH for a period of 13 months in a number of soils consequent on liming. Increase of pH is related to the mechanical composition of the soil and native calcium adsorbed by them. Kabeerathumma (1969) has reported that optimum dose of lime for maximum efficiency is half the lime requirement for the karapadom and full lime requirement for the kari soils and substantial increases in yield were recorded in respect of both the grain and straw in fractional levels of liming.

Bandyopadhyaya (1973) conducted pot experiments on four typical acid soils with pH from 4.9 to 5.4 and CEC from 3.6 to 6.2 meq/100 g. He concluded that there is no need for liming the rice crop on submerged soils unless the soils are below pH 5.0 and high in exchangeable aluminium. Haynes and Ludecko (1981) observed that liming resulted in an increase in the exchangeable calcium, and percent base saturation with concomitant decrease in the levels of exchangeable aluminium iron and manganese.

Nair et al (1957) found that a combination of lime, P_2O_5 and organic manure provides a congenial condition in an acid soil for enhanced microbial activity and plant growth which in turn results in improving the fertility of the soil.

Availability of nitrogen was increased in limed soil due to enhanced mineralization of organic nitrogen by increasing microbial activity of soil (Abichandini and Patnaik 1961, Srivastava et al 1972). Actinomycetes population increased by 20-30 percent in the limed soil, while the fungal microflora showed a decrease from 5 to 25 percent (Oblisami 1973).

2.3.2. Effect on availability of N and P.

The data reported by Volk and Bell (1944) showed a marked decrease in the loss of nitrogen and also indicates that liming reduces the leaching losses of nitrogen, causing thereby an increase in the residual effect of added nitrogen to subsequent crop. Aslander (1952) concluded that addition of lime will enhance the rate of decomposition of soil organic matter, resulting in an increased mineralization of nitrogen.

Mitsui (1955) showed that lime application on submerged soil increased the ammoniacal nitrogen three fold within 21 days. Subramoney (1964) reported that application of lime accelerated oxidation of organic carbon resulting in decrease in carbon nitrogen ratio with a consequent increase in N mineralization.

According to Kawaguchi and Kyuma (1969 b) the benefit of lime and phosphorus application may in part due to increased supply of N by stimulation of amonification and microbial fixation of N, processes that are strongly hampered in unamended acid sulphate soils.

The investigations of Cook and Miller (1935) showed that increased availability of P resulted in an increase in base saturation due to liming over a period of one to 20 days. Their study further indicated that increasing doses of lime added to acid soil consequently lowers the power of soil to fix added soluble phosphate. Ghani and Aleem (1942) studied the effect of liming on the P transformations in acid soils and their conclusion was that greater availability of soil P caused by liming is due to the decomposition of organic P compounds in the soil.

Ribertson *et al* (1954) on the other hand, reported that only soils low in residual P and high in sesqioxides gave increased P availability on liming and there was no interaction of lime and phosphorus.

Liming increased P availability by increasing the hydrolysis of phosphate minerals like varicite and strengite, by increasing mineralizations of organic P and through decreasing P fixation by iron and aluminium in acid soils (Dhar and Singh (1955), Koshi and Brito (1961), Mandal *et al* (1966); Janik and Schiachl (1973)).

Gupta (1958) noted that liming in general increases available P in the soil. The beneficial effect was found to be maximum at the early stages of growth of the rice plant and was minium at the flowering stage. Kurup (1967) from his fertility investigations on rice soils of Kuttanad concluded that lime applied at full lime requirement maximise P availability.

Kabeerathumma (1969) reported that lime application enhances availability of P in both *Kari* and *Karapadom* soils. Khanna and Mahajan (1971) observed that in acid soils added phosphorus was transformed mainly into Al-P and Fe-P. Kabeerathumma et al (1979) indicated that the efficiency of superphosphate can be improved by mixing it with lime just before application so as to reduce reaction of water soluble P with Fe, Al or Mn fractions and consequent reduction in its availability. She has reported that a dose of lime and superphosphate at the rate of 600 kg and 300 kg per hectare respectively for rice in Kerala are sufficient.

2.3.3. Effect on availability of K, Ca and Mg.

Enhanced K availability on liming due to increased release of K and increased K activity was reported by Hoover et al (1948) Pratt et al (1956) and Mandal and Sinha (1968).

York and Rogers (1947) reported that calcium addition enhances the release of non-exchangeable potassium while fixation of applied potassium is encouraged. Maclean (1956) in his investigations on the influence of lime application to soils and the availability of potash and other cations did not find any appreciable effect on the exchangeable potassium due to liming. According to him increased yield could be got if potassic fertilizers are also applied in conjunction with lime. Long et al (1973) reported that there was no defenite effect of lime on K availability in limed soil. However significant reduction in K availability in limed soil and was reported by Aeppli and Harrach (1971). Sreedeviamma and Aiyer (1973) reported that the Kari soils showed highest amount of potassium fixation and the kole soils showed the least amount of potassium fixation.

Dunn (1943) found from chemical analysis of the forage from a green house experiment that the available calcium supply was increased in proportion to the amounts of lime applied. The results of investigation by Heslep (1951) and others indicated that the beneficial influence on crop production obtained by liming was not due to the nutrient effect of calcium but was associated with change in soil reaction.

Lysenko (1957) reported that a combination of lime, phosphate and organic manure provide congenial condition in an acid soil for microbial activity. Increased availability of calcium due to liming was reported by Kothandaraman and Mariakulandai (1965); Prasad et al (1971).

According to Kobayashi et al (1956) magnesium application had little effect on yield and silicon content of rice crop. Calcium carbonate was found to reduce the exchangeable magnesium in soil while calcium silicate increased exchangeable magnesium though it had no significant effect on the magnesium content of plant (Tammi and Matsuyama 1972). Liming also caused vertical and slightly lateral migration of calcium and magnesium in soils (Morelli et al 1971).

Thenabadu (1969) reported that rice responded to liming of a clay loam (pH 5.3) and a sandy loam (pH 5.1) of Srilanka but did not respond to liming of a humic clay loam (pH 5.4).

2.3.4. Effect on iron and aluminium.

Schimehl et al (1950) observed reduced concentration of both iron and aluminium and also manganese in plants due to liming. Nikistikina (1951) showed that exchangeable aluminium content can be decreased by application of organic matter in the form of farm yard manure. Valmis (1953) concluded from his studies that failure of plants to grow properly in acid soils is due to the presence of aluminium in soil.

Moskal (1959) showed that the appearance of mobile aluminium was counteracted with corresponding reduction in soil acidity by the annual application of twenty tonnes per hectare of farm yard manure. Decreased aluminium toxicity on liming was reported by Thomas (1960) and also by Takabshi (1963).

Juste (1964) reported decrease in aluminium concentration of plants due to liming of the soil. Reeva and Somner (1970 a) found that response to lime, calciumsulphate and calcium silicate was due to the elimination of aluminium toxicity and consequent improvement in phosphorus uptake by plants rather than to any improvement in the rate of phosphorus applied to the soil. According to Beer et al (1972) and Wang (1971) lime reduce the toxicity of Fe and manganese by reducing their solubility under water logged conditions by precipitation as their hydroxides.

Martin et al (1977) suggested that liming to bring soil pH to 4.8 - 5.7 and to reduce exchangeable aluminium to 1.5 me per 100 g soil was a more valid means of increasing yields than by raising soil pH to neutrality. Maximum response to liming was obtained when the aluminium saturation fell below about 2 percent (Anon 1979).

In an incubation experiment with eleven acid soils Brauner and Catani (1967) found that addition of $CaCo_3$ at 100 mg and 300 mg per 100 g soil decreased both aluminium and titrable acidity and increased the pH of aqueous suspension. Similar results were obtained by Alley (1981) and also by Bache and Crooke (1981).

Iron toxicity on strongly acid soils has been corrected by liming (Ponnamperuma 1958); Nhung and Ponnamperuma (1965); Park et al 1971) and by the addition of Wollastonite (Park and Kin 1970).

Iron toxicity was the most important single soil factor which limited yield of new rice cultivars on acid soils. In a study on three acid soils the addition of organic matter served as an ameliorant for iron toxic soils and the severity of plant toxicity symptoms was reduced. Sahu (1968) suggested provision of drainage, soil application of lime, phosphate and potassium and foliar application of urea to overcome bronzing disease of rice due to iron toxicity. He also reported decreased iron concentration in paddy straw from limed laterite soil (IRRI 1970).

IRRI (1971) suggested flooding the soil for considerable length of time preferably with addition of organic matter to hasten reduction, before puddling and transplanting of rice to overcome iron toxicity.

Tadano (1976) based on a study of factors affecting iron concentration in soils recommend drainage and intermittent irrigation, use of fertilizers, particularly P and calcium silicate, salt removal from highly saline soils and increasing the root to shoot weight ratio by cultural practices and plant breeding.

2.3.5. Effect on nutrient contents and uptake by the crops.

Nambiar (1960) and Mandal (1971) reported beneficial effects of lime application on the nitrogen nutrition of rice grown on laterite and lateritic soils. Varghese (1963) noted that the nitrogen content of grain and straw of rice was appreciably increased by the application of lime. Prateep and Sims (1972) concluded that the nitrogen content and Ca content of grain were greatly enhanced by nitrogen and calcium fertilization whereas, lime lowered the concentration of nitrogen in the grain and straw. Kabeerathumma (1969) could obtain a notable increase in the uptake of important nutrients like N,P,Ca and Mg with increased dose of lime by rice variety - "Culture 28". Application of fertilizer nitrogen increased the nitrogen content and its uptake in presence of lime Throp and Hobbs (1956) Chew et al (1976).

Hunter (1949) observed an increase in the phosphorus content of alfalfa as calcium/magnesium ratio decreased. In the presence of calcium, magnesium had little effect on the uptake of phosphorus. Basak et al (1961) noted a reduction in the phosphorus concentration in oats by the application of lime.

Chang et al (1971) reported a progressive decrease in the phosphorus content of plant with the increasing rates of lime application. On the contrary Bhor et al (1970) obtained significant effect on the uptake of phosphorus and manganese and the uptake of calcium, was directly proportional to the lime content of the soil in paddy and Jowar plants. Mandal et al (1966) and Padmaja and Varghese (1972) reported increased phosphorus uptake by rice in limed soils. Ryan and Simullie (1975) found that each increment of lime significantly increased the phosphorus uptake by Italian rye grass.

Koshy (1960) found that potassium content of plant was decreased by the application of high levels of calcium. Similar results were obtained for potassium as well as phosphorus by Sivan Nair (1970)also. Than (1959) observed increased potassium uptake when lime was used with NPK fertilizers. On the contrary, decreased potassium uptake by rice also was reported by Sahu (1968) and Singh et al (1970) by liming.

Increased calcium uptake as a result of liming was reported by Mandal et al (1966) and Patnaik et al (1968). But Basak et al (1961) did not get any increase in the uptake of calcium due to liming. Krishnaswamy and Raj (1975) observed that the calcium content and its uptake were enhanced by lime plus fertilizers plus organic matter.

Bergomann et al (1967) reported that liming of acid soils often resulted in considerably increased yields and is more effective than N P K fertilizers. Ragland and Coleman (1959) noted marked improvement in root growth when sufficient lime was applied to hydrolyse exchangeable aluminium and it was only 1/6 th the amount required to raise the soil pH to 6.5. Wang (1971) reported that grain and straw yield of rice increased by 23% and 27% respectively by the application of lime at 5 t h^{-1} on a submerged lateritic soil of pH 4.8 and low in base saturation.

Kabeerathumma (1969) noticed that the uptake of Mg increased with liming whereas a decreased trend was observed by Butorac and Uscumlic (1978). However the hourly rate of calcium and Mg uptake decreased markedly with increasing plant age.

2.3.6. Effect of silica on the availability and uptake of nutrients by plants.

Experiment conducted at Regional Agricultural Research Station Pattambi (Anon 1975) showed a non-significant increase in yield by the application of magnesium silicate at the rate of 100 kg ha^{-1}, but the dose of 200 kg ha^{-1} tend to reduce yield. Yoshida et al (1962) reported that silicon was not essential for growth and tillering in rice but was beneficial during reproductive stage.

Experiments conducted at IRRI (Anon 1963) showed that increased yields could be obtained by the addition of silica in the forms of calcium and magnesium silicate at the rate of

100 kg/hectare. Money (1964) reported marked increase in grain yield of rice by the application of magnesium silicate. Sadanandan and Varghese (1969) found that calcium - magnesium silicate was better than sodium silicate in increasing grain yield.

Kobayashi et al (1956) obtained an increased percentage of nitrogen in rice due to slag application. Ishaburo Naga (1959) claimed that the absence of silicon, increased the nitrogen content of rice plant. Okuda and Takahashi (1965) reported that phosphorus uptake of rice plant was slightly decreased with increasing supply of silica.

Silva (1971) found that silica played an important role in phosphorus metabolism and in the correction of nutrient imbalance. Takijima et al (1959) and Sadanandan and Varghese (1969) noticed increased absorption of potassium by the application of silica to rice. But Islam and Saha (1969) reported that the application of silica decreased the potassium content of rice plant.

Halias a nd Parish (1963) opined that the silica uptake from soil was influenced by the iron and aluminium content of the soil. Tanaka and Park (1966); Vijayakumar (1977) noticed an increased percentage of silica in the leaves and shoots due to the application of silica.

Sadanandan and Varghese(1969)obtained an increase in the uptake of calcium by rice plant when silica was applied as calcium magnesium silicate. Takijima et al (1970) noted that silica application resulted in increased uptake of magnesium by rice. They found that at the early tillering stage the leaf blades of rice plants were seen visibly droopy for some weeks. The height of plant and tiller count were low even at maximum tillering stage (Okuda and Takahashi 1965). As the silicon supply increased, phosphorus uptake by rice plant slightly decreased.

According to Okuda and Takahashi (1962 a) silicon supply greately decreased the excessive uptake of iron and manganese by rice but did not decrease aluminium uptake. It was understood that silicon promotes oxidation power of rice roots and oxidises and deposits Fe^{2+} on the surface of roots. Thus, silicon reduces excessive iron uptake. Silicon was also found to hasten the time of heading. Silicon increases resistance to pests and diseases, maintains a balanced water economy, keeps the leaves errect and increases photosynthetic activity (Yoshida 1975). Alice Abraham (1984) reported that the use of steatite and organic materials along with lime was found to be very effective in suppressing the release of exchangeable aluminium in a highly acid soil.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The nature and magnitude of the soil problem in "Pazhamchira ela" in Chirayinkil taluk, Trivandrum district was investigated by carrying out a careful study of the soil and by conducting two field experiments using different soil amendments.

3.1. Soil studies

The study included the examination of typical soil profiles and surface soils from the area.

Profile studies

Since the main feature of the investigation was the conduct of field trial, only two profiles were described and investigated thoroughly. Exploratory pits to a depth of 82 cm were dug at ten sites about 300 meters apart to examine variation if any in profile characters. Since no marked differences was observed among the different profiles only two soil profiles (0-82 cm) were collected one from the site selected for the field experiment and another about 750 meters away from the first site for detailed investigations. The field description of the profile was done based on the proforma prescribed by the FAO for soil survey and classification (1973). Composite soil samples from each horizon were collected, thoroughly mixed and put seperately in polythene bags and brought to the laboratory for analysis.

Surface soil

Fifty samples of surface soils (0-15 cm depth) representing the problem soils of Pazhamchira "ela" were collected randomly during the first week of February 1984 immediately after the harvest of the second crop of paddy. The fresh samples were serially numbered and packed in polythene bags brought to the laboratory and the pH and EC were recorded. These samples were then air dried, powdered with a wooden mallet and passed through a 2 mm sieve and stored in airtight plastic jars for further analysis.

Soil analysis

The air dried soils from the different horizons of the soil profiles and the surface soils were analysed to determine the mechanical composition, pH, EC, organic carbon lime requirement, CEC, total nitrogen, available nitrogen, available phosphorus, exchangeable calcium, magnesium, potassium, sodium, iron, aluminium and water soluble aluminium. Fifty more soil samples also were collected after the dry spell in May 1984 before the commencement of Kharif crop to study the seasonal variation in pH and EC.

3.1.1. Mechanical analysis

The proportion of different fractions viz; coarse sand, fine sand, silt and clay were estimated by the Bouyoucos hydrometer method (Bouyoucos 1962) after removal of organic matter by hydrogen peroxide treatment.

3.1.2. Electro chemical properties

3.1.2.1. Soil reaction (pH)

The pH of fresh and air dried samples was determined in a 1:2.5 soil water suspension using a Perkin Elmer pH meter with glass and calomel electrodes (Hessee 1971).

3.1.2.2. Electrical conductivity

The electrical conductivity of the soils was determined by introducing a conductivity cell into the clear supernatent solution of the same soil suspension used for pH measurement using a direct reading ELICO conductivity bridge.

3.1.3. Chemical analysis

3.1.3.1. Organic carbon

Organic carbon was determined by the method of wet digestion as proposed by Walkely and Black (Jackson 1967).

3.1.3.2. Lime requirement

This was determined by SMP buffer method (Shoemaker *et al.* 1961).

3.1.3.3. Cation exchange capacity (CEC)

CEC was determined by saturating the soil with neutral normal ammonium acetate as proposed by Jackson (1973).

3.1.3.4. Total nitrogen

Total nitrogen status of the soil was determined by the microkjeldahal digestion and distillation method (Jackson 1973).

3.1.3.5. Available Nitrogen

Available nitrogen was determined by the alkaline permanganate method (Subbiah and Asija 1956).

3.1.3.6. Available phosphorus

The available phosphorus content was determined by the chlorostannous reduced phosphomolybdic blue colour method in hydrochloric acid system after extracting the soil with Bray No.1 reagent (Jackson 1973).

3.1.3.7. Exchangeable cations (Ca, Mg, K, Na)

The exchangeable cations were determined in neutral normal ammonium acetate extract of the soil after destroying organic matter by treatment with aqua regia (Jackson 1973). K and Na were estimated using an EEL flame photometer and Ca and Mg using a Perkin Elmer 3030 Atomic Absorption Spectrophotometer.

3.1.3.8. Exchangeable iron

DTPA extractable iron was determined in the 0.005 M DTPA extract (Viro 1955) of the soil using a Perkin Elmer 3030 Atomic Absorption Spectrophotometer.

3.1.3.9. Exchangeable aluminium

Exchangeable aluminium was determined in Normal KCl (Jackson 1973) extract. For this five gram soil was shaken with 50 ml of Normal KCl solution for 30 minutes. Centrifuged the mixture for 10 minutes and decanted the supernatant solution. The extraction procedure was repeated once again and aluminium in the extract was measured using a Perkin Elmer 3030 Atomic Absorption Spectrophotometer.

3.1.3.10. Water soluble aluminium

Water soluble aluminium was determined in the 1:5 soil water extract using Perkin Elmer 3030 Atomic Absorption Spectrophotometer.

3.2. Field experiment

With a view to finding out the efficiency of various soil amendments an experiment was laid out in the field of Sri.V.Gopinathan Nair, Kollanvilakom, Pazhamchira, Mel-kadakkavur of Chirayinkil taluk where the soil problem has been concurrently observed. Three liming materials viz., CaO (burnt lime),"Bhushakthi" and steatite (Magnesium silicate) at ¼ and ½ Lime requirement rates were tried during the Kharif and Rabi season of the year 1984-85.

The general cultural practices and season war details are classified and presented below.

3.2.1. Site and cropping history

The"Pazhamchira ela" is situated near the Kadakkavur Railway station and about 400 meters from the railway tract. The "ela" is divided by a central drainage cum irrigation canal which starts from the "Pazhamchira" an earthern dam at the eastern boundary of the ela. The canal empties the water into the adjoining Anjego backwater.

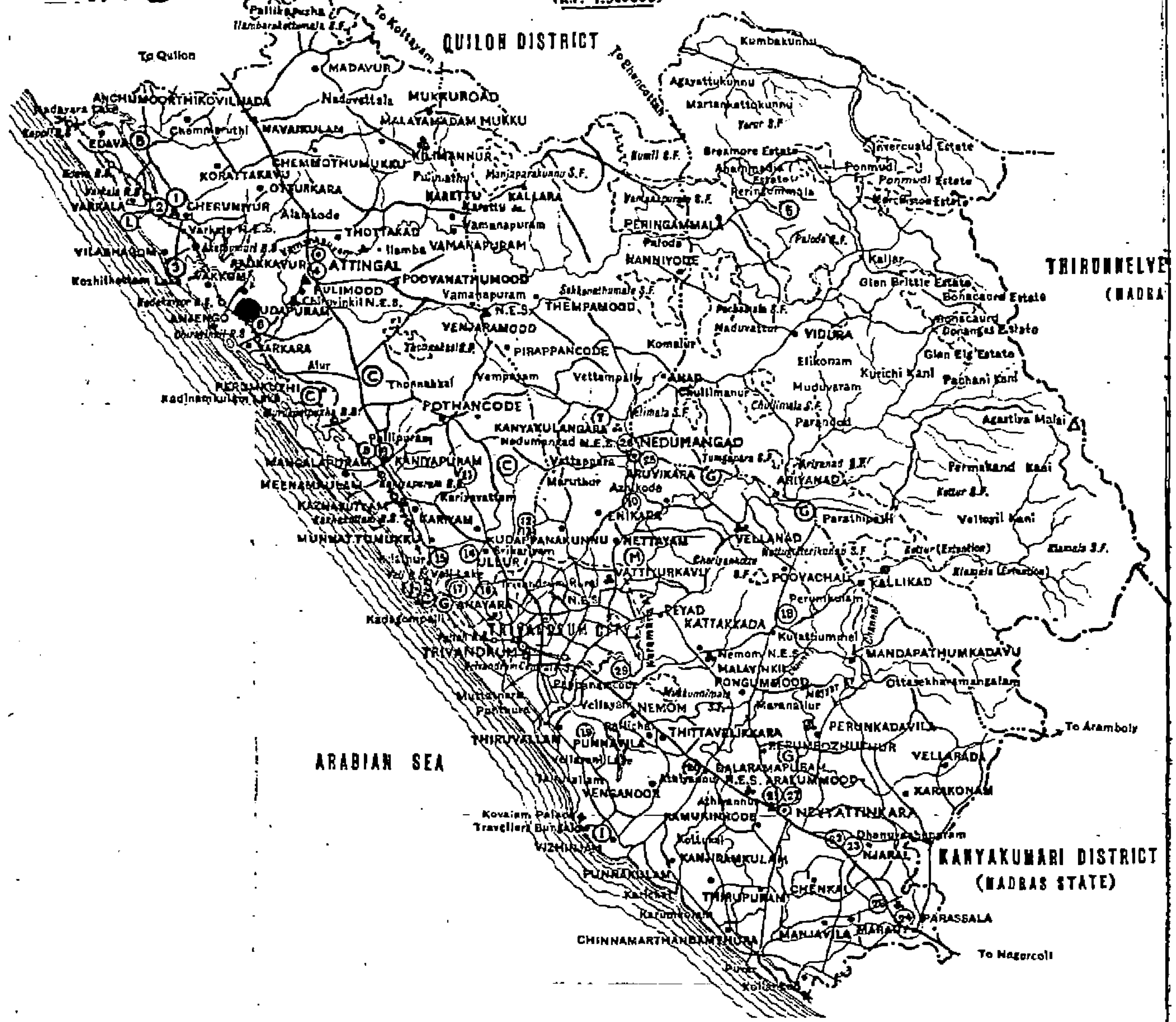
The "ela" (group of paddy fields) is a link in an interrupted chain of low lying paddy fields running along the seacoast which incidently is situated along the "Varkala formation". This is evidenced by the presence of large

GENERAL MAP
OF
TRIVANDRUM DISTRICT

FIG 1 a

Scale:-1 cm = 3 km.
(R.F. 1:300000)

● LOCATION OF PAZHAMCHIRA ELA



quantities of organic matter and woody materials just below the surface soil. The water received through the monsoons and that is stored in the "Pazhamchira" are the only source of irrigation for paddy fields.

Very severe burning of the crop in patches resulting in a heavy loss in yield is quite common during drought conditions. White salt encrustations are also noticed as patches on the soil surface where the crop has dried up.

3.3.2. Soil

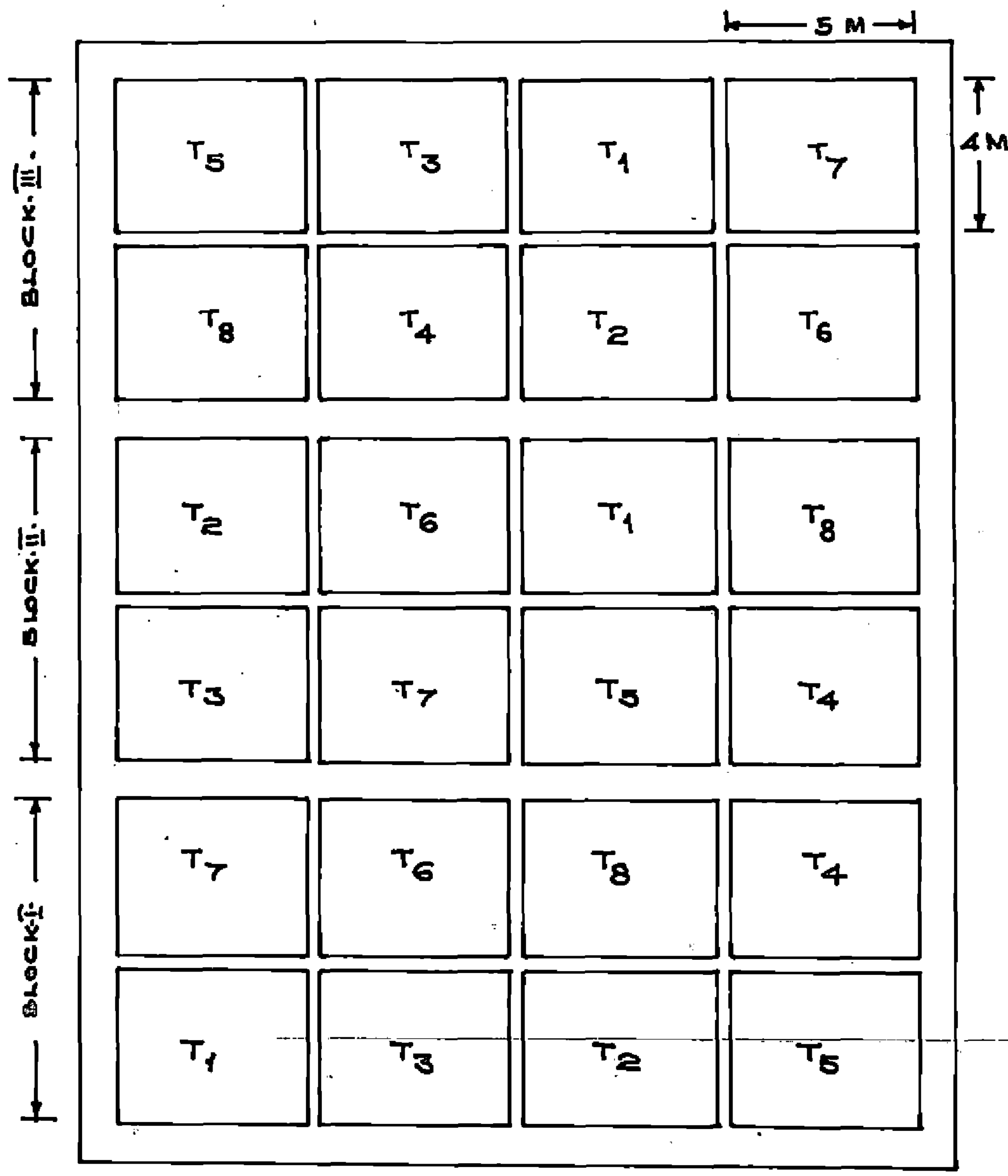
The soil belongs to the textural class of sandy loam derived from local lateritic aluvium with high organic matter content and salt concentration in the lower layers of the profile. The mechanical and chemical composition of the soil is given in Table 10.

3.3.3. Design and layout of experiment

The experiment was laid out in a Randomised Block Design with three replications. The plan of layout is presented in Fig.16. The details of the layout are furnished below.

Design	RBD
Treatments	8
Replications	3

FIG-1b LAY-OUT PLAN RANDOMISED BLOCK DESIGN



<u>NUMBER OF TREATMENTS</u> - 8

T_1 ~ CONTROL WITHOUT LIME

T_2 ~ 1488 Kg/Ha CaO

T_3 ~ 2976 Kg/Ha CaO

T_4 ~ 7296 Kg/Ha STEATITE

T_5 ~ 14592 Kg/Ha STEATITE

T_6 ~ 2091 Kg/Ha BHUSHAKTHI

T_7 ~ 4182 Kg/Ha BHUSHAKTHI

T_8 ~ 20 Kg/Ha K_2O

DESIGN - R.B.D.

REPLICATIONS - 3

PLOT SIZE GROSS 5 x 4 M

NET AREA KHARIF 3.2 x 4.1 M

RABI 3.2 x 4.4 M

Total no. of plots : 24

Season	Variety	Spacing
Kharif	Ptb 8	20 x 15 cm
Rabi	Vyttila-1	20 x 10 cm

Gross plot size : 4x5 m

Net plot size Kharif 3.2 x 4.1 m

Rabi 3.2 x 4.4 m

Two rows of plants were left out all around the plots as border rows. One additional row was left on the breadthwise side to facilitate sampling of the plants and an additional row was also left beyond the sampling row to avoid the possible effect on the net area.

3.3.4. Season and variety

The experiment was conducted for two seasons ie. during the first crop season (Kharif - May to September) and the second crop season (Rabi - September to December) of the year 1984. The locally cultivated variety Ptb-8 (Duration 135 days) was selected for the experiment in Kharif season. But the variety for the Rabi crop was changed and it was Vyttila-1 (Duration 95 days) which is an acid and saline tolerant pure line selection.

3.3.5. Treatments

There were eight treatments. The three liming materials were applied each at two levels based on their neutralising value and the lime requirement of the soil. The lime requirement of the soil was 8.2 tonnes Ca Co_3 (per hectare). The treatments were given over and above the fertilizer recommendations contained in the package of practices of the Kerala Agricultural University (1982) for rice.

The treatments are detailed below

Sl. No.	Treatments	Level of lime	Quantity of lime per hectare	Name of lime	Quantity of fertilizer NPK	Remarks
1	T_1	--	--	--	40:20:20	Control
2	T_2	¼ LR	1488	CaO	40:20:20	
3	T_3	½ LR	2976	CaO	40:20:20	
4	T_4	¼ LR	7296	Steatite	40:20:20	
5	T_5	½ LR	14592	Steatite	40:20:20	
6	T_6	¼ LR	2091	Bhushakthi	40:20:20	
7	T_7	½ LR	4184	Bhushakthi	40:20:20	
8	T_8	--	--	--	40:20:20 + 20 kg K_2O	

In addition to the treatment with liming material there was a control and another treatment with 20 kg K_2O as extra dose over the normal package of practices recommendation.

The field is drained 2 days after liming for 24 hours and water is let in afterwards. Two more drainages were also provided one at 30th day and another at 45th day after transplanting.

3.3.6. Liming materials and their preparations

The liming materials used were

1. Fully burned lime

Neutralising value	: 137.75
CaO content	: 77.34%
Source	: Locally available

2. Bhushakthi

Neutralising value	: 98
CaO content	: 52%
MgO content	: 5.7%
SiO_2 content	: 26%
Source	: Supplied by M/s Ferro Alloys Corporation Ltd, Andhra Pradesh

3. Steatite

Neutralising value	: 28
CaO content	: 1%
MgO content	: 29%
SiO_2 content	: 55%

The chemical formulae of the steatite is $Mg_3\ Si_4\ O_{10}(OH)_2$

Source - The Geological Survey of India

The CaO and Bhushakthi were applied without any processing. But the steatite obtained was in large lumps and was got ground in a commercial crusher and applied in the field after passing through a hundred mesh sieve.

Field Culture

3.3.7. Nursery

Wet nursery was raised adjacent to the main field. Five kilograms of sprouted seeds were sown in fifty square-metre nursery area on 25.4.84 and 17.10.84 for Kharif and Rabi crops respectively. Proper irrigation cum drainage were practiced as and when required. Seeds of variety Ptb 8 was locally procurred, while Vyttila-1 was supplied from Rice Research Station, Vyttila.

3.3.8. Preparation of main field

The experimental area was ploughed thoroughly. The layout of the experiment was made after measuring out the area for each plot. The plots were seperated with bunds of 30 centimetre width and individual blocks were given an outer bund of 50 cm width. Irrigation cum drainage channels were provided between alternate plots. The area within the plot was perfectly levelled.

3.3.9. Application of liming material, organic matter and chemical fertilizers

The liming materials were applied as basal dose 18 days prior to the date of transplanting. The field was flooded for two days and then drained off. Farm yard manure at the rate of 5000 kg per hectare was incorporated well in the puddled soil ten days prior to transplanting. The basal dose of fertilizer was applied at the rate of 20 kg N 20 kg P and 10 kg K per hectare at the last puddling of the soil a day before transplanting.

For Ptb 8, ten kg nitrogen per hectare was applied at the active tillering stage and the balance quantity of N and K were top-dressed a week prior to panicle initiation, while for Vyttila-1 a single top dressing was given prior to panicle initiation with 1/3rd N as 2/3 N and full P and K has already been applied as basal.

3.3.10. Transplanting

Vigourously growing seedlings from the nursery were pulled out on 33rd day and transplanted in the main field on 28-5-84 at the rate of 3-4 seedlings per hill. During the Rabi season seedlings of 20 days old were planted in the main field on 5-11-84.

3.3.11. Irrigation and drainage

After transplanting controlled irrigation cum drainage was given as and when required.

3.3.12. Weeding

The plots were hand weeded twice on the 23rd day and 40th day after transplanting of Ptb 8 during Kharif season, while weeding was done only once on the 20th day of transplanting of Vyttila-1 during the Rabi season.

3.3.13. Plant protection

Metacid was sprayed on 11-8-84 and 20-12-84 in the Kharif crop and Rabi crop respectively as a prophylatic measure against rice bug at milking stage.

3.3.14. General stand of the crop

The general stand of the crop was satisfactory. There was no lodging as well as pest and disease infestation in any of the crops.

3.3.15. Harvest

The variety Ptb 8 was harvested on 5-9-84, 101 days after transplanting. The Rabi crop with variety Vyttila-1 was harvested on 17-1-85, seventy four days after transplanting.

The grain from individual plots were cleaned dried and weighed separately. The weight of sundried straw was also recorded plot-wise.

3.4. OBSERVATIONS

After eliminating the border rows, three sampling units (2x2 hill)were selected randomly from each plot giving 12 hills for tiller counts and three hills for plant height as per the method suggested by Gomez (1972). The following growth yield characters were studied.

3.4.1. Height of plants

Height of plants was measured from the base of the plant to the tip of the top most leaf at maximum tillering, panicle initiation and flowering stages. At harvest, the height was recorded from the base of the plants to the tip of the longest panicle and the mean height was computed.

3.4.2. Tiller count

The Tiller count of the individual hill was recorded at maximum tillering stage, panicle initiation stage and also at harvest. At the final observation the number of productive tillers in each hill was also separately recorded.

3.4.3. Dry weight of plant

The plants from the destructive sampling row at the rate of four hills per plot were uprooted, cut off the underground portion, washed thoroughly, oven dried at 80°C ± 5°C until same weight was obtained consecutively. This was done at maximum tillering stage, at panicle initiation stage and also at harvest of the Ist crop and at booting stage and the harvest of IInd crop. The plant material dried in the air oven at 80°C and powdered and kept in air tight plastic containers were analysed for NPK, Ca, Mg and silica so as to study the uptake of nutrients.

3.4.4. Length of panicle

The panicle of the sampling units were cut out and length measured in centimetre from the last node to the tip of the panicle of the middle panicle of each hill and mean length computed.

3.4.5. Number of spikelets per panicle

The number of spikelets from each of the panicle in the observation unit was counted separately and the mean value taken.

3.4.6. Number of filled grains per panicle

The main culm panicles from all the 12 hills were seperated based on the height of individual panicles and were threshed and number of filled grains (f), and weight of filled grains (w) were determined.

The rest of the panicles from all the 12 hills were also threshed and weight of filled grains (W) were assessed.

From the above data, the number of filled grains per panicle was computed using the following formula.

Number of filled grains/panicle = $f/w \times \frac{W+w}{P}$

where P is the total number of panicles from all the 12 hills.

3.4.7. Yield of grain and straw

Yield of grain from the net area harvested was recorded and adjusted to 14% moisture using the adjustment coefficient given by Gomez (1972) and expressed the yield in t/ha. Adjusted grain weight = A x W where A is the adjustment coefficient and W, is the dry weight of grain. Straw obtained from the net area was uniformly dried, weighed and yield of straw expressed in t/ha.

3.4.8. Grain straw ratio

From the weight of grain and straw obtained from each plot the grain straw ratio was calculated.

3.4.9. Thousand grain weight

Thousand grain weight was calculated and adjusted to

14% moisture using the formula given below

$$\text{Thousand grain weight} = \frac{100-M}{86} \times \frac{w}{f} \times 1000$$

Where M is the moisture content of filled grains

3.5. CHEMICAL ANALYSIS

Soil

Chemical analysis of the soil of the experimental plot before the layout of the experiment was carried out for Mechanical composition, and chemical composition as per the methods mentioned earlier. Soil samples were drawn from each plot after the harvest of Ist and IInd crops respectively and analysed for pH, total N, available P_2O_5, K_2O, exchangeable Ca and Mg. Available silica was also determine colorimetrically (Imaizumi and Yoshida 1955).

3.5.1. Plant analysis

The chemical analysis of the plant samples collected at the maximum tillering stage, panicle initiation stage booting stage and harvest stages was done. The observation plants (the grain and the straw) were oven dried at 80°C $\pm$ 5°C till a constant weight was obtained.

3.5.1.1. Total Nitrogen

The total Nitrogen content of the plant samples was determined employing the modified microkjeldahl method (Jackson 1967).

Preparation of plant extract

Triple acid extract of the plant samples were prepared. One gram of the powdered plant sample was digested with 10 ml triple acid mixture. The digest was cooled diluted with distilled water and made up to 100 ml, filtered and stored for further analysis.

3.5.1.2. Phosphorus

From an aliquot of the triple acid extract of the plant sample , P was determined by Vanadomolybdic phosphoric yellow colour method in nitric acid system (Piper 1966).

3.5.1.3. Potassium

The triple acid extract was diluted ten times and was directly fed into an EEL flame photometer and the potassium content was determined (Piper 1966).

3.5.1.4. Calcium and Magnesium

Calcium and Magnesium in the plant extract were determined in a Perkin Elmer model 3030 Atomic Absorption Spectrophotometer after diluting the extract 10-20 times.

3.5.1.5. Silica

Silica was determined by modified molybdenum blue method (Nayar et al 1975)

0.1 g oven dry plant sample was seperately digested with 5 ml concentrated nitric acid in a 50 ml corning glass conical flask. The digestion was continued till the brown fumes ceased and the volume was reduced to about 2 ml. The resultant solution is transferred with repeated washings into stainless stell beakers containing 1 to 1.5 g of anhydrous A.R. Sodium carbonate in suspension so that there was sufficient alkali in excess after neutralisation of the acid. The alkali suspension in the beaker was then boiled for 3 to 5 minutes to ensure complete dissolution of silica. The resultant solution after cooling was made upto 250 ml and stored in polythene bottles.

A suitable aliquot (2 ml) was treated with 2 ml 1:1 HCl and agitated for a while. Added 2 ml of 10% ammonium molybdate and the contents in the flask were allowed to stand for 5 minutes. The interference of iron was then removed by the addition of 0.5 ml of 5% solution of hydroxylamine hydrochloride and of phosphor~~o~~us by addition of 1 ml of 10% oxalic acid. The resultant silica molybdate complex after dilution almost to volume was reduced by the addition of 2 ml of 0.5% ascorbic acid and the volume made up to 50 ml. The blue colour developed on standing for 15 to 20 minutes was read on a Klett Summerson colorimeter using red filter (660 mm). Silica is expressed as percentage of S_1O_2 in the whole rice plant.

3.5.2.1. Uptake studies

The total quantities of N, P, K, Ca, Mg and silica absorbed by the crop at the time of various stages were computed and the values were expressed in g/plot.

3.5.2.2. Statistical analysis

The statistical analysis of the data was carried out following the methods outlined by Snedecor and Cochran (1967). The important correlation studies were conducted with yield and uptake of nutrients as well as plant growth factors and uptake of nutrients at critical stages of crop growth. The soil analytical data were subjected to correlation studies and their significance recorded.

RESULTS

CHAPTER IV

RESULTS

With a view to understanding the characteristics of the soil profile and surface soils two profiles were exposed during the dry season (September 1984) as a case study and 50 surface samples representative of the most problem patches were collected and their physico - chemical aspects investigated. Further, field experiments with graded doses of different liming materials keeping the fertilizer doses as per the package of practices, were also laid out during the Kharif and Rabi seasons of 1984-85. The results on the analysis of profiles, surface soils and field experiment are presented in the following sections.

4.1. Profiles

Two typical profiles were cut just before the commencement of the Rabi crop when the surface of the field was apparently dry and with innumerable cracks. Water was struck at 64 cm and 73 cm respectively in the two profile pits and sampling could be done only upto a depth of 82 cm with great difficulty. After bailing out water further excavations were done to find out the nature of the subsoil. It was found in both cases that the mineral top soil was very shallow and was followed by deposits of organic clay, partially decomposed organic matter, logs and twigs. The top cultivated soils of these areas are limited to a depth of 10 to 12 cm.

Deep ploughing is not usually practiced due to the fear of the underlying highly sandy (> 90% coarse sand) subsoil coming up. The top soil is sandy loam in nature while the sub soils are highly sandy. Excepting the top soil the sub sandy soils showed pale white, straw and orange yellow colours on visual observation at the site indicating the presence of iron in different oxidation stages consequent to alternate wetting and drying. The smell of hydrogen sulphide was very strong in both the profiles when the pits were cut open. In both the profiles typical jarosite mottlings were present in the third layers.

The description of the soil profiles are given in tables 1 and 2. The chemical characteristics and mechanical composition of different layers of the profile are presented in tables 3 and 4.

4.1.1. pH

The pH of the first layer of the two profiles were 4.8 and 5.0 respectively. In both the profiles the pH decreased with depth and in the bottommost layer (5th layer in the first profile and 4th layer in the second profile) at a depth of 62-82 cm the pH recorded was 3.4 and 3.5 respectively.

Table 1

SOIL DESCRIPTION

I. Information on the site

a) Profile number	-	1
b) Soil name (Series) Phase or mapping index etc.	-	
c) Highest category of Classification	-	Inceptisol
d) Date of examination	-	15-9-84
e) Author description	-	V. GIRIJA
f) Location	-	Pazhamchira ela, Melkadakkavur in Chirayinkil Village
g) Physiographic position surrounding land form	-	Undulating
h) Microtopography	-	Flat to gently sloping
i) Slope	-	Level
j) Vegetation	-	Paddy
k) Climate	-	Humid tropical climate
1) Rainfall	-	1435 mm
2) Temperature	-	$23^{o}C$ - $34^{o}C$

Table 1 (continued)

II. General information on the soil

a) Parent material	-	Silty alluvium
b) Drainage	-	Moderately drained
c) Moisture condition in profile	-	Wet
d) Depth of ground water	-	64 cm
e) Presence of surface stones	-	Nil
f) Evidence of errosion	-	Nil
g) Presence of salt and alkali	-	Traces to moderate with seasonal fluctuations

III. Brief description of the profile

Surface soil is more of mineral nature while organic matter content was found in larger quantities in deeper layers. Colour ranges from brown, grey yellow, dark brown and black. Acidic in reaction. Slightly saline due to salt water intrusion at times and also due to salts released during the decomposition of organic matter. Texture ranges from sandy loam to loamy sand.

Table 1 (continued)

IV. Description of individual soil horizons

	1	2	3	4	5
a) Depth in cm	0-12	12-24	24-48	48-62	62-82
b) Colour	7.5YR	10 YR	2.5YR	10 YR	10 YR
Moist	3/2	7/1	5/0	3/2	2/1
	Dark Brown	Light grey	Grey	Dark Greyish Brown	Black
Dry	10 YR	10 YR	2.5YR	10 YR	10 YR
	4/4	7/1	6/6	2/2	3/2
	Dark yellowish brown	Light grey	Light red	Very dark brown	Very dark greyish brown
c) Motling	--	--	jarosite mottling	--	--
d) Texture	Sandy loam	Sand	Sand	Sand	Loamy sand

e) Consistency

Wet	Sticky	Friable	Slightly sticky
Moist	Firm	Friable	Friable
Dry	Hard	Loose	Slightly Hard

f) Cutans - Nil

g) Cementation - Weakly cemented

h) Pores - Discontinous

1	2 3	4 5
Moderate to Fine pores	Abundant macropores	Abundant to moderate pores

Table 1 (continued)

i) Content of mineral fragments	- quartz, garnet
j) Content of mineral nodules	- Nil
k) Pans	- Nil
l) Soluble salts	- Traces
m) Features of biological origin	- Nil
n) Contents of roots	- 1: Abundant; 2: —; 3: None; 4: —; 5: —
o) Nature of boundary	- Diffuse wavy
p) pH	- 4.8, 4.1, 4.0, 4.0, 3.5
q) EC	- 0.86 0.31 0.43 2.2 4.6
r) Number of samples if any taken for analysis	- 5

V. Interpreted information on the soil

These soils can be included under acid sulphate soils of Kerala.

Table 2

SOIL DESCRIPTION

I. Information on the site	-
a) Profile number	- II
b) Soil name (Series) phase or mapping index etc.	-
c) Highest category of classification	- Inceptisol
d) Date of examination	- 15.9.84
e) Author description	- V. GIRIJA
f) Location	- Pazhamchira ela Melkadakkavur in Chirayinkil Village
g) Physiographic position surrounding land form	- Undulating
h) Microtopography	- Flat to gently sloping
i) Slope	- Level
j) Vegetation	- Paddy
k) Climate	- Humid Tropical Climate
1) Rainfall	- 1435 mm
2) Temperature	- 23^{o}C - 34^{o}C

Table 2 (continued)

II. General information on the soil

a) Parent material	-	Silty alluvium
b) Drainage	-	Moderately drained
c) Moisture condition in profile	-	Wet
d) Depth of ground water	-	73 cm
e) Presence of surface stones	-	Nil
f) Evidence of errosion	-	Nil
g) Presence of salt and alkali	-	Moderate with seasonal fluctuations

III. Brief description of the profile

Surface soil is more of mineral nature while organic matter content was found in larger quantities in deeper layers. Colour ranges from brown, grey yellow, dark brown to black. Acidic in reaction, slightly saline due to salt water intrusion at times and also due to salts released during organic matter decomposition. Texture ranges from sandy loam to loamy sand.

Table 2 (continued)

IV. Description of individual soil horizones

a) Depth in cm	0-10	10-26	26-50	51-82
b) Colour	10 YR	10 YR	2.5 YR	10 YR
Moist	4/4	7/1	5/0	3/2
	Dark yellowish brown	Light grey	Grey	Very dark grey brown
Dry	10 YR	10 YR	2.5 YR	10 YR
	4/4	7/1	6/6	2/1
	Brown	Light grey	Light red	Black
c) Motling	--	--	Jarosite	--
d) Texture	Sandy loam	Sand	Sand	Loamy sand

e) Consistency

Wet	Sticky	Friable	Friable
Moist	Firm	Friable	Friable
Dry	Hard	Loose	Slightly hard

f) Cutans - Nil

g) Cementation Weekly cemented

h) Pores Discontinuous

Very fine	Abundant	Abundant
	Macropores	Macropores

i) Content of mineral fragments -quartz, garnet

j) Content of mineral nodules - Nil

Table 2 (continued)

k) Pans	- Nil				
l) Soluble salts	- Moderate				
m) Features of biological origin	- Nil				
n) Content of roots	- 1	2	3	4	5
	Abundant	—	None		
o) Nature of boundary	- Diffuse wavy				
	1	2	3	4	
p) pH	- 5.0	3.9	3.4	3.4	
q) EC	- 0.53	0.25	0.25	0.57	
r) Number of samples if any taken for analysis	- 4				

V. Interpreted information on the soil

These soils can be classified as acid sulphate soils.

4.1.2. Electrical conductivity

Both the profiles did not have any agreement in the vertical trend of electrical conductivity. In the first profile the EC was 0.86 mmhos cm^{-1} in the first layer and 4.6 mmhos cm^{-1} in the lowest layer. In the second and third layers the EC was lower than that of surface layer, but in the last two layers the EC was substantially higher (2.2 and 4.6 mmhos cm^{-1}).

In the second profile which was near to the main drainage channel recorded comparactively lower and similar electrical conductivity in the top and lowest layers. (0.53 and 0.57 mmhos cm^{-1} respectively). The middle two layers which were sandy recorded the same EC viz: 0.25 mmhos cm^{-1}.

4.1.3. Organic Carbon

The values varied from 1.4% to 3.7% in the first profile and from 1.3 to 3.5% in the second profile. In both profiles it was the highest in the lowermost layer. The percentage of organic carbon showed an increasing trend with depth of soil in both the profiles.

4.1.4. C/N ratio

Starting from the top to the bottom layer the carbon to nitrogen ratio widened with depth in both the profiles. The ratio varied from 11.7 to 25.3 in the first profile and from 13.5 to 31.8 in the second profile.

4.1.5. Organic matter

In the surface layer the organic matter percentage was 2.6 and 2.2 respectively and in both the profiles it increased with depth. The lowermost layers contained 6.4 and 6.1 percent organic matter respectively in both the profiles. In general the organic matter increased with depth with the exception of a slight decrease in the value for the second and third layer of profile I.

4.1.6. Total Nitrogen

The total nitrogen content did not vary widely between layers. It ranged from 0.09 to 0.14% in the first profile and 0.11 to 0.14% in the second profile. In the second profile the total nitrogen content showed a decreasing trend while in the first profile the highest value of 0.14% was recorded in the lowest layer.

4.1.7. Bray extractable P_2O_5

All the layers gave a very low available P_2O_5. The lowest value (8.4 kg ha^{-1} in profile I and 7.58 kg ha^{-1} in Profile II) was noticed in the 3rd layer of both the profiles while the lowermost layers gave 12.3 and 11.3 kg ha^{-1} respectively which were the highest values for P_2O_5 in the profile.

4.1.8. Cation exchange capacity

The cation exchange capacity of the soil was the highest in the lowest layers of both the profiles followed by the surface layers. The middle layer recorded lower values. The CEC ranged from 2.8 to 12.1 in profile I and from 2.21 to 6.7 in profile II.

4.1.9. Exchangeable sodium

The exchangeable sodium was found to be very low in all the profile layers. It showed a decreasing trend with depth in profile I and II except a slight increase in the lowest layer. The values ranged from 0.04 to 0.09 and 0.03 to 0.13 respectively in profile I and II.

4.1.10. Exchangeable calcium

The content of exchangeable calcium was the highest in the top layer ie. 1.51 me/100 g and 1.0 me/100 g respectively in profile I and II. Its value was much lower with depth with a slight increase in the lowest layer in both the profiles. The values ranged from 1.51 to 0.12 me/100 g in profile I and from 1.0 to 0.17 me/100 g in profile II.

Table 3

Properties of Profile I

Properties Depth in cm	1 (0-12)	2 (12-24)	3 (24-48)	4 (48-62)	5 (62-82)
I. Mechanical composition in percentage					
1. Coarse sand	64.0	88.0	90.0	86.0	80.0
2. Fine sand	5.0	3.0	2.0	2.0	4.0
3. Silt	24.0	3.0	3.0	4.0	10.0
4. Clay	6.0	3.0	2.0	4.0	4.0
II. Chemical properties					
1. pH	4.8	4.1	4.0	4.0	3.5
2. E.C.(mmhos/cm)	0.86	0.31	0.43	2.2	4.6
3. C/N ratio	11.7	12.7	12.7	21.7	25.3
4. Organic matter (%)	2.6	2.4	2.4	3.4	6.4
5. Organic Carbon (%)	1.5	1.4	1.4	2.0	3.7
6. Total Nitrogen (percentage)	0.12	0.11	0.11	0.09	0.14
7. Available P_2O_5 kg/ha	9.81	10.2	8.4	10.2	12.3
8. Cation Exchange capacity (me/100 g)	4.43	2.8	2.9	10.8	12.1

Table 3

Properties of Profile I (continued)

Properties Depth in cm	1 (0-12)	2 (12-24)	3 (24-48)	4 (48-62)	5 (62-82)
9. Exchangeable Na(me/100 g)	0.09	0.04	0.04	0.05	0.06
10. Exchangeable Calcium (me/100 g)	1.51	0.59	0.12	0.15	0.59
11. Exchangeable Mg(me/100 g)	0.53	0.07	0.05	0.16	0.45
12. Exchangeable K(me/100 g)	0.15	0.06	0.04	0.02	0.10
13. Exchangeable Al(me/100 g)	2.07	0.72	0.86	9.4	10.7
14. Exchangeable Fe(ppm)	137	53	72	214	112
15. Water soluble Al(ppm)	4.6	Traces	Traces	19.1	24.3

Table 4. - Properties of Profile II

Properties of soil/ Depth in cm	1 (0-10)	2 (10-26)	3 (26-50)	4 (51-82)
I. Mechanical composition in %				
1. Coarse sand	60.0	81.0	86.0	80.0
2. Fine sand	5.0	8.0	6.0	4.0
3. Silt	22.0	6.0	3.0	9.0
4. Clay	10.0	2.0	2.0	3.0
II. Chemical properties				
1. pH	5.0	3.9	3.4	3.4
2. EC (mmhos cm^{-1})	0.53	0.25	0.25	0.57
3. Organic carbon (%)	1.30	2.00	2.30	3.50
4. C/N ratio	13.5	15.6	20.9	31.8
5. Total nitrogen (%)	0.14	0.12	0.11	0.11
6. Organic matter (%)	2.2	3.4	4.0	6.1
7. Available P_2O_5 kg/ha	10.42	8.93	7.58	11.3
8. CEC (me/100 g)	6.1	2.21	2.53	6.7
9. Exchangeable Na(me/100 g)	0.13	0.07	0.03	0.08
10. Exchangeable Ca (,,)	1.0	0.76	0.17	0.51
11. Exchangeable Mg (,,)	0.52	0.07	0.03	0.06
12. Exchangeable K (,,)	0.15	0.04	0.04	0.06
13. Exchangeable Al (,,)	3.59	1.28	1.92	5.5
14. Exchangeable Fe in ppm	31.1	31.0	111.5	167.1
15. Water soluble Al in ppm	9.7	Traces	Traces	18.4

4.1.11. Exchangeable magnesium

Exchangeable magnesium content ranged from 0.51 to 0.05 me/100 g soil in profile I and from 0.52 to 0.03 me/100 g soil in profile II. In the lowest layer of profile I the exchangeable magnesium content was fairly high in comparison to lowest layer of profile II. However the middle layers contained lesser amounts of exchangeable magnesium.

4.1.12. Exchangeable potassium

The exchangeable K content was very low in both the profiles. Its value ranged from 0.15 to 0.02 me/100 g in profile I and 0.15 to 0.04 me/100 g in the second profile, with slightly higher values for the lowest layer. The middle layers in both the profiles recorded the lower values.

4.1.13. Exchangeable aluminium

The exchangeable aluminium content was 2.07 and 3.59 me/100 g soil respectively in the surface layer of profile I and II. The values slightly decreased in the second and third sandy layers of both the profiles. But the highest values were recorded in the lowest layer of both the profiles. The values were 10.7 and 5.5 me/100 g soil respectively.

4.1.14. Exchangeable iron

This did not show any regularity in distribution. Exchangeable iron was the highest in the 4th layer of both the profiles. The surface layer contained appreciable quantities of iron in profile I (134 ppm) but it was comparatively low in the surface layer of profile II (31.1 ppm). The second and third layer of both the profiles contained much lesser amounts of exchangeable iron.

4.1.15 Water soluble aluminium

The water soluble aluminium was the highest in the lower most layer of both the profiles. The values were 24.3 and 18.4 ppm respectively. The surface layer of profile II contained comparatively appreciable amount of water soluble aluminium (9.7 ppm) while that of profile I was 4.6 ppm. There were only traces of water soluble aluminium in the second and third layers of profile I and II.

4.1.16. Mechanical composition

The surface layer was sandy loam with about 30% of clay and silt. The second and third layers were coarse and with more than 90% sand fraction. The lowermost layer was texturally classified as loamy sand with more than 80% coarse sand in both the profiles. This gravulometric composition of the profiles clearly indicates that the soil of the area is not having the required fine tilth or effective soil texture required for rice cultivation.

4.1.17. Soil colour

The soil colour varied from dark brown, light gray, grey, dark greish brown to black in profile I and from dark yellowish brown to light grey, grey and very dark grey brown in Profile II as per Munsell colour notations. Another important observation is the occurrence of jarosite mottlings in the third layer (within 50 cm depth) of both the profiles.

4.2. Surface samples

The whole "Ela" was traversed and 50 surface samples were collected during the dry period (February 1984) to find out their similarities, variations and other characteristics based on physicochemical analysis. The results of chemical analysis of the 50 surface samples are supplied in table 5 to 9.

4.2.1. Soil reaction (pH)

The soils were all acidic in reaction. The fresh samples as well as dry samples were subjected to pH measurement. The pH of the fresh sample ranged from 3.4 to 4.9 with a mean value of 4.18. The pH of air dried sample showed slight decrease and the values varied between 2.6 and 4.8 with a mean value of 4.05. The pH of 31 samples were above the mean value. Fifty more soil samples also were collected after the dry spell in May 1984 before the commencement of the Ist crop and the pH and EC measured. The pH ~~ranged~~ varied between 2.6 and 4.5 with a mean value of 3.89 at this time.

4.2.2. Electrical conductivity (E.C.)

The Electrical Conductivity ranged from 0.25 to 1.27 mmhos/cm for the samples collected during February 1984. Its mean value was 0.65 mmhos/cm. Twenty nine samples had Electrical Conductivity below the mean value. Higher electrical conductivity values were recorded for the samples collected in May, 1984. The values ranged from 0.43 to 3.25 mmhos cm^{-1} with a mean value of 1.21 mmhos cm^{-1} (Table 5).

4.2.3. Lime requirement

The lime requirement of the soil varied from 1.6 to 14 t/ha of $CaCo_3$ with mean value of 5.48 t/ha of $CaCo_3$. Twenty one samples had an L.R above the mean value (Table 6).

4.2.4. Cation Exchange Capacity

The surface soil samples had a low cation exchange capacity ranging from 3.8 to 9.9 me/100 g soil with a mean value of 5.9 me/100 g. Only 22 samples had Cation Exchange Capacity above the mean value (Table 6).

Table 5

Seasonal variation in pH and EC of the soils of Pazhamchira ela

Sample No.	pH of		EC of	
	Fresh soil of Feb.'84	Fresh soil of May '84	Fresh soil of Feb.'84 mmhos/cm	Fresh sample of May 1984 mmhos/cm
1	4.4	4.1	0.42	0.95
2	3.7	3.4	0.80	1.63
3	3.7	3.4	1.18	2.41
4	4.0	3.5	0.76	1.36
5	4.1	4.0	0.84	1.43
6	4.2	4.0	0.42	0.83
7	3.7	3.4	0.93	2.53
88	4.1	3.9	0.59	1.10
9	3.7	3.6	0.80	1.31
10	3.8	3.6	0.59	1.03
11	4.4	4.1	0.38	0.63
12	3.7	3.5	1.06	2.01
13	4.3	4.0	0.51	0.93
14	4.1	3.9	0.51	0.89
15	4.5	4.1	0.51	0.91
16	4.5	4.1	0.45	0.74
17	4.5	4.2	0.38	0.65
18	4.2	4.0	0.42	0.73
19	4.5	4.1	0.59	0.91
20	4.6	4.2	0.68	2.13
21	4.4	4.2	0.59	0.95
22	4.3	4.1	0.51	0.83
23	4.3	4.1	0.76	0.96
24	3.6	2.6	1.01	1.64
25	3.4	3.0	0.76	1.58

Table 5 (continued)

26	4.0	3.5	0.59	0.95
27	4.4	4.0	0.76	1.47
28	4.4	4.0	0.42	1.06
29	4.6	4.3	0.59	1.08
30	4.2	4.0	0.55	1.01
31	4.3	4.1	0.51	1.47
32	4.2	4.0	0.93	1.06
33	4.2	4.0	0.25	1.08
34	4.5	4.2	0.93	1.01
35	4.1	3.7	0.67	1.03
36	4.6	4.3	0.51	1.53
37	4.0	3.7	1.01	1.35
38	4.3	4.0	0.42	0.84
39	4.5	4.2	0.34	0.43
40	3.9	3.6	1.27	3.25
41	4.2	3.8	1.01	1.93
42	4.2	4.0	0.67	1.37
43	4.8	4.5	0.34	0.86
44	4.2	4.0	0.59	0.91
45	4.1	3.9	0.76	1.05
46	4.3	4.0	0.51	0.73
47	4.1	4.0	0.59	0.78
48	4.4	4.2	0.34	0.51
49	3.5	3.3	1.01	1.93
50	4.2	4.1	0.59	0.63
Mean	4.18	3.89	0.65	1.21

Table 6

pH, lime requirement, cation exchange capacity total exchangeable bases and base saturation percent of rice soils of Pazhamchira ela

Sample No.	pH of air-dried soil	Lime requirement (t/ha)	CEC me/100 g	Total exchangeable bases me/100 g	Base saturation percent
1	4.3	8.2	4.3	2.25	52.0
2	3.6	10.1	6.3	2.11	33.5
3	3.7	9.5	9.9	6.44	65.0
4	3.9	6.4	6.3	3.85	61.0
5	4.0	5.4	5.8	2.86	49.0
6	4.2	5.8	4.4	2.36	53.6
7	3.5	11.0	9.9	3.27	33.0
8	3.9	6.4	6.8	3.15	46.0
9	3.7	7.0	9.6	5.65	58.9
10	3.6	6.4	6.8	2.46	36.0
11	4.3	6.2	4.8	2.89	60.0
12	3.5	6.4	6.8	1.73	25.0
13	4.2	5.2	5.1	2.39	46.9
14	4.0	5.4	4.9	2.00	40.8
15	4.4	3.5	6.3	4.44	70.5
16	4.4	3.5	5.1	3.13	61.0
17	4.4	3.8	4.9	3.12	63.7
18	4.0	8.2	5.9	2.31	39.0
19	4.3	7.4	6.1	4.73	77.5
20	4.4	5.2	5.8	3.76	64.8
21	4.2	5.2	4.3	2.79	64.9
22	4.3	4.5	6.2	3.31	53.0
23	4.2	3.8	7.1	5.02	70.7
24	2.6	14.0	6.8	3.53	51.9
25	3.2	11.7	8.6	1.98	23.0

Table 6 (continued)

26	3.8	11.0	8.5	2.57	30.0
27	4.2	5.2	6.1	3.67	60.0
28	4.3	3.4	5.8	3.74	64.0
29	4.5	4.8	6.3	4.54	72.0
30	4.0	11.0	5.1	2.71	53.0
31	4.3	5.0	4.6	2.55	55.0
32	4.1	4.5	6.5	2.84	43.7
33	4.0	5.8	6.6	2.77	42.0
34	4.3	3.8	4.7	3.15	67.0
35	3.9	5.4	6.4	1.68	26.0
36	4.6	2.2	5.5	3.73	67.8
37	3.9	2.8	5.5	2.64	48.0
38	4.2	1.8	3.8	2.28	60.0
39	4.5	1.6	3.9	2.30	59.0
40	3.8	4.5	5.3	1.90	35.8
41	4.0	3.4	4.8	2.21	46.0
42	4.1	2.8	4.9	2.65	54.0
43	4.8	1.6	3.9	2.59	66.0
44	4.1	2.8	5.1	1.86	36.0
45	3.9	6.4	6.4	2.34	36.6
46	4.2	5.2	5.5	2.25	40.9
47	4.1	2.8	5.0	2.46	49.0
48	4.3	1.6	4.6	2.44	53.0
49	3.4	2.8	6.0	2.12	35.0
50	4.2	1.6	3.9	1.37	35.0
Mean	4.05	5.48	5.9	2.93	49.66

4.2.5. Total exchangeable bases

This represents the sum total of exchangeable calcium, magnesium, sodium and potassium in soil. The values varied between 1.37 to 6.44 me/100 g with a mean of 2.93. Out of 50 samples analysed the total exchangeable bases of 32 samples were below the mean value.

4.2.6. Base saturation percent

The percent base saturation varied ~~ranged~~ between 23.0 to 77.5%. The mean value was found to be 49.66%. Out of 50 samples analysed 28 samples showed values higher than the mean.

4.2.7. Exchangeable aluminium

The exchangeable aluminium (IN.KCl extractable) of the surface soil samples varied from 46 ppm to 722 ppm with an average value of 248 ppm. Only twenty three samples had exchangeable aluminium above the mean value (Table 7).

4.2.8. Water soluble aluminium

The water soluble aluminium content of the surface sample was also high ranging from 1 ppm to 118 ppm with a mean value of 19.84 ppm. Only eight samples had water soluble aluminium above the mean value.

Table 7.- KCl exchangeable Al, water soluble Al and DTPA extractable Fe in the surface soils

Sample number	Exchangeable Al in ppm	Water soluble Al in ppm	Exchangeable Fe in ppm
1	77	6	137
2	369	26	16
3	343	70	103
4	252	3	129
5	228	8	178
6	128	11	119
7	722	118	61
8	317	12	93
9	400	16	82
10	377	23	184
11	195	10	197
12	454	11	91
13	226	11	124
14	265	6	116
15	133	11	106
16	142	13	146
17	156	12	169
18	317	12	108
19	103	12	124
20	179	11	99
21	108	11	164
22	284	11	135
23	155	12	149
24	291	8	93
25	606	27	76
26	520	15	94
27	220	7	262

Table 7.- KCl exchangeable Al, water soluble Al and DTPA extractable Fe in the surface soils (continued)

28	174	11	92
29	143	11	62
30	214	11	91
31	169	11	124
32	288	5	30
33	361	9	68
34	89	7	55
35	441	18	32
36	149	10	75
37	275	8	100
38	81	9	85
39	46	10	35
40	266	11	73
41	225	3	56
42	159	10	53
43	76	11	65
44	259	8	58
45	346	1	31
46	257	9	79
47	157	9	42
48	164	7	66
49	275	1	51
50	219	9	49
Mean	248	13.8	95.5

4.2.9. DTPA Extractable iron

The DTPA extractable iron ~~ranged~~ varied between 16.0 ppm to 262.0 ppm in the surface sample. There was wide fluctuations in the exchangeable iron content among the samples analysed. The average was found to be 95.5 ppm and about 20 samples were found to have values above the mean.

4.2.10. Exchangeable Calcium

The exchangeable Calcium in the surface samples varied from 0.79 to 4.61 me/100 g with a mean value of 1.88 me/100 g. Nineteen samples had exchangeable Calcium above this mean value (Table 8).

4.2.11. Exchangeable Magnesium

The exchangeable magnesium content varied from 0.32 to 1.74 me/100 g. Twenty nine samples were found to have exchangeable magnesium lower than the mean value of 0.77 me/100 g soil.

4.2.12. Exchangeable Potassium

The values for exchangeable potassium content of these soils ranged between 0.09 to 0.24 me/100 g, the average being 0.15 me/100 g. Out of 50 samples analysed, 21 samples exhibited exchangeable potassium content above the mean value.

4.2.13. Exchangeable sodium

In general, the exchangeable sodium content of these

Table 8. - Exchangeable Ca, Mg, Na and K in the surface soils

Sl. No.	Exchangeable Ca. me/100 g	Exchangeable Mg. me/100 g	Exchangeable Na. me/100 g	Exchangeable K. me/100 g
1	1.55	0.47	0.13	0.10
2	1.38	0.40	0.20	0.09
3	4.61	1.49	0.24	0.10
4	2.60	0.93	0.17	0.15
5	1.98	0.61	0.13	0.14
6	1.48	0.61	0.14	0.13
7	2.09	0.88	0.15	0.15
8	2.10	0.73	0.16	0.16
9	4.51	0.90	0.12	0.12
10	1.60	0.44	0.21	0.21
11	1.93	0.72	0.12	0.12
12	0.99	0.44	0.14	0.16
13	1.34	0.78	0.13	0.14
14	1.22	0.49	0.14	0.15
15	3.22	0.92	0.13	0.17
16	2.24	0.65	0.12	0.12
17	1.83	1.04	0.10	0.15
18	1.27	0.76	0.12	0.16
19	2.67	1.73	0.14	0.19
20	2.64	0.87	0.11	0.14
21	1.88	0.63	0.12	0.16
22	2.01	1.00	0.11	0.19
23	2.98	1.20	0.15	0.19
24	2.01	1.74	0.13	0.15
25	1.22	0.53	0.07	0.16
26	1.59	0.72	0.10	0.16
27	2.40	0.97	0.14	0.16

Table 8. - Exchangeable Ca, Mg, Na and K in the surface soils (continued)

28	2.40	0.94	0.17	0.23
29	2.79	1.37	0.15	0.23
30	1.46	0.91	0.17	0.17
31	1.77	0.54	0.10	0.14
32	1.88	0.71	0.11	0.14
33	1.65	0.80	0.14	0.18
34	2.12	0.77	0.11	0.15
35	1.09	0.38	0.07	0.24
36	2.31	1.08	0.10	0.24
37	1.43	0.96	0.14	0.11
38	1.49	0.54	0.11	0.14
39	1.41	0.68	0.29	0.16
40	0.82	0.63	0.29	0.16
41	1.30	0.52	0.16	0.15
42	1.57	0.85	0.09	0.16
43	1.88	0.46	0.09	0.16
44	1.33	0.32	0.09	0.12
45	1.18	0.86	0.14	0.16
46	1.40	0.59	0.12	0.14
47	1.50	0.73	0.11	0.12
48	1.74	0.50	0.08	0.12
49	1.32	0.50	0.14	0.16
50	0.79	0.32	0.13	0.13
Mean	1.88	0.77	0.13	0.15

soils were very low. The values obtained were between 0.07 to 0.29 me/100 g with a mean of 0.133 me/100 g. Only 21 samples had exchangeable sodium above the mean value.

4.2.14. Total nitrogen

The total nitrogen content varied in the surface soil from 0.073 to 0.237 percent. Thirty samples showed values below the mean (0.14%) (Table 9).

4.2.15. Available Nitrogen

The surface soils had the available nitrogen in the range of 84 to 364 kg/ha with a mean value of 204.4 kg per hectare. Available nitrogen content of 26 samples were above the mean value.

4.2.16. Available P_2O_5

The available P_2O_5 content ranged between 4.64 to 16.55 kg/ha. It was more than 14 kg/ha in 5 samples and less than 6 kg/ha in four samples. The average was found to be 10.17 kg/ha. In general all the surface samples can be rated as low in available P_2O_5.

4.2.17. Available K_2O

The available K_2O content varied between 86.4 kg/ha to 220.8 kg/ha with a mean value of 142.43 kg/ha. Out of 50 samples analysed 24 samples contained available K_2O above the mean value.

Table 9. - Total N, available N, P and K in the surface soil

Sample No.	Total N in %	Available N kg/ha	Available P_2O_5 kg/ha	Available K_2O kg/ha
1	0.128	112	14.8	96.0
2	0.146	336	11.7	86.4
3	0.165	224	11.3	100.8
4	0.183	112	13.02	139.2
5	0.146	140	14.0	120.0
6	0.110	308	8.24	115.0
7	0.165	280	10.50	144.0
8	0.146	196	8.24	148.8
9	0.110	196	9.09	115.2
10	0.220	84	3.24	196.8
11	0.146	112	14.60	110.4
12	0.128	336	5.47	153.6
13	0.165	308	7.65	134.4
14	0.110	140	7.65	144.0
15	0.165	140	11.74	163.2
16	0.092	224	16.3	110.4
17	0.165	112	9.68	144.0
18	0.165	256	7.65	153.6
19	0.178	196	6.15	182.4
20	0.110	308	6.34	134.4
21	0.128	196	15.50	153.6
22	0.219	140	9.48	182.4
23	0.146	168	5.62	144.0
24	0.183	224	4.64	148.8
25	0.128	224	5.03	148.8
26	0.073	252	9.29	148.8
27	0.201	252	12.60	148.8

Table 9.- Total N, available N, P and K in the surface soil (continued)

28	0.128	196	10.14	211.2
29	0.128	140	11.90	216.0
30	0.110	168	9.30	163.2
31	0.105	224	12.80	134.4
32	0.125	140	10.73	129.6
33	0.128	196	10.58	172.8
34	0.092	140	9.48	144.0
35	0.128	112	11.58	134.4
36	0.237	140	10.53	220.8
37	0.183	112	7.85	105.6
38	0.128	112	16.55	134.4
39	0.237	84	9.48	86;4
40	0.110	224	8.04	153.6
41	0.110	280	10.90	139.2
42	0.092	280	8.98	115.2
43	0.128	364	10.53	129.6
44	0.092	252	10.73	115.2
45	0.128	280	9.68	153.6
46	0.110	224	11.90	134.4
47	0.183	224	9.25	110.4
48	0.092	224	11.70	115.2
49	0.110	280	10.92	153.2
50	0.110	252	12.80	120.0
Mean	0.141	204.4	10.17	142.43

Correlation studies of the soil properties were also carried out. It was found that pH and lime requirement are negatively correlated significantly (r = -0.667). The correlation between pH and electrical conductivity of soil samples (r = -0.607) was also negatively significant. The correlation between exchangeable aluminium and pH were negative and significant (r = -0.699). The same trend was noticed between water soluble aluminium and pH (r = -0.54).

The sodium and potassium content of the soil were also negatively correlated though not significant. The exchangeable calcium and exchangeable magnesium were positively correlated significantly (r = +0.653). Similar trend was noticed between exchangeable aluminium and water soluble aluminium (r = +0.674).

4.3. Field experiment

The results of the observations and analysis recorded during the course of the field experiment are presented in tables 10 to 29 and the analysis of variance in Appendices I to XIX.

4.3.1. Physico-Chemical analysis of the experimental soil

The results on the physical and chemical properties and nutrient status of the soils are detailed below.

4.3.1.1. Physical properties

Mechanical analysis of the soil sample of the field

Table 10.- Basic data of the soil of the experimental area

I. Mechanical composition	
Coarse sand (%)	: 64
Fine sand (%)	: 5
Silt (%)	: 24
Clay (%)	: 6
II. Chemical composition	
Soil reaction (pH)	: 4.3
Lime requirement	: 8.2 tonnes/ha as $CaCO_3$
Electrical conductivity	: 0.48 mmhos/cm
Cation exchange capacity	: 4.43 me/100 g
DTPA extractable iron	: 137 ppm
Exchangeable Al	: 1.2 me/100 g
Water soluble Al	: 11 ppm
Available silica	: 0.0034%
Total N	: 0.134%
Available N	: 112.0 kg/ha
Available P_2O_5	: 14.6 kg/ha
Available K_2O	: 103.2 kg/ha
Exchangeable calcium	: 1.55 me/100 g
Exchangeable magnesium	: 0.60 me/100 g
Exchangeable sodium	: 0.13 me/100 g

experiment plot revealed that the soil is of sandy loam texture. The values for clay, silt, fine sand and coarse sand fraction of the composite soil sample are 6%, 24%, 5% and 64% respectively.

4.3.1.2. Chemical analysis of soil

The data on the chemical analysis of plot wise soil sample before planting and after harvest of Rabi crop are given in table 11 and 12.

The table 11 revealssignificant increase in soil pH in all the limed plots except in treatments T_5,T_4,T_8 & T_1. The treatments were not significant in the case of residual N, Na, Mg, Si and P_2O_5. The potassium content of the soil treated with CaO and Bhushakthi at the rate of ½ LR (T_3 and T_7) and the treatment with double the recommended dose of K (40 kg K_2O per hectare) (T_8) gave significantly high values for potassium. It was superior over control and steatite treatments. The residual calcium content of the treated plots gave significantly high values in treatments with calcium oxide and Bhushakthi at both the levels (T_2, T_7, T_3 and T_6) over the other treatments T_4, T_5, T_8 and T_1.

As per the data presented in table 12 and appendix II the treatments are not significant in respect of N, P, K, Na

Table 11.- Effect of different soil amendments on soil properties after the harvest of Kharif crop

Treatment	pH	Total N %	Available P_2O_5 kg/ha	Available K_2O kg/ha	Exchangeable Calcium me/100g	Exchangeable Magnesium me/100g	Exchangeable Sodium me/100g	Silica ppm
T_1	4.1	0.15	21.7	112.0	1.6	0.60	0.11	32.6
T_2	4.8	0.13	25.7	150.4	4.8	0.63	0.13	41.6
T_3	5.0	0.13	25.2	195.2	4.0	0.79	0.13	35.0
T_4	4.3	0.12	22.8	178.0	1.4	0.76	0.10	49.0
T_5	4.3	0.12	22.6	137.6	1.6	0.84	0.11	49.0
T_6	4.6	0.14	25.2	155.2	3.8	0.87	0.11	43.0
T_7	5.0	0.12	23.9	185.6	4.1	0.82	0.12	48.0
T_8	4.3	0.13	23.7	185.6	1.7	0.65	0.11	32.0
CD for comparing treatment Mean at 0.05 level	0.32	NS	NS	33.6	0.7	NS	NS	NS

Table 12.- Effect of different soil amendments on soil properties after the harvest of Rabi crop

Treatment	Total N %	P_2O_5 kg/ha	K_2O kg/ha	Na me/100 g	Ca me/100 g	Mg me/100 g	Si ppm
T_1	0.31	21.7	102.4	0.13	2.05	0.68	37.3
T_2	0.29	25.7	116.8	0.14	4.71	0.66	52.6
T_3	0.25	25.2	99.2	0.16	5.09	0.74	79.0
T_4	0.34	22.8	113.6	0.14	2.05	0.62	93.6
T_5	0.30	22.6	96.0	0.13	1.97	0.79	96.0
T_6	0.27	25.2	107.2	0.14	3.95	1.02	63.6
T_7	0.29	23.9	108.8	0.14	5.03	1.14	63.3
T_8	0.28	23.7	116.8	0.12	2.23	0.63	34.6
CD for comparing treatment Mean at 0.05 level	NS	NS	NS	NS	NS	0.289	57.30

and calcium content of the soil. The residual Mg content of the soil treated with two levels of steatite increased progressively though not significantly. But the residual magnesium content of the soil significantly increased with both levels of Bhushakthi. The residual silica content of the steatite treated plot was on par with T_3 (CaO at $\frac{1}{2}$ LR) and was superior over control plot. T_3, T_4, T_5, T_6 and T_7 were on par in respect of residual silica content of the soil.

4.3.2. Effect of different soil amendments on the biometric characteristics of rice (variety Ptb-8) Kharif 1984

4.3.2.1. Height of plant

The data relating to the height of plants at various stages of growth is presented in Table 13 and the analysis of variance in Appendix III. The table shows that the height of plants at the maximum tillering stage is significantly increased by the application of both the levels of Calcium oxide and Bhushakthi. The same trend was followed at the panicle initiation and booting stages also $(\overline{T_3T_7} > \overline{T_2T_6} > T_1)$. At the harvest stage T_3 (CaO $\frac{1}{2}$ LR) and T_7 (Bhushakthi $\frac{1}{2}$ LR) were significantly superior to all other treatments $(\overline{T_3T_7} > \overline{T_2T_6} > \overline{T_1T_8} > \overline{T_5T_4})$. However, treatment T_8 did not increase the plant height at all stages of plant growth, while T_5 and T_4 decreased the plant height significantly at

Table 13.- Influence of different soil amendments on the height of plants (Ptb 8)

Treatment	Plant height in Centimetre			
	Maximum tillering stage	Panicle initiation stage	Booting stage	At harvest
T_1	66.85	88.49	90.44	103.35
T_2	74.83	95.66	97.55	111.47
T_3	80.83	104.16	108.30	118.47
T_4	65.94	83.44	85.66	97.50
T_5	63.33	85.38	87.24	97.60
T_6	72.63	95.19	97.63	109.52
T_7	78.77	103.16	107.30	118.82
T_8	70.69	88.97	91.99	106.16
CD at 0.05 level	5.664	3.439	3.933	3.698

harvest. The mean plant height of T_3 and T_7 were 118.4 cm and 118.8 cm respectively as compared to 103.35 cm recorded in the case of control.

4.3.2.2. No. of tillers

The data relating to tillering is presented in Table 14 and Appendix IV. The results reveal that treatments T_8, T_4 and T_5 did not have any significant increase in the number of tillers at all the stages of plant growth. The number of tillers increased significantly by the application of both the levels of CaO and Bhushakthi (T_3, T_7, T_2 and T_6). At maximum tillering stage, T_3 was superior to all other treatments while at panicle initiation stage the trend was $\overline{T_3T_7} > \overline{T_2T_6} > \overline{T_5T_4T_8T_1}$. Average number of tillers in T_3, T_7T_2 and T_6 at harvest were 10.56, 9.14, 8.63 and 8.15 respectively.

4.3.2.3. No. of productive tillers

The number of productive tillers were significantly increased in treatments T_7, T_3, T_2, T_6 and T_8 over control. The application of steatite was not effective in increasing the number of productive tillers of the crop.

4.3.2.4. Panicle characteristics

The data relating to various panicle characters are presented in Table 15 and Appendix V.

Table 14.- Influence of different soil amendments on the tillering ability of rice (Ptb 8)

Treatment	Total number of tillers			No. of productive tillers
	Maximum tillering stage	Panicle initiation stage	At harvest	
T_1	7.67	7.22	7.12	5.58
T_2	9.24	8.66	8.63	6.08
T_3	10.85	10.66	10.51	6.37
T_4	8.11	7.66	7.56	5.68
T_5	8.20	7.77	7.67	5.94
T_6	8.90	8.25	8.15	6.04
T_7	10.19	9.74	9.64	6.39
T_8	7.91	7.64	7.54	6.04
CD at 0.05 level	0.665	0.852	0.892	0.457

4.3.2.4.1. Length of panicle

Treatments T_3, T_7 and T_2 gave panicle lengths in the range of 20.77 to 21.6 cm which were significantly higher than T_6 T_4 T_8 and T_1. Treatments $T_5T_6T_4T_8$ and T_1 were on par.

4.3.2.4.2. No. of spikelets per panicle

Treatments T_3 and T_7 were found to be superior to all other treatments. There were 89 spikelets per panicle in T_3 and 87 for T_7. The number of spikelets ranged from 75 to 80 for all other treatments.

4.3.2.4.3. Number of filled grains

The data revealed that the application of calcium oxide at ½ lime requirement and Bhushakthi at the ½ lime requirement were equally good in increasing the number of filled grains per panicle. There were 69 filled grains per panicle in T_7 and 67.45 in T_3. The effect of T_2 and T_8 were also positive in increasing the number of filled grains as compared to control plants.

4.3.2.5. Yield characteristics

4.3.2.5.1. Yield of grain

The data on grain yield is presented in Table 16 and analysis of variance table in Appendix VI. The highest grain

Table 15.- Influence of different soil amendments on the panicle characters of rice (Ptb-8)

Treatments	Panicle characters		No. of filled grains
	Length of panicle cm	No. of spikelets	
T_1	18.93	74.80	52.20
T_2	20.77	77.84	60.51
T_3	21.60	86.61	67.45
T_4	19.50	79.38	52.06
T_5	19.66	79.93	52.54
T_6	19.53	74.53	55.78
T_7	20.93	88.95	69.03
T_8	19.06	76.01	57.33
CD at 0.05 level	1.145	6.416	3.797

yield was obtained in T_7 and T_3 (Bhushakthi and Calcium oxide at $\frac{1}{2}$ LR each). These two treatments gave a per hectare grain yield of 3.7 and 3.5 tonnes respectively. T_2 T_6 and T_8 were on par in the case of grain yield but superior to ~~over~~ control. However T_4 and T_5 were not able to improve the grain yield.

4.3.2.5.2. Yield of straw

Straw yield was the highest in T_7 (6.03 t/ha) which was on par with T_3 (5.9 t/ha). The yield of straw was not significantly different among treatments T_6, T_4, T_8 and T_2.

4.3.2.5.3. Grain straw ratio

An increase in grain straw ratio was observed in treatments T_2 and T_7 alone compared to control. The values were 0.60 to 0.61. All other treatments were found to be on par with that of control.

4.3.2.5.4. Thousand grain weight

The application of Bhushakthi at both the levels alone was found to increase thousand grain weight significantly. The value was 24.9 g. All the other treatments were on par with control. Treatment T_5 was strikingly inferior to control and all other treatments. Treatment T_3 was superior to T_4, while T_6, T_7, T_3 and T_2 were on par.

Table 16.- Influence of different soil amendments on the yield characters of rice (Ptb 8)

Treatment	Yield characters			Thousand grain weight (g)
	Weight of grain t/ha	Weight of straw t/ha	Grain straw ratio	
T_1	2.256	4.066	0.55	23.30
T_2	2.980	4.825	0.60	23.90
T_3	3.480	5.914	0.59	24.40
T_4	2.380	4.513	0.53	22.90
T_5	2.210	4.074	0.55	21.66
T_6	2.790	4.825	0.58	24.93
T_7	3.660	6.037	0.61	24.90
T_8	2.730	4.609	0.59	23.10
CD at 0.05 level	0.2720	0.3502	0.042	1.211

4.3.3. Effect of different soil amendments on the biometric characteristics of rice (variety Vyttila-1) Rabi-1984.

4.3.3.1. Height of plants

The data relating to the height of plant at various growth stages is presented in Table 17 and the analysis of variance table in Appendix VII. The height of plant increased with the application of soil amendments. But this increase was not significant in the case of T_4, T_5 and T_8 treatments while T_7 and T_3 were found to increase the plant height significantly. T_7 was found to be superior to all other treatments at booting stage while it was on par with T_3 and T_5 at harvest stage. However T_8 and T_4 were not found to improve the plant height at both stages.

4.3.3.2. Number of tillers

The data relating to number of tillers under different treatment is presented in Table 18 and the analysis of variance table in Appendix VIII.

The number of tillers at booting generally increased with the application of all the soil amendments. The highest increase was recorded by T_3 followed by T_7 at this stage and T_3 and T_7 were on par at harvest stage also. Treatments T_2

Table 17.- Influence of different soil amendments on the height of plants (Vyttila-1)

Treatment	Plant height in cm	
	At booting stage	At harvest
T_1	77.75	93.88
T_2	83.72	100.15
T_3	87.01	107.23
T_4	78.41	98.13
T_5	80.26	100.32
T_6	81.55	99.65
T_7	91.13	104.48
T_8	79.62	94.10
CD at 0.05 level	3.355	4.616

Table 18.- Influence of different soil amendments on the tillering ability of the crop (Vyttila-1)

Treatments	No. of tillers		Number of productive tillers
	Booting stage	At harvest	
T_1	5.88	5.03	4.10
T_2	6.36	5.63	4.30
T_3	7.19	6.40	5.30
T_4	6.25	5.30	4.16
T_5	6.36	5.30	4.16
T_6	6.55	5.80	4.36
T_7	7.11	6.40	4.86
T_8	6.55	5.50	4.13
CD at 0.05 level	0.554	0.547	0.303

and T_6 were found to be superior over control at harvest but at booting T_2 was on par with the control. However, application of steatite or additional dose of potash could not increase plant height significantly at the harvest.

4.3.3.3. Number of productive tillers

The number of productive tillers also increased with the application of soil amendments though not significant in T_6, T_2, T_5, T_4 and T_8 at 5 per cent level. Treatment T_3 was superior to T_7, which was superior over control. The number of productive tillers were more for T_3 (5.3) followed by T_7 (4.9). No significant difference in the number of productive tillers were observed for all other treatments.

4.3.3.4. Panicle characters

The data pertaining to various panicle characteristics are presented in Table 19 and the analysis of variance table given in Appendix IX.

The length of panicle showed no significant difference. It ranged from 20 cm to 22 cm within the treatments.

The number of spikelets per panicle also did not show any significant difference among the treatments, the range being 40 to 45.

Table 19.- Influence of different soil amendments on the panicle characters of rice (Vyttila-1)

Treatment	Panicle characters		No. of filled grains
	Panicle length in cm	No. of spikelets per panicle	
T_1	20.95	44.02	35.73
T_2	21.72	44.90	37.10
T_3	20.94	43.90	37.90
T_4	20.04	41.50	34.50
T_5	20.88	41.50	34.90
T_6	21.33	43.62	37.40
T_7	21.33	43.59	38.50
T_8	20.51	40.22	34.30
CD at 0.05 level	N.S	N.S	N.S

The number of filled grains per panicle also were not significantly different among the treatments. Its range was between 34 and 39.

4.3.3.5. Yield characteristics

The data relating to yield characteristics are presented in Table 20 and the analysis of variance table is given in Appendix X.

4.3.3.5.1. Grain yield

The data revealed that the highest grain yield was obtained with the application of Calcium oxide and Bhushakthi at ½ lime requirement. Grain yield did not significantly differ between T_3 and T_7 but they were found to yield better than other treatments. Also T_6 was found to increase yield of grain over T_4 and T_8. The performance of T_2 was on par with T_5, T_1, T_4 and T_8.

4.3.3.5.2. Yield of straw

T_3 was superior to all the other treatments except T_7, which inturn was on par with T_4, T_2 and T_5. Straw yield was not significantly different from that of control for T_6 and T_8. The lowest straw yield was recorded in T_8. The effect of T_3 in increasing straw yield was equally good as that of T_7.

4.3.3.5.3. Grain straw ratio

This value did not vary significantly between treatments.

4.3.3.5.4. Thousand grain weight

The thousand grain weight was the highest in T_3 followed by T_7. The treatment T_6 recorded significantly higher values of thousand grain weight over control. The trend was in the order of $\overline{T_3 T_7} > T_6 > \overline{T_1 T_2 T_4 \text{ and } T_8}$.

4.3.4. CHEMICAL ANALYSIS OF PLANT

The grain and straw were analysed for the N,P,K,Ca, Mg and Si content. The results of the analysis, both Ptb-8 (Kharif 1984) and Vyttila-1 (Rabi 1984), are presented in Tables 21 to 24 and the analysis of variance table are supplied in Appendix XI to XIV.

Analysis of Grain

The analytical data of the grain (Ptb-8) is given in Table 21 and the analysis of variance table is presented in Appendix XI.

4.3.4.1. Nitrogen content of grain

The analysis of the data revealed that the effect of CaO and Bhushakthi at both levels are highly significant on

Table 20.- Influence of different soil amendments on the yield characters of rice (Vyttila-1)

Treatment	Yield characters			
	Yield of grain (t/ha)	Yield of straw (t/ha)	Grain straw ratio	Thousand grain weight (g)
T_1	1.983	3.551	0.556	27.33
T_2	2.121	4.139	0.506	27.40
T_3	2.599	4.965	0.526	27.80
T_4	1.914	4.213	0.453	27.40
T_5	1.988	4.085	0.488	27.30
T_6	2.258	3.643	0.613	27.60
T_7	2.555	4.514	0.563	27.76
T_8	1.895	3.377	0.506	27.36
CD at 0.05 level	0.2942	0.6361	NS	0.129

the nitrogen content of the grain. The application of steatite had no significant contribution in increasing the nitrogen content of the grain. However, T_8 was found to be significantly superior as compared to control.

4.3.4.2. Phosphorus content of grain

The phosphorus content of grain increased significantly in treatments T_3 and T_7, while all other treatments were on par with the control.

4.3.4.3. Potassium content of grain

Different treatments did not give any significant variation in the potassium content of grains.

4.3.4.4. Calcium content of grain

Treatments T_3, T_7, T_6, T_2 and T_8 were superior to control. This showed that the application of Bhushakthi and Calcium oxide at both the levels and also T_8 increased the Calcium content of grain significantly. The trend is in the order of $\overline{T_3 T_7} > \overline{T_6 T_2 T_8} > T_1$.

4.3.4.5. Magnesium content of grain

The content of magnesium was the highest in T_7(0.168%) which was on par with T_5 and T_6. This shows that the application of steatite and Bhushakthi has resulted in an increase

Table 21.- Influence of different soil amendments on the composition of rice grain (Variety Ptb-8)

Kharif 1984

Treatment	N %	P %	K %	Ca %	Mg %	Si %
T_1	1.26	0.26	0.60	0.068	0.105	3.73
T_2	1.42	0.23	0.50	0.087	0.130	3.16
T_3	1.54	0.33	0.46	0.102	0.137	2.95
T_4	1.29	0.27	0.43	0.077	0.145	3.90
T_5	1.18	0.26	0.40	0.071	0.156	4.13
T_6	1.42	0.29	0.50	0.092	0.149	3.21
T_7	1.53	0.33	0.46	0.100	0.168	3.11
T_8	1.37	0.27	0.60	0.084	0.106	3.41
CD at 0.05 Level	0.103	0.046	N.S	0.0119	0.0224	0.114

in the magnesium content of rice grain. T_2, T_4 and T_3 were superior over control at 5% level. T_8 was on par with the control (T_1).

4.3.4.6. Silica content of grain

The silica content of grain was the highest in T_5. Increasing levels of steatite were followed by an increase in the silica content of rice grain. The silica content of the grain was the least in T_3 while that of treatments T_8 and T_1 were significantly higher than that of T_6, T_2, T_7 and T_3 all of which involve CaO and Bhushakthi. The trend was $T_5 > T_4 > T_1 > T_8 > \overline{T_6 T_2 T_7} > T_3$.

4.3.5. Analysis of straw

The data pertaining to the chemical composition of straw of Ptb-8 is presented in Table 22 and the analysis of variance table is given in Appendix XII.

4.3.5.1. Nitrogen content of straw

The nitrogen content of straw was significantly increased by increasing levels of calcium oxide and Bhushakthi. Treatments T_8, T_4 and T_5 could not increase the nitrogen content of rice straw. The nitrogen content decreased as the levels of steatite increased though not significantly, the trend being $\overline{T_3 T_7} > \overline{T_6 T_2} > \overline{T_8 T_1 T_4 T_5}$.

Table 22.- Influence of different soil amendments on the composition of rice straw (Ptb-8)

Treatment	N %	P %	K %	Ca %	Mg %	Si %
T_1	0.49	0.053	1.10	0.583	0.215	9.70
T_2	0.63	0.063	0.90	0.773	0.231	9.36
T_3	0.77	0.076	0.83	0.916	0.215	9.34
T_4	0.47	0.056	0.80	0.676	0.247	10.77
T_5	0.43	0.056	0.76	0.590	0.226	11.48
T_6	0.63	0.066	0.90	0.796	0.247	9.49
T_7	0.72	0.066	0.83	0.896	0.241	9.36
T_8	0.51	0.056	1.13	0.780	0.227	9.64
CD at 0.05 level	0.083	0.0104	0.163	0.0601	N.S	0.829

4.3.5.2. Phosphorus content of straw

The phosphorus content of straw increased significantly in treatments T_3, T_7 and T_6 which were superior over control. Treatment T_3 was superior to T_2, T_4, T_5, T_8 and T_1. All other treatments had no significant effect on the phosphorus content of rice straw.

4.3.5.3. Potassium content of straw

The potassium content of straw was found to decrease in limed plots significantly. The highest content was recorded in T_8 which was on par with the control. All other treatments recorded lower levels of potassium content without any statistical significance.

4.3.5.4. Calcium content of straw

The calcium content of straw increased with increasing levels of the three liming materials though the effect of steatite was not significant. Treatments T_3 and T_7 were superior over all other treatments. The calcium content of rice straw was significantly high in treatment T_6 as well which was on par with T_8 and T_2.

4.3.5.5. Magnesium content of straw

There was no significant difference among treatments in the magnesium content of straw.

4.3.5.6. Silica content of straw

The silica content of rice straw increased significantly by the application of steatite in treatments T_4 and T_5 which were on par and were superior ~~over~~ all other treatments.

4.3.6. Analysis of grain (Vyttila-1) Rabi 1984

The data is furnished in Table 23 and Appendix XIII.

4.3.6.1. Nitrogen content of grain

Nitrogen content of grain increased significantly in treatments T_7, T_3, T_2 and T_6. All other treatments had the least effect on increasing the nitrogen content of grain.

4.3.6.2. Phosphorus content of grain

The phosphorus content of grain increased significantly in all treatments compared to T_1. The trend was $\overline{T_7T_3} > \overline{T_5T_2T_4}$ and T_8; $T_6 > \overline{T_4T_8}$ and T_1.

4.3.6.3. Potassium content of grain

The potassium content of grain was the highest in T_8 and it was superior to all other treatments. The application of steatite, calcium oxide and Bhushakthi decreased the potassium content of grain though the decrease showed a significant trend in T_3 only.

Table 23.- Influence of different soil amendments on the composition of rice grain (Variety Vyttila-1) Rabi 1984

Treatment	N %	P %	K %	Ca %	Mg %	Si %
T_1	1.14	0.273	0.326	0.169	0.126	3.61
T_2	1.32	0.310	0.306	0.238	0.127	3.23
T_3	1.37	0.353	0.300	0.287	0.132	3.04
T_4	1.18	0.303	0.316	0.223	0.131	3.87
T_5	1.14	0.320	0.306	0.204	0.135	4.03
T_6	1.32	0.330	0.310	0.223	0.121	3.26
T_7	1.37	0.370	0.306	0.228	0.129	3.07
T_8	1.23	0.303	0.360	0.174	0.114	3.42
CD at 0.05 level	0.138	0.0235	0.0253	N.S	N.S	0.182

4.3.6.4. Calcium and Magnesium content of grain

There was no significant difference between all the trêatments in the calcium and magnesium content of the grain.

4.3.6.5. Silica content of grain

The silica content of rice grain increased significantly in treatments T_4 and T_5 while its content decreased in T_6, T_2, T_3 and T_7. This shows that the application of CaO and Bhushakthi decreased the silica content of rice grain significantly.

4.3.7. Analysis of straw of Vyttila-1

The data relating to the chemical composition of straw of Vyttila-1 is given in Tables 24 and the analysis of variance table is presented in Appendix XIV.

4.3.7.1. Nitrogen content of straw

The nitrogen content of rice straw increased with increasing levels of calcium oxide and Bhushakthi. Treatments T_7, T_3, T_6 and T_2 were on par. The treatments T_7, T_3 and T_6 were found to increase the nitrogen content of straw significantly over the control.

4.3.7.2. Phosphorus content of straw

The phosphorus content was significantly higher in T_3 and

Table 24.- Influence of different soil amendments on the composition of rice straw (Vyttila-1)

Treatment	N %	P %	K %	Ca %	Mg %	Si %
T_1	0.72	0.083	2.06	0.387	0.311	9.41
T_2	0.82	0.096	1.93	0.522	0.339	9.11
T_3	0.92	0.110	1.70	0.734	0.349	9.06
T_4	0.72	0.083	1.90	0.583	0.339	10.03
T_5	0.77	0.083	1.83	0.494	0.335	10.35
T_6	0.91	0.093	2.03	0.553	0.328	9.33
T_7	0.94	0.106	1.93	0.653	0.323	9.40
T_8	0.77	0.090	2.16	0.448	0.302	9.48
CD at 0.05 level	0.124	0.0086	0.221	0.1132	NS	0.431

T_7. Treatments T_2, T_6 and T_8 were also superior over control while T_4 and T_5 were on par with T_1.

4.3.7.3. Potassium content of straw

The potassium content in the straw was found to decrease in treatments T_3, T_4, T_5, T_7 and T_2 while the K content was the highest in T_8 which was on par with T_6 and the control.

4.3.7.4. Calcium content of straw

Calcium content of straw was the highest in T_3 followed by T_7. The treatments T_4, T_6 and T_2 were also superior to control. All other treatments could not increase the calcium content of straw.

4.3.7.5. Magnesium content of straw

The treatments were not significant as far as the magnesium content straw was considered.

4.3.7.6. Silica content of straw

The silica content of straw also increased significantly with the application of steatite. T_4 and T_5 were superior to all other treatments which were on par.

4.3.8. Uptake of nutrients at different growth stages of Ptb-8

4.3.8.1. Maximum tillering stage

The data relating to the uptake of nutrients at maximum tillering stage is given in Table 25 and Appendix XV.

Table 25.- Influence of different soil amendments on the uptake of nutrients at maximum tillering stage (Ptb-8) in g/plot

Treatment	N	P	K	Ca	Mg	Si
T_1	24.12	5.42	52.53	9.00	4.08	107.73
T_2	60.13	12.83	95.84	23.73	9.14	223.73
T_3	82.89	18.48	113.07	40.33	11.62	305.78
T_4	31.60	6.01	76.75	21.13	7.62	183.59
T_5	27.26	4.62	70.10	19.53	7.73	185.46
T_6	36.47	8.86	67.11	24.43	6.57	187.57
T_7	72.51	16.04	105.82	40.66	13.67	272.20
T_8	36.87	8.00	73.23	15.26	4.73	144.70
CD at 0.05 level	10.390	2.342	14.193	7.883	2.366	37.600

4.3.8.1.1. Nitrogen

The uptake of nitrogen was significantly high in treatments T_3 and T_7. These two treatments were superior over T_2 which in turn was significantly superior over T_8 and T_6. All other treatments could not increase the uptake of nitrogen at this stage of plant growth.

4.3.8.1.2. Phosphorus

Treatment T_3 was superior to T_7 and the increased uptake was in the order of $T_3 > T_7 > T_2 > \overline{T_6 T_8} > T_1$. Calcium oxide at ½ LR ranked first in the uptake of phosphorus at maximum tillering stage and it was significantly superior to all other treatments. Application of steatite had no significant effect on the uptake of phosphorus.

4.3.8.1.3. Potassium

Treatments T_3 and T_7 were highly superior over all other treatments in the uptake of potassium. The trend was $T_3 > T_2 > \overline{T_4 T_8 T_5 T_6} > T_1$.

4.3.8.1.4. Calcium

The uptake of calcium was the highest in T_7 followed by T_3. This trend was followed by treatments T_2 and T_6 which were on par with T_4 and T_5. The least calcium uptake was in the control plot (T_1) and the plot receiving double dose of K_2O (T_8).

4.3.8.1.5. Magnesium

The uptake of magnesium increased significantly in treatments T_7, T_3, T_2, T_5, T_4 and T_6 while T_7 and T_3 were superior over the other treatments. $T_2 > T_6 T_8$ and T_1.

4.3.8.1.6. Silica

Treatment T_3 and T_7 recorded significantly increased uptake of silica followed by T_2, T_6, T_5 and T_4. The treatment T_8 could not increase the uptake of silica at maximum tillering stage and it was on par with the control.

4.3.8.2. Panicle initiation stage (Ptb-8)

The data relating to the uptake of nutrients at the panicle initiation stage of Ptb-8 is given in Table 26 and the analysis of variance table is presented in Appendix XVI.

4.3.8.2.1. Nitrogen

Treatments T_3 and T_7 were found to be superior over all other treatments. In general increasing levels of calcium oxide and Bhushakthi increased the uptake of nitrogen significantly. Treatments T_2 and T_6 ranked next. The trend was $\overline{T_3 T_7} > \overline{T_6 T_2} > \overline{T_5 T_8 T_4} > T_1$.

4.3.8.2.2. Phosphorus

The uptake of phosphorus also followed similar trend as that of nitrogen uptake. Treatments T_3 and T_7 recorded

Table 26.- Influence of different soil amendments on the uptake of nutrients at panicle initiation stage g/plot (Ptb-8)

Treatment	N	P	K	Ca	Mg	Si
T_1	42.15	6.06	63.52	19.60	9.95	301.36
T_2	81.69	14.30	103.19	39.72	21.30	528.80
T_3	122.25	23.92	131.23	72.15	28.94	782.70
T_4	59.07	12.60	98.91	36.33	18.91	522.36
T_5	65.08	12.63	101.94	41.91	19.20	593.10
T_6	93.44	15.75	104.33	51.54	20.72	579.23
T_7	115.78	22.07	130.09	70.22	27.79	748.66
T_8	64.90	11.56	91.93	30.61	16.23	415.86
CD at 0.05 level	12.686	1.924	16.578	11.027	5.011	70.570

the maximum phosphorus uptake over T_6, T_2 which were on par and superior over control. Treatments T_5, T_4 and T_8 also were superior over control in increasing the uptake of phosphorus.

4.3.8.2.3. Potassium

The uptake of potassium was significantly increased by treatments T_3 and T_7 and they were superior to all other treatments. The treatment T_2, T_6, T_4, T_8 and T_5 also increased the potassium uptake significantly over the control.

4.3.8.2.4. Calcium

T_3 and T_7 ranked first in the uptake of calcium at panicle initiation stage followed by other treatments except T_8 which was on par with control. The trend was $\overline{T_3T_7} > T_6 > \overline{T_2T_4} > T_1$. The treatments T_5 was superior to T_8 and T_1 which were on par.

4.3.8.2.5. Magnesium

The uptake of magnesium followed similar trend as that of calcium. The trend was $\overline{T_3T_7} > \overline{T_2T_6T_5T_4T_8}$ which were on par and superior over control. Both levels of steatite were equally good in the uptake of magnesium.

4.1.8.2.6. Silica

The uptake of silica also followed a trend exactly similar to that of magnesium as explained above at panicle initiation stage of Ptb 8. The trend was $\overline{T_3T_7} > \overline{T_5T_6T_2T_4} > T_8 > T_1$.

4.3.8.3. At harvest

The data relating to the uptake of nutrients as influenced by different soil amendments at harvest stage is given in Table 27 and the analysis of variance table is presented in Appendix XVII.

4.3.8.3.1. Nitrogen

The increasing levels of calcium oxide and Bhushakthi significantly increased the uptake of nitrogen at the harvest of the crop. The effect of steatite was not significant but T_8 was superior to T_1. The treatments followed a trend of $\overline{T_3T_7} > \overline{T_2T_6} > T_1 < T_8$.

4.3.8.3.2. Phosphorus

The uptake of phosphorus was the highest in T_3 followed by T_7 and was highly significant over T_2, T_6 and T_8. As in the case of nitrogen steatite application did not influence phosphorus uptake.

4.3.8.3.3. Potassium

The uptake of potassium in T_7, T_3, T_2, T_8 and T_6 were on par with the control. But K uptake was significantly reduced in T_4 and T_5.

Table 27.- Influence of different soil amendments on the uptake of nutrients at harvest g/plot (Ptb-8)

Treatment	N	P	K	Ca	Mg	Si
T_1	65.49	10.96	79.39	34.37	15.28	647.54
T_2	98.34	15.85	78.87	53.97	21.45	735.76
T_3	134.66	22.11	86.36	78.40	23.79	880.11
T_4	70.82	12.34	63.01	43.87	23.81	789.19
T_5	70.90	10.93	54.40	34.80	23.29	759.02
T_6	95.34	15.48	77.66	56.40	20.73	700.44
T_7	135.98	22.11	91.49	78.38	28.76	963.05
T_8	81.60	13.85	85.55	52.11	17.50	729.05
CD at 0.05 level	11.680	2.148	13.432	8.312	3.376	93.930

4.3.8.3.4. Calcium

The application of steatite increased the uptake of calcium though not significantly. Increasing levels of Bhu-shakthi and calcium oxide significantly increased the uptake of calcium. T_8 was found to be on par with T_6 and T_2. The trend was $\overline{T_3T_7} > \overline{T_2T_6T_8} > T_1$.

4.3.8.3.5. Magnesium

The uptake of magnesium was the highest in T_7 and it was superior over all other treatments. T_4, T_3, T_5, T_2 and T_6 were superior over control. T_8 was on par with T_1.

4.3.8.3.6. Silica

The uptake of silica was the highest in T_7 followed by T_3. Treatments T_4 and T_5 were also superior to the control. Treatments T_2 T_8 and T_6 could not influence the uptake of silica at the harvest. The trend was $T_7 > \overline{T_3T_4T_5} > T_1$.

4.3.8.4. Uptake of nutrients Vyttila-1

Booting stage

The data relating to the uptake of nutrients at booting stage of Vyttila-1 is given in Table 28 and the analysis of variance table in Appendix XVIII.

4.3.8.4.1. Nitrogen

The uptake of nitrogen increased in treatments T_3, T_7

Table 28.- Influence of different soil amendments on the uptake of nutrients at booting stage
Vyttila-1 g/plot

Treatment	N	P	K	Ca	Mg	Si
T_1	29.98	6.70	53.70	3.88	5.35	167.73
T_2	43.19	9.70	60.63	6.94	7.36	197.60
T_3	49.81	9.89	67.83	8.04	8.12	210.16
T_4	30.09	8.30	55.20	4.58	6.37	194.60
T_5	31.86	6.84	54.96	4.85	6.83	198.00
T_6	39.08	9.08	56.86	6.86	7.02	188.10
T_7	47.52	11.67	67.92	8.32	8.99	221.20
T_8	37.17	7.73	58.79	4.98	5.87	176.60
CD at 0.05 level	9.499	1.462	N.S	0.992	1.200	25.272

and T_2 significantly over the control. Other treatments could not increase the uptake of nitrogen at the booting stage of the crop.

4.3.8.4.2. Phosphorus

Treatment T_7 recorded the highest uptake of phosphorus and was superior over all other treatments. T_3, T_2 and T_6 were on par and superior to control. T_6 and T_4 were also on par and superior over control.

4.3.8.4.3. Potassium

No significant contribution was observed in the potassium uptake in the plots receiving different treatments.

4.3.8.4.4. Calcium

Increasing levels of calcium oxide and Bhushakthi increased the uptake of calcium in Vyttila-1 at the booting stage. The trend was $\overline{T_3T_7} > \overline{T_2T_6} > \overline{T_8T_5} > T_1$.

4.3.8.4.5. Magnesium

The uptake of magnesium was highest in T_7 which was on par with T_3. Treatment T_2, T_6 and T_5 were also superior over the control. But T_4 and T_8 could not influence the uptake of magnesium by the plant.

4.3.8.4.6. Silica

Increasing levels of calcium oxide, Bhushakthi and steatite were found to increase the uptake of silica by the plant. Treatment T_7, T_3, T_5, T_4 and T_2 were superior to control. Treatment T_6 and T_8 could not increase the uptake of silica at the booting stage of the crop.

4.3.8.5. At harvest (Vyttila-1)

The data relating to the uptake of nutrients at harvest is given in Table 29 and the analysis of variance table in Appendix XIX.

4.3.8.5.1. Nitrogen

The nitrogen uptake of the crop was increased with increasing levels of lime and Bhushakthi. The trend being $\overline{T_3T_7} > \overline{T_6T_2} > T_1$. But the application of steatite apparently increased the nitrogen uptake though not significant. Treatments T_4, T_5 and T_8 were found to have no effect on the increase in uptake of nitrogen.

4.3.8.5.2. Phosphorus

Increasing levels of Calcium oxide and Bhushakthi increased the uptake of phosphorus. T_3 amd T_7 were superior over T_2, T_5 and T_6 which were superior to control. Though there was apparent increase in the phosphorus uptake in steatite treatments it was not significant in T_4. Treatments T_8 and T_4 were on par with the control.

Table 29.- Influence of different soil amendments on the uptake of nutrients at harvest (Vyttila-1) g/plot

Treatment	N	P	K	Ca	Mg	Si
T_1	69.86	12.10	75.60	24.50	20.86	585.28
T_2	85.99	15.27	77.30	40.44	25.37	642.16
T_3	117.17	20.96	78.05	65.02	31.99	760.16
T_4	79.01	13.42	71.70	41.56	26.23	713.86
T_5	77.58	14.08	71.53	35.39	25.59	741.86
T_6	91.13	15.64	82.59	39.18	21.90	595.26
T_7	111.97	20.65	90.51	47.71	27.19	724.73
T_8	70.94	12.54	76.68	29.07	18.58	547.66
CD at 0.05 level	12.638	1.850	7.573	10.449	4.276	100.460

4.3.8.5.3. Potassium

T_7 was superior over all other treatments. T_6 gave increased uptake of potassium over T_4 and T_5. The application of steatite had no positive effect on increasing the potassium uptake by the plant. The other treatments did not differ significantly.

4.3.8.5.4. Calcium

The uptake of calcium was significantly higher in T_3. Treatments T_7, T_4, T_6 and T_2 were on par and superior over control. The calcium uptake of T_8 was not significant over control. T_5 also contributed to significant increase in the calcium uptake of the crop.

4.3.8.5.5. Magnesium

Treatmonts T_3 was superior over all other treatments. Treatments T_7, T_4, T_5 and T_2 were on par and superior over control. In general CaO, Bhushakthi and steatite application showed a significant increase in the magnesium uptake by rice. Treatments T_2 and T_6 were on par.

4.3.8.5.6. Silica

The uptake of silica was the highest with T_3 which was on par with T_5, T_7 and T_4. Treatments T_2, T_6 and T_8 could not increase the uptake of silica at the harvest. The data revealed that the higher level of calcium oxide, Bhushakthi and both levels of steatite increased the uptake of silica by the plant.

Crop in the experimental field

DISCUSSION

CHAPTER V

DISCUSSION

The drying up of rice crop during dry spells, bronzing symptoms, appearence of salt like crusts on soil surface under strongly evaporative conditions, presence of jarosite mottlings in the profile etc. point to the fact that these soils are acid sulphate in nature. Further, the "ela" is located along the Varkala formation, belt, which is known to have lignitic layer lower down the profile, organic matter deposits could be expected in the sub soils. This is proved by the presence of logs twigs and partially decomposed organic matter in the sub soils. Due to the striking of water at about 80 cm, profiles could not be deepened further. However, the material below could be probed and the nature of underlying materials also investigated. Further the materials excavated, from a drinking well bored at an elevated place close to the "ela" exposed large quantities of lignite like material, jet black in colour which can be called "kari" in vernacular, that was brought to the surface. This points to the acid sulphate nature of the soils of "Pazhamchira ela". A maximum ΔpH (shift in pH consequent to drying) of 1.0 pH unit has been observed in one sample (sample No.24) which for others however, is lower than 1.0.

5.1. Studies on profile samples

Texturally the surface layer of the profiles studied constituted sandy loam whereas the underlying layers were highly sandy. The sub surface sand layers were pale white, straw and orange yellow in colour, indicating presence of iron in different stages of oxidation and hydration. Typical jarosite mottlings were also present in the third layer of both profiles. Further the pH was below 4.0 within a depth of 50 cm. These are the characteristics of acid sulphate soils (van Breeman and Pons 1978). Moreover bronzing in rice grown in coastal plain soils often indicates acid sulphate soil (Brinkman and Pons 1973). The symptoms like bronzing, drying and even death of rice seedlings and plants in patches is common in this "ela" during periods of hampered water circulation (restricted drainage) in the field and also when the field starts drying up due to water scarcity.

The pH values decreased with depth with values of 4.8 and 5.0 in the top most layer and 3.5 and 3.4 in the lowest layer. The very low pH values observed in the subsoils is due to probably the oxidation of pyrites to sulphuric acid under aerobic conditions. This agrees with the findings of Abdul Hameed (1975).

Electrical conductivity neither showed any regular pattern nor wide variation. In one profile, an electrical conductivity of 4.6 mmhos cm^{-1} was obtained, while in the second profile the corresponding value was 0.57 mmhos cm^{-1}. In the first profile the E.C in the middle layer was much lower. In the second profile the EC was comparatively uniform through out the profile. The irregularity in the vertical distribution of soluble salts in the profiles may be due to the leaching effect of the receding water table which was found in the visinity of the fourth layer collected for analysis. The difference in salinity between the different layers in one profile can be explained only on the basis of colloidal and moisture content. The findings reveals that there is close association between the fluctuations in the ground water table and salinity in the profile as reported by Bandopadhaya ~~et al~~ and Adhikari (1968).

Organic carbon showed an increasing trend with depth. This agrees with the findings of Alexander and Durairaj (1968) and Menon (1975). The values ranged from 1.4% to 3.7% in the first profile and 1.3 percent to 3.5 percent in the second profile. The presence of large percentage of organic carbon below the sandy sub surface layers indicates organic deposits or peat in the sub soil (Menon 1975).

C/N ratio widened with depth in both the profiles. The value ranged from 11.7 to 25.3 and 13.5 to 31.8 in profile I and Profile II respectively. The heavy losses of nitrogen due to denitrification in submerged soils attribute to a wide C/N ratio in the profile. Similar observations were made by Rodrige (1962) and Abdul Hameed (1975). Organic matter content of the profiles had the highest values in the lowermost layer; 6.4% and 6.1% respectively for profile I and II. The top cultivated layer recorded 2.6% and 2.2% in profile I and II respectively. The middle layers constituted mainly of coarse and fine sand, the coarse sand content was being 80 percent.. It seems probable that a thick layer of sand was deposited over organic debris which was subsequently topped up by silty material on which cultivation was started.

Total nitrogen content of the different layers of the profiles were very low and ranged between 0.09 and 0.14 percent. There was not much variation in the total nitrogen in different layers of the profile. Bray extractable P_2O_5 was found to be higher in the lowermost layer exposed, the values being 12.3 and 11.3 kg ha^{-1} in profile I and II. Comparatively lower values were noticed in the upper layers. This may be due to the fact that the surface soils are predominantly silty and sandy and in the absence of exchangeable materials like organic matter and clay, the soluble P_2O_5 might have been leached down to the lower subsoil or it is possible that the higher bray extractable P_2O_5 in the lowest layer be associated with organic materials, as evidenced by large percentage of organic matter.

Cation exchange capacity values of the profile soils was ranging from 2.8 to 12.1 me/100 g soil in profile I and from 2.1 to 6.7 me/100 g in profile II. Highest values were recorded in the lowermost layers followed by the top cultivated layers. Again the phenomena may be attributed to the absence of colloidal fractions in the middle layers, absence of sufficient quantities of clay in the uppermost layer and presence of higher amounts of organic matter in the lowermost layer.

Exchangeable sodium was present only in very small quantities in both the profiles with values ranging ~~between~~ from 0.03 to 0.13 me/100 g soil. Highest value~~s~~ was recorded in the lowermost layer below which water was struck. The exchangeable potassium content of the profile samples was very low, the range being 0.02 and 0.15 me/100 g of soil. The vertical distribution of Na and K followed similar pattern. The above observations indicate that the dynamics of Na and K (mobility and availability) is associated with ground water movement and drainage.

Exchangeable calcium content was the highest in the topmost layer with values of 1.51 me/100 g soil and 1.0 me/100 g in profile I and II respectively. The soil being predominantly acidic higher values for exchangeable Ca cannot be expected. Comparatively higher amounts of exchangeable calcium found in top layer may be attributed to the influence of cultural practices like addition of organic matter and presence of silt.

Exchangeable magnesium content of the profile layers was much lesser than that of exchangeable calcium, the lowest and highest values being 0.03 to 0.53 me/100 g soil. As in many other properties of the soil, the middle sand layer contained lesser amount of exchangeable Mg.

KCl exchangeable aluminium increased with depth in both profiles except in the middle sand layer. The highest values recorded in the lowest layer were 10.7 me/100 g soil and 5.5 me/100 g soil for profile I and II respectively, followed by surface layers with values of 2.07 and 3.59 me/100 g soil. The result reveals that exchangeable aluminium is found in toxic amounts in the subsoils. Similar observations were made by Sumner (1970). He attributes this phenomena to low crop yield in some acid sandy soils of Natal. Ericco <u>et al</u> (1979) and Farina et al (1980) supports this view. Menon (1975) also reported the existence of aluminium mostly in lower layers.

The exchangeable aluminium content in the profile sample exceeds the amount of total exchangeable bases in the present investigation. This is in agreement with the findings of Helias and Coppenet (1970). The high concentration of exchangeable aluminium in the lower horizon reveals the potential acidity of the soil and probable aluminium toxicity to crop at pH levels < 4.8. It is also suggested that aluminium present on the surface of clays may be liberated in amounts toxic to crop plants, on application of inorganic fertilizers (Chatterjee 1949). The presence of large amounts of Al in subsoil may be attributed to the presence of ground water into which the exchangeable Al might have percolated.

DTPA Extractable iron did not show any regularity in its vertical distribution throughout the profile, though the highest values were recorded in the fourth layer (214 ppm and 167 ppm respectively for profile I and II). In the surface layer of profile I the value was 134 ppm while in the second profile it was 31.1 ppm. As is expected the middle layers contained lesser amounts of DTPA extractable iron. The concentration of ferrous iron in soil water system are enhanced by the presence of salts. Iron toxicity is reported to be common in submerged ultisols, oxisols and acid sulphate soils in the tropics (Tanaka and Yoshida 1970).

Water soluble aluminium, similar to exchangeable aluminium was found to be higher in the lowermost layer of both the profiles, the values being 24.3 ppm and 18.4 ppm respectively. Next to the lowermost layer the top layer also contained appreciable amounts of water soluble aluminium. (9.7 ppm and 4.6 ppm for profile I and II respectively). As discussed elsewhere due to the absence of colloidal fractions the middle sandy layers contained only traces of these fractions. The results prove that the soils of Pazhamchira ela harbour toxic levels of exchangeable and water soluble aluminium. Even 2 ppm aluminium was reported to be lethal to young rice seedlings (Thanornwong and Diest 1974).

Mechanical composition of the profile sample reveals that the surface soils are sandy loam, with subsequent layers of coarse sand as high as 90 percent. The lowermost layer is classified as loamy sand. The gravulometric composition of the profile samples clearly indicates that the soil of the area is not having the desired qualities for producing a fine tilth or effective soil texture required for rice cultivation. But the proper management of the surface sandy loam can be achieved by careful management practices like organic manuring, timely application of lime, addition of red earth and or lacustrine sediment to the possible extent. Addition of red earth and lacustrine sediment may seem impracticable, but worth trying, since people of this area resort to such practices for coconut. However, Kyuma (1981) suggested that as long as adequate water is available for the rice crop, physical properties of rice soils are unimportant in producing yields of 4 to 5 t ha^{-1}. This is probably true of this area also.

It can be summarised that the rice soils of Pazhamchira "ela" is highly acidic, low in available nutrients especially P, K, Ca and Mg. The soil is of low CEC, most of the exchange sites being occupied by exchangeable Fe, Al and H^+. The ground water is highly fluctuating which control the mobility of soluble and exchangeable cations both beneficial and harmful, soluble salts and probably sulphuric acid produced in the organic layer by oxidation of sulphur compounds. The intermediate sand layer of both profiles are characterised by higher percentage of coarse fraction that encourages heavy leaching losses of nutrients through the layers. This sandy subsurface layer is found to posses very low CEC and exchangeable cations.

Evolution of large quantities of H_2S detected by the characteristic smell of this gas in the profile pits dug is a clear evidence of sulphur reduction going on in the soils which may subsequently result in the formation of iron sulphides. The high amount of iron sulphides built up, may be oxidised mostly by microbial activity, while draining the field, to sulphuric acid which is the main cause of acute acidity encountered in the present investigation and subsequent crop failure of the dry sown first crop. Subramoney and Sukumaran (1973) reported that oxidation and hydrolysis of iron sulphide occur at a greater rate during summer.

The disease commonly known as"akiochi" is reported in areas where H_2S injury is possible. Helminthosporium leaf spot can be taken as an indication of akiochi (Tanaka and Yoshida 1970). This disease is very common in this "ela". IRRI (1973) reported that harmful concentration of hydrogen sulphide may be present in acid sulphate soils during the first few weeks after flooding.

The symptoms like bronzing; wilting and drying up of rice seedlings and plants have frequently been reported from this "ela". This wilting and drying up of seedlings in patches is associated with rise of water from sub soil by capillary action during periods of water scarcity. The wilting of seedlings at this juncture can be attributed not only to high acidity possible during such conditions but also to the phenomena of plasmolysis due to the presence of salt laden water in the root zone.

5.2. Studies on surface soil samples

The fertility status of Pazhamchira "ela" and the factors limiting their productivity and ways and means to increase the productivity of the rice soils on the basis of results obtained in the present investigation are discussed below.

It is an accepted fact that soil reaction has profound influence on the fertility and productivity of a soil. All the samples analysed were highly acidic, the pH ranging between 3.4 and 4.8 while fresh from the field. When the soils were dried powdered and then subjected to pH measurement gave a value between pH 2.6 and 4.8, the mean value being 4.05. Thirty one samples gave pH values above the mean. Another fifty more surface samples, collected from the "ela" after a dry spell of three months (May 1984), recorded a pH value ranging from 2.6 to 4.5 with a mean value of 3.89. This indicates that prolonged dryness of the soil lowers the pH. This agrees with the finding of Moorman (1963); van Breeman (1976) and Ponnamperuma (1969) in acid sulphate soils.

Subramoney and Sukumaran (1973) and Anilakumar (1980) obtained pH $<$ 4.0 in Kayal and Kari soils (3.85 and 2.90 respectively). In soil with a mean pH of 4.05, retarded release and uptake of plant nutrients, fixation of phosphate, decreased activity of beneficial microorganisms, toxicity due to soluble Fe and Al are most likely to be manifested. Soil properties inherent to such soils very often affect the soil plant relationship to an extent that lead to substantial reduction in yield and at times even a total failure of crop.

Electrical conductivity showed a range from 0.25 mmhos/cm to 1.27 mmhos/cm with a mean value of 0.65 mmhos/cm in moist sample collected during February 1984 while the EC of the soil samples collected from the same plots after a dry spell of three months recorded values between 0.43 and 3.25 mmhos cm^{-1} with a mean of 1.21 mmhos cm^{-1}. This marked increase in electrical conductivity in the second group of soil samples clearly indicates that soluble salts accumulate in the surface horizon by capillary rise as the dry period sets in after the harvest of the Rabi crop. Similar results of increase in specific conductance were obtained by Ponnamperuma (1969) and Beye (1971) on acid sulphate soils. The pH and EC of the fifty surface samples are correlated and found to have a negative correlation ($r = -0.607$).

Lime requirement of the different samples varied from 1.6 to 14.0 t ha^{-1} with a mean of 5.48 t ha^{-1}. This shows that different fields require varying doses of lime. Though high lime requirements are indicated it is neither economically feasible nor practicable to apply such high rates of lime. Maximum grain yield was reported by Anilakumar (1980) with fractional dose of half the lime requirement applied in laterite, kayal and kole soils. Therefore in the present investigation graded levels of lime to arrive at an economical dose of lime has been tried in the field experiment laid out in farmer's field. The correlation between pH and lime requirement were studied. The two were negatively correlated ($r = -0.66$).

Cation exchange capacity of the surface samples (Table 6) was low to medium low as per USDA standard ratings ranging from 3.8 to 9.9 me/100 g of soil with a mean of 5.9 me/100 g soil. Only twenty two samples had CEC above the mean value. The low CEC can be attributed to the low clay content of the surface soil and also due to low organic matter content. This indicates that the addition of organic manure will certainly go a long way in improving the CEC of these soils. The CEC values obtained in the present study are similar to those reported by Sudharmai Devi (1983) in a study on the nature of acidity in rice fallows.

Total exchangeable bases showed wide variation ranging from 1.37 to 6.44 me/100 g with a mean value of 2.93 me/100 g soil. In general the exchangeable bases were low in all the surface samples studied. The mean value of exchangeable calcium was 1.88 me/100 g soil, for magnesium 0.77 me/100 g, for potassium 0.15 me/100 g and that for sodium 0.13

me/100 g soil. The percent base saturation has recorded a low to medium level as per USDA standard ratings. According to Bear and Toth (1948) an ideal soil should have 65% of exchange complex occupied by calcium 10% by magnesium, 5% by potassium and 20% by hydrogen. In the present investigation only 49.66% of the exchange complex is occupied by Ca, Mg, K and Na. About 50.34% is occupied by hydrogen and allied ions. Though the percent base saturation apparently seems to indicate a fairly good productive soil, in view of the low CEC of the soil (5.9 me/100 g soil) the percentage base saturation of 49.6% is no index to the fertility of the soils of Pazhamchira "ela". Ways and means already indicated have to be resorted to improve the CEC of these soils. Moreover as the exchangeable K and magnesium are low in this soil deficiencies of these nutrients may contribute to low yield of rice in this ela.

There are wide variations in the values for exchangeable Al (46 ppm to 722 ppm) and watersoluble aluminium (1 ppm to 118 ppm). The exchangeable and water soluble aluminium content of the soils were comparatively high. The mean values for exchangeable Al was 248 ppm and that of water soluble fraction was 13.84 ppm. Twenty three samples recorded more than the mean value for exchangeable aluminium while only eight samples have water soluble aluminium higher than the mean. The values are similar to those reported by Karthikakuttyamma (1979) for acid soils of Kerala in respect of exchangeable aluminium but did not agree with the values reported for water soluble aluminium. It is also suggested that aluminium in the range of 1 to 2 mg per litre is toxic to rice seedlings (van Breeman 1976). Hence aluminium toxicity can be considered as a major soil problem in Pazhamchira "ela". The correlation between exchangeable Al and pH were studied and found that these two are negatively correlated significantly (r = -0.69) water soluble Al and exchangeable Al are positively correlated (r = 0.67).

The DTPA extractable iron showed wide variation among soils. The values ranged from 16.0 ppm to 262.0 ppm the mean value being 95.5 ppm (Table 7). These wide variations in iron and aluminium content of the soil can be explained only with reference to the topographic position of the field, its drainage potential, depth of sulphic horizon, fluctuations in ground water table etc. However, iron and aluminium toxicities are possible in many fields.

In the soils that are low in nutrients especially K and P, soluble iron concentration as low as 40 ppm may prove toxic

(Moorman and van Breeman 1978). Moreover, the concentration of ferrous iron is enhanced by the presence of salt. So it is quiet evident that iron toxicity can be another major problem in these soils. The bronzing symptoms generally occuring in Pazhamchira "ela" one to two months after transplanting or in a few instances at one to two weeks after transplanting and subsequent root damage and increased sterility of spikelet are in agreement with the symptoms of toxicity due to iron as described by Ponnamperuma (1958) and Sahu (1968).

Total nitrogen content of the soil varied from 0.073 to 0.237 percent (mean 0.14%). The total N content of this soil can be rated from low to medium. Available nitrogen status of the soil is low to medium, the range being 84 kg/ha to 364 kg/ha with a mean of 204.4 kg/ha.

The available P_2O_5 content of the surface samples ranged between 4.6 ~~to~~ and 16.55 kg/ha with a mean value of 10.17 kg/ha. The values are very low. Menon (1975) got similar low available phosphorus in kayal lands of Kuttanad. Phosphorus deficiency is the most important disorder in acid sulphate soils of pH 4.2 to 4.5 where phosphorus application alone can double rice yield (Motomura et al. 1975). The low grain yield reported from this problem "ela" can also be attributed to low level of phosphorus in the soil. Application of slowly soluble phosphates like rock phosphate can defenitely increase the availability of the nutrient to the crop.

The available K_2O content of these soils also showed wide variation. The values obtained ranged from 86.4 kg/ha to 220.8 kg/ha (mean 142.43 kg/ha). The fields can be rated from low to medium in available potassium content. Application of sufficient quantities of K_2O on the basis of soil tests can increase rice yield in many fields of this "ela". In general the NPK status of the soils of Pazhamchira can be catagorised as low to medium with respect to N, low in the case of P_2O_5 and low to medium with reference to K_2O. The correlation between exchangeable Ca and exchangeable Mg showed a significant positive correlation ($r = 0.653$). The exchangeable K and exchangeable Na were negatively correlated but not significant.

5.3. Field experiment

A field trial with eight treatments during the Kharif season of 1984 with variety Ptb 8 and another trial with the same treatment during Rabi 1984 with variety Vyttila 1 were conducted in farmer's field. The results obtained in the course of field experiment on the growth and yield characters of rice, on the composition of rice grain and straw and on the uptake of nutrients at critical growth stages of the crop are discussed below.

a. Growth characters

Height of plants

The results (Table 13) reveal that the height of plant increased significantly in treatments with calcium oxide and Bhushakthi each at both levels in Ptb-8 at maximum tillering stage and at panicle initiation stage. The initial growth of plant was retarded by steatite treatments. This may be probably due to the high rate of the material applied based on its neutralising value. At harvest the steatite treatment gave lower plant height. This reveals that the application of steatite at high doses as a liming material depresses the vegetative growth of the crop. This result is not in agreement with the report of Vijayakumar (1977) who had applied the material at a very low rate (600 kg/ha). But it agrees with similar results reported in Regional Agricultural Research Station, Pattambi (Anon 1975).

In the case of Vyttila 1 (Table 17) Treatments T_7 and T_3 were found to be significantly superior in increasing plant height during both observations. The height of plant at booting stage was not influenced by steatite treatment, but at harvest the plant height was superior over control in T_5. However T_4 and T_8 were not found to improve the plant height at both stages.

The effect of Calcium oxide in both the experiment is in agreement with the results reported by Krishnasamy and Raj (1974) and Anilakumar (1980). The performance of Bhushakthi in the present investigation is contradictory to the reports from the Rice Research Station, Moncompu (Anon 1981). This may be due to the difference in geological position and soil properties of Pazhamchira ela as compared to that of Moncompu and liming is indespensible for increasing the productivity of the crop.

A general setback in the growth of the rice plant in the steatite treated plot was observed from early stages of growth till flowering. At the maximum tillering stage the control plants showed bronzing symptoms typical of iron toxicity. There was striking response to application of calcium oxide and Bhushakthi on visual observation of the crop also.

Tiller number

In the case of Ptb-8 the number of tillers at maximum tillering stage was the highest in calcium oxide at ½ L.R treatment (T_3) and it was superior over all other treatments (Table 14). At booting stage and at harvest the increase in number of tillers were significant with increasing levels of Bhushakthi and calcium oxide.

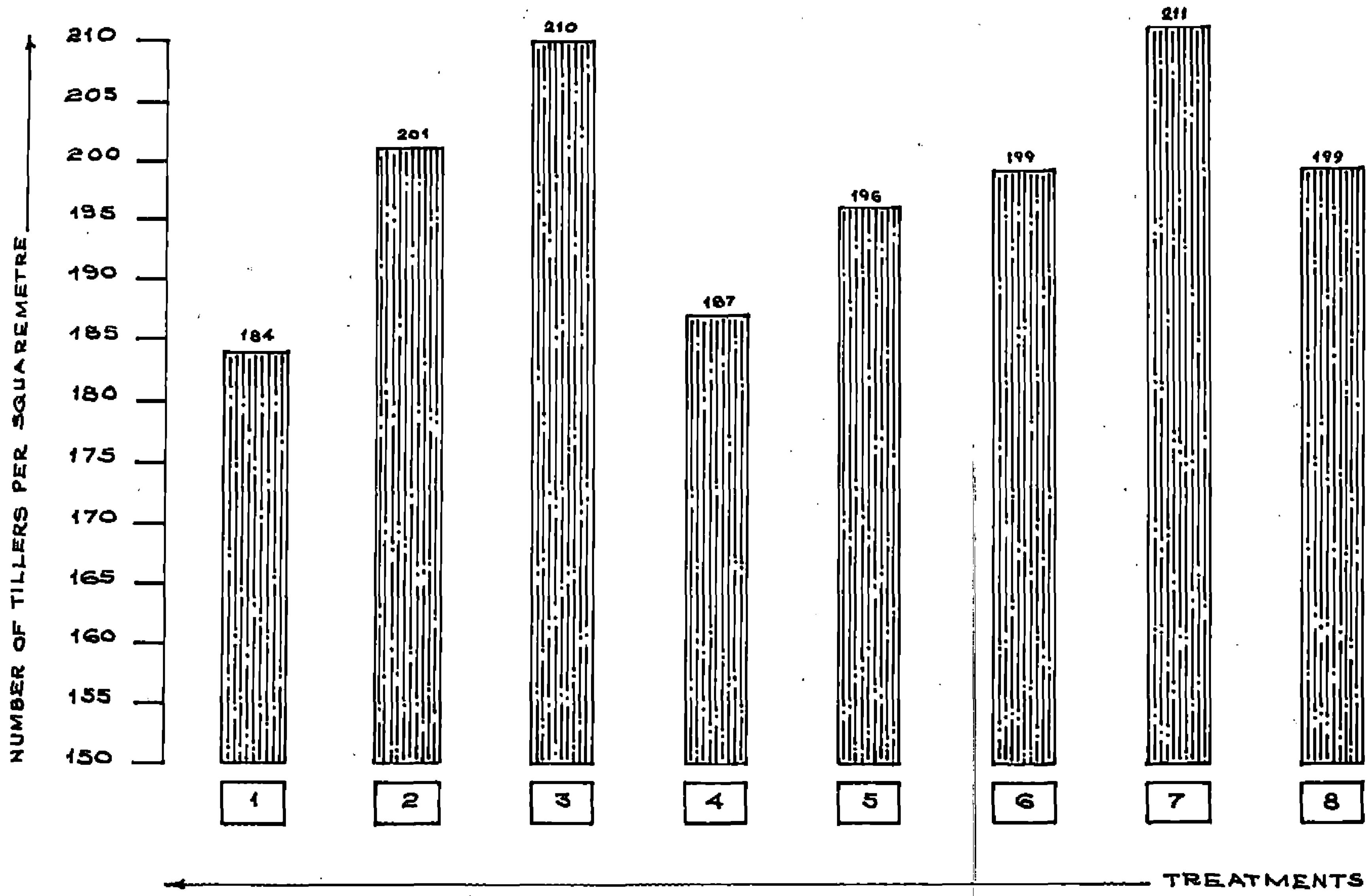
In Vyttila-1 also the number of tillers increased with both levels of calcium oxide and Bhushakthi. At booting stage CaO at ½ LR (T_3) and Bhushakthi at ½ LR (T_7) were found to increase the tiller number over all other treatments except T_6 (Bhushakthi at ¼ LR) which was on par.

In general, the overall effect of liming with calcium oxide and Bhushakthi is positive in respect of production of tillers and height of plant which accounts for the enhanced growth and tillering in the crop.

The steatite treatments (T_4 & T_5) were not significant in any stage of both the crops as far as tillering of the plant is considered. This result is in conformity with the results of Yoshida (1975) who have reported that silica is not essential for the tillering of rice.

The increase in plant height and tiller number due to liming can be attributed to the increased availability of soil nitrogen by liming and also due to the direct effect of Ca. The finding is in agreement with the results reported by Kwack (1970) and Anilakumar (1980).

FIG - 2. AVERAGE NUMBER OF PRODUCTIVE TILLERS PER SQUARE - METRE Ptb-8



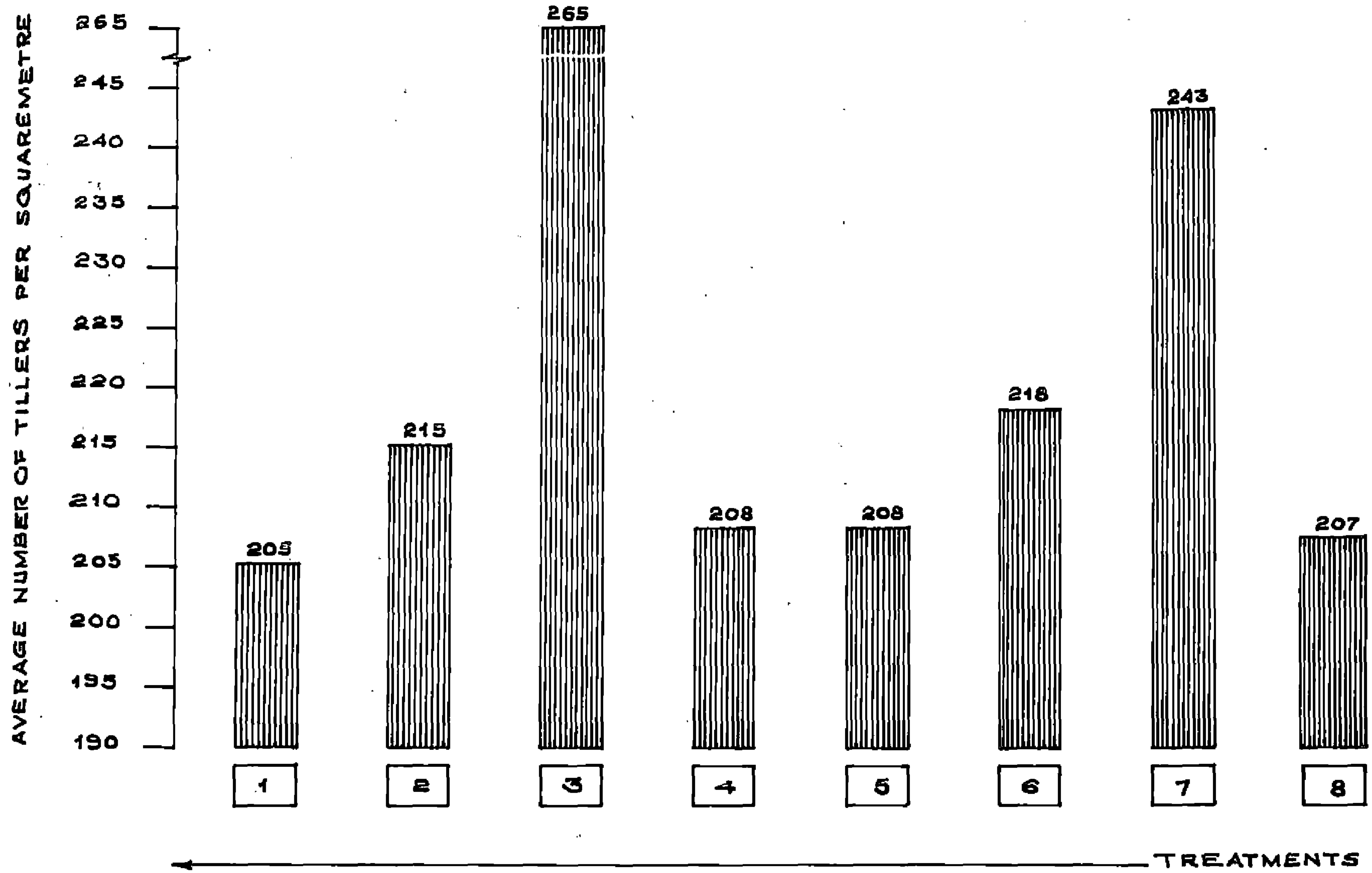
b. Yield components and yield

The number of productive tillers in Ptb-8 significantly increased in treatments with Bhushakthi and Calcium oxide at both the levels (T_7, T_3, T_2 and T_6) and in the T_8 treatment also. T_4 and T_5 (steatite at both levels) did not contribute to the increase in the number of productive tillers.

In Vyttila-1 treatment T_3 was found to be superior to T_7 though the application of all the amendments has contributed to some increase in the number of productive tillers. This increase in number of productive tillers can be attributed to the increased phosphorus availability as phosphorus has a direct role in the formation of productive tillers. Since the treatment with double dose of K (T_8) also increased the number of productive tillers, it can be assumed that K availability may also be a limiting factor in increasing the number of productive tillers.

It has been also reported that K content as high as 1.5% in the leaf blade increased the tillering rate as K is essential in activating enzymes such as starch synthetase (Nitsos and Evans 1969). The partial productive efficiency of K is generally high at early stages, declines, and becomes high again at later stages. K deficient plants often have a high iron content and may exhibit symptoms of iron toxicity,

FIG-3. AVERAGE NUMBER OF PRODUCTIVE TILLERS PER SQUARE METRE VYTILA-1



Since there is a physiological interaction between iron and K a low K content in the soil tend to aggravate iron toxicity. (Yoshida 1981)

2. Panicle characters

The results (Table 15) of Ptb 8 reveals that calcium oxide at both the levels and Bhushakthi at ½ LR level influenced the length of panicle significantly. This would mean that some of the genetic plant characters are susceptible to variation within certain limits under the different systems of management. The number of spikelets increased significantly with the higher levels of Bhushakthi and calcium oxide (T_7 and T_3) alone. T_7 and T_3 has also contributed to a significant increase in the number of filled grains in Ptb-8 Treatments T_2, T_8 and T_6 were also significantly superior to the control in this regard.

The treatments were not significant in Vyttila-1 with reference to the panicle (Table 19) characters. This may be due to the short span of the cropping season and the short interval between transplanting and flowering. In short the results reveal that the panicle characters of the plant are influenced by the treatments excepting T_4 and T_5. Similar results with lime was reported by Sivan Nair (1970) and Anilakumar (1980) with calcium oxide treatments.

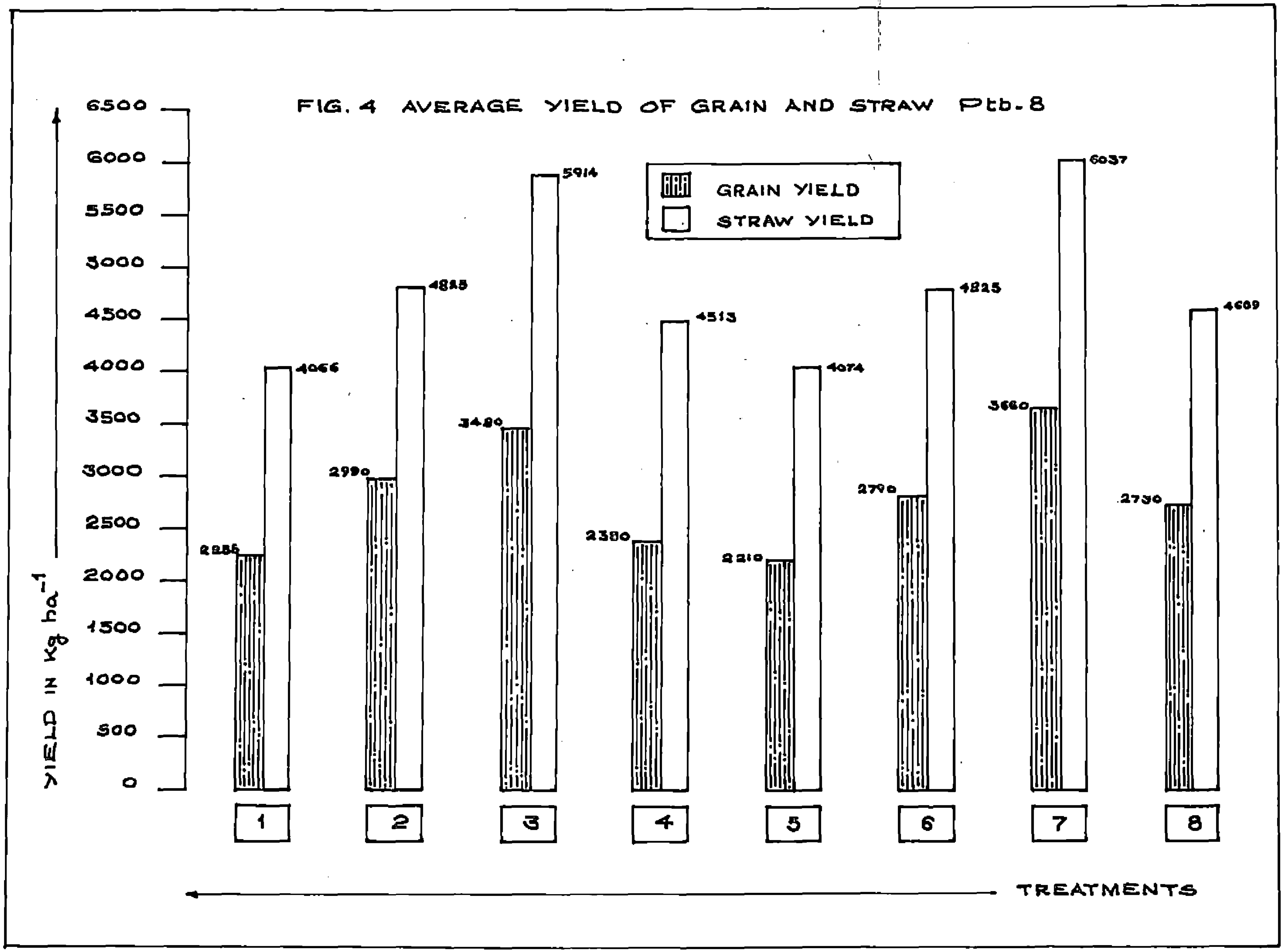


FIG. 4 AVERAGE YIELD OF GRAIN AND STRAW Ptb-8

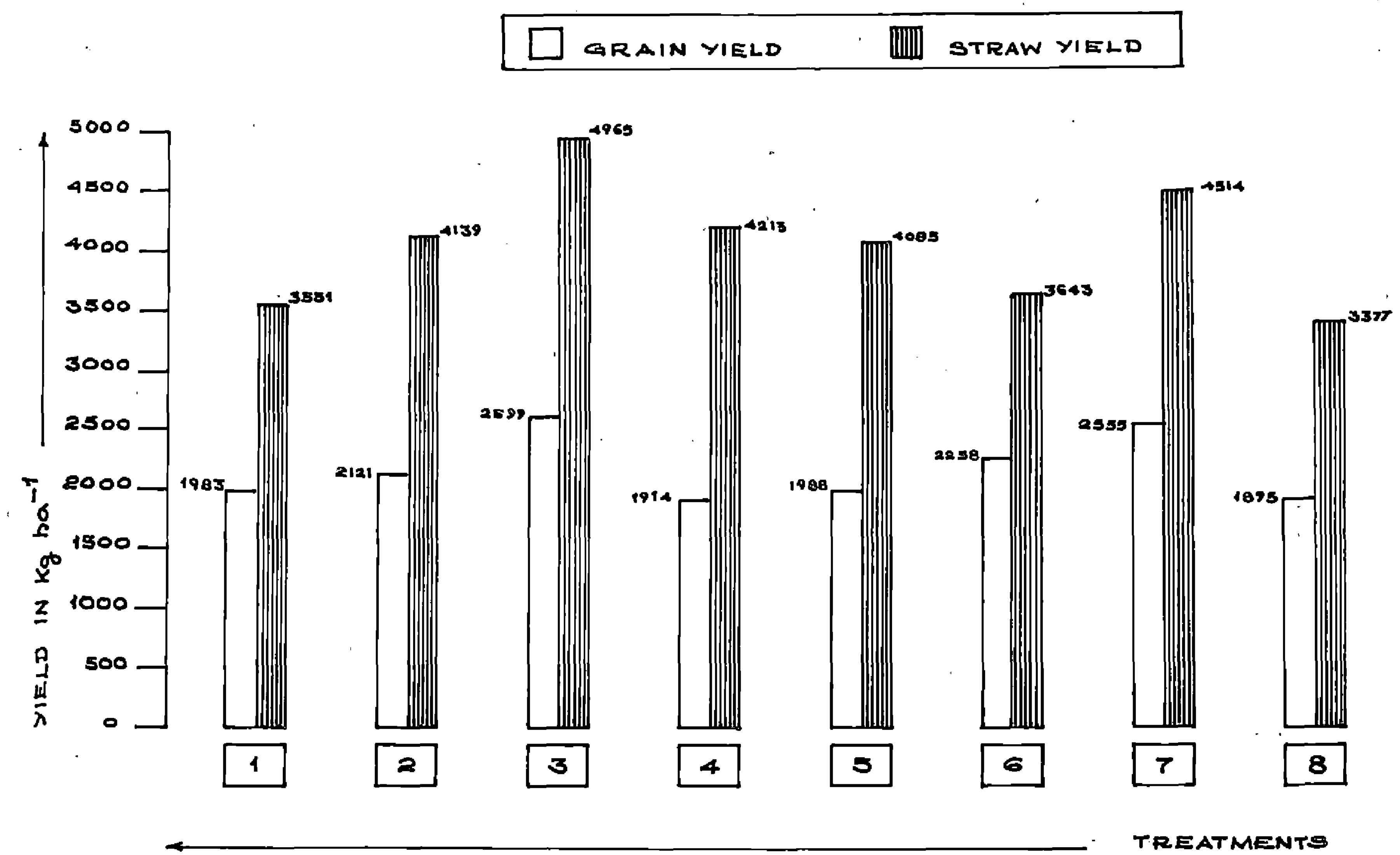
3. Grain yield

The data presented in Table 16 and Table 20 on grain yield reveals that the application of Bhushakthi at ½ LR (T_7) and calcium oxide at ½ LR (T_3) gave the highest per hectare grain yield over other treatments in Ptb 8 as well as Vyttila 1. This shows that higher doses of liming material especially CaO and similar materials like Bhushakthi are capable of increasing grain yield in problem areas.

The positive effect of calcium oxide in increasing grain yield obtained in the present investigation is in conformity with the observations of Kurup (1967), Kabeerathumma (1969) in Kuttanad soils and also Kanapathy (1971).

T_2, T_6 and T_8 were also found to give significantly increased yield over control in the case of Ptb 8. But in Vyttila 1, T_6 was found to be superior over control and other treatments. However, this indicates that even a lesser dose of a liming material may also be welcomed when a higher dose is not economically feasible. Another interesting observation is that in Ptb 8, T_8 (additional dose of K_2O over package of practices) has performed equally along with T_2 and T_6 in increasing grain yields. This aspect is worth for further investigation and is an indication that an additional dose of K_2O alone can some times increase grain yield.

FIG. 5. AVERAGE YIELD OF GRAIN AND STRAW VYTTILA-1



The decreased grain yield in steatite treated plants observed in the present investigation is in conformity with the findings of Vijayakumar (1977) in the pot culture experiment where maximum grain yield was recorded for the zero level of steatite application. This poor performance of steatite treatment in respect of grain yield can be attributed to the high quantity of steatite applied so as to meet ¼ and ½ lime requirement. This result is contradictory to the findings of Karunakara Panicker (1980) who applied steatite only upto 800 kg/ha in Kuttanad soil. Moreover the soils of Pazhamchira is sandy loam with higher percentage of coarse and fine sand fraction which may supply sufficient amounts of available silica and therefore, the effect exhibited by steatite on mature soils of Kuttanad need not be expected in Pazhamchira "ela".

4. Straw yield

The straw yield was the highest in T_7 followed by T_3 in Ptb 8 while, Vyttila-1 gave the highest yield with T_3 followed by T_7. Treatments T_7 and T_3 were on par in both the crops.

Thus, it is obvious from the result of the field experiment that application of lime at ½ LR in the form of either calcium oxide or Bhushakthi significantly increase both the grain yield and straw yield of both the varieties tried. These findings are in agreement with the results reported by Anilakumar (1980) for laterite, kayal and kole soils. The increased yield of straw and grain due to liming with CaO and Bhushakthi can be attributed to the correction of soil acidity, reduction of toxicity of iron and aluminium, increase in the availability of N and P and increased supply of calcium as a nutrient (Kwack 1969) (Gopalakrishnan 1973) and (Wang 1971).

In Ptb-8, T_2 and T_7 had the narrower grain straw ratio while all other treatments were as good as control. The treatment did not vary significantly in Vyttila-1 probably due to reasons already explained. The present finding is in agreement with the findings of Prateep and Sims (1972). Application of steatite widened the grain straw ratio. This is in conformity with the findings of Vijayakumar (1977).

5. Thousand grain weight

Bhushakthi alone at both the levels (T_6 and T_7) have contributed to the increase in thousand grain weight significantly in the case of Ptb 8. But in Vyttila-1, T_3 also gave significantly higher thousand grain weight over control in addition to T_7 and T_6. Similar results of increase in thousand grain weight consequent to liming was reported by Kwack (1970) and Anilakumar (1980) with the application of Calcium oxide. The increase in thousand grain weight by the application of CaO was not significant in Ptb 8. Similar result was reported by Vijayakumar (1977).

In short, calcium oxide and Bhushakthi ranked first in the amelioration of the adverse soil conditions existing in Pazhamchira ela as evidenced by the significant increase in yield of grain and straw, while steatite at ¼ LR rate was beneficial by way of increase in straw yield but not grain yield. The amelioration of rice soil without lime but with additional 20 kg ha^{-1} of K_2O gave significant increase in yield of grain and straw in the first crop with variety Ptb 8 but its consistency is not encouraging with the second crop Vyttila-1.

Increase in straw weight in steatite treatment and additional K treatment (T_8) can be attributed to the decreased effect of the toxicity of iron and aluminium in all the treatments. Wang (1971) obtained similar results in latosols by liming.

Liming decreased both the exchangeable Al and water soluble Al content markedly. Kabeerathumma (1975) reported that in the presence of adequate P in lateritic acid soils and in alluvial soils, 2 me of Al/100 g soil is found as a safe limit.

In soils low in available silica the application of silicate may record yield increase but not so in all soils. Further more increased uptake of silica has resulted in a decreased uptake of N and P and so it is logical to expect a decreased yield in soil having excess amount of soluble silica. This was reflected in the grain yield from T_4 and T_5 where, steatite was applied at $\frac{1}{4}$ and $\frac{1}{2}$ LR. Thus the decrease in yield with T_4 and T_5 in the present study can be attributed to a decreased uptake of N and a corresponding decrease in dry matter production.

The effect of soil ameliorants on the composition of rice grain.

In both Ptb-8 and Vyttila-1, the nitrogen content of the grain increased significantly with calcium oxide as well as Bhushakthi, irrespective of their levels. But the effect of steatite treatments (T_4 and T_5) was not significant.

In Ptb 8 the phosphorus content of the grain was significantly superior in treatments T_3 and T_7, while all other treatments were as good as control. This shows that only higher doses of liming material could increase the phosphorus content in this variety. In the case of Vyttila-1 the phosphorus content was significantly higher in all treatments compared to control. The differential behaviour of these two varieties can only be attributed to the genetic factors and short duration of the crop. The potassium content of grain did not show any significant difference in treatments in the case of Ptb-8 but in Vyttila-1, T_8 was found to increase the potassium content of grains. The K content of grain in T_3 (CaO ½ LR) was significantly lower.

The calcium content of grain was significantly higher in treatments T_3, T_7, T_6, T_2 and T_8 over control in Ptb-8 while in Vyttila-1 the effect of treatment was not significant. The magnesium content of grain increased significantly in treatments T_7, T_5 and T_6 followed by T_2, T_4 and T_3 (in the case of Ptb 8). No such trend was observed in Vyttila-1. In both the varieties increasing level of steatite treatment increased the silica content of grain. The application of CaO and Bhushakthi at both the levels (T_3 T_2 and T_7 T_6) reduced the silica content of rice grain significantly. This clearly indicates that there exist some antagonism between calcium and silica. This assumption is more strengthened from the fact that the silica content of grain was the least in T_3. Vijayakumar (1977) got similar results with liming.

In short, the N, P and Ca content of grain increased while K and Si content decreased in plants treated with Calcium oxide and Bhushakthi. The effect of Bhushakthi on the Mg content of grain was superior to that of calcium oxide treatment. In treatment with additional K (T_8) only N, Ca and K content of the grain increased significantly. The treatment with steatite (T_4 & T_5) decreased the N P K content of grain and increased the magnesium and silica content, without any significant effect on the calcium content of grain. These results are in agreement with the observations of Varghese (1963) and Vijayakumar (1977).

The effect of soil ameliorants on the composition of rice straw.

The nitrogen content of straw increased significantly in all plots treated with either CaO or Bhushakthi (T_3, T_2, T_6 and T_7) with an exception of T_2 in variety Vyttila-1. (Table 22 and Table 24). Phosphorus content of straw was found to increase significantly in both varieties with respect to T_3 and T_7. As a general trend, it was observed that even lower doses of CaO, Bhushakthi and additional dose of K increased the phosphorus content of straw. The potassium content of straw was found to decrease in all the limed plots in both varieties. Its value was the highest in T_8 (addl dose of K).

The calcium content of straw in both the varieties was significantly superior in treatments T_3 and T_7 followed by

T_2 and T_6. The magnesium content of straw in both the varieties did not show any significant difference between treatments. The silica content of straw was significantly higher in T_4 and T_5 in both varieties. The treatment with additional K (T_8) increased significantly the calcium and phosphorus content of straw but was inferior to T_3 and T_7 in both the varieties.

In general the percentage composition of N and P increased with graded level of Bhushakthi and calcium oxide. This reveals that liming with these two materials increased the availability of N and P which in turn increased the N and P content of the plant. These results are in agreement with the reports of Sivan Nair (1970) Chew et al (1976) and Anilakumar (1980). In the present study also calcium oxide and Bhushakthi helped in the better and more efficient utilization of applied N and P as reflected by the higher levels of these nutrients in the plant material.

Liming could not influence the chemical composition of plant potassium in the present investigation. This result is in conformity with the findings of Mandal and Sinha (1968) and Anilakumar (1980). The calcium and magnesium content of the plant increased with liming, while silica content decreased. The significant increase in the magnesium and silica content of plants treated with steatite may mainly be due to the increased availability of these elements present in these liming materials.

Nutrient uptake

Since the second crop variety (Vyttila-1) was of short duration of 95 days with its vegetative phase extenting only upto 35 days, plant sample at booting stage of the crop and at harvest alone were collected for nutrient uptake studies. But in the case of Ptb 8 nutrient uptake at maximum tillering stage, panicle initiation stage and at harvest are studied and discussed seperately hereunder.

Maximum tillering stage

The uptake of nitrogen was significantly higher in T_3 and T_7. However, T_2 was also significantly superior over control. Phosphorus uptake was appreciably increased by T_3 over all other treatments. This trend was followed by T_7, T_2 and T_8. This shows that calcium oxide at both the levels and Bhushakthi at higher level is effective in increasing the uptake of P at maximum tillering stage and also that additional dose of potassium (T_8) can enhance the uptake of phosphorus by rice. Higher level of CaO and Bhushakthi (T_3 and T_7) contribute to significant increase in the uptake of K though the percentage composition of plant was less in these treatments.

The uptake of calcium, magnesium and silica at this stage increased with T_3 and T_7 significantly. The trend was T_7 followed by T_3 in the case of magnesium as T_7 contains magnesium also over and above calcium. Treatments T_4 and T_5 also contributed to increased uptake of Mg and silica.

In general, the uptake of N, P, K, Ca, Mg and Si at maximum tillering stage of Ptb 8 was influenced by liming. Increase in uptake of the plant nutrients was significantly correlated with higher dose of calcium oxide and Bhushakthi (T_3 and T_7). The treatment with additional K showed a significant increase in the uptake of P and K over control and its effect was on par with that of the lower level of calcium oxide and Bhushakthi (T_2 and T_6). Both levels of steatite (T_4 and T_5) had equal positive effect on the uptake of calcium magnesium potassium and silica while it had no effect on the uptake of N and P.

Panicle initiation stage

Treatments T_3 and T_7 were significantly superior to other treatments in respect of uptake of N, P and K. This is followed by (T_2 and T_6) the lower doses. The Ca, Mg and silica uptake were also significantly increased with T_3 and T_7. The ½ LR doses of Bhushakthi and calcium oxide (T_6 and T_2) ranked next indicating that they also can increase the uptake of nutrients significantly.

The effect of steatite on the uptake of N, P, K and Mg was on par with T_8 and superior over control but on the uptake of Ca and Si it was superior to T_8 and T_1. T_8 increased the uptake of all nutrients except Ca at this stage.

At harvest

The increasing levels of Calcium oxide and Bhushakthi (T_2 T_3 T_6 T_7) significantly increased the uptake of N, P, Ca and Mg at the harvest. The uptake of K was also high in Calcium oxide ½ LR treatment and Bhushakthi ½ LR treatment. The effect of T_8 (additional dose of K) on the uptake of N, P and Ca were on par with the lower dose of CaO and Bhushakthi and superior to control. As expected, since Bhushakthi contains Mg, the treatment T_7 gave the highest significant Mg uptake. The other treatments excepting T_8 were effective in increasing the uptake of magnesium by the crop.

Silica uptake was also the highest in T_7 followed by T_3 T_4 and T_5 which were inferior to T_7 but superior over control. The steatite treatments did not significantly increase N, P and Ca uptake but decreased the K uptake. The uptake of magnesium and silica were significantly increased by steatite treatment but was inferior to T_7 . Similar results were reported by Vijayakumar (1975) in field experiment with steatite.

In short liming with CaO at ½ LR (T_3) and Bhushakthi at ½ LR (T_7) are found to be superior over all other treatments in the uptake of N, P, K, Ca, Mg and Si in all the growth stages of the crop variety Ptb 8 during Kharif 1984. This may be due to the general improvement of the physiological functions of the plant and the soil environment due to the application ½ LR CaO or ½ LR Bhushakthi.

Correlation studies were conducted on the results obtained from field experiment. The yield of grain and straw of Ptb 8 was found to be negatively correlated. The straw yield was found to be influenced directly by the uptake of all plant nutrients with r values as follows

N ($r = +0.94$) P ($r = +0.94$) K ($r = +0.58$)

Ca ($r = +0.94$) Mg ($r = +0.54$) and Si ($r = +0.80$)

The grain yield of this variety was found to be highly correlated with the uptake of

N ($r = +0.94$) P ($r = +0.97$) K ($r = +0.67$)

Ca ($r = +0.93$) and Mg ($r = +0.62$)

Effect of different soil amendments on the uptake of nutrients at Booting stage of Vyttila 1

The uptake of N increased significantly in T_3,T_7 and T_2. But 'P' uptake was the highest in T_7 and superior over T_3,T_2 and T_6. The effect of treatments on the uptake of K was not significant at this stage of the crop. The calcium and magnesium uptake was also superior with treatments T_7 and T_3 followed by T_2 and T_6. In the case of silica uptake T_7, T_3, T_5, T_4 and T_2 were superior to control indicating that all the ameliorants increased the silica uptake in step with the increase in dosage.

In short the uptake of N, P, Ca, Mg and Silica are influenced positively by liming with calcium oxide and Bhushakthi while the effect of treatment on K was not significant. The steatite treatment increased the uptake of P, Ca, Mg and Si while T_8 could influence the uptake of Ca only.

At harvest

The N and P uptake by Vyttila-1 at harvest stage showed similar trend. The uptake of these nutrients were higher in treatments T_3 and T_7 followed by T_2 and T_6 the later being inferior to the former but superior to control. The uptake of K was significantly higher in T_7 and T_7 was superior to ~~over~~ all other treatments, followed by T_6. The calcium uptake was the highest in T_3 and superior over all other treatments. The increase in Ca uptake was followed by all other treatments except T_8.

The treatments with steatite (T_4 and T_5) are also helpful in enhancing the calcium uptake. This may be due to the favourable environment created by the ameliorant which in turn might have assisted the crop to take up more of calcium from the soil. The magnesium uptake was the highest in T_3 followed by T_7, T_4, T_5 and T_2 revealing that steatite application helps in increased uptake of Mg. It was in conformity with the findings of Karunakara Panicker (1980). This may be because of the direct involvement of this treatment material which contain about 29 percent of MgO and 52 percent SiO_2. The addition of steatite might have increased the availability of these nutrients.

The uptake of silica was higher and superior in the treatments of T_7, T_3, T_4 and T_5. In toto the data reveal that the high level of CaO, Bhushakthi and both the levels of steatite increased the uptake of silica by rice.

In short, the uptake of N, P, Ca, Mg and Si is increased by treatments of CaO and Bhushakthi while the steatite treatments could influence the uptake of P, Ca, Mg and Si only. The effect of T_8 in uptake of nutrients at harvest of Vyttila-1 is on par with control.

The correlation studies were done on the results obtained from the field experiment. The yield of grain and straw of Vyttila-1 was found to be positively correlated. Straw yield was directly influenced by the uptake of N ($r = +0.71$), K ($r = +0.68$), Ca ($r = +0.87$) Mg ($r = +0.53$) and Si ($r = +0.58$).

Similarly the grain yield of this variety was found to exhibit a straight line relationship with the uptake of N ($r = +0.90$), P ($r = +0.86$) and Ca ($r = +0.70$) only.

SUMMARY

SUMMARY

Highly acid sulphate soils, apart from their widespread occurance in Kuttanad and other areas, occur locally in pockets in several situations creating management problems of innumerable magnitude. Pazhamchira "ela", comprising an area of 85 hectares cultivated to rice is one such area which came to the attention initially of Training and Visit Programme Monthly workshop held in the College of Agriculture, Vellayani in 1983 and later through the Regional Workshop of NARP. The highly location specific problems associated with the soil and the crop had to be studied in depth, the results of which are summarised below.

The soil studies were broad based in that both the profiles as well as general fertility status of the entire "ela" was investigated. The crop studies were based on two field experiments one initially with a variety locally and currently being cultivated in the "ela" and another with a saline as well as acid tolerant improved variety. Both the field experiments had, among its various treatments, various ameliorants. Some of the results obtained are highlighted below.

1. The profile studies revealed that the surface layer of sandy loam texture extends only upto 10 to 12 cm depth beneath

which is a highly sandy layer approximately 45 cm in thickness. Below this sandy layer is a ligniferrous layer rich in organic matter and containing fossilised wood. In view of the above situations, considerable difficulty is encountered in the management of a rice crop in the "ela".

2. The subsoil having higher percentage of coarse fraction encourages heavy leaching losses of nutrients through the layers.

3. The chemical properties of the profile show that there is a rich source of exchangeable and water soluble aluminium in the lower horizons which will be brought upwards easily by the capillary rise of water through the middle sandy layer and impose ill effects on the standing crop.

4. The evolution of H_2S in the profile pits consequent to sulphur reduction going on in the pyritic substratum increases the chances of H_2S injury to the crop.

5. The soil is of low CEC; most of the exchange sites being occupied by aluminium, iron and hydrogen ions. Leaching the soil with fresh water will reduce the toxicity of soluble salts. We may improve the soil in the long run by preventing pyrite oxidation during dry season and by inducing ground water level above the pyritic substratum. Also the drying up of the soil and subsequent oxidation of sulphur compounds beneath can be prevented during summer, by raising a catch crop of either

pulses or oil seeds, exploiting the residual moisture available in the field immediate to harvest of Rabi crop whereever possible.

The investigations on the general fertility status of the "ela" reveal that

1. The NPK status of the soils of Pazhamchira can be catagorised as low to medium with respect to N and K and low in the case of P_2O_5.

2. All the surface samples analysed were highly acidic, the pH ranging from 3.4 to 4.8 with a mean of 4.18. The prolonged dryness of the soil for a period of three months dry spell lowered the pH to a mean value of 3.89.

3. Lime requirement of the surface samples revealed that different fields require varying doses of lime ranging from 1.6 to 14 t ha^{-1}, with a mean of 5.48 t ha^{-1}. Split application of lime based on 1/10th of the total lime requirement to ½ LR may be advocated so that the availability of phosphorus can be increased with a simultaneous decrease in the toxicity of Al and Fe.

4. The prolonged drying of the soil during summer season raised the electrical conductivity of the surface sample from a mean value of 0.65 to 1.21 mmhos cm^{-1}. The pH and EC of the surface soil samples were negatively correlated significantly.

5. The cation exchange capacity was low to medium ranging from 3.8 to 9.9 me/100 g (Mean 5.9). The low clay content and organic matter content of the surface soil attribute to low CEC of the soil.

6. The exchangeable bases were low with a mean value of 2.93 me/100 g. The exchangeable Mg and Ca were low in these soils and their deficiencies may contribute to low productivity of the soil. The exchangeable Ca and Mg showed a positive significant correlation.

7. The base saturation percent has recorded a low to medium level with a mean of 49.7%. But about 50.3% of the exchange site is occupied by hydrogen and allied ions.

8. The mean values for exchangeable Al was 248 ppm and that of water soluble fraction was 13.84 ppm indicating aluminium toxicity as a major soil problem of the "ela". The bronzing symptoms and subsequent root damage and increased sterility of spikelets generally occuring in this "ela" points to the fact that iron toxicity is quite possible in many fields.

The salient findings from the field experiments conducted with graded doses of various ameliorants are the following.

1. Among the different growth characters studied, height of plant and tiller number were significantly influenced by

calcium oxide as well as Bhushakthi at both ¼ and ½ lime requirement. The performance of these two ameliorants was identical. The steatite treatments were not effective in improving the tillering ability of the crop.

2. The number of productive tillers were superior to control except in steatite treatments. The variation between levels of ameliorants was not significant in Kharif crop but in Rabi crop CaO at ½ LR was superior to Bhushakthi at ½ LR.

3. The influence of calcium oxide at half the lime requirement in increasing the length of panicle, number of spikelets and the number of filled grains were identical to that of Bhushakthi at half the lime requirement. The lower doses of calcium oxide and Bhushakthi (¼ LR) and the treatment with double the dose of potash could increase the number of filled grains only, over the control and their performance was inferior to the higher doses of CaO and Bhushakthi as far as panicle characters are concerned.

4. The grain and straw yield increased significantly by the application of calcium oxide and Bhushakthi at ½ LR in both the experiments. In Ptb-8 the lower levels of these two amendments as well as additional dose of K treatment could also increase the grain yield over control but inferior to the performance of T_3 (CaO ½ LR) and T_7 (Bhushakthi ½ LR). All other

treatments were ineffective in increasing yield of grain. The grain straw ratio narrowed in treatments with CaO and Bhushakthi.

5. The treatment with Bhushakthi at both the levels contributed to significant increase in thousand grain weight in both the experiments. In Vyttila-1. CaO at ½ LR level could also increase the thousand grain weight significantly.

6. The chemical composition of the plant, in respect of N, P, Ca and Mg contents increased in treatments with CaO and Bhushakthi while potassium and silica content decreased. In steatite treatments Mg and Si content increased but N P K and Ca content decreased. In treatment with additional dose of potassium, N, P, Ca and K content in the plant increased significantly.

7. The total quantity of different nutrients removed by the crop at maximum tillering stage of variety Ptb 8 recorded higher values in treatment with CaO and Bhushakthi at ½ LR levels. Steatite treatments could increase the uptake of Ca, Mg, Si and K only while N and P uptake was decreased. The treatment with additional dose of K could increase the uptake of P and K only.

8. The uptake of different nutrients at panicle initiation stage was influenced by increasing levels of CaO and Bhushakthi.

9. The uptake of major nutrients at booting stage of variety Vyttila-1 recorded higher values in soil limed with CaO and Bhushakthi at both levels. Steatite treatment increased the uptake of P, Ca, Mg and silica while the treatment with additional K increased the uptake of calcium only.

10. The liming with CaO at ½ LR and Bhushakthi at ½ LR is found to be superior over all other treatments in the uptake of NPK Ca Mg and Si in all the growth stages of the crop variety Ptb 8 during Kharif 1984. In Vyttila-1 the uptake of N, P, Ca, Mg and Si is increased by treatments of CaO and Bhushakthi while steatite treatments could increase the uptake of P, Ca, Mg and Si only. The effect of treatment with additional dose of K was not significant at the harvest.

The results obtained in the present investigation has yielded very valuable data on the physico chemical properties of the Pazhamchira paddy fields. Liming materials like Cao and Bhushakthi have been found to be very effective in bringing down the toxic levels of Al and Fe and thereby preventing the maladies affecting the rice crop. Eventhough CaO and Bhushakthi fared best at ½ LR, these ameliorants are seen to contribute towards higher yields of grain and straw even at ½ LR level.

Addition of organic manure in sufficient quantities, to improve the physical properties of soil like increase in the colloidal fraction which in turn will increase the CEC of the soil and also to bring down the amount of soluble Al and Fe, is a practice worth general consideration by the farmers of the locality. Washing out the field after the preplanting application of lime, split application of lime, good drainage and prevention of the field from getting completely drained and dried, shall be the standard methods for assuring a successful crop. If these fields are kept under 2 to 5 cm of water at all times during cultivation, will certainly prevent the oxidation of pyrite and also the upward capillary movement of acids and soluble salts. The avoidance of soluble phosphates and the use of rock phosphate will certainly prevent leaching and fixation losses of Phosphorus.

A detailed study of a number of profiles of the locality, the fractionation of phosphorus in these soils and the dynamics of sulphur transformations in the 'ela' are problems worth investigating, since similar pockets are scattered throughout the coastal belt.

REFERENCES

REFERENCES

Abdul Hameed, A. (1975) "Fertility investigations in the Kole soils of Kerala". M.Sc. Thesis. Kerala Agricultural University

Abichandani, C.T. and S.Patnaik (1961) Effect of lime application availability of N and rice yield on water logged soils. J. Indian Soc. Soil Sci. 9 : 55-61

Aditya Chaudhury, N. and Saha, G.N. (1973). Distribution and nature of organic matter along the profile of some rice soils of West Bengal J. Indian Soc. Soil Sci. 21 (1) : 77-82

*Aeppli, H. and Harrach, T. (1971) Effect of primary amelioration of loses on K fixation other chemical properties and productivity of parabranerde. Boderkundr 130 (2) : 97 - 108

Aiyer, R.S; Rajagopal, C.K. and Money, N.S. (1975) Available zinc, copper, iron and manganese status of the acid rice soils of Kuttanad, Kerala State Agri. Res. J. Kerala 13 (1) : 15-19

*Alam, S.M. (1981) Effect of Al and Fe on the growth and mineral content of barley. Pakistan J. Bot., 13:87-94

*Albercht, W.A., and G.E. Smith (1952) Soil acidity as Ca deficiency Indian Soc. Soil Sci. Comn II and Comn IV Trans L. 119-135

Alexander, M.T. and Durairaj (1968) Influence of soil reaction on certain soil properties and availability of the major nutrients in Kerala soils Agri. Res. J. Kerala 6 : 15-18

Alice Abraham, (1984) "The release of soluble Al in soils under submerged conditions and its effect on rice" Ph.D. Thesis, Kerala Agricultural University

Allaway, W.H. (1957) pH - Soil acidity and plant growth in soil. Year book of U.S.D.A. P.P. 67-71

Alley, M.M. (1981) Short term soil chemical and crop yield response to limestone applications Agron J 73 (4) : 687-689

Anilakumar, K. (1980). "Studies on the response of paddy to lime application in acid soils of Kerala". M.Sc. Thesis Kerala Agricultural University

Anonymous (1963) Annual Report of the International Rice Research Institute Phillippines P.P. 99-100

Anonymous (1975) Annual Report of the Regional Agricultural Research Station Pattambi 14 : 14-15

Anonymous (1979) Crop response to liming of ultisols and oxisols cornell Int. Agric. Bull No. 35

Anonymous (1981) Research Report 1981-82 Kerala Agricultural University

Arnon, D.I. and Johnson, C.M. (1942) Influence of hydrogen ion concentration on the growth of higher plants under controlled conditions. Pl. Physiology 17: 525-539

Aslander, A (1952) Standard fertilization and liming as factors in maintaining soil productivity Soil Soc. 74: 181-195

Bache, A.W. and Crooke, W.M. (1981) Interaction between Al, P and pH in the response of barley to soil acidity. Plant Soil. 61: 365-375

*Bandyopadhya, A.K. and Adhikari, M. (1968) Trace element relationship in rice soil. Alluvial soils of West Bengal

Bandyopadhayaya, B.K. (1973) " Lime requirement of and crop responses to liming on acid soils" M.Sc. Thesis Indian Agril. Research Institute, New Delhi.

Basak, M.N., Chaudhuri, S.B. and Bhattacharya, R (1961) "Effect of fertilizers on the nutritive value of rice grain" Ind. J. Agric. Sci. 31 (2)

*Baumgarther, J.G., Lopes, E.S., Dematto, J.D., Miysaka, S., Igue, T.A. and Guimaraes, G. (1974) Effect of liming and mineral fertilizers on yield of soyabean on low land soil Bragantia : 33 : 1-10

Baver, L.D. (1956) "Soil physics" John Wiley & Sons New York

Bear, F.E. and S.J. Toth (1948) Influence of Calcium on availability of other cations Soil Sci. 65: 69-74

Beater, B.E. (1945) The value of preliming primarily as a means of improving the absorption of phosphorus by plants Soil Sci. 60 : 337-352

*Beer, K; Grundler, C and Willing (1972) Effect of surface application of lime on the dynamics of Mn fractions on the sub soils and their relationship to Mn content in plants Arch ACK Pflzn Bodenkunde 15 (9): 707-718

Bekhari, A., Raden Kova Karavmova (1957) Effect of liming on structure and other characteristics of leached chernozen soil Abt. No.115 Soils and Fert June 1958

*Bergomann, W., K.Beer and W.Katzenberger (1967) Preliminary results on the effect of liming acid soils on yield and nutrient availability in soil. Albredit Jena Soils and Fert 31 (3): 55-60

*Beye, G. (1971) Amelioration of two acid sulphate soils for rice. IRRI Saturday Seminar. Int. Rice Res. Inst. Los Banos Laguina Phillippines

Bhor, S.M., Kibe, M.M. and Zende, G.K. (1970) Interrelationship between lime status of soils and the uptake of Mn, P and Ca by paddy and Jowar plants. J. Ind. Soc. Soil Sci. 18 (4): 479-484

Black, C.A. (1973) "Soil plant relationships" Wiley Eastern Private Limited New Delhi, P.P. 273-355

Blamey, P.C. Edwards, D.G. and Asher, C.J. (1983) Effects of Aluminium OH: Al and P: Al Molar ratio and ionic strength on soyabean root elongation in solution culture. Soil Sci., 136: 197-207

Bloom, P.R. McBride, M.B. and Weaver, R.M. (1979) Aluminium and organic matter in the acid soils Buffering and solution Aluminium activity. Soil Sci. Soc. Am. J. 43 (3): 489-493

Bloomfield, C. and Coulter, J.K. (1973) Genesis and Management of acid sulphate soils. Advan. Agron., 25: 266-319

Bouyoucos, G.J. (1962) Hydrometer method improved for making particle size analysis of Soil. Agron. J. 54: 464-465

*Brauner, J.L. and Catani, R.A. (1967) Effect of $CaCo_3$ on exchangeable Al in Soil. Anais ESC Sup Agric. Luiz Gueivor, 24 : 57-69

*Brinkman, R. and Pons, L.J. (1973) Recognition and prediction of acid sulphate soil conditions. Proc. Int. Symp. Acid sulphate soils Wagenigen, 1 : 169-203

Butorac, A. and Uscumlic, L. (1978) Accumulation of trace elements in the stem leaf of lucerne as affected by fertilizing with Mo and liming Soil and Fert. 41 (7): 432-434

Cate, R.B. and Sukhai, A.P. (1964) A study of Al in rice soils. Soil Sci., 98: 85-93

Chandler, W.V. (1941) Phosphorus absorption by five Alabama soils by reaction, base saturation and free sesquioxides J. Amer. Soc. Agron. 33: 1-12

*Chang, T.C. Trinh, R. and Li H.C. (1971) Effect of liming on the status of soil phosphate and nutrition of rice plants J. Chinese Agri. Chem. Soc. Spl issue 74-82

Chatterjee, B (1949) Role of Al in the interaction of clays and clay minerals with neutral salts and bases J. Ind. Chem Soc. Indust. Ed. 12 : 81-99

Chew, W.Y., William, C.N. Joseph, K.T. and Ramli, K (1976) Studies on the availability to plants of soil N in Malayasian tropical origotrophis peat. 1. Effect of liming and pH II. Effect of NPK and micronutrients Trop Agric 53 (1): 69-87

Cochrane, T.T., Satinas, J.G. and Sanchez, P.A. (1980) An equation for liming and mineral soils to compensate crop aluminium tolerance. Trop Agric 5 7 (2):133-140

Coleman, N.T. and Thomas, G.W. (1967) The basic Chemistry of soil acidity. In soil acidity and liming. Agron. Monogr., 12 : 1-41

Cook, R.L. and Miller, E. (1935). The influence of degree of base saturation on the availability of Phosphorus J. Amer. Soc. Agron. 21 : 292-310

Das, D.K., Das, B and Naskar, G.C. (1976) Physical and mineralogical characteristics of some acid soils Bull Indian Soc. Soil Sci. 11 : 134-145

Dhar, N.R. and Singh, P. (1955) Studies on available phosphate and exchangeable calcium in soil. Proc. Nat. Acad Sci. India 28 A: 236-240

*Dolman, J.D., and S.W.Baol (1967) A study of organic soils (Histosols) in the tide - water region of North Curolina. Tech. Bul. N.C. Agric. Expt. Sta. 181: PP 52

Droupathi Devi, G. (1963) Inter relationship between physical and chemical properties of Kerala State soils in relation to pedogenic factors. Abst. of dissertation work done at the Regional P.G. Training Centre, A.C. & R.I., Coimbatore. Madras Agri. J : 51(9): 408 (964)

Dunn, L.E. (1943) Effect of lime on availability of nutrients in certain soils of Western Washington Soil Sci. 56: 297-316

Erico, G.E., Kamprath, E.J., Naderman, G.C. and Soares W.J. (1979) Effect of depth of lime incorporation on the growth of corn on an oxisols of Central Brazil Soil Sci. Soc. Am. J. 43 (6): 1155-1158

FAO (1973) "Guide lines for soil profile Description" Published by FAO of U.N. Rome

Farina, M.P.W., Sumner, M.E., Plank, C.O. and Lezsch, V.S. 1980. Al toxicity in corn at near neutral soil pH levels J. Pl Nutr. 12: 683-697

Ghani, M.O. and Aleem, S.A. (1942) Effect of liming on the transformation of P in acid soils Indian J. Agric. Sci. 12: 873-882

Ghildyal, B.P. (1969) Soil compaction - a new system of rice cultivation, Indian. Fmg 19: 19-22

Ghosh, S.K., D.K.Das and D.L.Deb (1973) Physical chemical and mineralogical characterization of kari soils from Kerala presented in the symposium on acid sulphate and other acid soils of India held at Trivandrum in Feb.1973

Gomez, K.A. (1972) Techniques for field experiments with rice. International Rice Research Institute, Los banos, Phillippines.

Gopalakrishnan, R. (1973) Rice cultivation, in saline soils of Kerala Souv. Symp. on acid sulphate and other acid soils of India 27-31

Goswami, N.N. Leelavathi, C.R. and Dravid M.S. (1976 b) Response of cereals to lime as affected by its rate of application and fertilizer treatments on acid soils. Bull Indian Soc. Soil Sci. No: 11: 238-245

Gupta, S.P. (1958) Fluctuations of available phosphate in Ganga Low land soils as affected by different manurial treatments J. Ind. Soc. Soil Sci. 6 : 255-259

Hallas, P and Parish, D.H. (1963) quoted by Jones, L.P.H. and Hondriks, K.A. (1967) Silica in soils, plants and animals. Advances in Agronomy 19: 107-149

*Hanes, J. (1973) pH changed in loassic brown earth in relation to the intensive application of fertilizers and manures Poenophospodarstvo 119 (1) : 11-15

Haynes, R.J. and Ludecko, T.E. (1981) Effect of lime and phosphorus application on concentrations of available nutrients and on P, Al and Mn uptake by two pasture legumes in an acid soil Plant and soil 62 (1): 117

*Helias, M and Copponet, M (1970) Exchangeable Al in soils of Brittany Bull Ass Fr Etude Sol 6: 13-22

Heslop, J.A. (1951) A study of infertility of two acid soils Soil Sci. 72: 67-80

Hesse, F.R. (1963) Phosphorus relationship in a mangrove swamp mud with particular reference to aluminium toxicity Plant and soil 19: 205-218

Hessee, P.R. (1971) A text book of soil chemical analysis William clowes and Sons Limited, London

Hunter, A. (1949) Yield and composition of alfalfa at changing the Ca, Mg relation in soil Soil Sci. 67: 53-62

Ikehashi, H., and F.N. Ponnamperuma (1978) " Varietal tolerance of rice for adverse soils - Iron toxicity" soils and Rice IRRI Los Banos, Loguna, Phillippines P.P. 813-814

*Imaijumi, K. and Yoshida, S. (1959) Edaphological studies on the silicon supplying power of paddy soils. Bull. Nat. Inst. Agric. Sci. Tokyo 8: 261-304

IRRI (1968) Ann. Rep. (1965) Int. Rice Res. Inst. Philippines

IRRI (1970) Anu. Rep. 1969. Int. Rice Res. Inst. Philippines

IRRI (1971) Ann. Rep. 1970. Int. Rice Res. Inst. Phillippines

IRRI (1973) Ann Rep. 1972 Int. Rice Res. Inst. Phillippines

*Ishaburo Naga (1959) Japonica rice - its breeding and culture Yokendo Ltd., Tokyo P.P. 575

Islam, A. and Saha, R.C. (1969) Effect of breeding on the chemical composition of rice plant. Pl. Soil XXX : 446-58 Abst. in soils and Fert. 33 117 : 684

Jackson, M.L. (1967) "Soil Chemical Analysis" Prentice Hall of India Pvt. Ltd., New Delhi

Jackson, M.L. (1973) Soil physical and chemical analysis Prentic Hall of India Pvt. Ltd. New Delhi

Janik, V and Schachl, R (1973) Effect of liming on soil properties and crop yields Bodenkulture 24(1): 31-39

Juste, S.C (1964) The effect of liming on the phytotoxicity of mobile Al in a reclaimed soil rich in mineral colloids Ann Agron Paris 15: 5-22

Kabeerathumma, S. (1969) Effect of liming on exchangeable cations and availability of nutrients in acid soils of Kuttanad M.Sc. (Ag.) Thesis Kerala University

Kabeerathumma, S and S.Patnaik (1978) Effect of submergence on the availability of toxic and deficient nutrients in acid sulphate soils of Kerala. Agri. Res. J. 16 (2) : 181-187

Kabeerathumma, S., Padmaja, P and Koshy, M.M. (1979) On increasing the efficiency of superphosphate in slightly acid submerged soils. Agri. Res. J. of Kerala 17 (1) : 11-13

Kanapathy, K (1971) Acid sulphate soils in Malaysia FAO/UNDP Seminar on soil survey and soil fertility research New Delhi FAO World Soil Resources Reports 41: 30-31

Kanwar, J.S. (1976) "Soil fertility - Theory and practices" Indian Council of Agricultural Research, New Delhi. 272-282

Kar, A.K. and Chakravarthy, S.N. (1969) Availability and fixation of applied phosphates in some Indian Acid Soils. J. Ind. Soc. Soil Sci. 17 : 47

Karthikakutty Amma, Alice Abraham and Aiyer, R.S. (1979) Extractable Al in the rice soils of Kerala Agri. Res. J. Kerala 17 (1) : 44-49

Karunakara Panicker, N (1980) " The utility of an indigenous source of Magnesium silicate for rice in Kuttanadu soils". M.Sc. (Ag.) thesis Kerala Agrl. Univ.

*Kawaguchi, K., and K. Kyuma (1969) Low land rice soils in Malaysia. Natural Science Series N-4. Centre for South East Asian studies. Kyoto University 270 P & 154 P

*Kawaguchi, K and Kyuma, K (1977) "Paddy soils in tropical Asia their material nature and fertility". The university press of Hawaii, Honolulu, Hawaii, U.S.A.

Keogh, J.L., Maples, R and Wells J.P. (1968) Effect of limestone on rice and soyabean that follow pasture on a silt loam. Bull Ark Agric. Exp. Sta. No.: 733 PP 14

Khanna, S.S. and K.K. Mahajan (1971) A study of the behaviour of added phosphates in soils of variable physico-chemical properties. Proc. International Symposium in soil fertility evaluation Indian Soc. Soil Sci. 725-736

Khanvilkar, G.S. Shingle, A.K. and Patil N.D. (1972) Liming of acid soils of Maharashtra Indian J agric chem 5 (1): 13-17

Kobayashi, T., T.Sakurai, and Y.Sato (1953) Some chemical characteristics of the strong acid soils found on the restored lands in Shikuko coal mine field. Bull Kyushu Agric Exp Sta. 2: 81-96

Kobayashi, H., Kawaguchi, Y. and Ota, M. (1956) The effect of slag on paddy rice. Soil plant Food. 1: 45-46

Koshy, M.M. (1960) Influence of lime and application to these soils on yield and nutrient uptake by sorghum Thesis presented to the University of Tennessee

Koshy, M.M. and Brito - Muthunayagam, A.P.A. (1961) Fixation and availability of phosphate in soils of Kerala Agric Res. J. Kerala. 1: 70-78

Koshy, M.M. (1970) The chemical nature of organic complexes in Kerala soils Curr Sci. 39: 353-354

Kothandaraman, G.V. and Mariakulantha, A (1965) Change in pH, exchangeable calcium and available P_2O_5 due to liming of acid soils of Nanjunad in Niligiris Madras Agric. J. 60 (8) : 659-

Krishnaswamy, R and Raj, D (1975) Effect of lime organic matter and fertilizers on the availability of various forms of Fe in acid alluvials soils Madras Agric. J 62 (7) : 439-444

Kurup, T.K.B. (1967) "Fertility investigations on rice soils of Kuttanad, Kerala". M.Sc. Thesis submitted to University of Kerala

Kuruvila, V.O. and Patnaik, S. (1973) "Problems of Acid sulphate soils of Kerala and their amelioration". Symposium on acid sulphate and other acid soils of India.

Kwack, B.H. (1969) The effect of slaked lime application in degraded paddy fields on rice grain yield and its residual effect on succeeding barely growing. Res. Rep office Rur. Dev. Siwar 12 (3) : 63-74

Kwack, B.H. (1970) Extended trials of slaked lime application on improving degraded paddy fields and rice yields. Res. Rep. Office. Rur. Dev. S. Korea Plant environment 13 : 99-108

Kyuma, K. (1981) "Productivity of low land soils, presented at symp on Potential productivity of field crops under different Environments" IRRI Los Banos, Leguna, Phillippines

Leite, N., Garganteni, H and Hungria, L.S. (1970) Effect of N, P lime and micronutrients on irrigated rice in the Paraeba valley Bragantia 29 : 272-285

Long, F.E., Langdale, G.W. and Mybre D.L. (1973) Response of an Al tolerant and on Al sensitive genotype to lime P and K on three Atlantic coast flat wood soils Agron J 95 (1) : 30-34

*Lysenko, T. (1957) "Soil nutrition of plants" Foreign Language publishing House Moscow

Maclean, A.J. (1956) Influence of addition of lime to soil on the availability of K and other cations for Alfalfa Canadian J Agric Sci 36: 213-220

Mandal, S.C.; Sinha, H.; Prasad, C.R. and Alim, M.A. (1966) studies on liming of acidic red loam soil J. Indian Soc. Soil Sci 14 (2) : 127-131

Mandal, S.C. and Sinha, M.K. (1968) Potassium nutrition of plants in a limed soil. J. Ind Soc Soil Sci. 16 (1) : 37-40

Mandal, S.C. (1971) Acid red soils of India and their management. Presidential address, Agric. Sci. Section 58th Indian Science Congr., Bangalore

Manua, O; Bajescu, I and Chiriac A (1965) Contribution to the verification of methods used in the determination of lime requirements of acid soils. Anal Inst Cent Agril. Sect Pedsol. 32: 173-186

Martin, J.A; Kochhan, R.A.; Gomez, E.P. and Langer, F.(1977) response of wheat cultivars to liming in some hight Aluminium oxisols Brazil Agron J 69 (4) : 612-616

Menon, P.K.G. (1975) Morphological and physico-chemical properties of the kayal lands of Kuttanad (Kerala. M.Sc. (Ag) Thesis Kerala Agricultural University

*Mitsui, S (1955) "Inorganic nutrition, fertilizations and soil amelioration for low land rice". Yokendo Ltd Tokyo

Money, N.S. (1964) Paper read at the conference of State Agricultural Chemists 1964

Moorman, F.R. (1962) Acid sulphate soils (catclays) of tropics. Soil Sci. 95 (4) : 62-65

Moormann, F.R. (1963) Acid sulphate soils (cat clay) of the tropics Soil Sci. 95: 271-275

Moormann, F.R. and van Breeman, N (1978) Rice, Soil, Water land. IRRI Losbonos Laguna Philippines

*Morelli, M. Jgue, K and Fuentes, R. (1971) Effect of liming on the exchange complex and on the movement of Ca and Mg. Turrialba 21 (3) : 317-322

Moskal, S (1959) The effect of mobile aluminium on P uptake by oats Soils and Fert (1961)

Motomura, S., A. Seirayosakol and W. Cholitkul (1975) Liming effect on the growth and yield of rice in combination with various rates of N and P on an acid sulphate soil Int. Rice Res. Conf. April 21-24 1975 Int. Rice Res. Inst. Contribution 13.9 P

Nair, K.S., Varadarajan, S and Rajagopala Iyyengar (1957). Preliminary studies on raising sesbania speciosa for green manure in the laterite Madras agric J 44: 447-456

Nambiar, E.P. 1960 "Studies on the effect of liming laterite soils of West Coast Kerala". M.Sc. Thesis submitted to University of Coimbatore

Nayar, P.R.; A.K. Misra and S.Patnaik, 1975. Rapid microdetermination of silicon in rice plant. Plant and Soil. 42 (2) : 491-494

Nhung Nai - Thi My. and F.N. Ponnamperuma (1965) Effects of Calcium carbonate, Manganese dioxide, Ferric hydroxide and prolonged flooding on chemical and electrochemical changes and growth of rice in a flooded acid sulphate soil soil Sci. 102: 29-41

*Nikistickina, P.J. (1951) Effect of dung on the dynamics of the acidity of peat podzolosed soil. Pock Inst. Dokuchaeve 33: 113-126

Nistos, R.E., and H.J. Evans (1969) Effect of univalent cations on the activity of starch synthetase Plant physiol 44 : 1260-1266

Oblisami, G. (1973) Effect of liming on changes of micro flora of acid soils. Madras Agri J. 60 (8) : 1080-1082

*Okuda, A. (1952) "Plant nutrition and fertilizers" Yokendo Press Tokyo

*Okuda, A and E. Takahashi (1962 a). Effect of silicon supply on the inferior of excessive amount of Fe^{++}, Mn^{++}, Cu^{++} Al^{+++} Co^{++} in barely and rice plants 5. J Sci. Soil and Manure Jpn 33: 1-8

Okuda, A., and E.Takahashi (1965) The role of silicon Page 123-146 in IRRI. The mineral nutrition of rice plant. Johns Hopkins Press, Baltimore, Maryland

Oldershan, A.W. and Gardener, H.V. (1949) Liming experiment on light sand at Tunstall J. Roy Agric Soc. 110 England

*Ota, V. (1968) "Mode of occurence of Bronzing in rice plant". Jap agric Res., J. 3: 1-5

Padmaja, P. and Varghese, E.J. (1972) Effect of Ca, Mg and Si on the uptake of plant nutrients and quality of straw and grain of paddy. agric. Res. J. Kerala 10 (2) : 100-105

Park, N.J. and Y.S.Park (1969) A study on the physicochemical properties of acid sulphate soil in Kimhar plains J. Korean Soc. Soil Fert. 2: 15-26

*Park, Y.D. and Y.S.Kim (1970). The effect of woolastonite and manganese dioxide on rice grown on flooded acid sulphate Soil J. Korean Soc. soil Sci. 3 (1) : 23-28

Park, N.J., Y.S.Park, and Y.S.Kim (1971). Effect of lime on growth of rice and changes in pH Fe^{2+} and Al in acid sulphate soils. J. Korean Soc. Soil Sci. Fert. 4:167-175

*Park, N.J., Y.S.Park, K.H. Lee and Y.S.Kim (1973). The effect of P on rice in relation to lime and Wollastomite in an acid sulphate soil Res. Rep. Office. Rural Development. Suweon, Korea. 15: 49-58

Patnaik, S., Bandyopadhya, A.K. and Nanda, B.B. (1968). Effects of different liming and phosphorus material on rice yields and nutrient uptake in acid laterite soil. Indian J agric. Sci. 38 (2): 261-269

Patnaik, S. (1971) Laterite soils of India. FAO/UNDP Seminar on soil survey and soil fertility Research. New Delhi FAO World Soil Resources Reports No: 41: 52-56

*Pearson, R.W. and Adanis, F (ed) (1967) Soil acidity and liming. Agron. Mono: No.12 Americal Society of Agronomy Madison, Wis

Pillay, T.R.N., and Subramonian, V. (1931) The origin and nature of peaty soils of Travancor Jour. Ind. Inst. Sci. 14: A.99

Piper, C.S. (1966) Soil and plant analysis. Hans publishers, Bombay

Ponnamperuma, F.N. (1958). Lime as a remedy for physiological disease of rice associated with excess iron Int. Rice Comm. Newsl. 7 (1) : 10-13

Ponnamperuma, F.N. (1960). Lime as an amendment for the acid laterite rice soils of Ceylon. Trop Agric. 116 (2) : 243-252

Ponnamperuma, F.N. (1972). "The chemistry of submerged soils" Adv Agro. 24: 29-96

Ponnamperuma, F.N.; Attanandana, T. and Beye, G. (1973) Amelioration of three acid sulphate soils for low land rice. Proc. Int. symp: Acid sulphate soils, Wageningen, 2: 391-406

Ponnamperuma, F.N. (1977) Screening rice for tolerance to mineral stresses page 341-354. Proceeding of Workshop on plant adaptations to mineral stress on problem soils. Beltsvilla Maryland, Nov. 22-23

Ponnamperuma, F.N. (1978) Toxic rice soils in Plant Nutrition Proceedings on the 8th International Colloquin on plant analysis and fertilizer problems. Auckland, Newzealand

Pratt, P.E., Jones, W.W. and Chapman H.D. (1956) Changes in P in an irrigated soil during 28 yrs of differential fertilization Soil Sci. 82: 295-306

Prasad, R.N; Shamuddin, C.R. and Singh, B.N. (1971). Effect of continuous application of manures fertilizers and lime on some chemical properties and acid red loam soil of Bihar. Proc. int symp Soil Fert. Evaln. New Delhi 1: 865-872

Prateep Krasae Sindu and Sims, J.L. (1972). Response of rice to N and Ca nutrition Soil Sci. Soc. Amer. Proc. 36 (3) :

Ragland, H. and Coleman, N.T. (1959). The effect of soil solution aluminium and calcium on root growth. Proc. Soil Sci. Soc. 19 (2) : 203-208

Rajagopal, C.K; Sheriff, M.M. Selvakumari, G and Jabarani,N. (1977) Status of available minor nutrient cations in the soils of Kerala. Agric. Res. J. Kerala 15 (2) : 165-171

Ray Chaudhuri, S and Mukherjee, M.K. (1941) Studies on Indian red soils II. Fixation of phosphates Indian J. agric. sci., 11: 205-219

Reeve, N.G. and Sumner, M.E. (1970 a) Effects of Al toxicity and P fixation on crop growth on oxisols in Natal Proc soil Sci Soc Am 34 : 263-267

Reeve, N.G. and Sumner, M.E. (1970 b) Lime requirement of Natal oxisols based on exchangeable aluminium Proc Soil Sci Am. 34. 595-598

Ribertson, W.K. Neller, J.R. and Bartlet, F.D. (1954) Effect of lime on available of P in soil of high to low sesquioxides content proc. soil Sci Soc Amer. 18 : 184-187

*Richmond, T. DE, A., J. Williams, and U.Datt (1975). Influence of drainage on pH sulphate content and mechanical strength of a potential and sulphate soil in Figi Trop Agric (Trinidad) 52: 325-334

Rodrigo D.M. (1962) The variation of chemical and physical characteristic of paddy soils on submergence Experiment II Trop Agrist 118: 139-218

Russel, E. John (1937) "Soil conditions and plant growth" Longmans, Greew & Co Toronto. London

*Ryan, J and Simullie, G.W. 1975. Liming in relation to soil acidity and P fertilization efficiency communication in soil science and plant analysis 6 (4)

Sadanandan, A.K. and Varghese, E.J. (1969) Role of Si in the uptake of nutrients by rice plant in the lateritic soils of Kerala Agric. Res J of Kerala 7 : 91-96

Sahu, B.N. (1968) Bronzing decrease of rice in Orissa as influenced by soil type and management and its control J. Indian Soc. Soil Sci. 16 : 41-54

Sanchez, P.A. (1973) Puddling tropical soils. Growth and nutritional aspects. Soil Soc. 115: 149-158

Sanchez, P.A. (1976) "Properties and management of soils in the tropics". John Wiley & Sons. Newyork

*Santos, J.Q. and Doss (1966) Soil Acidity and Ca deficiency. Anais. Inst. Sup. Agron Univ tec. Lisb. 29: 263-269

Schimehl, W.R.; Peech, M and Bradifield, R (1950) causes of poor growth of plants on acid soils and the beneficial effects of liming soil sci 70: 393-410

Shoemaker, H.E., Mclean, E.O. and P.F.Pratt (1962). Buffer method for determination of lime requirement of soil with appreciable amounts of extractable Al. Proc.Soil Sci. Soc. Amer. 25: 274-277

Singh, T.A., Sharma, S.K., Tamholi, P.M. (1970) Effect of liming on chemical properties and growth of rice (Oryza Sativa L) on some acid soils of Madhya Pradesh Ind. J. Agri Sci. 40 (1) : 526-532

Singh, R.N. and Aleoshin, S.N. (1983) Nature of soil acidity in some acidic soil of USSR J. Indian Soc Soil Sci. 31: 373-380

*Silva, J.A. (1971) Possible mechanisms of crop response to silicate application. Int symp soil Fert. Evaluation proc. 1: 805-14

Sivan Nayar, P.N. (1970). "The influence of different levels of Ca and P on the growth yield and composition of two high yielding varieties of rice". Thesis submitted to the University of Kerala for M.Sc. (Ag.) Degree

Snedecor, George, W and Cochran, William, G. (1967) Statistical methods Oxford and IBH publishing Co., Calcutta-16. 6th ed.

Sree devi Amma, S and R.S.Aiyer (1973) Potassium status of acid rice soils of Kerala State. Thesis submitted to University for M.Sc. (Ag.) Degree

Sri Vastava, K.K; Ali, S and De.S.K. (1972). A note on availability of soil Nitrogen phosphorus in the presence of calcium salts. Indian J Agric Chem 5 (1) : 7-12

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for estimation of available nitrogen in soils. Curr. Sci. 25 : 259-260

Subramoney, N (1958) "Chemical and morphological studies on the acid peats of Kerala". Ph.D. Thesis Univ. of Travancore

Subramoney, N (1964) Nutrient status of peaty soil and a red loam laterite soil and the availability of nutrients from added fertilizer Bull Nat Inst Sci. India 26: 48-58

Subramoney, N (1965) Injury to paddy seedlings by production of H_2S under field conditions J. Indian Soc. Soil Sci. 13 (2) : 95-98

Subramoney, N and E.P. Nambiar (1969) Soil test crop response correlation studies in Kerala J. India Soc. Soil Sci. 17 : 179-186

Subramoney, N and Sukumaran, K.M. (1973) The chemical microbiologicals and agronimic aspects of acid saline water logged soil of Kerala. Souv. Symp on Acid Sulphate and other acid soils of India P.P. 21-25

Subramoney, N and Gopalaswamy, V. (1973). Proceedings of the symposium on acid sulphate soils held at Trivandrum Kerala

Sudharmai Devi, C.R. (1983) "The nature of acidity in upland and rice fallows in relation to response of pulses crop to liming". Thesis submitted for M.Sc. (Ag.) Kerala Agricultural University

*Sudjadi, M., I.M. Widjik and M. Soleh (1973) Chemical Characteristic of major soil groups in Jelapat, South Kalimantan Proc. Second Asean Soil Conf. Soil Res. Inst. Bogor, Indonesia 2: 165-176

*Sumner, M.E. (1970) Aluminium toxicity a growth limiting factor in some Natal sands proc. 44th Congr. S afr symp. Technel. Ass 187-203

*Tadano, T. (1976) Studies of the methods to prevent iron toxicity in low land rice Mem. Fac. Agric. Hokkando Univ. 10 (1) : 22-63

Tadano, T and S. Yoshida (1978) Chemical changes in submerged soils and their effect or rice growth pages 399-420 in soils and Rice IRRI Los Banos Phillippines

*Takahashi, T (1963) Effect of exch. Al on Ca absorption by barely in volcame ash soil. Soil Sci and Pl Nutr Japan 9 (5) : 36

*Takijima, Y.; Shiojema, M. and Konno, K (1959) Studies on the soils of paty paddy fields XI Effect of Si in the growth of rice plant and its nutrient absorption J Sci. Soil Tokyo 30: 181-184

Takijima, Y; Wizayaretna, H.M.S. and Sereviratne, C.J.(1970) Nutrient deficiency and physiological deseases of low land rice in ceylon 3. Effect of silicate fertilizers and dolomite for increasing rice yield Soil Science Pl Nutr 16 : 11-16

*Tanaka, A., Patnaik, S and Abichandini, C.P. (1958) Studies on the nutrition of rice plant Influence of increasing levels of P & K on growth yield and nutrient absorption by rice plants Proc. Ind. Accad Sci. 50 (B): 305-318

Tanaka, A and Park, Y.D. (1966) Significance in the absorption and distribution of Si in the growth of the rice plants. Soil Sci. Plant Nutr. 12 (5) : 23-28

Tanaka, A., R.Loe, and S.A. Navasero. (1966) Some mechanisms involved in the development of iron toxicity of the rice plant. Soil Sci. Plant Nutr. 12: 158-164

*Tanaka, A and T.Tadano. (1969 a) Studies on the iron-nutrition of rice plant (1) Absorption and distribution of iron in rice plant as affected by the level of iron in the culture solution J Sci. Soil Manure, Jpn. 40: 380-384

Tanaka, A and Yoshida (1970) Nutritional disorders of the rice plant in Asia Int. Rice Res Int. Tech. Bull 10: 51 P

Tammi, Y.N., Matsuyama D.T. (1972) Effect of Ca SiO_3 and $CaCO_3$ on growth of sorghum Agric Digest No.25 pp 37-44

Than, S.T. (1959) Effects of pH on the uptake of native and applied N, P, K Diss. Abstr. 20: 450-451

Thawornwong, N. and Diest, A. Van (1974). Influence of high acidity and aluminium on the growth of low land rice. Plant Soil 41: 141-145

*Thenabadu, M.W. and B.L. Ferndo (1966) Rice soils of Hewayan Korale Trop. Agric. 122: 71-83

Thenabadu, M.W. (1969) The effect of slacked lime on rice yield at panagoda. Pussellawa and Bobuwellan Trop. Agric. 125: 11-118

Thomas, G.W. (1960) Forms of Al in Cations exchanges Trans 7th int congr soil sci 2: 364-369

Throp, F.C., and Hobbs, J.A. (1956) Effect of lime application on nutrient uptake of Alfalfa Soil Sci. Soc Amer.Proc. 20: 544-546

Tripathi, R.S. and Panda, H.K. (1971) Studies on toxicity factors and nutritional imbalance of soil for wheat culture in acid laterite soil Int. Symp. soil Fert Evaluation 1: 821-830

Valmis, J (1953) Acid soil infertility as related to soil solution and solid phase Soil Sci. 75: 383

*van Breeman, N. (1976) Genesis and solution chemistry of acid sulphate soils in Thailand. Agri.Res.Rep. 848. PUDOC, Wageningen 263 P

van Breeman, N. and L.J. Pons (1978) Acid sulphate soils and Rice. Soils and Rice IRRI Publication Los Banos Philippines, P.P. 739-779

Varghese Thomas (1963) The influence of Ca and Mg in increasing the efficiency of fertilizers for rice and Ca and Mg status of some typical rice soils". Thesis submitted to the University of Kerala for M.Sc. (Ag.) degree

Vijayakumar, K (1977) "Use of indegenous source of magnesium silicate as a soil amendment" Thesis submitted to the Kerala Agricultural University for M.Sc.(Ag.) Degree

Viro, P.J. (1955) "Use of EDTA in Soil Analysis" Soil Sci. 79: 459

Volk, G.M. and Bell, C.E. (1944) Soil reaction Florida Agr. Exp. Sta Bull 400

*Wang, T.S.L. 1971 Effect of $CaCo_3$, $CaSio_3$ and organic manure on the growth and yield of rice on flooded acid latorolic soil J. Taiwan Agric. Res. 20:47-55

Wright, K.E. (1937) Effects of P and Lime in reducing Aluminium toxicity of acid soil. Plant Physiol., 12: 173-181

Yadav, J.S.P. (1976). Saline, Alkaline and acid soils in India and their management. Fert. News: 15-23

York, E.T., Jr. and Rogers, H.T. (1947). Influence of lime on solubility of potassium in soils and on its availability to plants Soil Sci. 63: 467-477

Yoshida, O., Ouishi, K and Kitachishi.L (1962) Chemical forms, mobility and deposition of silicon in rice plant Soil sci pl nutr. 8 (3) : 15-21

*Yoshida, S. (1975) The physiology of silicon in rice. Tech. Bull. No: 25. ASPAC - FFTC, Taipei Taiwan. 27 p

Yoshida, S. (1981) Fundamentals of Rice Crop Science IRRI Los Banos Laguna Philippines pp. 150 & 192

* Originals not seen

APPENDICES

APPENDIX I

Summary of analysis of variance table for the properties of soil after harvest of Ptb 8

Source	df	pH ** M.S	Total N M.S	Available P_2O_5 kg/ha M.S.	Available ** K_2O M.S	Exchangeable sodium M.S	Exchangeable** Calcium M.S	Exchangeable Magnesium M.S	Silica in ppm M.S
Total	23								
Block	2	0.075	0.0004	326.44	882.24	0.00048	0.139	0.076	0.0000060
Treatment	7	0.378	0.00024	225.26	2733.94	0.00429	5.960	0.0324	0.0000016
Error	14	0.035	0.00023	125.46	369.87	0.01530	0.188	0.0213	0.0000009

** Significant at 1% level

APPENDIX II

Summary of analysis of variance table for the properties of soil after harvest of Vyttila 1

Source	df	Mean sum of square						
		Total N	P_2O_5 kg/ha	K_2O kg/ha	Na me/100 g	Ca me/100 g	Mg** me/100 g	Si** ppm
Total	23							
Block	2	0.0029	326.44	214.08	0.0026	6.77	0.076	0.000000102
Treatment	7	0.0020	225.26	188.16	0.0039	6.25	0.112	0.000017500
Error	14	0.0006	125.46	256.86	0.0239	2.22	0.014	0.000000158

** Significant at 0.01 level

APPENDIX III

Summary of analysis of variance table for height of plant at four stages
Mean sum of square

Source	df	Maximum tiller-ing stage**	Panicle initia-tion stage**	Booting stage**	At harvest**
Total	23				
Block	2	11.90	12.255	6.384	32.445
Treatment	7	89.80	182.383	220.384	201.472
Error	14	10.46	3.857	5.044	4.458

** Significant at 0.01 level

APPENDIX IV

Abstract of analysis of variance table for the tillering ability of rice

Mean sum of squares

Treatment	df	Maximum tillering stage**	Panicle initiation stage**	At harvest**	No. of productive tillers*
Total	23				
Block	2	1.26	0.876	1.335	0.0053
Treatment	7	4.24	3.901	4.257	0.248
Errors	14	0.236	0.144	0.259	0.0681

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX V

Abstract of analysis of variance table for length of panicle Number of spikelets and number of filled grains

Mean sum of squares

Source	df	Length of panicle **	No. of Spikelets**	No. of filled grains**
Total	23			
Block	2	0.886	15.758	24.750
Treatment	7	2.831	86.220	137.260
Error	14	0.427	13.424	4.694

** Significance at 1% level

APPENDIX VI

Abstract of analysis of variance for yield of grain, straw, grain straw ratio and thousand grain weight

Mean sum of squares

Source	df	Wt. of grain**	Wt. of straw**	Grain straw* ratio	Thousand grain weight**
Total	23				
Block	2	0.126	0.086	0.0013	0.125
Treatment	7	0.377	0.684	0.0240	3.865
Error	14	0.024	0.0399	0.0053	0.478

* Significant at 5% level

** Significant at 1% level

APPENDIX VII

Abstract of analysis of variance table for plant height of variety Vyttila-1 at booting stage and at harvest stage

Mean sum of squares

Source	df	Plant height (cm)	
		At booting stage**	At harvest**
Total	23		
Block	2	21.906	3.795
Treatment	7	64.182	63.36
Error	14	3.67	6.94

** Significant at 1% level

APPENDIX VIII

Abstract of analysis of variance table for the tillering ability of the crop two stages and no. of productive tillers

Mean sum of squares

Source	df	No. of tillers		No. of productive tillers**
		At Booting stage*	At harvest**	
Total	23			
Block	2	0.014	0.303	0.030
Treatment	7	0.570	0.777	0.385
Error	14	0.10	0.097	0.029

* Significant at 5% level

** Significant at 1% level

APPENDIX IX

Abstract of analysis of variance table on the panicle characters of rice variety Vyttila-1

Mean sum of squares

Source	df	Panicle length	No. of spikelets per panicle	No. of filled grains
Total	23			
Block	2	1.097	2.527	2.715
Treatment	7	0.815	1.700	8.038
Error	14	0.422	3.370	2.876

APPENDIX X

Abstract of analysis of variance table on yield characters of rice variety Vyttila-1

Mean sum of squares

Source	df	Yield of grain**	Yield of Straw *	Grain/ straw ratio	Thousand grain weight**
Total	23				
Block	2	0.059	0.006	0.002	0.001
Treatment	7	0.236	0.837	0.007	0.112
Error	14	0.028	0.131	0.002	0.054

* Significant at 5% level

** Significant at 1% level

APPENDIX XI

Abstract of analysis of variance table on the composition of rice grain (Variety Ptb-8)

Mean sum of squares

Source	df	N ** %	P* %	K %	Ca** %	Mg** %	Si** %
Total	23						
Block	2	0.005	0.011	0.007	0.00006	0.000048	0.00387
Treatment	7	0.049	0.002	0.015	0.00047	0.001515	0.5368
Error	14	0.003	0.0007	0.004	0.00004	0.000163	0.00427

* Significant at 5% level

** Significant at 1% level

APPENDIX XII

Abstract of analysis of variance table on the composition of rice straw
(Variety Ptb-8)

Kharif 1984

Mean sum of squares

Source	df	N** %	P* %	K** %	Ca** %	Mg %	Si** %
Total	23						
Block	2	0.0078	0.00011	0.0729	0.0238	0.005	0.190
Treatment	7	0.0471	0.00018	0.0559	0.0475	0.0009	1.90
Error	14	0.0022	0.00003	0.0079	0.0015	0.0004	0.224

* Significant at 5% level

** Significant at 1% level

APPENDIX XIII

Abstract of analysis of variance table on the composition of rice grain
(Variety Vyttila-1)

Rabi 1984

Mean sum of squares

Source	df	N* %	P** %	K* %	Ca %	Mg %	Si** %
Total	23						
Block	2	0.0047	0.0072	0.000041	0.0069	0.0010	0.101
Treatment	7	0.0280	0.0628	0.001110	0.0042	0.0001	0.396
Error	14	0.0062	0.00018	0.000208	0.0012	0.0001	0.018

* Significant at 5% level

** Significant at 1% level

APPENDIX XIV

Abstract of analysis of variance table on the composition of rice straw
(Variety Vyttila-1)

Rabi 1984

Mean sum of squares

Source	df	N* %	P** %	K* %	Ca** %	Mg %	Si** %
Total	23						
Block	2	0.0075	0.0028	0.027	0.01005	0.021	0.216
Treatment	7	0.0270	0.00033	0.062	0.0372	0.0007	0.585
Error	14	0.0050	0.000024	0.016	0.00418	0.0005	0.060

* Significant at 5% level

** Significant at 1% level

APPENDIX XV

Abstract of analysis of variance table on the uptake of nutrients at maximum tillering stage (Ptb 8) in g plot^{-1}

Mean sum of squares

Source	df	N**	P**	K**	Ca**	Mg**	Si**
Total	23						
Block	2	46.69	2.69	471.74	260.15	9.319	496.28
Treatment	7	1488.17	80.39	1311.77	374.49	32.04	13568.4
Error	14	35.19	1.788	68.67	20.26	1.82	460.90

** Significant at 1% level

APPENDIX XVI

Abstract of analysis of variance table on the uptake of nutrients at panicle initiation stage (Ptb 8) in g $plot^{-1}$

Mean sum of squares

Source	df	N**	P**	K**	Ca**	Mg**	Si*
Total	23						
Block	2	17.84	3.13	35.31	917.4	462.73	6637.04
Treatment	7	2386.14	100.09	1384.7	1020.6	111.22	75730.05
Error	14	52.46	1.20	89.59	39.64	8.18	1623.69

* Significant at 5% level

** Significant at 1% level

APPENDIX XVII

Abstract of analysis of variance table on the uptake of nutrients at harvest (Ptb 8) in g plot^{-1}

Mean sum of squares

Source	df	N**	P**	K**	Ca**	Mg**	Si**
Total	23						
Block	2	94.62	25.60	1010.84	150.73	20.80	917.17
Treatment	7	2346.01	60.73	465.75	881.09	51.67	30995.6
Error	14	44.48	1.5	58.82	22.52	3.71	2876.6

** Significant at 1% level

APPENDIX XVIII

Abstract of analysis of variance table on the uptake of nutrients at the booting stage (Vyttila-1) g plot^{-1}

Mean sum of squares

Source	df	N*	P**	K	Ca**	Mg**	Si**
Total	23						
Block	2	19.64	0.131	123.06	9.80	0.890	1758.01
Treatment	7	180.24	8.54	95.03	8.59	4.186	832.3
Error	14	29.41	0.696	37.26	0.32	0.469	208.2

* Significant at 5% level

** Significant at 1% level

APPENDIX XIX

Abstract of analysis of variance table on the uptake of nutrients at harvest of Vyttila-1 in g $plot^{-1}$

Mean sum of squares

Source	df	N**	P**	K*	Ca**	Mg**	Si*
Total	23						
Block	2	166.95	43.66	23.79	20.13	17.89	827.66
Treatment	7	963.63	35.55	114.94	453.01	52.85	19893.0
Error	14	52.07	1.12	18.69	35.59	5.96	3290.6

* Significant at 5% level

** Significant at 1% level

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ABSTRACT

An investigation into the causes of the poor productivity of the rice fields in the Pazhamchira "ela" at Melkadakkavur of Chirayinkil Taluk was taken up to suggest ways and means to increase rice and straw production and to bring to light the physico-chemical characteristics of the soil. Fifty surface soil samples and two profiles were examined, analysed and investigated. Field trials in Randomised Block Design spread over the Kharif and Rabi seasonsof 1984-85 with rice varieties Ptb-8 and Vyttila-1 respectively were conducted in a cultivator's field.

The surface soil studies revealed that the soils were highly acidic with appreciable electrical conductivity. The soils were of low CEC, with an average base saturation of 49.7 with more than 50 percent of the exchange sites occupied by exchangeable Al and iron. The N and K content of the soils were low to medium and P content was low.

The profile studies revealed that the surface cultivated portion of the soil is very shallow with a depth of about 10-12 cm which was sandy loam in texture. There was a predominantly sandy layer (about 90% sand) underlying the surface cultivated layer which was followed by a highly ligniferrous layer abundant in organic matter, twigs and wood fossils. The pH showed a decreasing trend with depth. The soluble Al content of the lowest layer dug was very high (10.7 me/100 g soil).

These soils can be included under the category of acid sulphate soils because of the presence of jarosite mottlings found in the third layer and the prevalance of a pH value of less than 4.0 within a depth of 50 cm.

In the field experiment, CaO, Bhushakthi and steatite were tried at $\frac{1}{2}$ L.R. and $\frac{1}{4}$ L.R levels along with a control without lime and fertilizer dose as per state package of practices and another treatment, without lime but with double the dose of K recommended in the package of practices. The results of the experiment showed that the treatment with CaO and Bhushakthi at $\frac{1}{2}$ L.R gave the best results followed by $\frac{1}{4}$ L.R doses. Lime and Bhushakthi were able to increase grain and straw yield and grain-straw ratio. The nutrient uptake by the crops was also significantly higher in treatments receiving calcium oxide and Bhushakthi at half the lime requirement. Eventhough the treatment with double the dose of K was significantly superior over the control and steatite treatments in the Kharif crop in many aspects, the results during the Rabi season was not consistent with that of the previous season. The steatite seemed to exert a dwarfing effect on the crop growth and did not contribute to higher grain yields.

Application of organic matter, liming and proper water and fertilizer management appears to be the best solution to ensure successful raising of rice in these paddy fields.