EFFECT OF SUBMERGENCE ON THE SOIL TESTING PARAMETERS OF PADDY SOILS

BY

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DECLARATION

I hereby declare that this thesis entitled "Effect of submergence on the soil testing parameters of paddy soils" 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 of any other University or Society.

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Certified that this thesis entitled "Effect of submergence on the soil testing parameters of paddy soils" is a record of research work done independently by Kum. Usha Mathew 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

INTRODUCTION

Most of the world's rice crop is grown during the wet season when rice fields remain waterlogged for the greater part of the growing period. In soils, which remain permanently waterlogged or only temporarily during the rainy season, farmers have opted to grow rice possibly since no other crop can be grown. In the past, rice has been continuously produced in flooded soils in vast areas of Asia without even moderate fertilizer inputs, indicating their inherent potential to provide and possibly regenerate a satisfactory fertility level.

Many physical, chemical and biological systems vitally important to the nutrition of rice plants are known to be influenced by anaerobic conditions prevailing. The chemical changes are mainly set in motion as a consequence to the biological oxidation process taking place under oxygen deficient status of flooded soils where alternate electron acceptors are available. The net result of these changes provide both benefits in terms of increased nutrient availability and disadvantages such as toxicity due to excess of iron, manganese etc. for rice cultivation.

The cognisable effects following soil submergence are an increase in the content of available forms of both major and some of the micronutrients, decrease in the availability of zinc, an excessive increase in the content of ferrous iron and formation of sulphides and organic acids.

The flooded soils that support rice culture thus serve as a natural source of increased nutrient supply. In the present system of fertilizer-use in rice production technology, Agronomists and Soil Scientists have not paid adequate attention to this aspect of the flooded soils acting as a potential source for increased nutrient supply to rice. A definite idea on the pattern and magnitude of the changes that are taking place in the various parameters of practical significance to the rice crop is highly imperative for drawing up a package of practices for wet land rice cultivation.

The chemistry of submerged soils has been elaborately reviewed by Ponnamperuma (1965, 1972), Patrick and Mahapatra (1968), Patnaik and Reddy (1978) and several others. The chemical changes in submerged rice soils and their effect on rice growth have also been generally characterised (De Datta, 1981).

Much information on the changes in the natural supply of plant nutrients in rice fields, which are flooded by irrigation or by natural rains, is not available for the rice soils of Kerala which show wide variation in nutrient status as well as physico chemical properties.

Routine testing of soils in the soil testing laboratories for making fertilizer recommendations for specific crops is done only on the air dried soil samples. However, the recommendations for rice based on the results of such analysis can only be an escalated one in the event of the nutrient status of soils getting improved due to the onset of flooding and related management operations for rice culture. Thus recommendations very often are much higher than what are optimally needed.

The recommendations can become more meaningful only when they are based on the available nutrient status of each soil type under wetland conditions. It is needless to say that the scope for such analysis is often impracticable and very remote. Nevertheless, a quantification of the net changes in the various soil testing parameters of rice soils due to submergence assumes great importance in the light of the soaring cost of fertilizers and the socio-economic conditions of the farmers which compels him to prefer a wider cost benefit ratio.

It is in the light of these most important considerations that the present investigation is undertaken with the following as the main objectives.

(i) To quantify the changes due to submergence in the status of available N, P, K, Ca, Mg and lime requirement in four important types of paddy growing soils of the State.

(ii) To correlate the above variation in nutrient status in each soil type with the basic physico chemical properties of the soil.

(iii) To compute possible changes that can be made in the fertilizer recommendations based on soil testing in each soil type.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The majority of the rice soils of Kerala are subject to rhythmic spells of wet and dry periods consequent to changes in weather conditions. Alternate wetting and drying brings about changes in the physical, physico chemical, bio-chemical and electro chemical properties of the soils which are of wide ecological and agricultural importance.

Rice is a crop suited to grow under such situations because many of these changes consequent to flooding in water are often favourable for its growth and nutrition. Such changes that take place in a soil when it remains submerged in water for a continuous period of three to four months, covering the entire duration of the rice crop have been monitored and amply reported in literature. A brief review of the more recent literature on changes in electro chemical properties and nutrient availability in the submerged soils is presented.

A. Electro chemical properties

(i) Oxidation - Reduction potential (Eh)

One of the most important electro chemical parameters used to characterise submerged soils is the redox potential, which is a measure of the oxidation - reduction potential of a soil. It is a useful guide to the sequence of soil reduction, but it does not indicate the capacity of the soil to resist Eh changes. Once the soil is waterlogged, the air from the pore space is fully displaced and it is never replenished to the original level. Pearsall (1938) has observed that when the oxygen supply is limited, a proportion of the soil micro organisms make use of electron acceptors other than oxygen for their respiratory oxidation, leading to a state of chemical reduction, which is reflected in the lowering of the oxidation - reduction potential. He also showed that the high demand for oxygen in the flooded soil as compared to the low supply rate leads to the formation of two distinct soil layers - an oxidised or aerobic surface layer and underlying reduced or anaerobic layer where no free oxygen is present (Ponnamperuma, 1972).

The diffusive movement of oxygen in waterlogged soils is very slow and consequently in a freshly flooded soil, respiring aerobic micro organisms will reduce the oxygen concentration to zero within a few hours (Scott and Evans, 1955).

Savant and Ellis (1964) noticed a sharp decrease in redox potential values within 15-20 days after submergence which reached near equilibrium conditions after 75 days submergence.

Ponnamperuma (1955, 1965) has reported that when an aerobic soil is submerged, its Eh decreases during the first few days and reaches a minimum, then it increases, attains a maximum, and decreases again asymptotically to a value characteristic of the soil after 8-12 weeks of submergence.

Chakraverthi et al. (1970) have stated that redox potential on submergence is characterised by a sharp fall for a period of three weeks followed by a more gradual decrease to an almost constant value at the end of three months.

Mukherjee and Basu (1971) have shown that Eh values decrease gradually under waterlogged conditions and the values are lower with increasing soil depth. He has found that the rate and magnitude of the Eh decrease depends on the kind of organic matter, the nature and content of electron acceptors, temperature and the duration of the submergence.

According to Ponnamperuma (1972) when an aerobic mineral soil is submerged, it undergoes reduction and the redox potential drops to a fairly stable value of +0.2 to -0.3 v depending on the soil, while the potential in the surface water and the first few millimetres of top soil remains at +0.3 to +0.5 v.

Islam and Islam (1973) observed a sharp decline in redox potential and indicated negative values after five weeks of submergence.

Moraes (1973) has stated that the Eh of soils decreased slowly between the fifth and seventh week of submergence and then became stable showing values ranging between -200 and -300 mv.

Ohlsson (1979) reported that after one day of water-logging the redox potential declined and reached negative values after six days.

(ii) Soil reaction (pH)

Soil reaction is perhaps the most important single chemical character of soils which affects the growth of plants both directly and indirectly through its control on the availability of nutrients and the activity of micro organisms. Considerable changes in the pH values of soils have been noticed during submergence in water.

Ponnamperuma et al. (1966a, 1966b, 1967, 1969) have reported that the pH of most soils tends to change toward neutrality after submergence. An equilibrium pH in the range of 6.5 to 7.5 is usually attained. The pH buffering action of submerged soils is attributed to iron and manganese redox systems and carbonic acid.

Mukherjee and Basu (1971) observed a gradual increase in soil pH after a slight initial depression and reached neutrality under waterlogged conditions.

Incubation studies conducted by Dev and Sharma (1971) on 12 soil samples, collected from areas essentially growing paddy year after year, revealed that on submerging for 15 days, pH values increased in all soils except those which are not calcareous in nature. Submergence for 30 days did not increase pH further and they suggested that increase in pH was primarily due to an increase in reducible manganese content in soil on submergence.

Ponnamperuma (1972) observed that pH increase in iron deficient soil is usually small. Peat soils and some acid sulphate soils may have pH values of 5.0 even in the flooded state. Soils high in organic matter and reducible iron attain a pH of 6.5 within a few weeks of flooding at temperatures above 30°c.

According to Moraes (1973), flooding increased the pH of acid soils and decreased that of alkaline soils. The pH of acid soils increased to 6.6 during the first few days and then remained steady.

Naphade and Childyal (1973) have shown by laboratory experiments that increasing the degree of puddling and modifying the water regimes from field capacity to saturation and flooding significantly increased the pH of the soil solution. The pH increase was found to be associated with reduction processes in the soil.

Kuruvilla and Patnaik (1973) reported that the pH of most flooded acid sulphate soils increased slowly and rarely exceeded 6.0 evenafter 6 months of submergence. The increase in pH upon flooding was mainly due to reduction of ferric oxides to soluble Fe^{2+}, a process that consumes acidity.

The slow increase in pH in most acid sulphate soils has been attributed to adverse conditions for microbial reduction, low contents of metabolizable organic matter and easily reducible ferric oxide (Ponnamperuma et al. 1973).

In samples of two sandy loam soils of pH 5.55 and 6.65, flooded to a depth of 2.5 cm and incubated for 100 days, Ghosh et al. (1975) observed an increase in pH which reached more or less constant values at near neutral point during the first 30 days of incubation.

The overall effect of submergence, according to Ponnamperuma (1976) was to increase the pH of acid soils and to depress the pH of sodic and calcareous soils. Thus, submergence makes the pH values of acid soils (except those low in iron) and alkaline soils converge to pH 7. Although the pH values of acid soils increase after submergence and sodic soils decrease, soil properties markedly influence the pattern of changes. Soils high in organic matter and active iron rarely exceed a pH of more than 5.0 even after months of submergence. Organic matter magnifies the decrease in pH of sodic and calcareous soils (IRRI, 1966) Low temperature (IRRI, 1968) and presence of nitrates (IRRI 1965) retard the increase in pH.

Moore et al. (1982) stated that during submergence of soils under laboratory conditions, soil pH and exchange acidity gradually increased to stabilized values in the neutral range, while pH dependent acidity showed a decrease and reached fairly stable values.

Kabeerathumma and Patnaik (1982) reported an increase in pH on flooding of the acid soils of Kerala.

Alice Abraham (1984) has reported significant rise in pH of the different soil types of Kerala due to submergence in water. Changes in pH over a period of flooding for two months were highest for the coastal sandy soils and lowest in the case of kari and pokkali soils.

(iii) Specific conductance (EC)

The specific conductance of flooded soils represents a balance between the production of ions and their inactivation or replacement due to the various processes that result during flooding.

Ponnamperuma (1955) reported that specific conductance increased after submergence, attained a maximum and then declined. According to him, the increase in conductance during the first few weeks after flooding is due to mobilisation of Fe^{2+} and Mn^{2+}, accumulation of NH_4^+, HCO_3^- and $RCOO^-$ and displacement of cations from soil colloids by Fe^{2+} Mn^{2+} and NH_4^+ ions.

Kamara et al. (1963) were of the view that the increase in electrical conductivity was due to the increased ionic concentration in the soil solution caused by reduction of insoluble oxides of Fe, Mn and accumulation of ammonia during flooding.

Ponnamperuma (1965) stated that flooding a soil caused an increase in the concentration of ions such as Ca^{+2}, Mg^{+2}, K^{+1}, NH_4^{+1}, Fe^{+2}, Mn^{+2} and HCO_3^{-1} which become more mobile in the soil under waterlogged conditions. The increase in concentration of these ions is considered to be a secondary effect of flooding and subsequent reduction and is mainly due to solvent action of CO_2. Ponnamperuma et al. (1966b) periodically determined the specific conductance of a soil solution from submerged soils in pots and reported that it increased after submergence, attained a maximum and then declined.

Incubation studies by Dev and Sharma (1971) in paddy soils revealed that on submerging the soils for 15 days, EC values of supernatant liquid showed an increase.

According to Ghosh et al. (1975), conductivity of a soil increased from 0.2 to 0.7 mmhos/cm on submergence for 100 days. Similar results have been obtained by Naphade et al. (1973).

Moore et al. (1982) reported that due to submergence, the electrical conductivity of soils almost doubled and the peak values were obtained at the fourth week of submergence which remained constant upto five weeks and then slowly decreased. The initial increase in the electrical conductivity was due to the increased ionic concentration in the soil solution caused by reduction of insoluble oxides of Fe, Mn and accumulation of NH_3.

According to Alice Abraham (1984), changes in EC were significant in the different rice soils of Kerala during submergence. She reported that maximum rise in EC was observed by the 20th day and after that a significant diminution was observed. This trend persisted till the end of the two months period, showing a quadratic pattern in the sequence of changes.

Effect of submergence on available nitrogen

Nitrogen in flooded soils is subjected to a variety of transformations. Ammonia sources are subjected to fixation by clays, loss by volatilisation and to nitrification followed by loss through denitrification. Immobilisation of nitrogen due to microbial fixation into organic fraction of wetland soils, although lower than in dry land soils is taking place to a certain extent.

Japanese Agronomists have long recognised that drying of rice soil before submergence makes the rice grow better (Mitsui, 1960). The effect was attributed to the accumulation of inorganic nitrogen in the soil by microbial mineralisation of organically bound soil nitrogen.

Hirose and Kumada (1963) reported that nitrogen mineralisation increased with increasing moisture and length of incubation period. According to them, air drying a soil prior to flooding increased the rate of mineralisation of native nitrogen. Waring and Bremner (1964) stated that mineralisation was more rapid in flooded soil than in non-flooded soil. A rapid rate of N mineralisation due to alternate wetting and drying cycles of soils has also been reported (Patrick and Mahapatra, 1968).

Ponnamperuma (1964, 1965) was of opinion that soils vary widely in their capacity to produce ammonia. He found a rapid release of nitrogen when soils rich in organic matter are submerged. He obtained nearly 3000 ppm of NH_3 - N when such soils were submerged in water for a period of 30 days. However, soils low in organic matter, liberate only much smaller amounts of NH_3 and that too at a slower rate. He also reported that availability of nitrogen in flooded soils is higher than in non flooded soils. Eventhough organic matter is mineralised at a slower rate in anaerobic soils than in aerobic soils, the net amount mineralised is greater because only less nitrogen is immobilised. The availability of nitrogen in flooded soils increases with increase in nitrogen content of the soil, soil pH and temperature (Ponnamperuma, 1965).

Bartholomew (1965) attributed the observed increase in ammonia production in flooded soils to a consequence of the shift in microbial community on flooding. When the aerobic population is replaced by the anaerobic flora, there is lesser assimilation with a corresponding increase in the net release of available nitrogen. Similar observations have been made by Broadbent and Reyes (1971).

Kawaguchi (1966) observed that under flooded conditions the nitrogen supplying power of many soils was high in Philippines. He was of the view that soils having a fine texture and high CEC were less easily exhausted in plant nutrients than sandy soils low in organic matter and low CEC. Kawaguchi and Kyuma (1968) found that the amount of ammonium nitrogen produced during two weeks of anaerobic incubation ranged from 4.1 to 9.7% of the total nitrogen in the soil.

Bhattacharya (1971) reported an increase in the exchangeable NH_4 - N content in many soils on waterlogging as a result of the expansion of crystal lattices of the clay minerals to release the fixed ammoniacal nitrogen. Lin et al. (1973) found that ammonia production after one week of waterlogged incubation closely approximated nitrogen uptake by the rice plant. IRRI (1975) has reported continuous nitrogen mineralisation in flooded soils at a constant rate throughout an incubation period of two weeks. Reddy et al. (1976) observed that the existence of aerobic and anaerobic zones in close proximity in the rice soils is responsible for the occurrence of denitrification. Diffusion of ammonium from the anaerobic to the aerobic soil layer accounted for more than 50% of the total nitrogen loss from columns of flooded soils.

Shiga and Ventura (1976) have shown that mineralisation processes of soil nitrogen under field conditions were simulated by submerged incubation of air dried soils. Castro and Lantin (1976) reported that keeping a soil in a reduced state by continuous submergence encourages nitrogen accumulation.

The studies conducted by Vancleemput et al. (1976) have revealed that under acid conditions, significant amounts of N_2O and NO were formed in reduced situations. At higher pH, nitrate reduction rate was slightly less. The significant production of NO under acid conditions suggested the likelihood of self-decomposition of nitrous acid as a major mechanism of nitrogen loss.

Hassan (1977) reported an increase in the status of available nitrogen as well as P and K in the laterite soils of Kerala consequent to submergence for a period of 10 days.

Reports from IRRI (1978) have shown that drying of a wet field may encourage mineralisation of nitrogen and thereby increase its availability.

Dei and Yamasaki (1979) have reported that water management and temperature markedly influence the rate and amount of ammonium released and that a dry soil when flooded release more ammonium than a wet soil.

Vlek and Craswell (1979) have shown that soil pH has little effect on the pH of the flood water and thus on the ammonia volatilization losses. Ammonia volatilisation losses were generally reduced by factors such as increasing soil CEC and reduced nitrogen application which help to reduce the level of ammoniacal nitrogen in the flood water. Correlation analysis by Sahrawat (1983) has shown that ammonium production was correlated to total nitrogen, organic carbon and C/N ratio. Organic carbon content is considered to be a good index of mineralisable nitrogen in tropical wetland rice soils.

According to Reddy and Rao (1983) the sequential nitrogen transformations operating in a flooded organic soil include ammonification in the anaerobic soil layer, upward diffusion of NH_4^+ from the anaerobic soil layer to the flood water, nitrification in the flood water, downward diffusion into the anaerobic soil layer and denitrification in the anaerobic soil layer. Ammonification and ammonium diffusion functioning at a slower rate are probably the limiting processes of nitrogen loss from a flooded organic soil. Kai et al. (1984) have shown that tropical wetland rice soils are very diverse in their inherent fertility. Incubation of air dried soil resulted in a large increase in the quantity of nitrogen mineralised, the main source of mineralised nitrogen being the amino acid and amino acid sugars.

Effect of submergence on available phosphorus

Phosphorus is not directly involved in oxidation - reduction reactions in the redox potential range encountered in submerged soil. But, because of its reactivity with a number of redox elements like iron, manganese etc. its behaviour is significantly affected by flooding. The increase in concentration of water soluble and available P due to soil submergence was reported as early as 1940 (Aoki, 1940, Mortimer, 1941).

According to Mitsui (1960), the most important effect of the anaerobic condition on phosphate was its increased availability to wetland rice.

Basak and Bhattacharya (1962) reported organic phosphorus to be the dominant fraction (41.6% of the total phosphorus) in alluvial soils of West Bengal. They observed a release of about 420 kg P_2O_5/ha from the mineralisation of organic phosphorus in the course of a rice growing season.

Savant and Ellis (1964) were of the view that the increase in availability of native soil P on flooding of soils was related more to a decrease in redox potential.

Broeehart et al. (1965) have observed that flooding increased the availability of soil phosphate in rice soils in which free $CaCO_3$ is absent. Purnachandra Rao (1966) noted that availability of phosphorus increases with flooding due to solubilization of ferric phosphates to ferrous phosphate associated with a lowering of oxidation - reduction potential of the soil. Chakravarti and Kar (1970) reported that water soluble phosphorus increased in all soils gradually with the period of submergence. Savant et al. (1970) observed that submergence followed by drying of soil prior to resubmergence increased the availability of native phosphorus in acid soils of Maharashtra. Mahapatra and Patrick (1969, 1971) have stated that available soil phosphorus is known to increase when a soil is submerged. The increase in water soluble phosphorus has been attributed to the release of P from organic matter.

Mandal and Nandi (1971) found that the higher organic matter content, the higher intensity of soil reduction under submerged conditions, as a result of which available P increased.

Islam and Islam (1973) reported that the concentration of water soluble phosphorus increased upon submergence, reached a maximum and then decreased. Sanchez and Briones (1973) found that the increase in availability of phosphorus on flooding benefited rice only on low phosphate soils.

The results of laboratory incubation studies by Patel (1975) have indicated that the rice soils (sandy loam to sandy clay loam) have low P fixation capacity and on submergence the availability of native phosphorus increased.

Mandal and Khan (1975) concluded that continuous waterlogging increased the availability of native soil phosphorus in acid soils. Chang (1976) noted that during submergence crystallised iron phosphate tends to change into colloidal iron phosphate through solution and precipitation resulting in its greater availability.

Singh and Rahaman (1976) obtained an increase in available P after 10 days of incubation when clay loam acid soils with pH 5.7 and organic carbon 0.9% were kept waterlogged. They have also recorded a decrease in available phosphorus after 20 days of incubation.

Mohanty and Patnaik (1977) found that submergence increased available P during the first 20 to 30 days because of reduction of iron and manganese compounds; afterwards there was a decrease because of the precipitation as phosphates.

Singh and Ram (1977) concluded that available phosphorus increased during tillering stage of wetland rice and that it tended to decrease after that stage. They related the increase in available P in slightly acidic soil (pH 6.6) to a decrease in Fe-P and Ca-P concentrations. The decrease in available P was considered to be due to the reformation of insoluble Fe-P and Ca-P. According to Khalid et al. (1977) anaerobic soils have a strong capacity for fixing phosphates from solutions high in phosphates.

Panda et al. (1981) reported that phosphorus availability is low in alluvial soils because of their high P fixing capacity.

Verma and Tripathi (1982) reported that all the native inorganic phosphate fractions increased upon waterlogging with the maximum increase of 70.7% in Fe-P.

Reddy and Rao (1983) opined that the major processes that take place in an anaerobic soil with phosphorus were mineralisation of organic phosphorus, adsorption, desorption and diffusion from underlying sediments to overlying water.

<u>Effect of submergence on exchangeable potassium, calcium and magnesium.</u>

Sturgis (1957) has reported that the availability of soil potassium increased by flooding particularly as the water temperature increased. Ponnamperuma (1965) has shown that flooding a soil increased the potassium concentration in the soil solution as a result of an exchange reaction due to increase in Fe^{2+} and Mn^{2+}. Ramanathan and Krishnamoorthy (1973) were of the view that the available K increased with the period of submergence due to release of K from the non exchangeable form. Islam and Islam (1973) observed that soil submergence increased the concentration of potassium in the soil solution. They also observed a rapid increase in the concentration of Ca and Mg with time of submergence. Calcium concentration continued to increase and attained peak value in the ninth week while magnesium concentration reached its peak in the fifth week. After attaining the peak value, both calcium and magnesium showed a tendency to decrease.

Islam and Ullah (1973) reported that soil submergence favoured an increase in the uptake of nutrients by rice including potassium. Kadrekar and Kibe (1973) showed that potassium release took place only after 50-60 days in a continuously moist soil. Biswas (1974) attributed the differential release of non exchangeable potassium in submerged and non submerged soils to the more vigorous growth of the crop in waterlogged soils.

According to Gaikwad et al. (1974) in flooded rice soils, the soil maintains a fairly high concentration of exchangeable and non exchangeable potassium due to transformation of potassium from minerals. They postulated a dynamic equilibrium between reserve, non exchangeable and exchangeable form of potassium.

Singh and Ram (1975) reported that the potassium fixing capacity of paddy soils rich in clay increased with a rise in pH, consequent to flooding.

Murty and Singh (1975) reported an initial decrease in available potassium during the first week of flooding, followed by a gradual increase. They also observed a sharp increase in water soluble calcium during the first week, but later the changes were found to be inconsistent.

Singh and Ram (1976) found that continuous submergence as well as a drying and wetting cycle at 30 days intervals increased the exchangeable potassium content.

Mohanty and Patnaik (1977) reported that the transformation and availability of potassium, calcium and magnesium were primarily governed by the silt and clay content of the soil which inturn determined the total amounts present. The availability of these three cations increased on flooding on account of their displacement by the action of water through hydration and hydrolysis and reached a peak in about 30 days and then decreased.

Laboratory incubation experiments with acid sulphate soils by Kabeerathumma and Patnaik (1978) showed that flooding resulted in increased availability of calcium and potassium.

According to Silverman and Munoz (1980) the rate of release of calcium and magnesium differed in soils incubated in air and under anaerobic conditions. In air the quantities of calcium and magnesium concentrations increased for the first 3-10 days and then decreased. Under anaerobic incubation, calcium and magnesium concentrations either reached maximal values in 7-10 days with no subsequent decrease or continued to increase during the period of submergence.

Muthuvel and Krishnamoorthy (1981) reported that the available potassium content of soils was not influenced by the soil moisture regimes.

MATERIALS AND METHODS

MATERIALS AND METHODS

The effect of submergence on soil testing parameters of paddy soils was investigated using four soil types representing the alluvial, acid saline, acid sulphate and saline soils of Kerala.

1. Collection of soil samples

Surface soil samples (0-15 cm) were collected during December, 1984, after the second crop season from farmers' fields. The details and locations of collections are given below.

	Soil type	Order	Location	District	No. of samples
1.	Alluvial	Inceptisol	Kozhencherry, Pathanamthitta and Punaloor.	Pathanamthitta & Quilon.	12
2.	Acid saline	Inceptisol	Vytilla	Ernakulam	12
3.	Acid sulphate	Entisol	Ambalapuzha, Karumadi, Thottapally and Kallara.	Alleppey & Kottayam.	12
4.	Saline	Alfisol	Narakkal, Puthuvaippu.	Ernakulam	12

The soils were collected in bulk, air dried, powdered, passed through a 2 mm sieve and used for subsequent studies.

2. Physico chemical properties

The basic physico chemical characters of the soils such as pH, EC, mechanical composition, cation exchange capacity, lime requirement, organic carbon, total and available nitrogen and phosphorus, exchangeable cations like potassium, calcium and magnesium were determined by adopting standard analytical procedures as detailed below:-

pH	pH meter method	Jackson (1973)
EC	Solu bridge method	Jackson (1973)
Mechanical Analysis	Hydrometer method	Black (1965)
Cation exchange capacity	Ammonium acetate method	Jackson (1973)
Lime requirement	Hutchson and Mc Lennal's method	Hutchson and Mc Lennal (1914)
Organic carbon	Walkley and Black's rapid titration method	Jackson (1973)
Total nitrogen	Microkjeldahl method	Jackson (1973)
Available nitrogen	Alkaline - permanganate method	Subbiah and Asija (1956)

Total phosphorus	Chlorostannous - reduced molybdo phosphoric blue colour method, in sulphuric acid system	Jackson (1973)
Available phosphorus	Dickman and Bray's molybdenum blue method	Jackson (1973)
Exchangeable cations	Neutral normal ammonium acetate extraction method	Black (1965)

3. Incubation Experiment

The soil samples were filled in tall porcelain pots of size 23 x 13 cm and flooded with water to remain above the soil surface. The soil in each pot was stirred with a thick glass rod to ensure uniform mixing. The pots were placed for incubation on a level surface in the laboratory. The level of water on the soil surface was maintained at 5 cm by addition of fresh water so as to simulate the situation available in flooded paddy soils. Wet soil samples were drawn by a funnel using the technique suggested by Abichandani and Patnaik (1957) from each pot at fixed intervals of 12 hours, 1, 2, 3, 4, 5, 6, 8, 10 and 12 weeks and analysed for the various parameters.

4. Analysis of soil samples

The wet soil samples were analysed for the different parameters, after making suitable allowance for the amount of moisture present in each sample.

a. pH:- The pH of the samples were determined in 1:2.5 soil water suspension using the glass electrode of the Perkin-Elmer pH meter.

b. Total soluble salts:- Total soluble salts were determined in 1:5 soil water suspension using a solu-bridge and expressed on mmhos/cm^2.

c. Lime requirement:- The lime requirement of the soil was determined by the method of Hutchson and Mc Lennan (1914). A weighed quantity of soil was treated with measured volume of standard $Ca(HCO_3)_2$ solution. The suspension was stirred well and filtered after 3 hours. Measured volume of the filterate was titrated against standard sulphuric acid using methyl orange as indicator. A blank was run with the same volume of standard $Ca(HCO_3)_2$ solution. The difference between the titre values showed the amount of $Ca(HCO_3)_2$ used, from which the amount of lime (as $CaCO_3$) per hectare of soil to a depth of 6 inches was calculated.

d. Available nitrogen:- Available nitrogen was determined by alkaline - permanganate method (Subbiah and Asija, 1956) by distilling 20 g of soil in a distillation flask with

0.32% potassium permangnate and 2.5% sodium hydroxide solutions for 30 minutes. The ammonia released was absorbed in standard acid and the excess acid was titrated with standard alkali. From the volume of acid consumed by ammonia, the nitrogen content was calculated.

e. Available phosphorus:- Available phosphorus was estimated by Dickman and Bray's molybdenum blue method (1940) in a Klett Sumerson photo electric colorimeter. The soil was extracted with Bray's reagent No. 1 (0.03 N NH_4F in 0.025 N HCl). Estimation was done in 5 ml aliquot of the extract.

f. Exchangeable potassium:- Exchangeable potassium was determined in the neutral normal ammonium acetate extract by the flame emission method using EEL Flame photometer.

g. Exchangeable calcium and magnesium:- Exchangeable calcium and magnesium were determined in the neutral normal ammonium acetate extract using a Perkin - Elmer 3030 model Atomic Absorption Spectrophotometer.

Statistical Analysis:-

The data generated from the incubation experiment in completely randomised design with four soil types were analysed statistically for each character. The pooled analysis of variance was also done for the 11 periods of observation. Correlations among various characters for each soil type in different periods were computed to bring out the relationship between the characters (Panse and Sukhatme 1967).

RESULTS

RESULTS

The results of the laboratory studies for monitoring the changes in nutrient availability on flooding of four typical soil types of Kerala are presented in this chapter.

1. Basic physico chemical properties of rice soils: Alluvial soils (Table 1a).

The 12 samples of this soil type were representatives of riverine alluvial soils of Pathanamthitta and Quilon districts. These soils were slightly acidic and showed pH values ranging from 4.8 to 5.9 with an average lime requirement value of 9.7 t/ha. The electrical conductivity was very low and it was less than 0.1 mmhos/cm for most of the soils. The mean value for organic carbon was 1.8%. The total nitrogen content was rather high and ranged from 0.07 to 0.18% and the available nitrogen varied from 83 to 191 ppm with an average of 115 ppm. The total phosphorus was also similarly high and ranged from 0.04 to 0.17% with mean value for available phosphorus as 107 ppm. The CEC was also fairly high and ranged from 9 to 12 me/100 g soil with an average of 10 me/100 g. Of the exchangeable cations, the mean values for potassium, calcium and magnesium were 131, 336 and 98 ppm

Table 1(a) Physico chemical properties of alluvial soils.

Sample No.	pH (H_2O)	EC mmhos/cm	Organic carbon (%)	L.R (t/ha)	Total N (%)	Total P (%)	Available N (ppm)	Available P (ppm)	CEC (me/100 g)	Exchangeable cations (ppm)			Texture
										K	Ca	Mg	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	4.9	-	1.7	10.5	0.09	0.17	83	186	9	76	193	68	Clay loam
2	4.8	-	1.4	11.0	0.10	0.04	92	58	11	124	474	110	Clay
3	5.0	-	1.4	10.2	0.08	0.08	144	105	10	118	312	107	Clay
4	5.3	-	1.9	9.6	0.10	0.07	76	107	11	122	304	89	Clay
5	5.1	0.1	1.1	9.8	0.08	0.09	118	140	12	160	207	33	Clay
6	5.9	-	1.6	8.3	0.09	0.06	149	116	12	208	516	116	Clay
7	5.2	0.1	2.9	9.8	0.07	0.11	191	119	8	76	315	96	Clay loam
8	5.4	-	1.9	9.5	0.11	0.04	83	49	7	76	504	145	Clay loam
9	5.5	-	2.6	9.6	0.14	0.12	122	177	12	204	296	123	Clay
10	5.3	-	1.6	9.6	0.11	0.07	113	116	10	118	339	100	Clay loam
11	5.6	0.1	1.1	8.9	0.18	0.08	104	114	12	156	221	71	Clay
12	5.7	-	1.9	9.0	0.15	0.06	110	95	11	128	346	116	Clay

respectively. These 12 samples of alluvial soils varied in texture from clay to clay loam.

Of the different soil characters studied, the pH in water showed a significantly high negative correlation to lime requirement (-0.90), while the relation of pH with clay content was positive and significant (0.59). Though not significant, a positive correlation was there between pH and available nitrogen, exchangeable potassium, calcium and magnesium. A similar relationship was evident in the case of available nitrogen and phosphorus to their total contents and organic matter level in the soil.

Other correlations of significance were between exchangeable calcium and magnesium (0.78), exchangeable potassium and clay content (0.81) and CEC (0.84) and between CEC and clay (0.94).

Acid saline soils (Table 1b).

The acid saline soils were located mainly along the coastal parts of Ernakulam district, locally known as "Pokkali" soils. A single crop of paddy alone is raised during the period between May and August-September. These soils were sandy loam in texture and showed a variable pH

Table 1(b) Physico chemical properties of acid saline soils.

Sample No.	pH (H_2O)	EC (mmhos/cm)	Organic C (%)	L.R (t/ha)	Total N (%)	Total P (%)	Available N (ppm)	Available P (ppm)	CEC (me/100 g)	Exchangeable cations (ppm) K	Ca	Mg	Texture
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	4.2	1.9	6.2	15.0	0.20	0.08	110	58	10	196	355	368	Sandy loam
2	4.9	2.0	6.1	14.4	0.17	0.07	114	51	10	202	434	564	Sandy clay loam
3	3.8	2.9	8.3	16.0	0.15	0.05	118	42	9	140	382	573	Loamy sand
4	4.9	1.5	5.8	14.5	0.13	0.05	113	70	9	136	309	400	Sandy loam
5	3.2	2.4	6.60	16.4	0.03	0.05	50	44	11	206	160	536	Sandy clay loam
6	3.5	2.0	6.5	16.2	0.21	0.05	87	55	9	66	131	65	Loamy sand
7	5.0	1.3	6.5	14.4	0.20	0.06	120	116	10	151	602	37	Sandy loam
8	4.6	1.2	4.8	14.8	0.11	0.09	84	76	10	202	128	1050	Sandy clay loam
9	5.3	2.6	5.6	14.0	0.15	0.15	92	167	9	64	619	46	Sand
10	3.6	1.6	7.6	16.2	0.64	0.10	130	84	10	176	817	36	Sandy loam
11	4.4	1.9	7.1	15.2	0.11	0.12	52	81	9	128	816	92	Sandy loam
12	4.1	1.7	5.5	15.0	0.42	0.14	131	86	9	124	339	94	Sandy loam

from 3.2 to 5.3. The EC ranged from 1.2 to 2.9 mmhos/cm with average value of 1.9 mmhos/cm. Their lime requirement was very high with an average value of 15.2 t/ha. These soils had a high organic carbon content ranging from 4.8 to 8.3%. The average content of total nitrogen and phosphorus were 0.21 and 0.08% respectively. The available nitrogen varied from 52 to 131 ppm and that of available phosphorus from 44 to 165 ppm. The mean value of CEC was 10 me/100 g. The exchangeable potassium ranged from 64 to 206 ppm with a mean value of 149 ppm and the average value of exchangeable calcium and magnesium were 424 and 322 ppm respectively.

In this soil type the pH did not show any significant relationship with other soil characters except with available phosphorus which was positive and significant (0.62). The relationship of available nitrogen with total nitrogen was positive while that with organic carbon was negative. The influence of total phosphorus on available phosphorus was also positive and significant (0.62). The available phosphorus was negatively correlated with clay content (-0.63), while it was weak and negative (-0.28) with organic carbon. A significant and negative correlation was obtained between pH and lime requirement (-0.89) and a significant and positive correlation between pH and organic carbon (0.72).

The CEC was correlated significantly and positively with clay content (0.80). The effect of clay on exchangeable cations like potassium and magnesium also were significant and positive (0.97, 0.64). A similar relationship was evident in the case of available potassium and CEC (0.77).

Acid sulphate soils Table 1(c).

The 12 samples of this soil type belonged to the kari soils of Alleppey and Kottayam districts. Three samples of acid sulphate soils from Kottayam district showed distinctly different values for all soil properties compared to other samples.

These soils recorded the lowest pH among the four soil types and ranged in values from 2 to 3.7. The mean value of EC was 1.0 mmhos/cm coming in the range from 0.2 to 3.3 mmhos/cm. The organic carbon varied from 1.1 to 10.4% with a mean value of 6.3%. The lime requirement ranged from 15.7 to 17.1 t/ha. The CEC varied from 13 to 30 me/100 g with a mean of 20 me/100 g. The total nitrogen

Table 1(c) Physico chemical properties of acid sulphate soils.

Sample No.	pH (H_2O)	EC (mmhos/cm)	Organic C (%)	L.R (t/ha)	Total N (%)	Total P (%)	Available N (ppm)	Available P (ppm)	CEC (me/100 g)	Exchangeable cations (ppm)			Texture
										K	Ca	Mg	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	3.6	0.6	4.6	15.8	0.10	0.05	108	58	19	204	515	330	Sandy clay
2	3.7	0.4	1.1	15.7	0.09	0.03	85	81	21	120	577	425	Clay loam
3	3.6	0.3	5.1	15.9	0.25	0.03	93	77	13	144	194	171	Sandy loam
4	3.0	0.4	4.9	16.3	0.08	0.02	155	88	16	100	267	191	Sandy clay loam
5	2.9	0.4	7.2	16.4	0.14	0.03	68	56	20	68	116	88	Sandy clay
6	2.0	3.2	10.4	17.0	0.44	0.08	530	63	28	22	704	868	Clay
7	3.0	0.5	7.0	16.3	0.17	0.01	63	70	13	52	281	174	Sandy loam
8	3.1	0.2	7.4	16.2	0.11	0.04	67	151	16	118	134	77	Loam
9	3.4	0.3	4.4	16.0	0.06	0.02	117	51	16	52	327	264	Sandy loam
10	2.3	2.6	9.9	17.1	0.42	0.07	495	44	28	20	548	648	Clay
11	2.8	0.2	3.6	16.4	0.10	0.02	43	91	14	50	109	104	Sand
12	2.1	3.1	9.6	17.1	0.42	0.07	488	39	30	36	577	1488	Clay

was very high and ranged from 0.1 to 0.4% while the total phosphorus was low with a mean value of 0.04%. The available nitrogen for the three samples was very high (530, 495 and 488 ppm), while it ranged only from 43 to 155 ppm for the other samples. The status of exchangeable calcium and magnesium was also distinctly high, while available phosphorus and exchangeable potassium were very low for the three samples. In addition, these three samples were highly clayey (45% clay) in texture and rich in organic matter (10.4%) recording the lowest pH (2.0) and highest CEC (30 me/100 g).

The texture of acid sulphate soils varied from clay to sand. Of the exchangeable cations, magnesium showed values as low as 77 to as high as 1488 ppm and calcium from 116 to 704 ppm, while potassium ranged from 20 to 204 ppm with a mean value of 82 ppm only.

In this soil type, pH showed a significant negative relationship with EC (-0.84), lime requirement (-0.98), available nitrogen (-0.82), exchangeable magnesium (-0.67), organic carbon (-0.84) and CEC (-0.72). EC was significantly and positively correlated with lime requirement, CEC, clay, available nitrogen, exchangeable magnesium and organic carbon (0.85, 0.91, 0.76, 0.98, 0.9 and 0.78 respectively). The relationship of available nitrogen with total nitrogen (0.92) and organic carbon (0.77) was direct and significant while that of available phosphorus with total phosphorus (-0.34) and organic carbon (-0.26) was weak and inverse. CEC had a significant and positive influence on exchangeable calcium (0.79), exchangeable magnesium (0.87) and to organic carbon (0.63). The effect of CEC and clay on exchangeable potassium was weak and negative while that of pH was significant and positive (0.79).

Saline soils Table 1(d).

These soils were mostly clayey in texture and were frequently subjected to sea water intrusion, from different parts of Vyppin island. These soils, eventhough rich in exchangeable bases, were extremely acidic with pH values ranging between 2.9 and 3.5. The mean value of EC was 5.5 mmhos/cm which is above the critical level fixed for the rice crop. The CEC ranged from 20 to 30 me/100 g with an average of 24 me/100 g. The average value of lime requirement was 16.4 t/ha. The organic carbon ranged from 4.1 to 6.8%. The mean values of total nitrogen and phosphorus were 0.3% and 0.08%. The available nitrogen ranged

Table 1(d) Physico chemical properties of saline soils.

Sample No.	pH (H_2O)	EC (mmhos/cm)	Organic C (%)	L.R (t/ha)	Total N (%)	Total P (%)	Available N (ppm)	Available P (ppm)	CEC (me/100 g)	Exchangeable cations (ppm) K	Ca	Mg	Texture
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	3.4	5.0	4.7	16.2	0.24	0.09	102	93	30	26	1084	791	Clay
2	3.2	6.2	4.8	16.2	0.29	0.08	188	74	22	88	1123	781	Clay
3	2.9	5.3	6.5	16.8	0.34	0.08	83	74	25	80	909	1086	Clay
4	3.5	6.0	4.8	16.2	0.36	0.11	199	119	21	96	654	1071	Clay
5	3.0	5.7	4.1	16.4	0.23	0.04	242	51	21	44	630	1042	Clay
6	2.9	5.0	6.8	16.9	0.21	0.07	129	81	22	80	650	1428	Clay
7	3.0	5.1	5.6	16.4	0.24	0.08	98	75	25	100	1118	1239	Clay
8	3.2	6.1	5.2	16.3	0.26	0.10	132	113	25	80	648	1434	Clay
9	3.0	6.6	6.7	16.4	0.32	0.07	148	80	25	88	926	1258	Clay
10	3.3	5.9	4.1	16.3	0.34	0.05	190	42	27	94	1142	1294	Clay
11	3.1	4.1	4.2	16.3	0.35	0.06	191	61	20	84	904	1489	Clay
12	3.1	5.8	4.9	16.2	0.36	0.08	214	86	22	95	897	799	Clay

Table 2 Physico chemical properties of rice soils : mean values.

Soil type and texture	pH (H_2O)	EC (mmhos/cm)	Organic C (%)	L.R (t/ha)	Total N (%)	Total P (%)	Available N (ppm)	Available P (ppm)	CEC (me/100 g)	Exchangeable cations (ppm)		
										K	Ca	Mg
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Alluvial (Clay)	5.3	-	1.8	9.7	0.11	0.08	115	107	10	131	336	98
Acid saline (Sandy loam)	4.3	1.9	6.4	15.2	0.21	0.08	100	77	10	149	424	322
Acid sulphate (Sandy clay loam)	3.0	1.0	6.3	16.4	0.20	0.04	193	72	20	82	362	402
Saline (Clay)	3.1	5.5	5.2	16.4	0.30	0.08	160	79	24	80	890	1143

from 83 to 242 ppm. The average of available phosphorus was 79 ppm which ranged from 42 to 119 ppm. The mean value of available potassium was 80 ppm and the average values of exchangeable calcium and magnesium were 890 and 1142 ppm.

The pH in water was significantly and negatively correlated to organic carbon (-0.59) and clay content (-0.66), while the relationship with lime requirement was inverse and weak (-0.23). The available nitrogen was only weakly correlated to the total nitrogen (0.32) and showed a negative correlation to organic carbon (-0.64). Available phosphorus showed a high correlation to total phosphorus (0.94), while that with pH and organic carbon was weak and positive (0.41 and 0.3). A significant negative correlation was observed for clay with total phosphorus (-0.66) and available phosphorus (-0.65).

2. Incubation studies on typical rice soils.

The results of the laboratory incubation studies on the effect of submerging four important soil types of Kerala under five centimetres of standing water for a period of three months on the soil testing parameters are presented.

The data on changes in pH, EC, lime requirement, available nitrogen, available phosphorus and exchangeable cations like potassium, calcium and magnesium are presented in tables 3 to 10 and figures 1 to 8.

pH Tables 3(a) to 3(e).

From the results it may be seen that significant changes in pH were obtained for the different soil types due to submergence in water for varying periods of time. Average values of pH over a period of flooding for three months was highest for saline soils (7.3) immediately followed by acid saline soils with a value of 7.2. The samples representing the alluvial and acid sulphate soils recorded comparatively lower values (6.4 and 4.9) only. It may be noted that the maximum shift in pH from the initial values was recorded for saline and acid saline soils (4.2 and 2.9) followed by the acid sulphate soils recording a shift of 1.9 units. The minimum shift of 1.1 units was registered by the alluvial soils.

The pH of acid sulphate and saline soils rapidly increased even after twelve hours and it continued to increase significantly till the end of second week, after which it attained a more or less steady state in acid sulphate soils, while it was stabilized at the end of six weeks only in saline soils. The alluvial soils showed a decrease in pH

Table 3(a) pH of alluvial soils on submergence in water for 10 periods of sampling over a period of three months.

No.	1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
	Periods (weeks)									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	4.0	6.0	6.0	6.1	6.1	6.1	6.1	6.1	6.2	6.2
2	5.2	5.9	6.0	6.0	6.0	6.0	6.0	6.2	6.2	6.2
3	5.1	5.8	5.9	5.9	6.0	6.0	6.2	6.2	6.3	6.3
4	4.9	6.1	6.3	6.5	6.5	6.5	6.5	6.5	6.5	6.5
5	5.1	5.5	5.7	5.9	6.0	6.0	6.2	6.2	6.3	6.4
6	5.3	5.5	5.6	5.8	6.3	6.3	6.5	6.5	6.7	6.7
7	5.4	6.2	6.2	6.2	6.2	6.2	6.2	6.4	6.4	6.4
8	4.9	5.5	5.5	6.0	6.1	6.1	6.1	6.5	6.5	6.5
9	5.2	5.8	5.9	5.9	5.9	6.2	6.5	6.5	6.5	6.5
10	4.5	5.5	5.9	6.0	6.0	6.0	6.3	6.3	6.5	6.5
11	4.8	5.8	5.8	5.8	5.9	6.0	6.5	6.5	6.5	6.5
12	5.1	5.9	5.9	5.9	5.9	6.3	6.3	6.5	6.5	6.6

Table 3(b) pH of acid saline soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	4.6	4.8	6.5	6.6	6.8	6.8	7.0	7.1	7.2	7.2
2	5.3	5.3	6.5	6.6	6.7	6.7	7.0	7.1	7.2	7.2
3	3.8	6.0	6.0	6.5	6.5	6.5	6.9	7.0	7.1	7.1
4	4.7	4.9	6.0	6.5	6.5	6.5	6.9	7.0	7.0	7.1
5	3.6	4.8	6.0	6.5	6.7	6.8	7.0	7.0	7.1	7.2
6	3.7	5.2	6.6	6.6	6.9	7.0	7.0	7.2	7.2	7.4
7	5.1	5.1	6.4	6.5	6.5	6.5	7.0	7.0	7.0	7.0
8	4.8	5.4	6.5	6.5	6.6	6.7	7.0	7.0	7.0	7.1
9	5.4	5.5	6.5	6.5	6.5	6.7	7.1	7.1	7.1	7.1
10	3.8	4.7	6.3	6.6	6.7	7.0	7.2	7.2	7.3	7.4
11	4.6	5.4	6.4	6.4	6.8	6.8	7.0	7.2	7.2	7.2
12	4.4	4.9	6.5	6.7	6.9	7.0	7.0	7.3	7.3	7.3

Table 3(c) pH of acid sulphate soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	4.2	5.5	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
2	4.5	5.6	6.0	6.0	6.2	6.4	6.4	6.4	6.4	6.4
3	4.5	5.5	5.8	5.8	6.2	6.2	6.4	6.4	6.4	6.4
4	4.3	5.5	5.5	5.6	5.6	5.8	5.8	5.8	5.8	5.8
5	3.8	4.0	4.0	4.1	4.1	4.1	4.1	4.1	4.1	4.1
6	3.8	4.0	4.0	4.0	4.0	4.0	4.1	4.1	4.1	4.1
7	4.0	4.0	4.0	4.1	4.1	4.2	4.2	4.2	4.2	4.2
8	4.0	4.2	4.2	4.2	4.2	4.3	4.3	4.3	4.3	4.3
9	4.2	5.0	5.5	5.5	5.6	5.6	5.6	5.6	5.6	5.6
10	3.7	4.0	4.0	4.1	4.2	4.2	4.2	4.2	4.2	4.2
11	4.1	4.1	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
12	3.8	4.0	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1

Table 3(d) pH of saline soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	4.7	5.6	6.2	6.5	6.5	6.8	7.0	7.1	7.2	7.2
2	4.0	5.4	6.2	6.3	6.4	6.6	6.9	7.1	7.1	7.1
3	4.0	5.0	5.5	5.6	5.9	6.5	6.7	6.9	6.9	7.0
4	4.5	5.5	6.0	6.3	6.4	6.9	7.1	7.1	7.2	7.3
5	3.9	5.0	5.8	6.0	6.1	6.5	6.6	6.9	7.0	7.1
6	4.5	5.7	5.9	5.9	6.0	6.3	6.5	6.8	7.0	7.0
7	4.2	5.5	6.0	6.0	6.2	6.3	6.6	6.7	6.9	7.1
8	3.9	5.0	6.0	6.1	6.3	6.5	6.8	7.1	7.1	7.1
9	4.1	5.0	5.7	6.0	6.2	6.5	6.9	7.0	7.1	7.1
10	4.0	5.4	5.9	6.2	6.4	6.8	6.8	7.0	7.0	7.2
11	4.3	5.1	5.8	6.0	6.0	6.5	6.6	7.0	7.1	7.1
12	4.0	5.0	5.7	6.1	6.1	6.5	6.7	6.9	7.0	7.1

Table 3(e) pH in water of rice soils on submergence in water : mean values for 10 periods of sampling over a period of three months.

Soil type	1 (12 hours)	2(1)	3(2)	4(3)	Period (weeks) 5(4)	6(5)	7(6)	8(8)	9(10)	11(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Alluvial	5.0	5.8	5.9	6.0	6.1	6.1	6.3	6.4	6.4	6.4
Acid saline	4.5	5.2	6.4	6.5	6.7	6.8	7.0	7.1	7.1	7.2
Acid sulphate	4.1	4.6	4.8	4.8	4.9	4.9	4.9	4.9	4.9	4.9
Saline	4.2	5.3	5.9	6.1	6.2	6.6	6.8	7.0	7.1	7.3
C.D for soils	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

C.D for periods - 0.4

at first and then recorded a significant increase, recording the peak value in the first week itself. The pH continued to increase significantly for acid saline soil, registering peak values in the second week.

EC Tables4(a) to 4(e).

Changes in EC were also significant in the four soil types during submergence. Electrical conductance was highest in the saline soils (5.5 mmhos/cm) and lowest in alluvial soils (0.03 mmhos/cm). Maximum rise in EC was observed by the fourth week in alluvial and saline soils (0.4 and 11.5 mmhos/cm), sixth week in acid saline and fifth week in acid sulphate soils (5.6 and 4.1 mmhos/cm). Thereafter a significant diminution was observed in all the soil types, which persisted till the end of the three month period. The highest EC was noted for the saline soils (11.5 mmhos/cm) and minimum for the alluvial soils (0.4 mmnos/cm).

Lime requirement Tables 5(a) to 5(e).

Submerging the soils in water for a period of three months brought about appreciable reduction in lime requirement of all the soils. Initial lime requirement was maximum for the acid sulphate and saline soils and minimum for allu-

Table 4(a) EC (mmhos/cm) of alluvial soils on submergence in water for 10 periods of sampling over a period of three months.

								Periods (weeks)		
No.	1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	-	0.1	0.2	0.2	0.3	0.3	0.2	0.2	0.1	0.1
2	-	0.1	0.2	0.2	0.3	0.3	0.2	0.2	0.1	0.1
3	-	0.1	0.2	0.3	0.4	0.3	0.3	0.2	0.1	0.1
4	-	0.1	0.2	0.3	0.4	0.3	0.3	0.2	0.1	0.1
5	0.1	0.1	0.3	0.3	0.4	0.3	0.3	0.2	0.1	0.1
6	-	0.1	0.3	0.4	0.4	0.4	0.3	0.3	0.1	0.1
7	0.1	0.1	0.2	0.4	0.4	0.4	0.3	0.3	0.1	0.1
8	-	0.1	0.2	0.4	0.4	0.4	0.3	0.3	0.1	0.1
9	-	0.1	0.2	0.3	0.4	0.3	0.2	0.2	0.1	0.1
10	-	0.1	0.2	0.3	0.3	0.3	0.2	0.2	0.1	0.1
11	0.1	0.1	0.3	0.4	0.4	0.3	0.2	0.2	0.1	0.1
12	-	0.1	0.2	0.3	0.3	0.3	0.2	0.2	0.1	0.1

Table 4(b) EC (mmhos/cm) of acid saline soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Period (weeks)									
	1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	11(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	2.6	2.6	3.2	3.9	4.4	5.5	5.6	2.9	2.0	1.8
2	2.9	2.9	3.3	4.0	4.5	5.4	5.6	2.9	1.9	1.8
3	3.6	3.8	4.0	4.4	4.9	5.6	5.8	3.2	2.4	2.4
4	2.5	2.8	3.3	4.1	4.6	5.5	5.6	3.0	2.1	1.8
5	3.0	3.2	3.7	4.3	4.9	5.7	5.8	3.1	2.1	2.1
6	3.0	3.2	3.6	4.3	4.8	4.9	5.4	2.7	1.9	1.9
7	3.0	3.1	3.1	4.3	4.8	5.3	5.7	3.0	2.0	1.7
8	2.4	2.5	3.6	4.3	4.8	5.2	5.3	2.7	1.9	1.6
9	3.0	3.1	3.4	4.3	5.0	5.7	5.8	3.0	2.0	2.0
10	2.6	2.9	3.6	4.1	4.7	5.3	5.5	2.8	1.9	1.8
11	2.9	3.1	3.7	4.4	5.0	5.4	5.5	2.9	1.9	1.9
12	2.6	3.0	3.5	4.7	5.1	5.3	5.4	2.6	1.8	1.8

Table 4(c) EC (mmhos/cm) of acid sulphate soils on submergence in water for 10 periods of sampling over a period of three months.

	Periods (weeks)									
No.	1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	0.9	1.5	2.9	5.8	3.9	3.9	1.6	1.6	1.5	1.2
2	0.6	1.3	2.5	3.3	3.3	3.3	1.2	1.2	1.1	1.0
3	0.6	1.2	2.4	3.1	3.3	3.3	1.2	1.1	1.0	0.9
4	0.6	1.2	2.0	3.0	3.1	3.1	1.0	1.0	0.9	0.9
5	0.6	1.2	2.0	3.0	3.2	3.2	1.2	1.0	0.9	0.9
6	4.2	5.0	5.3	6.0	6.0	6.0	4.8	4.0	4.0	3.8
7	0.8	1.6	2.9	4.0	4.1	4.1	3.1	3.0	3.0	2.6
8	0.4	1.0	2.0	3.0	3.8	3.8	1.5	1.0	1.0	0.9
9	0.6	1.2	2.2	3.0	3.3	3.3	1.2	1.0	1.0	0.9
10	4.0	4.1	5.1	6.0	6.0	6.0	5.0	4.0	4.0	3.9
11	0.5	0.8	1.9	2.9	3.6	3.6	1.3	1.1	1.0	0.9
12	4.2	5.0	5.2	6.1	6.1	6.1	4.8	4.1	4.0	3.8

Table 4(d) EC (mmhos/cm) of saline soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Period (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	5.1	7.1	9.1	9.3	9.9	11.3	9.2	7.1	6.1	6.1
2	6.6	7.4	9.2	9.5	10.3	11.5	10.0	8.1	7.1	6.9
3	5.8	7.8	9.5	9.7	10.7	11.6	10.0	7.9	7.1	6.6
4	6.1	7.9	9.7	9.9	10.8	11.7	10.1	8.1	7.1	6.7
5	5.9	7.7	9.5	9.6	10.2	11.4	9.2	7.1	6.3	6.1
6	5.1	7.0	9.1	9.2	9.9	11.8	10.1	8.1	7.1	6.2
7	5.1	7.1	9.1	9.3	9.8	11.2	8.8	6.7	5.9	5.7
8	6.1	8.0	9.7	9.9	10.7	11.6	9.7	7.3	6.2	5.8
9	6.9	7.9	9.7	9.9	10.8	11.8	9.8	7.2	6.2	6.1
10	6.0	7.1	9.1	9.3	9.8	11.0	8.8	6.7	5.8	5.6
11	5.0	6.6	9.1	9.4	10.2	11.3	9.1	6.9	6.1	6.0
12	6.1	7.9	9.7	9.5	10.3	11.4	9.3	7.1	6.0	5.3

Table 4(e) EC (mmhos/cm) of rice soils on submergence in water : mean values for 10 periods of sampling over a period of three months.

Soil type	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Alluvial	0.03	0.10	0.23	0.32	0.37	0.33	0.25	0.23	0.10	0.10
Acid saline	2.8	3.0	3.5	4.3	4.8	5.4	5.6	2.9	2.0	1.9
Acid sulphate	1.5	2.1	3.0	3.9	4.1	4.1	2.3	2.0	2.0	1.8
Saline	5.8	7.4	9.4	9.5	11.5	9.5	7.4	7.3	6.4	6.1
C.D for soils	0.7	0.7	0.6	0.6	0.5	0.5	0.7	0.6	0.6	0.6

C.D for periods - 0.8

Table 5(a) LR (t/ha) of alluvial soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	9.8	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.1	9.1
2	9.8	9.5	9.4	9.5	9.2	9.2	9.1	9.0	9.0	9.0
3	10.0	9.9	9.6	9.5	9.4	9.4	9.3	9.2	9.2	9.2
4	9.4	9.4	9.4	9.4	9.3	9.3	9.1	8.9	8.9	8.9
5	9.6	9.4	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.1
6	9.4	9.4	9.4	9.3	9.2	9.2	8.9	8.7	8.7	8.7
7	10.0	9.9	9.5	9.5	9.4	9.4	9.2	9.1	9.1	9.1
8	9.8	9.5	9.4	9.5	9.4	9.4	9.3	9.2	9.2	9.2
9	9.4	9.4	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.1
10	9.4	9.4	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.1
11	9.6	9.5	9.5	9.3	9.2	9.2	9.1	9.0	9.0	9.0
12	9.4	9.4	9.4	9.3	9.2	9.2	8.9	8.7	8.7	8.7

Table 5(b) LR (t/ha) of acid saline soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Period (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	14.9	14.6	14.1	13.9	13.5	13.1	11.9	11.9	11.9	11.9
2	15.1	14.9	14.2	14.0	13.6	13.2	12.0	11.9	11.9	11.9
3	15.3	15.0	14.4	14.2	13.8	13.2	12.0	12.0	12.0	12.0
4	14.9	14.9	14.0	13.9	13.4	13.1	11.9	12.0	12.0	12.0
5	15.1	15.1	14.1	14.0	13.6	13.3	12.1	12.2	12.2	12.1
6	14.9	14.8	14.1	14.0	13.5	12.9	12.7	11.5	11.5	11.5
7	15.1	14.9	14.3	14.2	13.7	13.2	12.1	12.1	12.1	12.1
8	14.9	14.8	14.3	14.1	13.7	13.4	12.0	12.2	12.2	12.1
9	14.7	14.4	14.0	13.8	13.4	13.0	12.1	11.7	11.7	11.7
10	15.1	14.9	14.5	14.4	14.0	13.4	11.7	12.3	12.2	12.2
11	15.0	15.0	14.6	14.3	13.9	13.4	12.3	12.3	12.2	12.2
12	14.9	14.5	14.1	13.9	13.4	12.9	11.7	11.7	11.6	11.6

Table 5(c) LR (t/ha) of acid sulphate soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	15.5	14.2	14.2	14.0	14.0	13.8	13.6	13.5	13.5	13.5
2	15.5	14.5	14.1	14.1	13.9	13.8	13.5	13.5	13.5	13.5
3	15.6	14.6	14.3	14.0	14.0	14.0	14.0	14.0	14.0	14.0
4	15.8	14.4	14.3	14.2	14.1	14.0	14.0	14.0	14.0	14.0
5	15.8	14.6	14.4	14.2	14.2	14.2	14.0	14.0	14.0	14.0
6	16.8	16.4	16.0	16.0	16.0	16.0	16.0	16.0	16.0	16.0
7	15.6	14.5	14.5	14.3	14.3	14.2	14.2	14.0	14.0	14.0
8	15.6	14.3	14.3	14.0	14.0	14.0	14.0	14.0	14.0	14.0
9	15.8	14.2	14.0	14.0	13.8	13.8	13.6	13.6	13.6	13.6
10	16.9	16.6	16.0	16.0	16.0	16.2	16.0	16.0	16.0	16.0
11	16.0	14.5	14.5	14.1	14.1	14.1	14.0	14.0	14.0	14.0
12	16.8	16.3	16.3	16.0	16.0	16.2	16.0	16.0	16.0	16.0

Table 5(d) LR (t/ha) of saline soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	16.0	14.2	14.2	14.0	14.0	13.8	13.4	13.2	13.0	13.0
2	16.0	14.6	14.2	14.2	14.2	14.0	13.6	13.4	13.0	13.0
3	16.4	15.8	15.8	15.6	15.6	14.8	14.2	14.0	13.6	13.6
4	16.0	14.8	14.4	14.0	14.0	13.8	13.2	13.2	13.0	13.0
5	16.1	14.9	14.4	14.3	14.2	14.0	13.4	13.4	13.2	13.0
6	16.5	15.7	15.7	15.6	15.6	15.0	14.2	14.0	13.5	13.5
7	16.1	15.2	15.2	15.2	15.2	14.8	14.0	14.0	13.6	13.5
8	16.0	14.9	14.4	14.2	14.2	13.9	13.2	13.2	13.0	13.0
9	16.1	15.6	15.5	15.2	15.2	14.6	14.0	13.8	13.4	13.4
10	16.0	15.4	15.0	15.0	15.0	14.5	13.8	13.8	13.5	13.4
11	16.0	15.4	15.0	15.0	15.0	14.5	13.8	13.5	13.5	13.2
12	16.0	14.8	14.5	14.2	14.0	13.8	13.2	13.2	13.2	13.0

Table 5(e) Lime requirement (t/ha) of rice soils on submergence in water : mean values for 10 periods of sampling over a period of three months.

Soil type	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(11)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Alluvial	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.0	9.0	9.0
Acid saline	15.0	14.8	14.2	14.0	13.6	13.2	12.0	12.0	12.0	12.0
Acid sulphate	16.0	14.9	14.7	14.6	14.5	14.5	14.4	14.4	14.4	14.4
Saline	16.1	15.1	14.9	14.7	14.7	14.3	13.7	13.6	13.3	13.2
C.D for soils	0.3	0.5	0.4	0.4	0.5	0.5	0.3	0.5	0.4	0.4

C.D for periods - 0.4

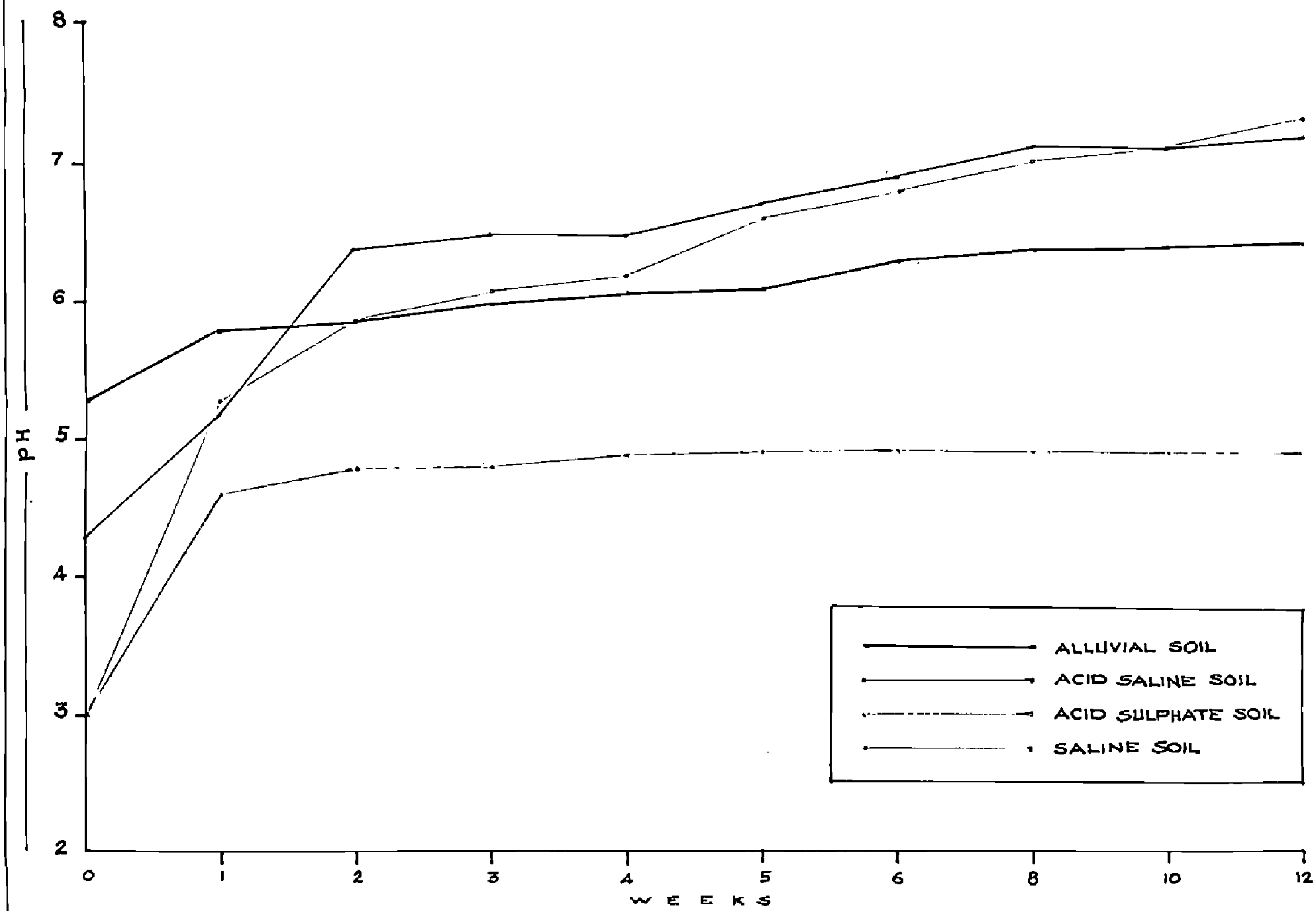

FIG. 1. CHANGES IN pH OF SOILS WITH TIME DUE TO FLOODING.

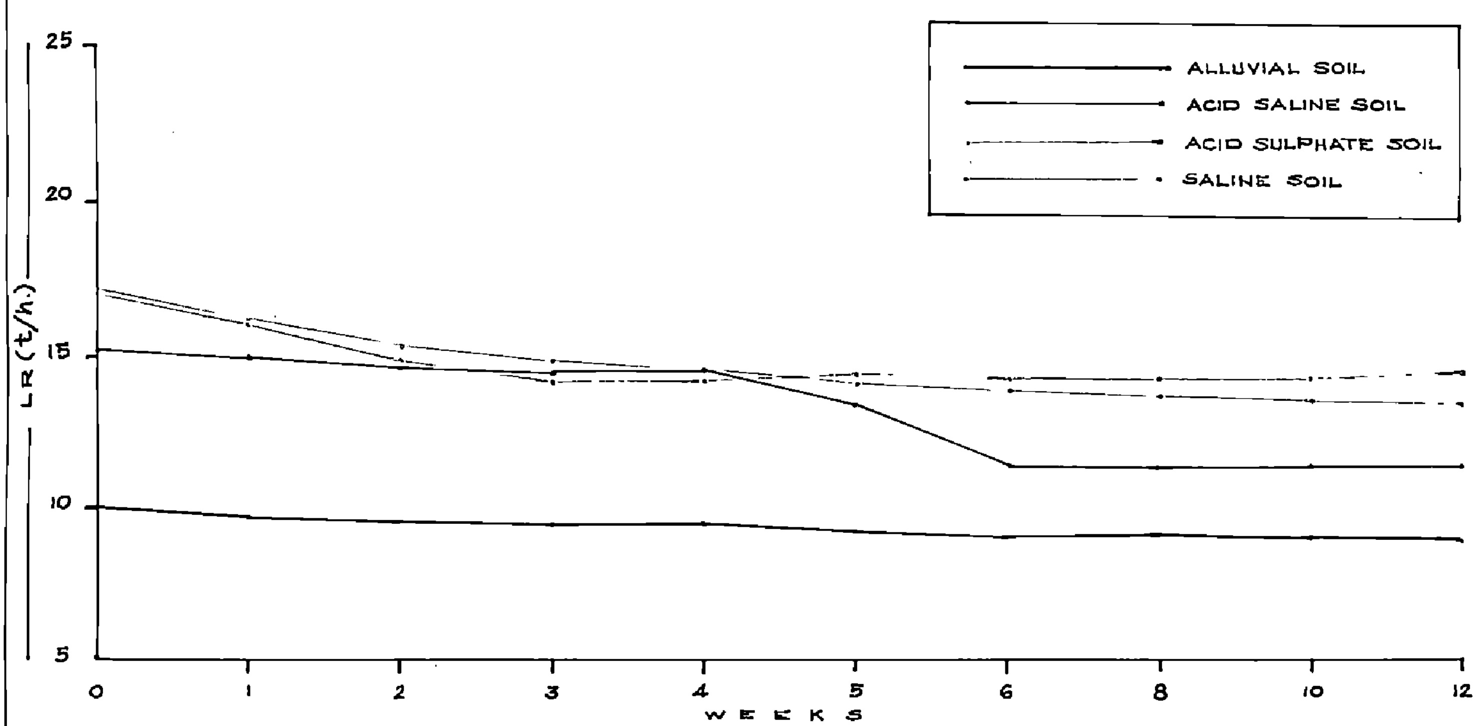

FIG. 2. CHANGES IN LR OF SOILS WITH TIME DUE TO FLOODING

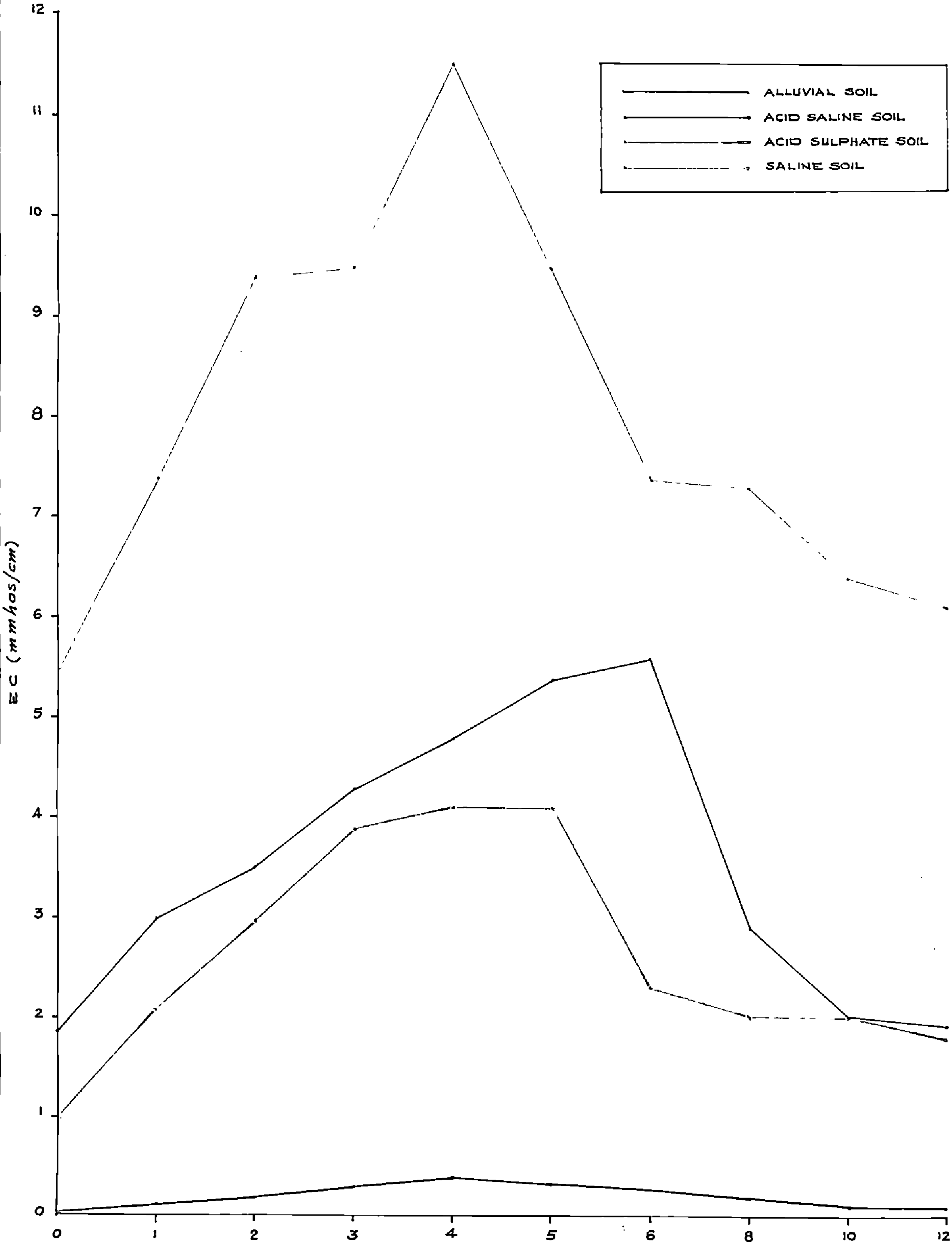

FIG. 3. CHANGES IN EC OF SOILS WITH TIME DUE TO FLOODING.

vial soils. The reduction in lime requirement at the end of one week period of submergence was in the order of 1.3, 1.4, 1.0 and 0.2 t/ha for saline, acid sulphate, acid saline and alluvial soils respectively. With increase in the period of submergence, the lime requirement value decreased for all the soils. The reduction in lime requirement was maximum in saline and acid saline soils (3.2 t/ha) and minimum for alluvial soils (0.7 t/ha).

Available nitrogen Tables 6(a) to 6(e).

The available nitrogen was significantly different for the different periods in all the four soil types. It may be noted that the available nitrogen of all the soils used in the present study registered an increase due to flooding.

The effect of submergence in increasing the content of available nitrogen was maximum in saline soils, followed by acid saline and acid sulphate soils and it was minimum in alluvial soils. After 12 hours of submergence, alluvial soils showed a slight decrease in available nitrogen (13 ppm), while acid saline soils recorded a slight increase (4 ppm). The increase was in the range of 20 to 38 ppm for saline and acid sulphate soils at this period.

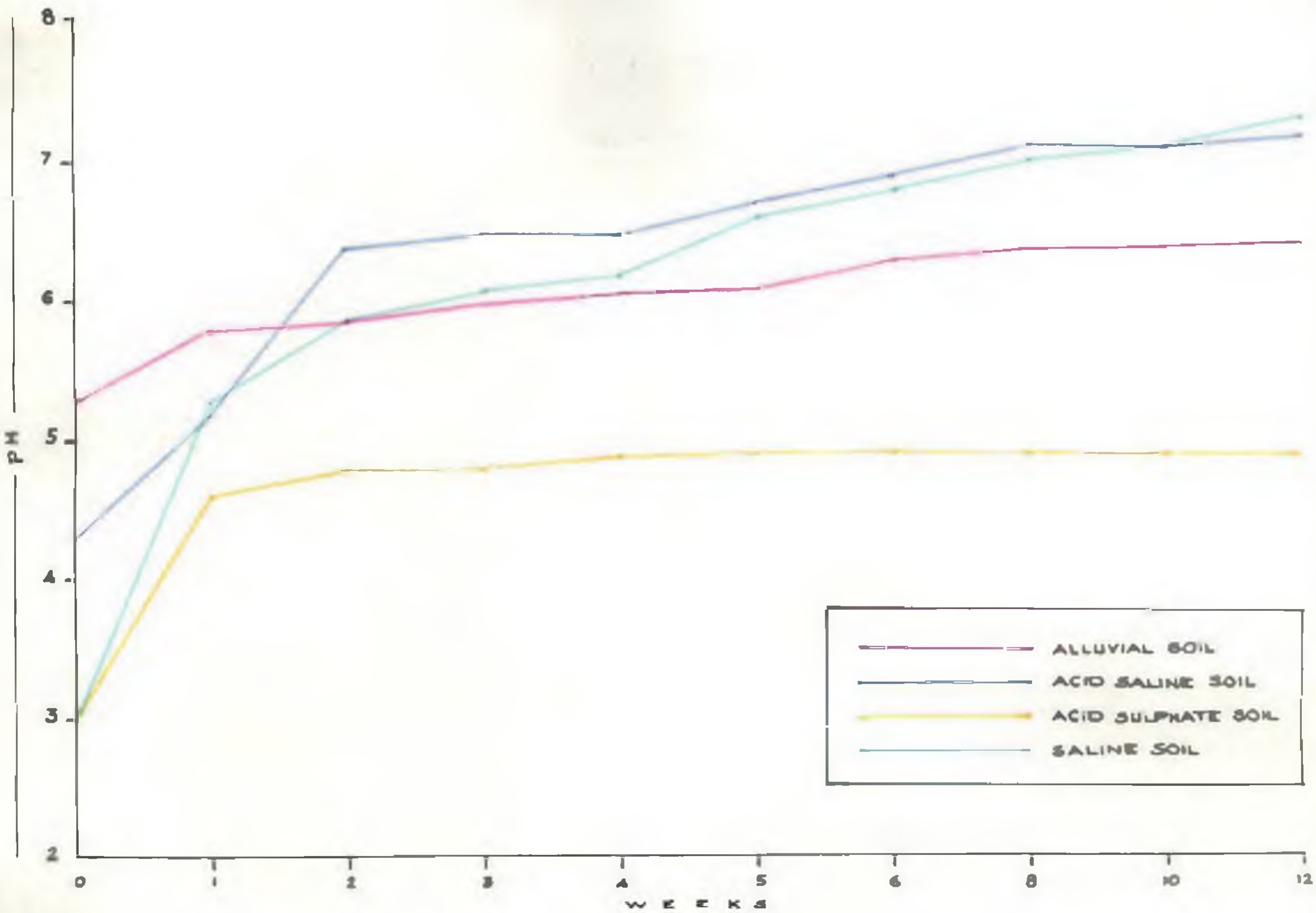

FIG. 1. CHANGES IN pH OF SOILS WITH TIME DUE TO FLOODING

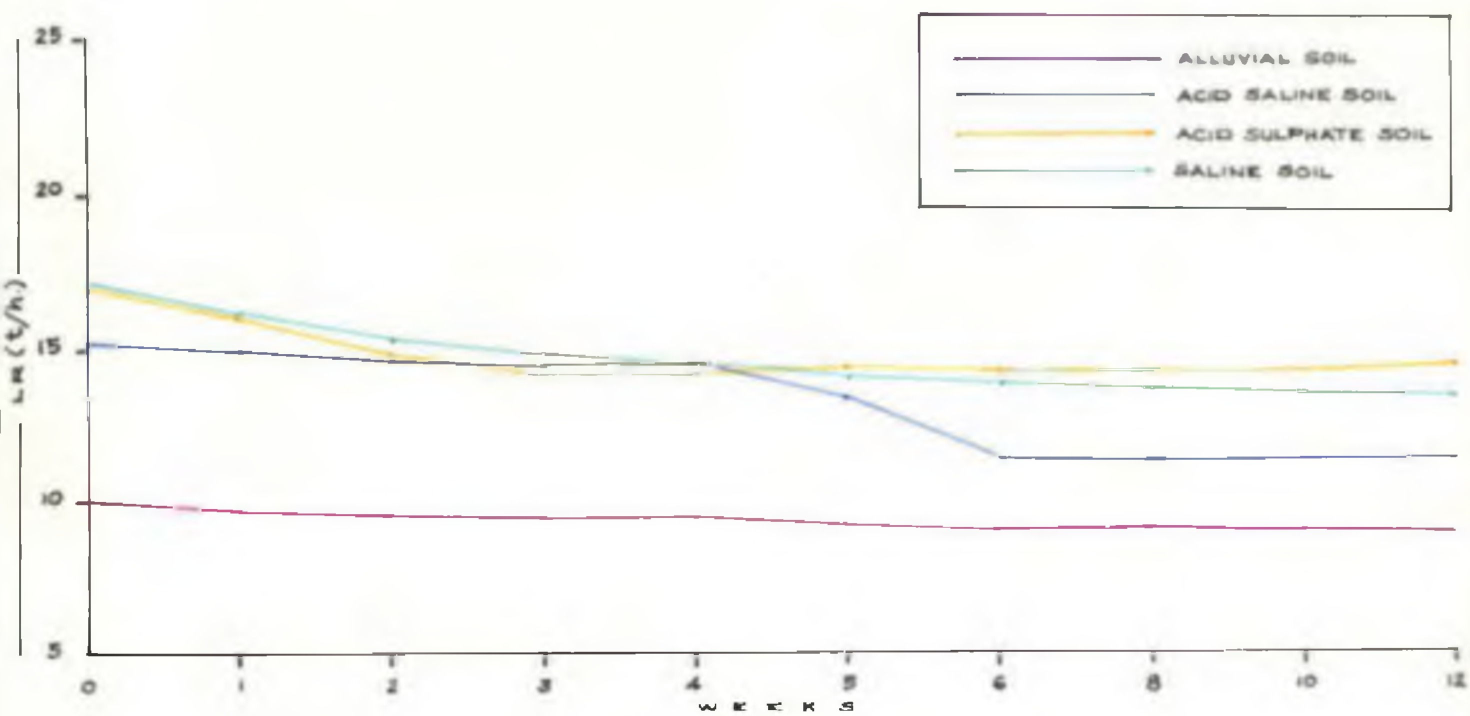

FIG. 2. CHANGES IN LR OF SOILS WITH TIME DUE TO FLOODING

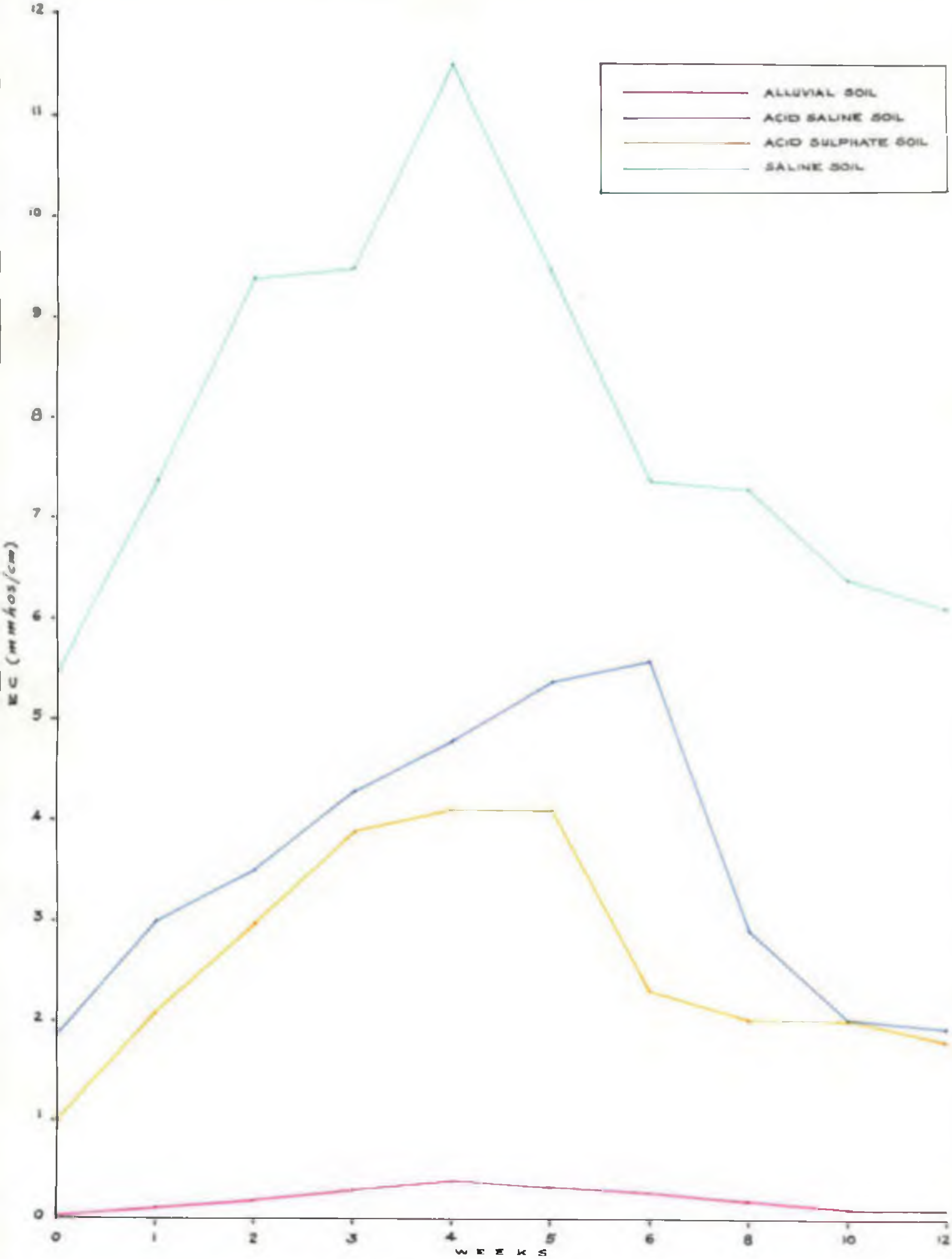

FIG 3. CHANGES IN EC OF SOILS WITH TIME DUE TO FLOODING

Table 6(a) Available nitrogen (ppm) of alluvial soils on submergence in water for 10 periods of sampling over a period of three months.

	Periods (weeks)									
No.	1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	98	141	152	164	168	179	203	210	213	230
2	130	156	187	201	217	220	224	235	245	265
3	56	139	148	153	160	180	191	200	200	219
4	98	143	152	168	182	212	226	261	280	295
5	63	140	150	154	161	184	205	212	217	237
6	84	147	156	164	175	198	224	244	266	287
7	112	154	161	168	182	200	224	253	273	294
8	175	182	190	197	217	245	273	288	301	312
9	98	147	151	156	168	198	219	222	231	250
10	98	141	148	156	161	182	203	208	210	224
11	128	161	174	189	210	213	224	238	259	278
12	89	141	150	158	161	196	202	208	210	234

Table 6(b) Available nitrogen (ppm) of acid saline soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks)									
	1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	112	133	171	212	259	268	280	320	354	359
2	114	135	180	228	273	279	283	328	360	365
3	118	137	178	231	273	279	291	335	372	375
4	115	135	170	211	252	264	280	322	361	365
5	49	70	108	142	189	189	189	210	231	236
6	91	104	135	166	198	229	246	273	301	305
7	132	148	193	238	287	338	374	400	428	430
8	84	99	130	166	196	199	199	226	259	262
9	95	105	131	162	190	208	224	245	268	270
10	145	160	212	259	308	345	385	411	431	431
11	52	75	112	147	180	190	190	211	235	241
12	147	165	207	259	308	345	385	415	441	443

Table 6(c) Available nitrogen (ppm) of acid sulphate soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	105	210	329	290	247	354	398	440	472	490
2	92	182	266	238	212	273	279	284	288	303
3	98	189	272	259	231	281	289	290	294	300
4	147	238	339	300	278	399	431	468	497	499
5	85	166	288	261	210	309	324	339	350	362
6	686	691	707	700	698	719	728	743	756	761
7	77	140	192	179	158	214	248	262	273	279
8	81	169	292	264	212	306	324	341	357	364
9	110	224	336	311	275	385	428	474	495	498
10	629	640	688	677	669	700	721	739	748	750
11	37	131	196	172	150	210	237	259	270	281
12	626	644	674	663	658	690	718	729	740	752

Table 6(d) Available nitrogen (ppm) of saline soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	121	159	194	236	272	350	448	554	616	658
2	207	240	318	399	462	531	580	622	651	690
3	104	145	182	228	260	348	459	512	581	647
4	210	45	339	420	476	540	594	646	698	728
5	257	98	390	498	581	634	678	710	748	769
6	140	80	230	280	320	400	443	529	588	626
7	120	154	195	231	266	322	428	509	567	598
8	149	188	231	289	334	424	518	590	621	658
9	160	196	242	300	340	437	509	582	628	660
10	219	240	340	418	460	511	568	619	659	694
11	224	243	341	420	462	510	575	621	662	710
12	240	266	358	432	497	558	660	697	722	761

Table 6(e) Available nitrogen (ppm) of rice soils on submergence in water : mean values for 10 periods of sampling over a period of three months.

Soil type	Periods (weeks)									
	1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Alluvial	103	149	160	167	180	201	218	215	242	202
Acid saline	105	122	161	200	243	261	277	303	337	353
Acid sulphate	231	302	382	360	333	403	427	447	462	484
Saline	179	213	280	311	394	464	537	599	645	683
C.D for soils	107.9	93	86.4	114.2	99.7	91.7	91.2	93.2	89.1	91.2

C.D for periods - 95.7

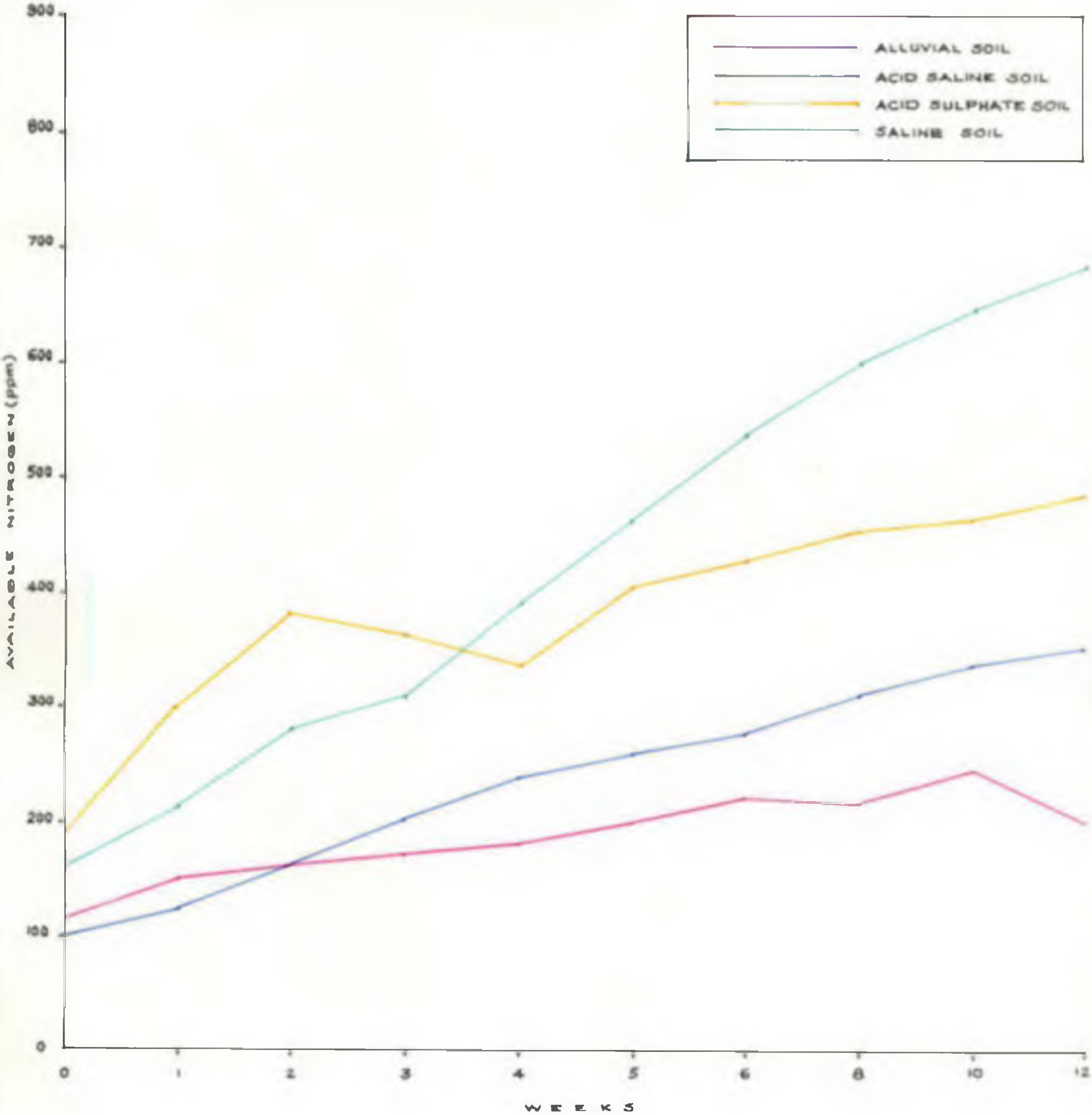

FIG. 4. CHANGES IN AVAILABLE NITROGEN OF SOILS WITH TIME DUE TO FLOODING.

The available nitrogen continued to rise in the saline and acid saline soils during the rest of the submergence period. In alluvial soils maximum increase was observed at 10 weeks of submergence which was given 110% increase greater than the corresponding values for the dry soil and after that it decreased. The acid sulphate soils showed 98% increase in available nitrogen at the end of two weeks period. The content of available nitrogen registered a decreasing trend during the third and fourth weeks, which again increased and reached the maximum values by the end of the three months incubation period. Over a period of submergence for 12 weeks, the mean value of available nitrogen recorded nearly four times increase for acid saline and saline soils, the maximum being obtained after 12 weeks of incubation. Maximum values obtained for available nitrogen were 242, 333, 484 and 683 ppm for alluvial, acid saline, acid sulphate and saline soils respectively.

Available phosphorus Tables 7(a) to 7(e).

Flooding of the soils resulted in a rise in the content of available phosphorus in all the soils, the most significant changes being shown by the acid saline and saline soils. The saline soils showed 68% increase in available

Table 7(a) Available phosphorus (ppm) of alluvial soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	200	148	175	201	227	258	294	220	157	106
2	118	65	70	74	77	84	92	67	52	32
3	130	69	75	81	88	96	109	92	74	52
4	136	74	82	93	105	123	142	110	81	56
5	168	120	127	135	143	164	197	152	125	80
6	156	104	111	117	125	144	167	132	98	70
7	161	116	130	145	158	178	204	160	128	82
8	100	63	68	73	78	86	93	73	54	35
9	191	139	160	188	206	234	265	200	145	90
10	156	103	110	117	124	142	160	130	100	70
11	148	82	90	100	112	128	145	118	93	60
12	128	65	69	74	77	84	95	74	56	38

Table 7(b) Available phosphorus (ppm) of acid saline soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	114	345	385	432	480	432	368	398	421	450
2	110	252	310	392	442	378	286	287	290	320
3	98	209	274	350	381	314	244	240	288	319
4	134	298	340	392	460	392	319	337	356	388
5	101	224	299	375	423	364	257	324	395	422
6	116	238	311	369	407	300	264	270	284	310
7	160	305	389	430	462	400	336	342	367	394
8	134	351	400	440	487	337	368	389	407	424
9	171	704	780	839	892	751	705	700	700	700
10	126	389	432	478	512	469	397	400	411	428
11	124	506	620	709	784	682	550	579	597	610
12	131	517	624	700	798	648	558	584	600	612

Table 7(c) Available phosphorus (ppm) of acid sulphate soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	130	162	194	223	254	250	216	241	274	280
2	139	179	227	269	309	308	248	252	255	258
3	99	147	189	234	281	275	174	250	324	332
4	193	181	230	262	284	284	179	240	280	300
5	65	90	129	171	200	172	158	145	138	140
6	34	58	61	63	68	65	77	160	54	55
7	137	179	190	209	221	200	182	127	86	95
8	198	189	200	207	226	200	189	130	98	100
9	65	88	127	157	182	165	151	140	138	142
10	44	65	65	168	68	68	83	80	72	76
11	134	167	184	197	207	210	219	220	222	225
12	40	59	59	60	61	65	80	75	66	70

Table 7(d) Available phosphorus (ppm) of saline soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	162	165	201	241	271	279	284	390	477	488
2	158	158	183	200	235	243	256	344	453	465
3	158	158	180	204	235	245	258	371	448	454
4	170	227	242	261	287	292	293	394	479	489
5	94	99	110	128	145	181	215	258	278	290
6	120	121	130	142	155	198	246	297	324	340
7	111	120	131	140	152	185	216	299	358	360
8	176	230	252	271	294	295	257	392	481	492
9	120	124	138	147	157	208	244	336	422	430
10	85	98	109	121	132	179	204	314	411	418
11	111	121	128	136	144	191	232	278	427	431
12	132	142	145	150	155	197	246	348	431	437

Table 7(e) Available phosphorus (ppm) of rice soils on submergence in water : mean values for 10 periods of sampling over a period of three months.

Soil type	1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Alluvial	149	97	106	117	127	143	164	127	95	64
Acid saline	126	361	430	494	544	456	388	404	426	448
Acid sulphate	106	130	155	185	197	189	163	172	167	173
Saline	133	147	162	178	197	224	246	335	416	425
C.D for soils	30.8	67.9	75.2	76	87	78.2	71.6	70.5	75.6	72.3

C.D for periods - 71.8

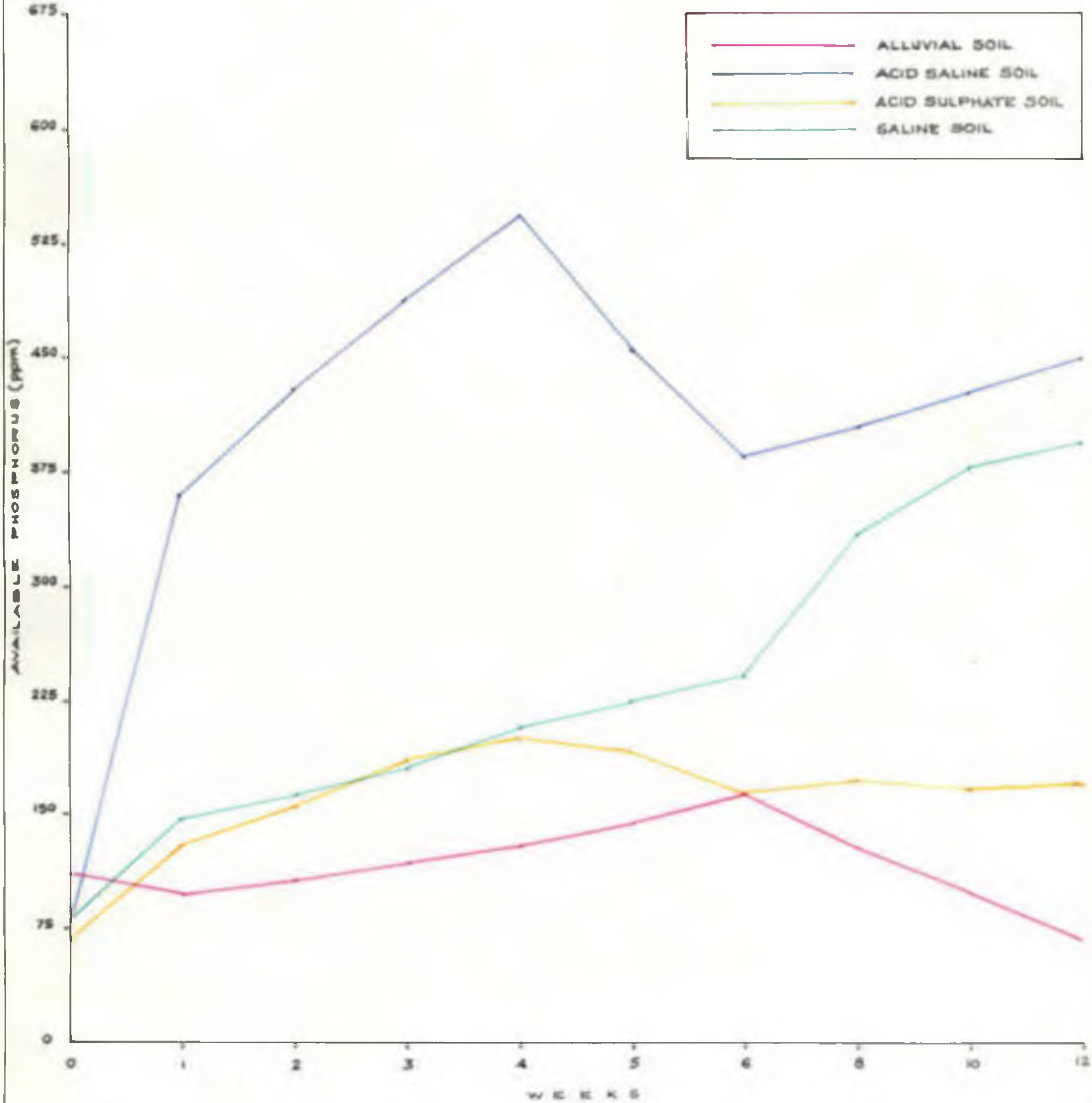

FIG. 5. CHANGES IN AVAILABLE PHOSPHORUS OF SOILS WITH TIME DUE TO FLOODING.

phosphorus at the end of 12 hours of submergence and after that by a steady increase reached the maximum value of 425 ppm by the end of 12 weeks. The available phosphorus content recorded 47% increase in the case of acid sulphate soils at the end of 12 hours of flooding. It continued to increase and reached the peak value (197 ppm) after four weeks of submergence and decreased slowly from the fifth week, till the end of 12 weeks.

The acid saline soils recorded more than four fold increase in available phosphorus in the first week of submergence. In the second and third weeks the increase was 19% and 15% and at the end of four weeks attained the maximum value (544 ppm). After the fifth and sixth weeks, a decrease of 15-16% of available P was obtained, followed by an increasing tendency during the remaining periods of submergence.

A 40% increase in available phosphorus was observed in alluvial soils at 12 hours of flooding, after which, submergence showed no effect on phosphorus availability over the initial value till the end of four weeks. The highest increase obtained at the end of six weeks was 164 ppm in alluvial soils after which a significant decrease was noted.

Exchangeable potassium Tables 8(a) to 8(e).

A decrease in exchangeable potassium was observed in all the soil types after one week of submergence and after that it showed an increasing trend. The maximum increase was noted for saline soils (292 ppm) at the end of six weeks of submergence (four times greater than the initial value) after which a declining trend was noticed. The acid sulphate soils recorded three times increase in exchangeable potassium after being submerged for five weeks showing a significant decrease afterwards.

The mean values of exchangeable potassium showed fluctuations between different periods of submergence in alluvial soils. However, a 44% increase was recorded after two weeks of flooding with a value of 188 ppm. The content of exchangeable potassium in acid saline soils doubled at the end of six weeks. The initial level of exchangeable potassium was more for acid saline and alluvial soils (149 and 131 ppm) compared to the saline (80 ppm) and acid sulphate (82 ppm) soils.

Exchangeable calcium Tables 9(a) to 9(e).

Table 8(a) Exchangeable potassium (ppm) of alluvial soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	87	87	98	107	120	270	270	228	200	191
2	90	99	101	112	126	103	72	72	72	72
3	90	93	100	115	126	120	114	100	104	100
4	90	96	105	116	128	82	78	77	75	74
5	141	158	221	246	279	271	270	230	220	200
6	123	222	258	293	303	288	270	232	217	198
7	66	78	78	78	78	78	78	75	72	72
8	54	78	78	78	75	78	78	76	76	75
9	72	213	220	225	228	171	122	122	120	120
10	72	90	100	118	125	125	74	70	66	65
11	108	123	184	252	271	139	135	107	90	90
12	96	105	108	139	139	128	126	120	114	108

Table 8(b) Exchangeable potassium (ppm) of acid saline soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	159	180	201	228	231	261	282	201	114	111
2	162	189	204	231	238	267	288	204	234	204
3	126	186	282	300	312	312	309	300	300	282
4	121	138	156	171	174	243	285	225	192	183
5	161	178	195	231	246	261	290	195	168	150
6	90	120	141	174	180	243	243	189	120	120
7	159	170	255	300	315	315	312	306	303	300
8	160	181	204	234	240	273	270	213	184	162
9	78	86	111	162	171	282	288	198	141	120
10	132	138	153	180	186	248	248	201	171	153
11	90	108	162	195	210	222	243	165	117	111
12	84	96	159	189	201	228	240	153	105	93

Table 8(c) Exchangeable potassium (ppm) of acid sulphate soils on submergence in water for 10 periods of sampling over a period of three months.

	Periods (weeks)									
No.	1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	204	180	243	291	312	312	282	261	228	222
2	168	126	237	288	309	312	135	128	128	120
3	186	135	225	282	303	309	162	153	152	150
4	102	90	192	252	294	300	126	126	123	120
5	69	69	174	201	234	282	66	90	114	111
6	60	60	90	102	126	147	57	90	88	88
7	90	84	108	111	144	192	60	102	102	96
8	156	123	198	252	291	297	126	126	118	109
9	90	87	120	141	150	172	120	105	114	102
10	36	33	90	102	120	144	56	54	48	48
11	54	60	96	114	141	165	117	105	111	99
12	36	40	93	99	123	141	54	57	50	48

Table 8(d) Exchangeable potassium (ppm) of saline soils on submergence in water for 10 periods of sampling over a period of three months.

No.	1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	36	60	72	102	120	282	303	300	294	291
2	93	78	84	120	141	243	282	246	240	234
3	87	84	108	129	150	255	306	300	303	294
4	102	90	111	123	150	261	303	300	300	291
5	48	48	66	126	156	285	315	310	312	299
6	87	84	105	120	150	240	285	267	258	252
7	111	93	102	117	153	240	261	236	234	234
8	93	78	90	105	108	252	297	282	282	270
9	99	81	93	111	117	246	291	270	262	252
10	108	84	108	132	147	213	264	246	244	241
11	96	75	87	110	111	258	282	252	252	246
12	105	96	108	132	144	294	309	306	306	300

Table 8(e) Exchangeable potassium (ppm) of rice soils on submergence in water : mean values for 10 periods of sampling over a period of three months.

Soil type	Periods (weeks)									
	1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Alluvial	91	120	188	157	167	154	142	126	119	114
Acid saline	127	147	185	161	225	96	275	213	179	166
Acid sulphate	104	91	156	186	212	231	113	116	115	130
Saline	89	79	95	119	137	256	292	276	274	267
C.D for soils	31.4	32	42.3	50	52.7	47.9	43.6	41.5	43.7	45.6

S.E for periods - 16.8

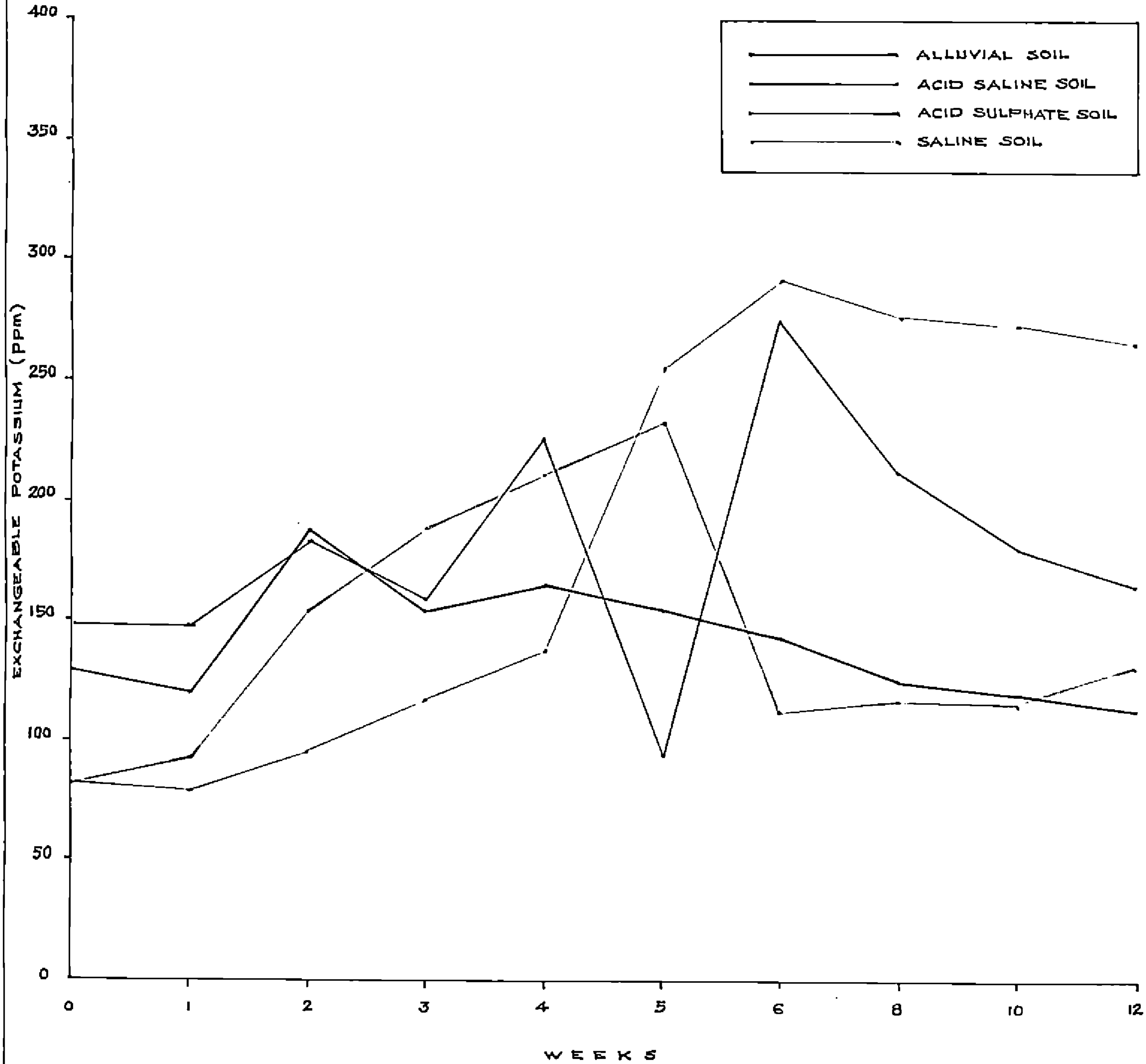

FIG. 6. CHANGES IN EXCHANGEABLE POTASSIUM OF SOILS WITH TIME DUE TO FLOODING.

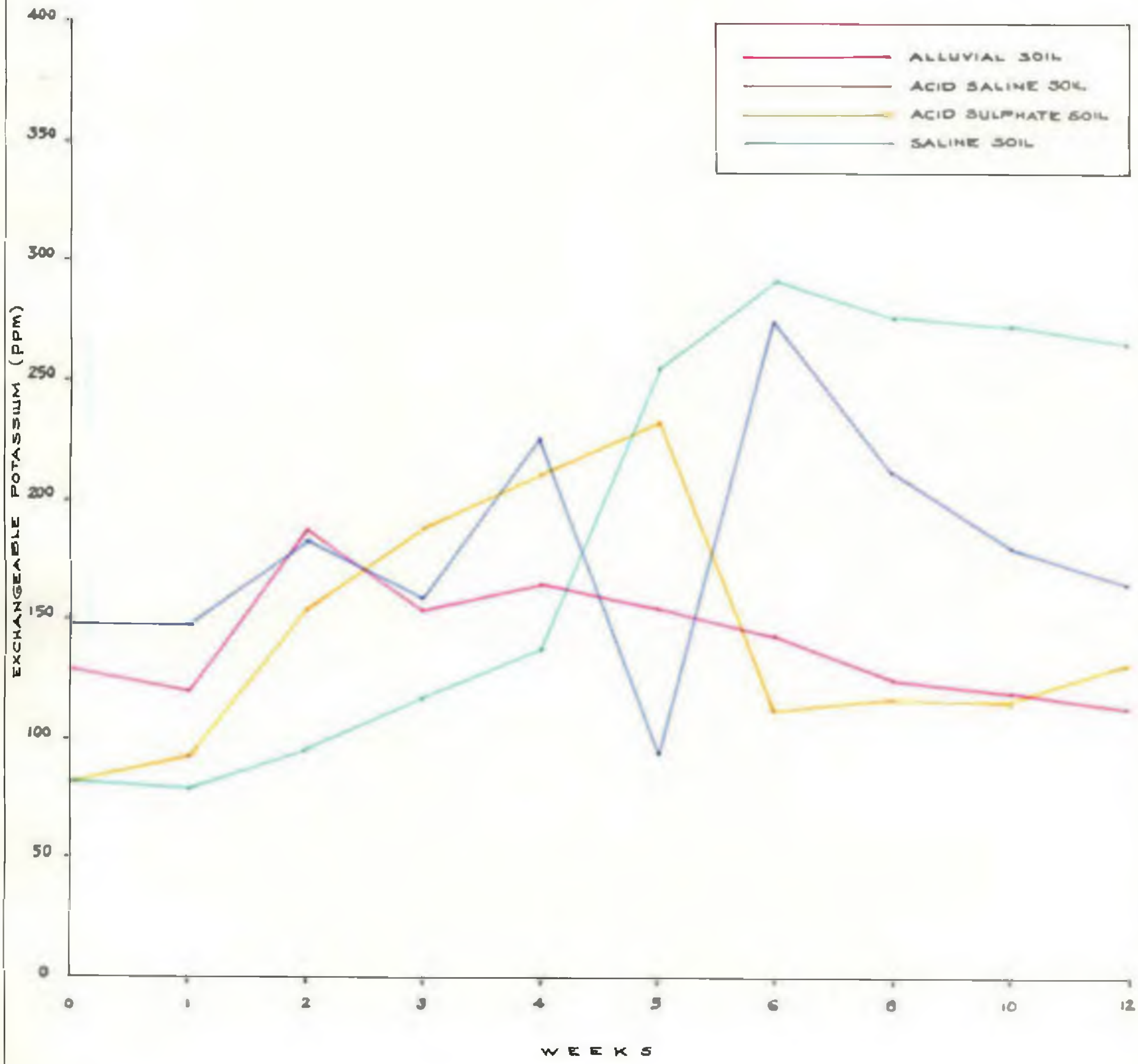

FIG. 6. CHANGES IN EXCHANGEABLE POTASSIUM OF SOILS WITH TIME DUE TO FLOODING.

Table 9(a) Exchangeable calcium (ppm) of alluvial soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	104	120	158	174	204	194	183	180	174	170
2	383	371	649	815	904	624	492	485	472	468
3	381	292	342	375	403	368	310	298	284	275
4	284	196	248	285	332	304	301	285	248	240
5	203	156	229	279	321	244	200	200	200	188
6	499	398	788	959	1142	758	508	500	398	364
7	310	205	258	329	394	342	296	286	253	250
8	490	392	780	950	1010	741	500	500	439	400
9	286	185	256	300	358	313	282	269	242	228
10	294	193	282	389	465	380	339	309	289	265
11	210	152	235	286	324	268	192	178	175	172
12	345	345	389	414	480	414	339	310	300	285

Table 9(b) Exchangeable calcium (ppm) of acid saline soils on submergence in water for 10 periods of sampling over a period of three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	371	398	400	356	316	271	235	231	223	222
2	440	466	466	370	335	284	237	235	231	230
3	390	396	400	351	306	264	237	230	225	225
4	312	320	325	294	265	230	200	183	178	175
5	174	196	200	158	120	101	91	85	85	83
6	148	174	190	132	110	99	88	88	84	81
7	614	628	632	574	502	424	320	300	279	254
8	136	144	145	118	98	89	77	75	75	71
9	628	634	637	568	500	442	319	260	232	224
10	923	1013	1015	794	732	728	725	720	720	719
11	914	998	1000	782	730	728	728	725	725	723
12	339	353	360	344	321	320	316	310	310	303

Table 9(c) Exchangeable calcium (ppm) of acid sulphate soils on submergence in water for 10 periods of sampling over three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	621	688	793	833	893	664	570	494	329	320
2	756	789	809	831	986	653	560	482	357	332
3	243	275	301	328	352	324	294	261	234	219
4	350	370	398	412	431	388	320	310	306	291
5	178	198	204	219	227	210	196	195	191	189
6	940	988	1020	1048	1094	945	854	798	721	709
7	359	389	404	421	433	372	314	312	310	294
8	176	201	208	212	221	200	192	138	96	88
9	400	409	428	440	463	393	326	289	254	239
10	943	505	712	942	1047	923	809	762	700	684
11	243	136	152	168	177	165	156	118	77	72
12	95	500	781	918	999	912	791	730	712	692

Table 9(d) Exchangeable calcium (ppm) in saline soils on submergence in water for 10 periods of sampling over three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	1124	525	500	432	469	396	320	300	292	284
2	1248	606	581	549	528	440	334	310	300	289
3	1094	520	421	391	360	305	258	256	239	228
4	825	470	384	346	244	204	160	150	134	128
5	810	462	370	292	239	199	156	150	140	131
6	830	472	374	300	249	200	162	150	136	131
7	1259	609	584	551	531	438	337	322	307	292
8	828	470	380	314	245	206	160	150	140	130
9	1106	522	392	328	266	228	192	180	168	150
10	1268	610	587	562	541	448	340	318	300	291
11	1088	521	463	402	365	315	264	250	240	230
12	1014	500	431	340	258	226	180	168	155	141

Table 9(e) Exchangeable calcium (ppm) of rice soils on submergence in water : mean values for 10 periods of sampling over a period of three months.

Soil type	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(11)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Alluvial	132	284	385	463	361	413	328	150	238	275
Acid saline	432	477	481	404	361	332	298	287	281	276
Acid sulphate	442	454	517	564	610	512	449	407	357	344
Saline	1041	524	456	401	358	300	234	225	213	202
C.D for soils	230.8	156.2	196.2	204.6	242.6	175.6	150.7	155	141.4	139.3

S.E for periods - 46

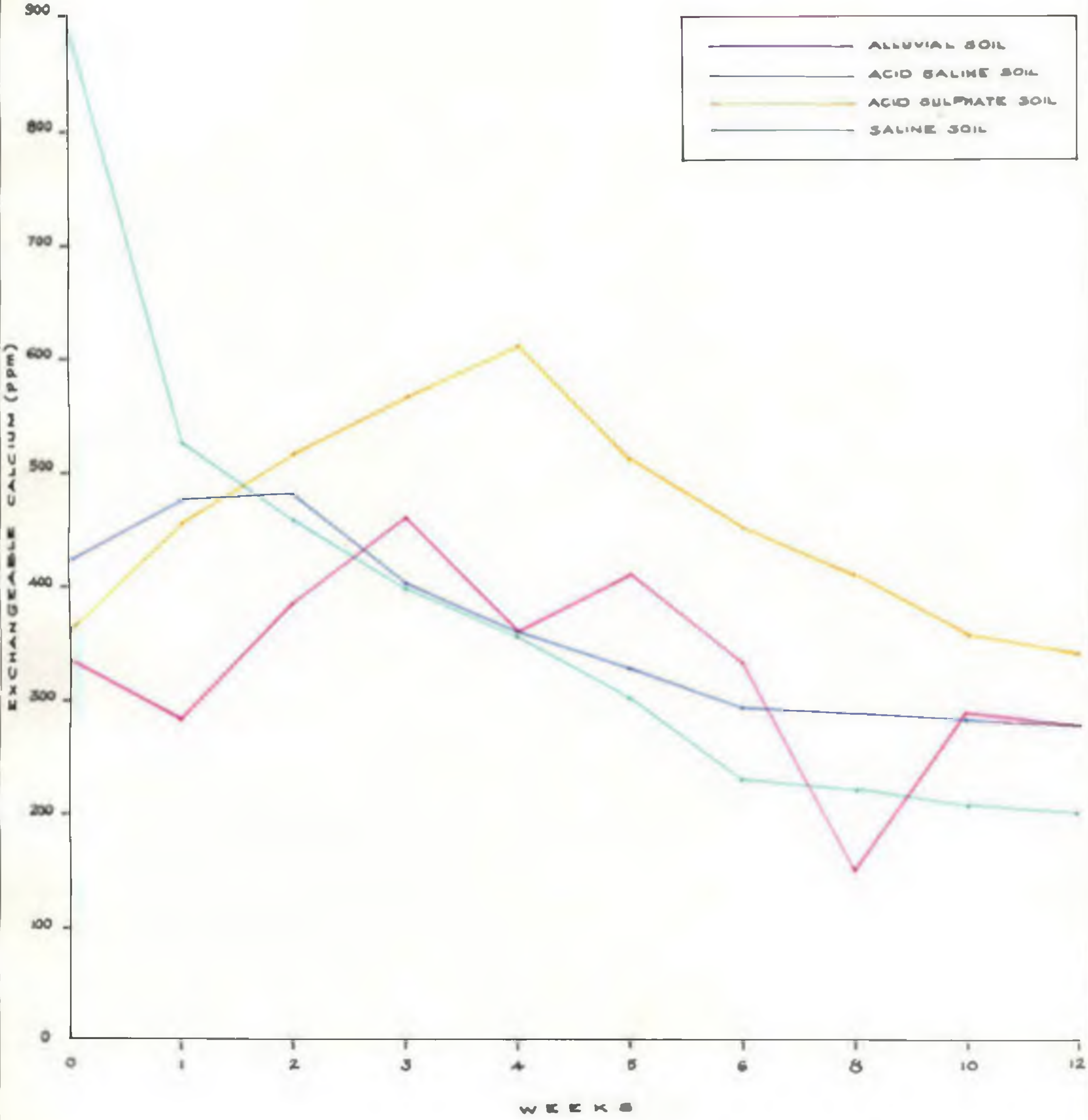

FIG. 7. CHANGES IN EXCHANGEABLE CALCIUM OF SOILS WITH TIME DUE TO FLOODING.

The tendency of exchangeable calcium to decrease with increasing periods of submergence was evident from the results obtained for all soil types. However, the alluvial soils showed 38% increase at the end of three weeks. The mean values of exchangeable calcium recorded a gradual increase in acid sulphate soils though not significant between periods and reached the maximum (610 ppm) at the end of four weeks of flooding, after which it significantly decreased. No significant change in exchangeable calcium was noted for two weeks in acid saline and 12 hours in saline soils, eventhough a significant decrease was observed in both the soils after this period.

Exchangeable magnesium Tables 10(a) to 10(e).

Highly significant decrease in the mean values of exchangeable magnesium were observed in saline and acid saline soils at the end of 12 hours of flooding. A gradual increase between periods was noted until they attained maximum values of 1254 and 477 ppm at the end of six weeks of submergence. After this period, the content of exchangeable magnesium gradually decreased. The acid sulphate soils registered a maximum value of 634 ppm in the first week, a 58% increase over the initial level and after that it showed a significant decrease. Changes in exchangeable magnesium

Table 10(a) Exchangeable magnesium (ppm) in alluvial soils on submergence in water for 10 periods of sampling over three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	91	120	148	172	203	162	150	129	100	95
2	150	196	305	688	903	690	339	265	209	194
3	144	185	296	670	890	618	309	250	200	190
4	115	152	198	232	320	289	252	208	181	149
5	68	90	120	152	190	185	183	140	121	90
6	158	202	400	722	938	647	390	300	237	188
7	130	156	208	271	324	311	296	251	194	151
8	204	278	432	794	1100	708	411	321	266	203
9	168	205	329	706	1002	669	398	310	274	198
10	131	163	234	295	358	321	303	278	220	180
11	92	130	179	200	234	219	200	188	171	163
12	160	202	394	700	985	592	391	298	240	199

Table 10(b) Exchangeable magnesium (ppm) in acid saline soils on submergence in water for 10 periods of sampling over three months.

No.	1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	58	153	214	280	376	494	580	555	549	520
2	89	160	231	329	383	634	783	692	585	540
3	92	205	338	482	540	780	821	740	621	600
4	60	90	199	288	353	528	684	630	557	508
5	85	144	200	250	287	449	539	518	507	500
6	5	121	170	200	240	242	259	250	244	238
7	2	6	31	79	101	123	148	100	64	60
8	113	208	341	495	614	897	1215	1012	919	854
9	3	60	80	94	114	138	150	110	67	65
10	2	59	70	99	111	131	153	120	75	75
11	8	140	145	150	150	170	192	125	82	80
12	8	144	150	151	155	169	198	128	88	85

Table 10(c) Exchangeable magnesium (ppm) in acid sulphate soils on submergence in water for 10 periods of sampling over three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	608	776	504	462	390	338	314	300	293	290
2	773	805	598	521	468	387	340	328	357	355
3	177	405	328	300	281	254	235	225	220	216
4	380	468	288	232	193	185	182	181	176	175
5	117	154	122	100	83	80	77	73	69	68
6	96	900	804	709	616	564	506	470	364	360
7	346	472	398	335	281	255	221	170	120	115
8	103	105	88	73	66	65	64	62	60	60
9	599	772	464	371	296	290	288	280	280	171
10	779	799	508	434	381	370	365	358	354	350
11	303	430	281	260	253	240	232	228	220	218
12	1500	1520	1100	953	870	800	752	682	585	580

Table 10(d) Exchangeable magnesium (ppm) in saline soils on submergence in water for 10 periods of sampling over three months.

No.	Periods (weeks) 1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	41	600	632	758	824	898	971	952	940	930
2	31	580	625	750	815	890	969	948	940	932
3	57	612	686	720	780	920	1015	1000	990	950
4	58	614	699	781	849	1000	1118	1053	1110	1000
5	55	610	680	714	787	980	1099	1000	1000	998
6	158	718	740	772	800	1200	1498	1400	1400	1200
7	64	651	700	758	800	1195	1390	1300	1298	1110
8	165	765	790	800	807	1200	1589	1509	1484	1239
9	65	620	690	724	798	1195	1400	1364	1320	1115
10	70	692	722	755	799	1190	1410	1355	1300	1100
11	172	772	818	842	895	1400	1614	1519	1500	1300
12	46	600	678	700	719	815	980	955	950	940

Table 10(e) Exchangeable magnesium (ppm) of rice soils on submergence in water : mean values for 10 periods of sampling over a period of three months.

Soil type	Periods (weeks)									
	1 (12 hours)	2(1)	3(2)	4(3)	5(4)	6(5)	7(6)	8(8)	9(10)	10(12)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Alluvial	134	174	270	467	229	451	302	243	203	167
Acid saline	44	124	181	241	195	395	477	415	363	344
Acid sulphate	482	634	457	396	348	319	298	280	255	255
Saline	82	651	705	756	806	1074	1254	1196	1111	1058
C.D for soils	170.7	163.3	133	160.6	136.2	181.7	197.3	178	206.9	139.8

S.E for periods - 39

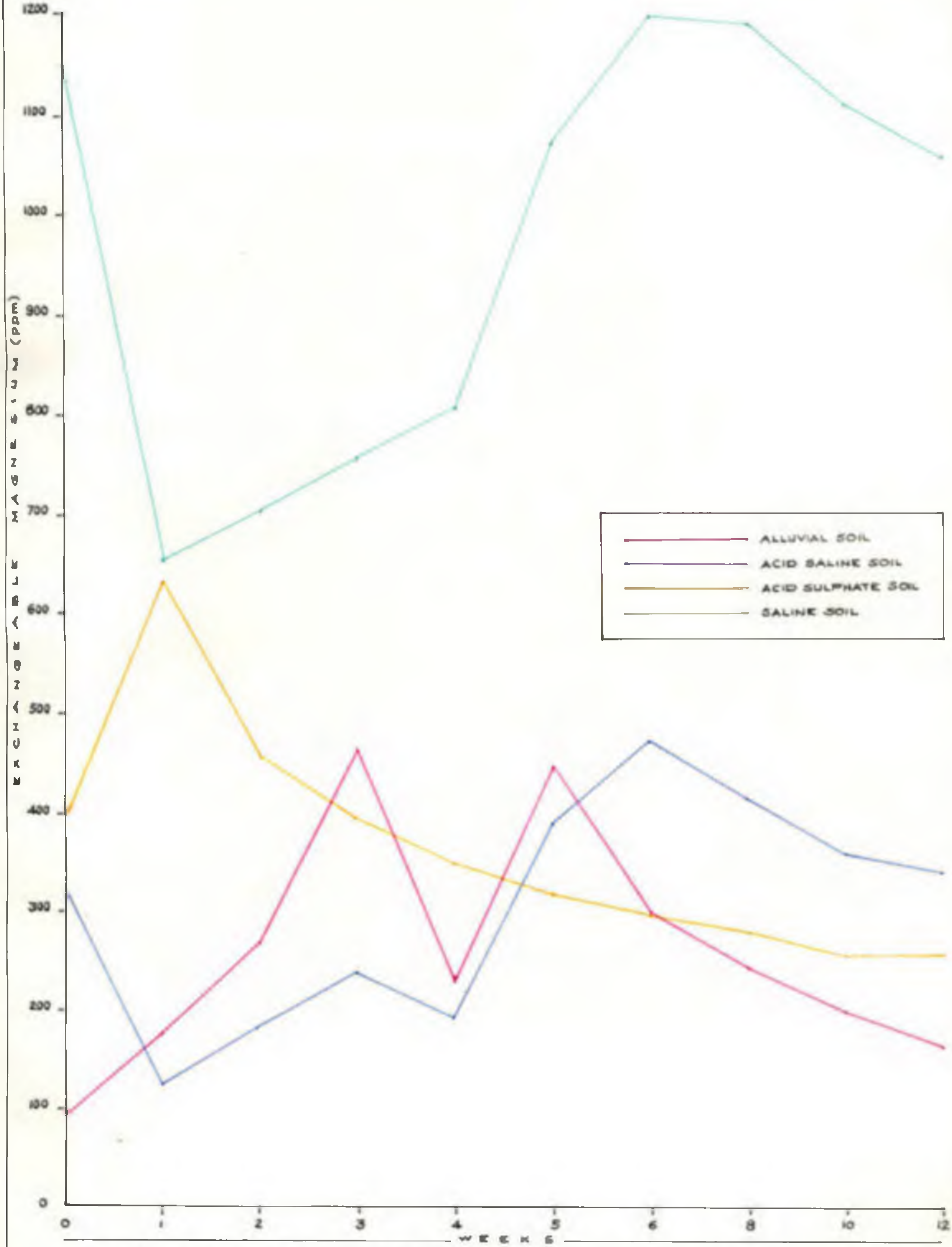

FIG 8. CHANGES IN EXCHANGEABLE MAGNESIUM OF SOILS WITH TIME DUE TO FLOODING.

were significant between periods in the alluvial soils and it recorded five times increase over the initial level at the third week with a maximum value of 467 ppm. After this period, the content of exchangeable magnesium decreased considerably.

3. A comparison of the effect of submergence on changes in physico chemical properties of four soil types.

The results of the pooled analysis of the data obtained after flooding of soils in water for various periods are given in appendix 1.

From the results it may be seen that of the soil properties studied, pH, EC, lime requirement, available nitrogen and available phosphorus were significantly affected by submergence while the effect of flooding for different periods was not significant for exchangeable cations like potassium, calcium and magnesium.

4. Correlation between different soil properties and periods of submergence.

From the results of correlation analysis it may be seen that the pH of the soils throughout the period of submergence did not significantly influence the EC values in alluvial, acid saline and saline soils. But a negative and significant correlation was obtained between these factors in the acid sulphate soils.

The pH of the soils showed a negative effect on lime requirement in all the soil types, which was significant in acid sulphate and saline soils and not appreciable in alluvial and acid saline soils. Its relationship with organic carbon was negative and significant in acid saline and acid sulphate soils.

The pH of the soils showed no significant effect on available nitrogen of the four soil types. Similar was the case with available phosphorus also except in acid sulphate soils, where the effect was positive and significant. Among the exchangeable cations, potassium recorded a significant positive correlation with pH at different periods of submergence in acid sulphate soils while in all other soil types the exchangeable cations were least influenced by pH throughout the period of submergence.

EC showed positive and significant correlation with organic carbon during initial and later periods of incubation in acid saline soils, while in acid sulphate soils the relationship of EC with all available nutrients and organic carbon was significant throughout the period of submergence.

The correlation between lime requirement and organic matter was positive and significant in all the soil types. Lime requirement and available P showed a negative and significant relation during the initial periods in acid saline soils and throughout the period of submergence in acid sulphate and saline soils.

The available nitrogen presented a significant and positive correlation with total nitrogen and organic carbon and a significant negative correlation with exchangeable potassium throughout the 12 week period of flooding in acid sulphate soils. In saline soils, the relationship of available nitrogen was negative and significant with organic carbon.

The available phosphorus showed a significant positive correlation with total phosphorus throughout the period of submergence in all the soil types, except in acid sulphate soils, where it showed a significant negative correlation with total phosphorus, organic carbon, lime requirement and clay content.

The relationship of exchangeable potassium with CEC and clay was positive and significant during the first few weeks of flooding in alluvial and acid saline soils, while it was significantly negative in acid sulphate soils.

The exchangeable calcium and magnesium were correlated to each other positively and significantly in alluvial and acid sulphate soils. A similar relationship was observed between CEC and exchangeable calcium and magnesium in acid sulphate soils.

DISCUSSION

DISCUSSION

Soil test values for rice soils based on the air dried samples do not very often reflect actual field conditions prevailing under submerged conditions. Flooding of a soil instantly sets in motion a series of physical, chemical and biological changes which affect the status of nutrients coming into available form. This altered condition is known to create a more congenial soil environment favourable for the growth of paddy. Therefore, it is important to monitor the changes in soil properties, especially the dynamics of nutrient availability of flooded rice soils in order to manage soil, fertilizer and moisture regimes and to maximise production in a given environment.

The salient results obtained on the pattern of changes in soil reaction, lime requirement and nutrient availability of four important types of paddy soils in Kerala due to flooding for a continuous period of 12 weeks are discussed here.

In general, the soil reaction as indicated by pH, of all the soil types tended to change towards neutrality after being submerged for a period of 12 weeks. The lime requirement also showed a decreasing trend throughout the period of submergence for all the soil types. The specific conductance increased due to flooding, attained a maximum within four to six weeks period and then declined. The available nitrogen and phosphorus increased appreciably in all the soil types, while the estimated values of exchangeable cations like potassium, calcium and magnesium widely varied showing a pattern of random increase and decrease.

Soil reaction and lime requirement

The pH values of the alluvial, acid saline and saline soils increased and reached near neutral values (6.4, 7.2 and 7.3) whereas the acid sulphate soils recorded maximum value of 4.9 only during the 12 weeks of submergence. Such an increase in pH values on flooding of soils has been amply reported in literature. This phenomenon has been explained as a consequence of the reduction of oxides of iron, sulphates, manganic salts etc. and to an accumulation of ammonia due to the stoppage of biological nitrification under the anaerobic conditions that prevail in a flooded soil.

Bostrom (1967) found that the increase in pH of acid soils after submergence depends not only on the release of OH^- ions and consumption of H^+ ions but also on the ratio of H^+ ions consumed to electrons consumed. Since this ratio is maximum for the reduction of iron, it follows that higher pH values on flooding can be obtained for soils rich in iron. Gotoh et al. (1974) have attributed the rise in pH to the reduction of ferric oxides to ferrous iron, a process that consumes acidity.

One of the most important factors responsible for the rise in pH of the soils used in the present study may be attributed to a reduction of large amounts of ferric oxides present in them. Kabeerathumma (1975) and Alice Abraham (1984) have reported very high concentrations of ferrous iron coming into solution due to flooding of these soils for a period of two to three months. Since most of the paddy soils of Kerala contain appreciable amounts of manganese salts (Rajendran, 1981) their reduction may also bring about a rise in pH as proposed by Dev and Sharma (1971).

The existence of sulphide toxicity in the acid soils of Kerala (Subramoney and Kurup, 1961) is an indication of large quantities of sulphates getting reduced to soluble sulphides under the reduced soil conditions of flooded soils. The accumulated ammonia released by anaerobic mineralisation of soil organic matter and smaller amounts of ammonium resulting from the release of entrapped ammonium ions from the clay minerals (Broadbent 1978) may also help to maintain a higher pH level throughout the period of submergence.

The resistance of acid sulphate soils to rise beyond a pH value of 5.0 as observed in the present study has been previously reported by IRRI (1964), Kabeerathumma (1975) and Alice Abraham (1984). This may be attributed to the greater buffering capacity of the acid sulphate soils owing to the presence of a rather high content of organic matter and/or to the buffering action of iron and manganese redox systems (Ponnamperuma et al. 1966, 1967, 1969).

The slight decline in the pH of alluvial soils during the 1st week of submergence (from 5.3 to 5.0) may be due to an accumulation of CO_2 produced by the aerobic soil microflora as pointed out by Patrick and Reddy (1978).

Eventhough, the pH values of the soils registered a gradual rise, the lime requirement values have not come down to an appreciably low level. This finding may not have much practical relevance, since the farmers are not advised to resort to liming practices based on LR values which are very high and hence uneconomic for practical purposes. Only 600 kg lime/ha is normally recommended for neutralising the acidity generated from applied fertilizers.

The raising of pH and neutralization of soil acidity can however, have some stimulatory effects on the anaerobic heterotrophic community of the soil which are engaged in the mineralisation of soil organic matter. Under the improved conditions of soil reaction, their activities may result in a greater release of available nutrients into the environment.

Electrical conductivity:-

With the onset of reducing conditions consequent to flooding, the specific conductance in all the soils showed an appreciable increase during the first few weeks and then diminished to values which were only slightly higher than the initial values.

The maximum increase in electrical conductivity was observed in the saline soils (6 units) followed by acid saline (3.7 units), acid sulphate (3.1 units) and alluvial (0.38 units) soils over the dry soil values at the end of four, six, five and four weeks of submergence after which it decreased significantly.

The high increase in specific conductance especially of the saline soils might be due to the effect of reduction of iron and manganese as well as to a part of the soluble ions already present in the soil solution exchanging with ions of higher conductance present in the exchange complex. The increase in specific conductance of the other soils may be attributed mostly to the reduction of ferric and manganic compounds which result in more of ferrous ions coming into soluble form (Ponnamperuma, 1965).

The specific conductance of most soils after submergence was found to be highly correlated to the original organic matter content of the soil. A high organic matter content of the soil is known to speed up the reduction processes which inturn have enhanced the successive reduction process of various elements (Ponnamperuma, 1972 and Yoshida, 1975).

Nitrate, manganic oxides and ferric oxides which are reduced by facultative anaerobes in the process of anaerobic respiration contribute to soluble ionic forms (Redman and Patrick, 1965). Such an increase in the concentration of soluble ions in the soil solution due to flooding has been identified as the main reason for the rise in conductance of soils due to flooding (Ponnamperuma, 1955, 1965).

The ionic species of calcium, magnesium, potassium, ammonium, ferrous iron and manganous as well as bicarbonate anions are highly mobilised in waterlogged soils, which have contributed largely to the observed increase in specific conductance.

The decline in specific conductance after a steep increase noted for all the soil types might be due to the reprecipitation of water soluble iron and manganese compounds due to surface oxidation (Ponnamperuma, 1973). Lack of appreciable rise in EC in the alluvial soils might be due to a lower rate of release of soluble ions, as these soils have inherently low conductivity values. Similar rise and fall of the EC values for the important soil types of Kerala have been reported by Kabeerathumma (1974) and Alice Abraham (1984).

Based on the values of air dried samples for electrical conductivity, the alluvial soils are grouped under class 'zero', acid sulphate soils under class 'one', acid saline soils under class 'three' and saline soils under class 'five' as per the classification of soil test values and guidelines for recommendations by Kerala Agricultural University. The class zero is rated as normal for all varieties and class 'one' as normal for semitolerant varieties, while class three and five are rated as high for all varieties of rice.

Values of electrical conductivity exceeding 4 mmhos/cm which normally come under class 'four' and 'nine' for clayey, loamy and sandy soils is deemed harmful for rice (Ponnamperuma, 1978). The results obtained from the present study reveal that the effect of submergence on electrical conductivity is not significant in the case of alluvial soils as the specific conductance did not exceed even the lower limit fixed for rice. The specific conductance of the saline soils (5.5 mmhos/cm) which was very high even in the air dried state itself reached the peak value of 12 mmhos/cm after a period of four weeks of submergence. This enhanced salinity level may definitely create a very unfavourable condition for rice growth in them.

Apart from the direct effect of high salt content on the rice plant which may result in reverse osmosis, the accumulation of ions increases the ionic strength and alters the ionic composition of the soil solution. This inturn may affect the ionic equilibria and upset the uptake of plant nutrients by the rice roots and magnify or modify ionic antagonisms. The weaker tolerance of rice plant for high levels of ion concentration at the early growth stages than at later growth stages (Ponnamperuma, 1978) indicates the significance of the altered specific conductance during submergence. Of the various parameters that are affected by flooding, the rise in conductance of soils which already possess a high degree of conductance seems to assume more practical implication in badly affecting the establishment of rice plants.

Available nitrogen

Flooding of the soils for varying periods of time has resulted in a rapid increase in the status of available nitrogen in all the soil types. The increase was highest (327%) in the case of saline soils followed by acid saline soils (250%), acid sulphate soils (203%) and alluvial soils (110%). Significant increase in available nitrogen was obtained after five weeks in the case of alluvial soils and one, two and three weeks in the case of the acid sulphate, saline and acid saline soils respectively.

This rapid increase in the content of available nitrogen in all the soils might have resulted from the mineralisation of soil organic matter or through biological nitrogen fixation taking place more efficiently under the anaerobic conditions existing in flooded soil systems. The activity of nitrogen fixing blue green algae encountered in the rice fields of Kerala is studied and reported by Aiyer (1965).

Nitrogenous compounds present in the soil organic fraction alone account for nearly 95% of the total supply of soil nitrogen (Brady, 1984). Addition of organic matter in the form of crop residues, organic manures, green manures etc. helps to maintain a sufficiently large organic pool in the soils. Isotope studies have suggested that even crops receiving a regular supply of nitrogenous fertilizers may derive more than 60% of their nitrogen requirement from mineralisation of organic nitrogen (Koyama et al. 1973). It follows that the organic nitrogen pool in the soil can be managed to satisfy both long term and short term goals of crop production.

It is quite possible that the major factor contributing to the increased status of available nitrogen in all these soils might be due to the mineralisation of organic materials present in them (Kai et al. 1984, Sahrawat, 1983). It may be noted that all the soil types except the alluvial soils possessed a very high content of organic matter in them which qualify them to be classified under the highest class "9" for available nitrogen based on soil organic matter level as per the guidelines for fertilizer recommendations based on soil tests evolved during the workshop on package of practices held in 1975 by Kerala Agricultural University. This state denotes the capacity of the soil to provide a very high status of available nitrogen for an ensuing rice crop. The alluvial soils recorded comparatively lesser amounts of organic matter and could be classified under the class "7" which also is considered to be capable of supplying a fairly high amount of available nitrogen.

It is interesting to find that in all the soils except the saline soils, there existed a positive correlation between available nitrogen and organic matter content. The process of mineralisation of soil organic matter to release fixed or immobilised nitrogen is largely controlled by the availability of oxygen and other environmental conditions. However, under the anaerobic conditions of a flooded soil where the availability of oxygen can be critical and influenced by other prevailing conditions, nitrogen mineralisation can only proceed at a slower rate than in the aerobic soil (Alexander, 1975). Anaerobes in the submerged soils, eventhough are less efficient and derive only much less energy for growth and activities from a given amount of organic matter mineralised, release more nitrogen into the available pool since the rate of immobilization of nitrogen under such conditions is comparatively very low (Abichandani and Patnaik, 1958, Broadbent and Nakashima, 1970).

The four soil types studied here, eventhough are in the moderately acidic range which can limit heterotrophic mineralisation processes, are better conditioned due to flooding, as their acidity is brought down to a near neutral level. This is a condition most congenial for microbial activities. In the absence of the rice plant to utilize the released nitrogen, it is being accumulated to give a cumulative value with progressive periods of submergence.

The available nitrogen recorded for the acid sulphate soils however, showed a decreasing tendency during the third and fourth weeks and for alluvial soils after 10 weeks of submergence. This might be explained as due to some of the mineralised nitrogen being immobilised or getting denitrified due to the presence of oxidised and reduced interfaces (Mitsui, 1955, Patrick and Reddy, 1976). It may also be due to fixation of ammonium ions in the exchange sites on the exchange complex (Pasricha and Ponnamperuma, 1976).

In addition to the nitrogen becoming available from the organic pool through mineralisation, the possibility of biological nitrogen fixation contributing to the available nitrogen pool cannot be precluded. A wide range of anaerobic and microaerophilic organisms are known to fix nitrogen in flooded soils (Chang and Knowles, 1965).

Rewetting of air dried soils are also known to release more available nitrogen (Shiga and Ventura, 1976) which may also contribute appreciably to the total level of available nitrogen when an air dried soil is flooded.

The results of the study have revealed a rapid and significant increase in the status of available nitrogen in all the soil types at the end of six weeks which continued till the end of 10 weeks, after which it either slightly decreased or remained more or less static.

Based on soil test values for available nitrogen in the air dry state, the alluvial (230 kg/ha) and acid saline soils (200 kg/ha) could be classified as low ($<$ 250 kg/ha) and the acid sulphate (384 kg/ha) and saline

(318 kg/ha) soils as medium (250 to 500 kg/ha) in their ability to supply nitrogen as per the ratings for classification of soils as established by Subbiah and Asija (1956).

The levels of available nitrogen obtained during submergence for the acid sulphate, saline and acid saline soils were much higher than the limit fixed (> 500 kg/ha) by Subbiah and Asija (1956) for classifying soils as having a very high capacity to supply available nitrogen for crop. The alluvial soils were raised to a medium level (250 to 500 kg/ha) only due to submergence.

In view of more nitrogen becoming available due to flooding, it appears that application of nitrogenous fertilizers at the usual recommended levels to flooded soils cultivated to paddy in the soil types studied here can in effect provide much more nitrogen to the crop than what is anticipated from usual soil test data. It is possible that under such conditions, a judicious application of nitrogenous fertilizers may be resorted to prevent luxury consumption of nitrogen which may lead to more succulent vegetative growth making the rice plant more prone to pest infestation as well as to lodging.

Phosphorus:

The phosphorus supplying capacity of a flooded soil is reported to be much higher than that of aerobic upland soils (Aoki, 1941 and Mitsui, 1960). Phosphorus is not directly involved in oxidation reduction reactions in the redox potential range encountered in submerged soils. However, because of its reactivity with a number of redox elements like iron, manganese etc., its behaviour is also significantly affected by flooding.

The results obtained from the present study reveal a significant increase in the status of available phosphorus even after a very short period of submergence for 12 hours in the acid sulphate and saline soils and after one week in the case of acid saline soils. Though not significant, the alluvial soils also showed an increase in the phosphorus availability immediately after submergence followed by a periodical decrease and increase till the end of 12 weeks. The highest increase in phosphorus availability was obtained in the acid saline soils (606%) at the end of four weeks followed by saline (431%), acid sulphate (174%) and alluvial (54%) soils at the end of twelve, four and six weeks of submergence respectively.

Soil phosphorus is constituted by organic fractions like phospholipids nucleic acids, phytin etc. and inorganic phosphates such as those of iron, aluminium and calcium. The available phosphorus status of a soil is to a great extent determined by the mineralisation of organic phosphorus and solubilisation of inorganic phosphates.

Mineralisation of organic phosphorus and solubilisation of inorganic phosphates is largely brought about by biological and chemical processes regulated by soil physical and chemical conditions.

Both these processes play an important role when an air dry soil is submerged for paddy cultivation. Mineralisation of organic phosphorus is related to the analogous reactions of nitrogen and phosphate release is found to be more rapid under conditions favouring nitrogen mineralisation (Alexander, 1975). It follows from the results of the present study (tables 6(e) and 7(e) that the rate of which the available phosphorus is getting mobilised from the organic pool roughly parallels the nitrogen mineralisation rates in the acid sulphate, saline and acid saline soils. The alluvial soils which showed only lesser increase in available nitrogen also showed the least increase in available phosphorus status.

The increase in water soluble and available phosphorus on flooding of soils is attributed to the release of phosphorus from organic matter particularly iron phytates (Mahapatra and Patrick, 1971). Ponnamperuma (1972) has proposed that upto 60% of the water soluble phosphorus can originate from organic forms. It may be noted that available phosphorus showed a strong positive correlation with total phosphorus which inturn was positively correlated to organic matter in all the four soil types. This observation highlights the significance of mineralisation processes in maintaining a high levels of available phosphorus.

Phosphate chemistry in flooded soils is linked to iron chemistry and conditions that increase solubility of iron in the soil is known to increase the phosphorus solubility also. The lowering of oxidation - reduction potential due to flooding is associated with more solubilization of iron phosphates in the form of ferrous phosphate. Under favourable reduced conditions, organic acids released from the decomposition of organic matter may stabilize ferrous ions by complex formation (Savant and Ellis 1964 and Purnachandra Rao, 1966) and maintain phosphorus in an available form. The higher the organic matter content, the greater will be the intensity of soil reduction under submerged conditions, as a consequence of which release of available phosphorus due to submergence will be highest (Mandal and Nandi, 1971).

When an acid soil is submerged, there is a striking increase in the content of soluble phosphorus compared to soils which are not so acidic. This increase in concentration of soluble phosphorus can result from the hydrolysis of ferric and aluminum phosphates and through the reduction of ferric to ferrous form with liberation of chemically bound phosphorus into soluble products (Ponnamperuma, 1972).

Submerging of the acid soils of Kerala is reported to release appreciable amounts of iron (Kabeerathumma, 1975 and Alice Abraham, 1984) which may be regarded as an indication of the magnitude of phosphate coming into soluble form (Chang 1976, Shinde et al. 1978).

Thus, the increase in availability of phosphorus observed in the various soil types can be the result of a cumulative effect of both mineralisation and solubilisation processes. Increase in available phosphorus due to submergence of soils has been reported by Ponnamperuma, 1972 and Goswani, 1978.

The positive correlation of available phosphorus to pH observed in these soils suggests that the phosphorus increase can also be due to pH effect (Lindsay and Moreno, 1960, Tanaka et el. 1969 and Verma and Tripathi, 1982). The increase in pH favours the solubility of aluminum and iron phosphates and desorption of phosphorus from surfaces of clay and oxides of aluminum and iron (Stumm and Morgan, 1970).

Hayman (1975) reported that CO_2 produced abundantly in the soil enhances solubility of phosphates in soil. He also concluded that with the anaerobic conditions of flooded soils, many bacteria produce H_2S, which may increase the availability of iron phosphates by converting them to ferrous sulphide and liberating phosphoric acid. Reports on the existence of hydrogen sulphide toxicity (Subramoney and Kurup, 1961) in the acid soils of Kerala lend support to this view.

The lack of appreciable rise in the available phosphorus status of the alluvial soils and the observed decrease in available phosphorus after eight weeks of submergence may be attributed to their high phosphorus fixing capacity (Panda et al. 1981). The significant negative correlation obtained for available phosphorus with exchangeable calcium in alluvial soils suggests that the decline in the available phosphorus content after eight weeks may be due to reformation of insoluble calcium phosphates as these soils possessed a high content of exchangeable calcium (336 ppm). Corresponding decrease in the level of available phosphorus of the other soil types may be due to its reprecipitation as iron phosphates on account of the high content of iron becoming soluble due to flooding (Singh and Ram, 1977).

The levels of available phosphorus recorded for the four soil types in the air dry state itself were much higher than the values fixed (34.5 kg/ha) for classifying them as "highest" in the status of P. They come in the highest class "9" as per the guidelines for fertilizer recommendation based on soil tests. Submerging of these soils result in further increase in the levels of available phosphorus which are very much higher than the estimated requirements of the rice crop.

Application of phosphatic fertilizers as basal dressing even at 25% of the generalised recommendation for medium class soils appears unnecessary and wasteful under such conditions. The lack of response to applied phosphorus reported from the various Rice Research Stations of the State (Anon 1984) may be explained in the light of this observation. When very high phosphorus levels of the order of 328 to 1088 kg/ha are being maintained by the soils under flooded conditions, further addition of phosphorus contributed from 1/3rd of the recommended levels of phosphatic fertilizers (35 to 45 kg/ha) for paddy may not produce any remarkable effect on the rice crop.

The results from the present study thus point to the need for a reevaluation of the phosphorus requirements of rice crop and management of phosphorus under flooded conditions. Skipping of phosphatic fertilizers may be thought of for specific areas on a scientific basis taking into account the total phosphorus status and organic matter content of the soil and the probable amount of phosphorus coming to the available pool during a cropping period.

Exchangeable potassium, calcium and magnesium

The transformations and availability of potassium, calcium and magnesium in soils have not been studied extensively, possibly because these nutrients have not so far been known as limiting factors for optimum rice production, although at times, their application is found to improve yields. The transformation and availability of potassium, calcium and magnesium are primarily governed by the silt and clay content of the soil and this inturn is determined by the total amounts of these elements present in a soil (Mohanty and Patnaik, 1977).

The availability of these cations showed periodical increase and decrease on flooding in all the four soil types.

The exchangeable potassium in the alluvial soils showed a 31% decrease from the dry soil value immediately after submergence, followed by an increase (376 kg/ha) at the end of 2 weeks of submergence after which it decreased. In acid saline soils, the exchangeable potassium levels recorded little variation till the end of one week and it began to show an increase upto four weeks followed by a decrease (36% of the value on dry basis) in the fifth week. The maximum increase (84% over dry soil value) was observed at the end of six weeks of submergence after which a decreasing tendency was noted for the remaining period. The acid sulphate and saline soils recorded a gradual increase in the status of exchangeable potassium with its peak (462 and 582 kg/ha) at the end of five and six weeks of submergence after which they showed a significant decrease.

The significant and positive correlations obtained for exchangeable potassium with clay content and CEC in the alluvial and acid saline soils suggest that the increased K^+ concentration upon flooding might be the result of an exchange reaction due to increase in Fe^{2+} and Mn^{2+} (Ponnamperuma, 1965). This may also be due to their displacement by the action of water through hydration and hydrolysis of clay (Mohanty and Patnaik, 1977).

The increased concentration of exchangeable potassium in acid sulphate and saline soils upon submergence can result from the release of potassium from weathered primary minerals (Bunoan et al. 1970). The release of K^+ from the non exchangeable forms (Ramanathan and Krishnamoorthy, 1973) may also contribute to an increase during submergence. The significant negative correlation obtained between available nitrogen and exchangeable potassium in acid sulphate and saline soils suggests that the decrease in exchangeable potassium and an increase in available nitrogen towards the later stages of incubation might be partly due to isomorphus replacement of ammonium ions by potassium ions because of their similarity in ionic radii

(Bear, 1964).

Since the potassium fixing capacity of soils is known to increase with rise in soil pH, the soils which showed a rise in pH due to submergence may promote potassium fixation and show a low level of exchangeable potassium (Singh and Ram, 1975). The high clay content of alluvial, saline and acid sulphate soils may be considered as a factor in bringing about potassium fixation as proposed by Singh and Ram (1975). Fixation of K may result in a decrease in exchangeable potassium as observed in the alluvial, saline and acid sulphate soils which possess a high clay content.

Based on the exchangeable potassium values obtained for dry soil, the acid sulphate and saline soils can be grouped under as low, alluvial soils and acid saline soils as medium as per the guidelines for fertilizer recommendations based on soil tests. Submergence has helped to raise the levels of exchangeable K in all these soils to values coming in the very high or moderately high categories.

In alluvial soils both the exchangeable calcium and magnesium reached peak values (463 and 467 ppm) after three weeks of submergence, after which they tended to decrease. The exchangeable calcium increased gradually and reached its peak (481 and 610 ppm) at the end of two and four weeks of submergence in the case of acid saline and acid sulphate soils, after which a decreasing tendency was noted. The saline soils on the other hand recorded a significant increase in exchangeable calcium immediately after submergence at the end of 12 hours and then showed a drastic decrease until the end of 12 weeks.

The pattern of changes in exchangeable magnesium throughout the period of submergence followed the same trend in acid saline and saline soils. A highly significant decrease in exchangeable magnesium was observed till the end of four weeks and then increased gradually and the maximum values (477 and 1254 ppm) were attained at the end of six weeks of submergence in acid saline and saline soils which then tended to decrease gradually. The highest increase (58% over dry soil value) in exchangeable magnesium was at the end of one week period in acid sulphate soils after which it showed a decreasing trend till the end of 12 weeks period of submergence.

The peak values of exchangeable calcium availability may be attributed to increase solubility of calcium compounds in the soil due to combined effect of CO_2 plus increased pH (Kabeerathumma and Patnaik, 1978).

The increased calcium eluviation in flooded soils of reduced condition due to exchange of calcium ions by ferrous iron as proposed by Kawaguchi and Kawachi (1969) might be the reason for the decrease in exchangeable bases.

Fixation by clay minerals from soil solution might be a reason for decreased magnesium availability during submergence. Mg^{2+} replaces Al^{3+} in 2:1 clay minerals through isomorphus replacement (Bear, 1964).

The Chlorite and vermiculite minerals have a greater amount of magnesium in the lattice. Therefore, these minerals may fix magnesium and micaceous minerals may fix potassium. The shifting of mont morillonite to vermiculite or chlorite type minerals in sea water seems to confirm the view that the high content of magnesium in sea water is responsible for bringing about this alteration of mineral type (Kanwar, 1976). Similar type of chlorotisation like reactions can happen in soils when excess of magnesium is available. Gopalaswami (1969) has pointed out the presence of chlorite like minerals in some of the acid soils of Kerala.

The differential pattern of shift in the content of exchangeable potassium, calcium and magnesium may be thus due to the difference in the total content of these elements in inorganic soil components in various soils as well as to the rise in pH and specific conductance which can alter the ionic strength and induce ionic displacement.

SUMMARY

SUMMARY AND CONCLUSIONS

An investigation was carried out to quantify the changes due to submergence in the status of available, N, P, K, Ca and Mg, EC, pH and lime requirement in four important types of paddy growing soils of the state. The study consisted of the following two parts:

1. Studies on the basic physico chemical properties of the soils.
2. Incubation experiment to monitor the changes in nutrient availability under flooded condition with 5 cm of standing water.

The first part of the investigation was carried out by analysing 12 samples each of typical alluvial, acid saline, acid sulphate and saline soil samples collected from different parts of the state. The various physico chemical properties of these soils in the dry state were determined and their inter relationships studied.

The incubation experiment was conducted by keeping the rice soils under flooded conditions with 5 cm of standing water for a period of three months. The periodical changes in soil reaction, lime requirement, specific conductance and available status of N, P, K, Ca and Mg were estimated by analysing the wet soil samples withdrawn at weekly intervals. The data obtained were subjected to statistical analysis to bring out the significance of the important changes observed in the various parameters in the different soil types.

The important findings from these studies are summarised below:

(1) The alluvial soils were only slightly acidic in reaction and clayey in texture. The electrical conductivity was very low and suited for even the most sensitive crops.

(2) The acid saline soils were sandy loam in texture. These soils were moderately acidic in reaction and the electrical conductivity was slightly above the critical limit fixed for all crops (1.9 mmhos/cm).

(3) The acid sulphate and saline soils were extremely acidic. The CEC of these soils was found to be very high (20-24 me/100 g). The electrical conductivity of acid sulphate soils was normal for semi tolerant crops, while it was very high and maximum in saline soils (5.5 mmhos/cm) and exceeded the maximum tolerance limit fixed for rice.

(4) The organic matter content was high in all the four soil types. It was lowest in alluvial soils (1.8%) and highest in acid saline and acid sulphate soils (6.4 and 6.3%).

The saline soils recorded a value of 5.2%.

(5) Based on the soil test values in the air dry state, the alluvial and acid saline soils were classified as low and acid sulphate and saline soils as medium in the status of available nitrogen. The values of available nitrogen were 115, 100, 193 and 160 ppm in alluvial, acid saline, acid sulphate and saline soils respectively.

(6) The available phosphorus content was in the high range for all soil types. The highest value of available phosphorus (107 ppm) was observed in alluvial soils.

(7) The exchangeable potassium status was high for alluvial and acid saline soils (131 and 149 ppm) and medium for acid sulphate and saline soils (82 and 80 ppm).

(8) Of the exchangeable cations, calcium and magnesium contents were minimum for alluvial soils and maximum for saline soils. The values of these exchangeable cations were in between those for saline and alluvial soils in acid saline and acid sulphate soils.

(9) Lime requirement was least for alluvial soils (9.7 t/ha) and maximum for saline and acid sulphate soils (16.4 t/ha) and intermediate for acid saline soils (15.2 t/ha).

(10) A significant negative correlation was observed between

pH and lime requirement in all the soil types.

(11) The relationship of CEC with clay was significant and positive in all the soil types except in saline soils. CEC and organic matter showed a negative relationship in the alluvial and acid saline soils indicating that the exchange properties of these soils were mainly due to the inorganic fractions. The CEC of acid sulphate soils was dependent on both organic and inorganic fractions since the relationship of CEC with organic carbon and clay was significant and positive. The positive correlation of CEC with organic carbon alone in the saline soils attribute their exchange property mostly due to organic fraction.

(12) The exchangeable potassium, calcium and magnesium showed significant positive correlation either to clay or to CEC in most of the soils.

(13) The available nitrogen and phosphorus had a positive correlation either to their total contents or to organic carbon in all the four soil types.

(14) Considerable difference was noticed between the values obtained for available nutrients by routine methods of soil testing of dry soils and their actual availability

under submerged condition in all the soil types. Similar was the case with pH, lime requirement and electrical conductivity also.

(15) Flooding for a period of three months resulted in a rise in pH of all the soil types. The saline and acid saline soils recorded the maximum shift in pH values. pH remained more or less steady after reaching the peak values in a period of one week in acid sulphate soils and in all other soil types stability was attained after four to eight weeks. Consequent to the increase in pH, a corresponding decrease in lime requirement was observed in all the soils.

(16) A rise in EC was observed in all the soil types due to submergence. The highest value of 12 mmhos/cm was obtained after four weeks of submergence in saline soils. The rise in conductance of soils which already possess a high degree of conductance assumes more practical importance in affecting the rice plant unfavourably. EC showed a decreasing tendency with time after four to six weeks, owing to the reprecipitation of some of the dissolved ions.

(17) All the soils showed a progressive increase in available

nitrogen content with increase in the period of flooding. The alluvial soils were raised from low to a medium level after the first week of submergence and remained more or less steady till the end of the 12th week. In the other soil types, the levels of available nitrogen attained values which were much higher than that fixed for classifying a soil as high in available nitrogen. Significant increase in available nitrogen content was observed after one, two and five weeks of submergence in acid sulphate, saline and acid saline soils respectively and it was maintained till the end of 12 weeks.

(18) A significant rise in the content of available phosphorus was observed in all the soils. The acid saline soils recorded the maximum increase in available phosphorus at the end of four weeks of submergence, after which it gradually decreased. The peak values for available phosphorus were recorded at the end of four and six weeks in acid sulphate and alluvial soils, after which it decreased. The saline soils showed a progressive increase throughout the period of flooding. The levels of available phosphorus recorded for the four soil types in the air dried state itself were much

higher than the value fixed for placing them in the highest class for available P as per the guidelines for fertilizer recommendations. Submerging of these soils has resulted in a further manifold increase in the content of available P. In the light of these observations, it may be concluded that in these soil types further addition of phosphatic fertilizers is not likely to produce any remarkable response on the paddy crop which can meet its complete P requirement from the native soil P itself.

(19) The availability of exchangeable cations like potassium, calcium and magnesium, however, showed a periodical increase and decrease on flooding in all the four soil types. This differential pattern of shift in the content of exchangeable cations may be due to the differences in the total content of these elements in various soils as well as to the changes in soil reaction, ionic displacement and other related properties that arise consequent to flooding.

From the investigation carried out, it has been possible to obtain a systematic account of the extent and nature of the changes in soil reaction and nutrient availability that result from flooding in water in some of the typical rice soils of Kerala.

The results of the study have clearly brought out the magnitude of the changes that result in the status of each nutrient upon flooding of soils for wetland paddy cultivation. There has been more than three fold increase in the content of available N and P in all the soils after two to four weeks of submergence. It clearly implies that addition of fertilizer N and P under such conditions is not likely to produce any significant effect on rice unless the varieties are highly responsive to these two nutrients. Obviously, the lack of response to phosphorus in paddy reported on several occasions may be fully explained in the light of these results. The feasibility of reducing the quantity of fertilizers to be applied or even skipping of fertilizers for one or two seasons may be considered taking into account the responsiveness of the rice variety as well as other economic factors. These may be verified and ascertained by careful and planned location specific experimentation and if the results are found encouraging, a substantial reduction in the quantity of fertilizers and other related inputs can be made without affecting the net returns from a given area.

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*Originals not seen.

APPENDIX

APPENDIX-I.

Physico chemical properties of soils on submergence in water - Abstract of ANOVA.

Source	df	pH	EC	LR	Available N	Available P	Exchangeable K	Exchangeable Ca	Exchangeable Mg
Period (p)	10	13.6[x]	5.7[x]	11.5[x]	9.7[x]	2.4[xx]	1.6	1.4	1.2
Soil (s)	3	29.0[x]	143.5[x]	9.2[x]	30.0[x]	21.4[x]	1.8	2.1	2.6
P x s (error)	30	11.2	16.9	9.3	4.0	11.6	14.8	5.7	8.4

x significant at 1% and 5% level

xx significant at 5% level

EFFECT OF SUBMERGENCE ON THE SOIL TESTING PARAMETERS OF PADDY SOILS

BY

USHA MATHEW

ABSTRACT OF THE
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ABSTRACT

Laboratory incubation studies were conducted to quantify the changes in pH, EC, lime requirement and availability of important nutrients such as N, P, K, Ca & Mg due to submergence of alluvial, acid saline acid sulphate and saline rice soils of Kerala.

The study has revealed that pH of all the soil types increased immediately after flooding of the air dried soils, reached a maximum and remained more or less steady throughout the period of three months submergence. Consequent to the increase in pH, a corresponding decrease in lime requirement was observed in all the soils. Maximum reduction in lime requirement was noticed for the saline and acid saline soils.

A rise in EC was observed in all the soil types due to submergence during the first four to six weeks. It showed a decreasing tendency afterwards.

All the soils showed a progressive increase in available nitrogen content with increase in the period of flooding. The increase was in the range of 75 - 395% for the various soil types. Maximum increase was recorded by saline soils (395%) and minimum by alluvial soils (75%).

The levels of available phosphorus recorded for the four soil types in the air dried state were in the low to medium range for rice. Submerging of these soils has resulted in a manifold increase in the content of available phosphorus. The increase was maximum for acid saline soils (700%) and minimum (55%) for alluvial soils.

The availability of exchangeable cations like potassium calcium and magnesium, however, showed a periodical increase and decrease on flooding in all the four soil types.

The results of the study have clearly brought out the magnitude of the changes that result in the status of each nutrient upon flooding of soils for wetland paddy cultivation.

The manifold increase in the status of major nutrients like N and P upon flooding of soils indicates that addition of fertilizer N and P under such conditions is not likely to produce any significant effect on rice unless the rice varieties are highly responsive to these nutrients. The feasibility of reducing the quantity of fertilizers to be applied or even skipping of fertilizers for one or two seasons may be considered taking into account the responsiveness of the rice variety as well as other economic factors.