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EFFECT OF SUBMERGENCE ON THE AVAILABILITY OF TOXIC AND DEFICIENT NUTRIENTS IN ACID SULPHATE SOILS OF KERALA.

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Continuous flooding of soil, as obtained under rice growing conditions, sets in motion a series of physical, physicochemical, chemical and microbiological changes which are quite different from that of uplands. Flooding results in the depletion of O_2 jn the soil profile partially due to mechanical displacement and partially due to consumption of oxygen through root respiration and microbial decomposition of organic matter. Though several reports are available on the dynamics of water logging in paddy soils little work has been reported on the dynamics of flooding of the acid sulphate soils of Kerala. Hence such a study is undertaken with a view to study the possible problems arising on flooding of the above soils. Since high acidity coupled with Fe and Al toxicity is one of the baffling problems that the Kuttanad cultivators face, major importance has been given to these factors in this study.

Materials and Methods

Surface (0 - 15 cm) samples of acid sulphate soils were collected from the districts of Alleppey, Kottayam, Ernakulam and Cannanore. These soils have been termed according to the local nomenclature such as *Kan, Kayal Karapadam, Kole, Pokkali* and *Swamp* soils. The pH (1 :2.5 water) varied from 3.2 to 5.0 except the kayal which had a pH of 6.5. These soils had a lime requirement (Woodruff, 1948) of 4000 to 20,000 kg/ha and were high in salt concentration 5.2 to 16 m. mhos/cm.

These soils had moderate to high content of total N (0.095 to 0.37%) (Micro Kjeldhal) and organic carbon (1.5 to 7.3%) (Walkley and Black) and were low in available P (1 to 10 ppm. Olsen P.).

The cation exchange capacity (Neutral normal Ammonium acetate method) of these soils ranged from 8 to 28 me/100 g of soil. Exchangeable calcium and K (Flame photometer) were between 0.9 to 11.5 and 0.14 to 0.3 me/100 g soil respectively. Exchangeable Fe (Thiocynate method) and Mn (Periodate method) were found to be between 8 to 32 and trace to 77 ppm respectively. These soils had very high exchangeable Aluminium (Aluminon method in INKCl extract) (20-580 ppm) and exchange acidity (Barium chloride TEA method) was between 8 and 30 me/100 g soil.

Table 1

Characteristics of acid sulphate soils

Soil type and location	District of Kerala State	Textural class	pH 1:2.5 water	Exchange acidity me/100 g.	ECe mmho/cm	C%	N%	Available P ppm Bray	Available P ppm Olsen	CEC me/100g	Exchangeable cations me/100g K	Exchangeable cations me/100g Ca	Exchangeable cations ppm Al	Exchangeable cations ppm Mn	Fe	Active Fe%
Kari Thottappally	A[redacted]oy	Clay loam	3.2	39.6	8.7	7.3	0.34	5[illegible]	[illegible]	24	0.14	3.8	510	43	[illegible]	0.75
Kari Kottayam	Kottayam	,,	3.4	30.[illegible]	5.5	8.4	0.37	63	[illegible]	28	0.20	2.6	580	51	19	3.28
Saline	E[redacted]alam	,,	3.[illegible]	[illegible]0.0	16.0	3.5	0.24	62	7	22	0.30	6.2	504	77	13	1.00
Pokkali I			3.8	25.0	15.5	3.6	0.26	55	10	25	0.45	6.3	200	42	10	1.02
Pokkali II																
Swamp Kattampally	Cannanore	,,	3.8	26.0	11.2	2.5	[illegible].18	72	10	20	0.25	[illegible].8	584	31	13	1.37
Karapad[redacted] A	Alleppey	Sandy	5.0	8.3	5.2	4.3	0.24	51	5	8	0.17	0.9	30	Tr	8	0.06
Karapadam B	Alleppey	Clay loam	[illegible].5	10.9	[illegible].4	1.5	0.11	45	9	[illegible]	0.30	1.5	130	26	13	0.78
Kayal	Alleppey	,,	6.5	8.[illegible]	9.8	1.5	0.[illegible]9	55	5	20	0.40	11.5	20	2[illegible]	22	2.76
Kole	Trichur	,,	5.[illegible]	14.6	5.2	1.4	0.15	54	9	20	0.22	2.8	102	66	8	3.28

Minerological analysis (Ghosh *et al.* 1973) of these soils indicated that kaolinite was the dominant mineral in the clay fraction, associated with fairly large amounts of smeclite and small amounts of halloysite. The fine silt and course silt fractions contained quartz, mica, feldspar, kaolinite and chlorite minerals as the dominant minerals.

With the above soils laboratory incubation experiments were conducted to study the effect of flooding on the changes in pH exchangeable Fe, Mn, Al, Ca and K. Ten gram lots of soil contained in 50 ml plastic centrifuge tubes were flooded with 10 ml distilled water and incubated in dark at 30 ± 2°C. Moisture loss due to evaporation was made up periodically.

Samples were drawn at the start of the experiment (0 days) and at 10 20, 30, 50, 70 days after flooding and analysed for exchangeable A1 in INKCI extract, for exchangeable Fe, Mn, Ca and K in neutral normal ammonium acetate extract. Duplicate samples were used for each of the extracts. Analysis was done as per the methods mentioned earlier.

The change in pH was studied separately in beakers containing 50 g soil flooded with 50 ml distilled water which were also incubated.

From the description of soils given in the table (1) it might be seen that, the presence of high amounts of soluble salts and high acidity coupled with high concentrations of toxic elements such as A1 and extremely low P content might pose problems in raising a rice crop in these soils.

Results and Discussion

Flooding resulted in a slight increase in soil pH during the 70 day period of incubation (Fig.1). The maxiimum pH attained for different soils was in the range of 4.7 to 5.7. Only Kayal soil which had an initial pH ti.5 attained a pH of 6.8 on submergence. The reason for this was (with the exception of Kayal soil) possibly because of low microbial activity due to very low initial soil pH and high concentration of exchangeable A1 (Brinkman and Pans 1973). Further, the presence of large amounts of undecomposed organic matter in Kari, Saline and Swamp soils might have resulted in the release of organic acids and phenols on decomposition which resulted in keeping the soil pH at a considerably low level. Similar observations on the exchange in pH of acid sulphate soils due to flooding have been reported from IRRI (1964) and Nhung and Ponnamperuma (1966).

Changes in exchangeable A1 : Flooding resulted in a general tendency of the exchangeable A1 in soils to decrease during the first 20-30 days. In two *Kari* soils, *Pokkali* *Swamp* and *Kari* soils submergence brought about a marked decrease in exchangeable A1 during the first 20 days to attain minimum value in the range of 88-310 ppm, after which there was a gradual increase during the next 50 days of flooding. In the *Karapadam* B and *Pokkali* II soils there was a decrease in exchangeable A1 during the first 20 days of flooding after which the value remained more or less unchanged. (Fig. 1). This decrease in A1 was due to increase in pH resulting in hydrolysis and polimerization. These polimerized forms were not replaced by N KCl (Jackson, 1963 and Mc Lean *et al.* 1964). Further, A1 was likely to get precipitated as A1 (OH), in the pH ranges occurring in the flooded soil system (Nhung and Ponnamperuma, 1966 and Kuruvila, 1974).

A coincidence of decrease in A1 with peak concentration of ferrous iron suggested the possibility of a neutralization reaction as suggested by Cate and Sukhai (1964).

$$2 \text{ A1 -clay} + \text{Fe}(OH)_2 — 3 \text{ Fe-clay} + 2 \text{ A1 (OH),}$$

The tendency of exchangeable A1 to increase in soils after the concentration of Fe started its decline suggested the possibility of reversal of the nutralization reaction, From the experimental data it could be inferred that these soils are likely to show A1 toxicity if proper ameliorative measures are not taken to raise the pH in order to decrease the exchangeable A1.

Changes in exchangeable Fe : From the results it is seen that in *Karapadam A, Kale. Karl, Pokkali* end *Swamp* soils exchangeable Fe (Fig. 2) increased during the first 20 to 30 days of flooding and then decreased rapidly during the remaining period of flooding. In Thottappally *Kari* soil, there was however no change in the exchangeable Fe after reaching the peak while in the Kayal soil, there was an increasing trend of exchangeable Fe **till** 50 days of submergence after which there was a decrease. In *Karapadam* B soil on the other hand there was a gradual increase in exchangeable Fe during the entire period of submergence. The peak values of Fe in *Karapadam Kole* and *Kayal* soils were in the range of 30-270 ppm while of those of *Kari, Pokkali* and *Swamp* soils were in the range of 1508 and 3411 ppm. This increase in available Fe might be atrributed to the reduction of higher oxides of iron. The reduction of hydrited oxides of Fe in flooded soils appeared more due to eletrochemical reaction rather than intrinsically biological (Ponnamperuma, 1965; IRRI 1964; and Ponnamperuma *et al.* 1967). Subramoney and Kurup (1967) however found that considerable amount of Fe was brought into solution by iron reducing bacteria and by soil acidity.

The decrease in Fe during the latter periods of submergence might be attributed to the precipitation of Fe as Fe, $(OH)_8$ or Fe_3O_4-n H_2O ith increase in pH of the system (Ponnamperuma, 1972). From the data it might re seen that the rice crop grown in these soils is likely to suffer from iorn toxicity if proper ameliorative measures are not adopted.

Changes in exchangeable **Mn**: The data on variations of exchangeable Mn under submergence are presented in Fig. 2, which showed that exchangeable Mn increased to attain peak value in about 30 to 40 days of submergence after which there was a rapid decrease. Among the acid sulphate soils studied, only *Kole* and *Kayal* soils showed a higher release of Mn to attain values of 224 and 403 ppm. Mn respectively at the peak period (30th day). On the other hand, *Kari, Pokkali Swamp* and *Karapadam* soils showed very little change. The magnitude of increase in exchangeable Mn in these soils was less than 10 20 ppm, and exchangeable Mn at 70th day was less than that present initially.

The increase in exchangeable Mn was due to reduction of the soil resulting in the formation of more soluble bivalent Mn compounds which readily entered the exchangeable complex (Mandal, 1961 ; IRRI, 1964). The decrease in exchangeable Mn beyond 30 days was possible due to precipitation of Mn as Mn carbonates (IRRI, 1664) and might also be due to removal of Mn by occlusion or sorption by hydrated Fe oxides which get precipitated at Eh-pH values than were necessary for precipitation of Mn (Collins and Boul, 1970 a).

Change in exchangeable **Ca** and K: Data is summarised in Fig. 3. In general, there was an increase In exchangeable Ca due to submergence. But the trend was different in different soils.

In *Karapadam* B, *Kole* and *Kari* soils increasing period of flooding resulted in a gradual increase in the exchangeable Ca content during the entire period of incubations; the *Kari* soil from Kottayam, however, showed a marked increase. In the *Kayal, Pokkali* and *Karapadam* soils there was an increase in the exchangeable Ca during the first 10-20 days, of flooding followed by a small decrease during next 10 days, after which the values remained more or less unchanged. The peak values of exchangeabie Ca availability may be attributed to increased solubility of Ca compounds in the soil due to the combined effects of Co_2+ increased pH.

In the case of K, there were variations in the pattern of K transformation. *Kari, Pokkali,* and *Karapadam* soils registered a marked increase in the first 10-20 days of submergence attaining values in the range of 140 to 920 ppm, after which there was sharp decrease during the next 10-40 days. In *Karapadam* B soil flooding did not bring any marked change on K transfomation, whereas, it the *Karapadam* A and *Kole* soils there was an initial increase during the first 10 days of submergence and then a marked decrease in the next 20 days. After this period, the values of exchangeable K in the Karapadam A soii remained more or less unchanged **till** the end of 70 day period of flooding, whereas in the *Kole* soil there was an increase in the exchangeable K during this period.

Just as in the case of Ca the increase in K availability may be due to combined effect of CO_2 and increase pH. For decrease in K availability it is probably presumed that the K held in the exchangeable site would have been squeezed into the interlattice portions which are not easily exchanged as those held at plamar exchange sites (Powell and Hatcheson 1965) leading to decrease in exchangeable K estimated.

Summary

Laboratory incubation experiments were conducted with acid sulphate soils of Kerala to investigate the changes in pH exchangeable iron, manganese, aluminium, calcium and potassium. It was noted that flooding resulted in an increase in the soil pH and the extent of increase was determined by certain inherent characters of the soil. The exchangeable Fe content increased and reached a peak value in 30 days and then decreased. The amount of Fe released was dependent on the active iron content of the soils, of submergence. As for Mn *Kole* and *Kayal* soils showed a higher release of Mn on flooding. But all the other soils showed only very little change. The course of change of exchangeable Mn was similar to that of Fe. The overall effect of submergence was towards an increased availability of Ca and K.

സംഗ്രഹം

കുട്ടനാട്ടിലെ അമ്ല സൾഫേറ്റ് മണ്ണുകളിൽ ജല നിമഗ്നത കൊണ്ടുണ്ടാകുന്ന രാസപരമായ മാററങ്ങൾ കേന്ദ്രീയ നെല്ല് ഗവേഷണ കേന്ദ്രത്തിലെ rocroron^ പരീക്ഷണ ശാലയിൽ പഠനത്തിന് വിധേയമാക്കിയതിൽ താഴെപറയുന്ന മാററങ്ങൾ കാണപ്പെട്ടു.

1. ജല നിമഗ്നതയുടെ ഫലമായി മണ്ണിൽ പി. എച്ച്. കൂടുന്നതായും, അതിന്റെ തോതു മണ്ണിന്റെ പ്രകൃത്യായുള്ള സ്വഭാവത്തെ ആശ്രയിച്ചിരിക്കുന്നതായും കാണപ്പെട്ടു.

2. ലേയത്വമുള്ള ഇരുമ്പിന്റെ rerooOTJo ജല നിമഗ്നതകൊണ്ടു 30 ദിവസം വരെ കൂടുന്നതായും പിന്നെ കുറയുന്നതായും കാണപ്പെട്ടു. മണ്ണിൽ നേരത്തെ അടങ്ങിയിട്ടുള്ള ഉത്തേജിത ഇരുമ്പിന്റെ അളവു അതിന്റെ ലേയത്വത്തെ നിയന്ത്രിക്കുന്നതായി തെളിഞ്ഞു.

3. മാംഗനീസ് എന്ന മൂലകത്തിന്റെ ലേയത്വത്തിലുള്ള മാററങ്ങൾ ഇരുമ്പിന്റേതുമായി സാമ്യമുള്ളതായിരുന്നു.

4. ജല നിമഗ്നത പൊതുവിൽ കാത്സ്യം പൊട്ടാസ്യയം എന്നീ മൂലകങ്ങളുടെ ലഭ്യത കൂടുന്നതായും കാണപ്പെട്ടു.

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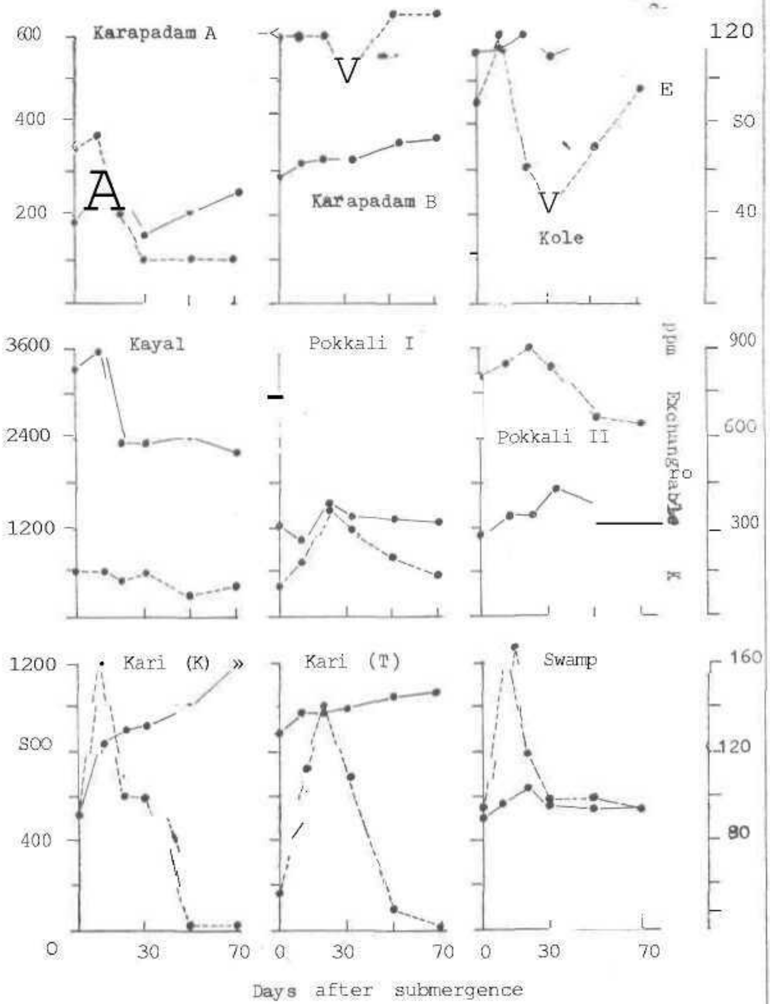

Fig. 3. Effect of flooding on the change in exchangeable K and Ca of acid sulphate soils

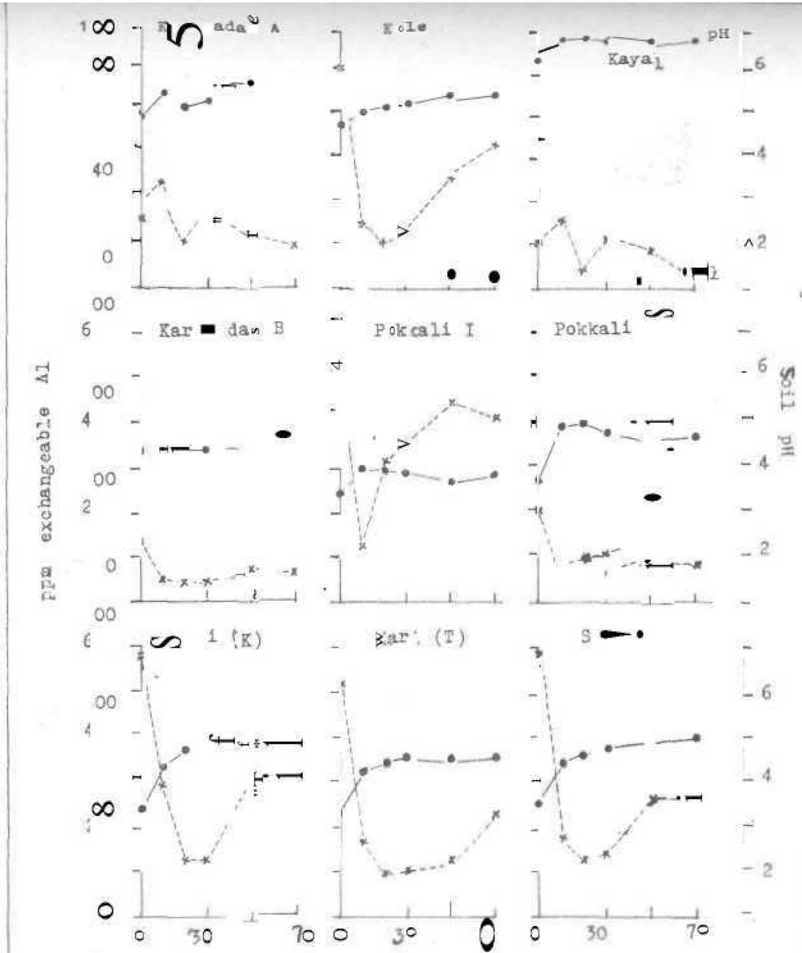

Fig. 1. Effect of flooding on the change in pH and exchangeable Al of acid sulphate soils

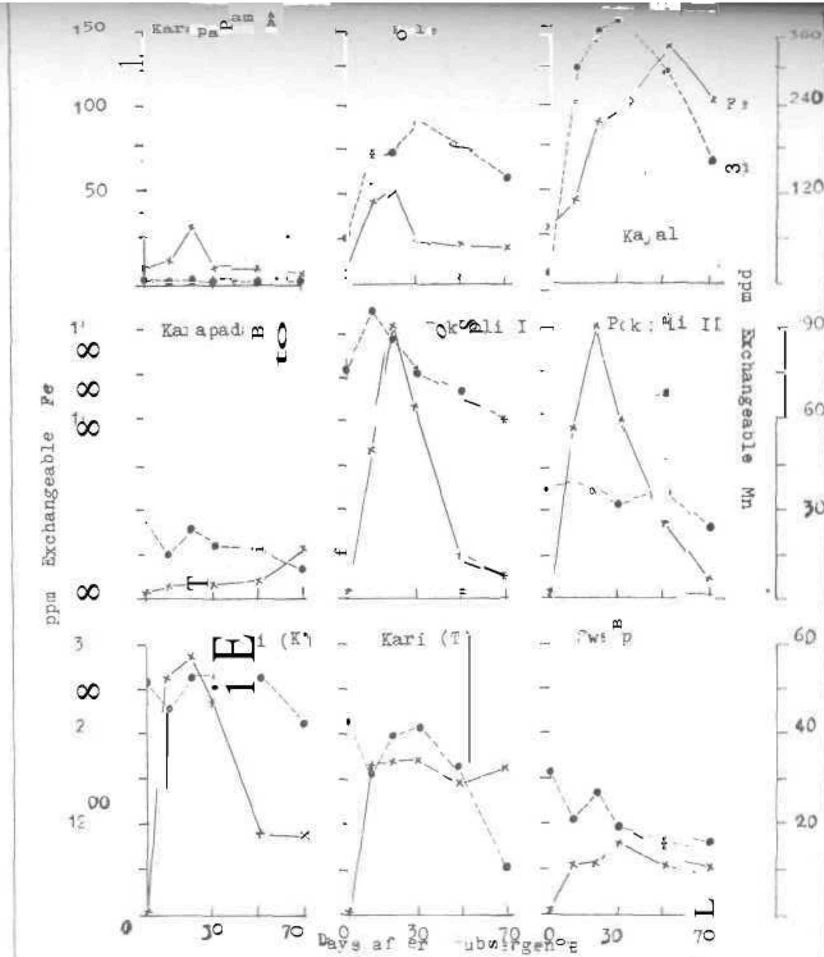

Fig. 2. Effect of flooding on the change of exchangeable Fe and Mn of acid sulphate soils