Studies on the Soils of Kuttanad - Part

TOXIC FACTORS *

N. S. MONEY * *

(Received for publication on 10-3-1961)

INTRODUCTION

KUTTANAD THE RICE BOWL OF KERALA, is a unique agricultural tract, occupying about 334 sq. miles and having 200,000 acres under paddy. Practically the whole of this area is about four feet below sea level. Four of the biggest rivers, besides many smaller ones, pour their flood waters into this area during the monsoon, submerging the land to a depth of four to six feet and depositing large quantities of silt. When the rainy season is over and flood waters recede, sea water from the bar at Cochin, floods the area and makes it too saline for raising crops. And yet, paddy, which is one of the most important crops here is cultivated under these unique conditions.

Indeed, paddy growing in this region, is a very risky agricultural operation. The agriculturists grow paddy in fields surrounded by heavy mud embankments, outside which, there is water standing five to seven feet above the field level. The waves constantly lash these bunds, breaking them down. At the close of the rainy season every year, these embankments have to be strengthened or laid afresh. Seven to eight feet of water in the enclosed fields is pumped out before the crop is sown. Only one crop is raised. Since a large part of this area is reclaimed from the Vembanad lake, a deep layer of acid-peaty clay is found in the sub-surface.

Another unique feature of agriculture, in the area is that co-operative farming is practiced here without its being recognised as such. The irrigation water must come from common sluices and devvatering has to be carried out by common engines. The dewatering of blocks extending to 500-1000 acres—as well as the letting in of water are supervised and directed by a committee. The Punja Special Officer of Government is in overall charge of cultivation. (1) Each block consists of 500 to 1000 acres belonging to different individuals.

* This work was carried out by the author in partial fulfilment of the requirements for the Degree of Doctor of Philosophy, University of Kerala, Trivandrum.

* * Junior Professor of Agricultural Chemistry, Agricultural College and Research Institute, Vellayani.

(1) The word cultivation as used in Indian scientific literature aften means cropping or agriculture and is not restricted to soil-digging operations.

— Editor.

Topography.

The paddy fields *in* Kuttanad fall under three categories.

Kara padams (raised fields) are situated on the banks of rivers and waterways. The soils get enriched by the silt brought down by the rivers. Paddy grows luxuriantly and the yields are proportionately high.

Kayal lands are the fields reclaimed from the Vembanad lake and form the most extensive Punja lands covering about 20,000 acres. Reclamation dates back to 1836 A.D. In the early years of reclamation, cultivation was carried on for two to four years continuously and the lands were then left fallow for one to two years. Continuous cropping has decreased the yield.

Kari or marshy or peat soils occur in Kuttanad. The cultivation practices on these soils are also the same as those described earlier. Ploughing here consists of mixing clay and water, which serves to leach out the salt adhering to the surface soil.

Sprouted seeds are sown in six to nine inches of water. Within two days the water is drained to enable the seedlings to take root in the soil. After keeping the field dry up to six days, water is let in through sluices to the big and small channels. The soil is colloidal and so loose that it is next to impossible for men or animals to trample in the field. After two weeks the transplanting starts which consists in throwing the seedling with the clay in to places where there is a thin stand. Manure is also applied at this time. During the period of cultivation, water is let in and drained two or three times.

The entire harvest and threshing operations need only two weeks to complete.

Flooding due to torrential rains and unsatisfactory soil conditions are responsible for frequent crop failures. The production of acidity by bacterial and chemical oxidation of sulphur compounds is a peculiar feature of the soil.

Toxic factors in Kuttanad soils.

It is well known that the reaction of a soil exerts a direct toxic effect on plants. Hoagland (1919) and Truog (1930) have indicated the direct effect of excessive ' H' ions on root tissues. Mitra and Phukan (1929) have demonstrated the effect of acidity on rice roots. The presence of ferrous and aluminium sulphates and its possible effect on crops have been shown in the work of "Villa" (1928). Wijk (1951) found that poisoning of rice is possible with even 0.01% of Fe SO_4. In the present paper a study was made to investigate the various toxic factors limiting crop production in Kuttanad soils.

Materials and Methods.

A few typical soils were taken from selected areas. The methods of chemical analysis followed were those outlined in A. 0. A. C. (1946). Mechanical analyses were carried out by International Pipette Method.

Experimental results and discussion.

The results of mechanical analysis, of the selected surface soil samples are given in Table I.

TABLE I

Mechanical Analysis of soils on oven dry basis.

Area	Depth in inches.	Textural separates.				Organic matter. %
		coarse sand %	Fine sand %	Silt %	Clay %	
Vechoor	0 to 9"	1.35	3.5	21.5	34.50	37.75
Thottappally	,,	2.49	15.85	31.75	36.45	11.90
Momkompu	,,	8.40	34.75	20.35	30.35	5.26
I. C. A. R. station	,,	5.15	36.62	18.75	33.7	5.10
Kayamkulam	,,	40.5	26.90	11.00	19.60	2.50
	,,	1.85	3.40	11.50	15.9	42.50

Chemical determinations.

In Table II are given the pH, loss on ignition, total nitrogen, P_2O_5, K_2O CaO and the water soluble chlorides and sulphates of the different soils studied.

It is observed that lower horizons of most of the profiles have a markedly low pH which goes down as low as 2.5. The loss on ignition varies from 19.4 to 74.2 and is directly proportional to the amount of organic matter present in the various layers. Vazhappalli and Ambalapuzha samples record very low pH values. The nitrogen values of the soils vary from 0.2 to 0.85%. Potassium is comparatively higher. Kumarakam samples give the highest CaO values and it may be noted that lime shells are present in appreciable quantities there.

The typical clays collected from the river and fields were analysed for their water soluble iron and aluminium. The results are given in Table III.

TABLE III.

Soluble iron **and aluminium in river clay** and field clay.

Clay.	*Water soluble iron and aluminium. (in mg. per 100 gram of soil).*		
	Fe_2O_3	Al_2O_3	PH
River Clay	] .0	0.00	5.5
	4.0	0.03	6.1
Acid subsoil	542.9	2.21	! 7
	672.9	3.11	2.0
	392,3	2.12	2.1

It was noted that in the river clay the water soluble iron and aluminium are very low when compared with the water soluble iron and aluminium present in the acid sub soil. The pH of acid sub soil is also very low.

The changes in acidity and sulphate content in a few typical soils were determined periodically after drying and exposing them to air. The results are given in table IV.

There is considerable variation in the character of the soils in different regions. The sub soil clay contains a high amount of organic matter and they are rich in sulphur compounds. The iron sulphates are often

TABLE II (Oven dry basis)

Profile No.	Place	Depth in inches	Loss on ignition %	pH	Nitrogen %	PA %	K.,0 %	CaO %	Chloride %	Sulphates %
I	Thalavady	0 -9"	20.2	5.2	0.21	0.19	0.31	0.21	Trace	Trace
		9″–18″	19.4	5.1	0.20	0.29	0.29	0.22	,,	55
		18″–down	20.1	5.1	0.22	0.19	0.27	0.21		
II	Padarath Kayal	0 - 9"	40.3	3.9	0.39	0.01	0.34	0,12	0.04	0.21
		9″–18″	48.3	4.1	0.41	0.01	0.39	0.11	0.14	0.05
		18″–down	49.7	3.7	0.44	Trace	0.38	0.12	0.17	0.05
III	Ambalapuzha	0 - 9*	22.30	4.1	0.19	55	0.17	0.11	0.17	0.24
		9″–18″	31.30	2.9	0.21	55	0.16	0.10	0.21	0.22
		18″–down	34.30	2.5	0.21		7.18	0.11	0.20	0.21
IV	Monkompu	0 - 9"	25.90	5.2	0.29	0.12	0.17	0.14	0.12	Trace
		9″–18″	32.30	4.5	0.31	0.13	0.21	0.41	0.13	55
		18″–down	34.20	5.00	0.33		0.27	0,44	0.11	
V	Vazhapally	0 - 9"	24,4	3.5	0.19	0.11	0.15	0.21	0.12	0.09
		9″–18″	25.9	2.5	0.17	0.09	0.14	0.15	0,13	0.12
		18″– ft.	37.5	2.5	0.19	0.02	0.21	0.12	0.13	0.14
VI	Kumarakam	0 -18"	21.2	7.00	0.21	0.10	0.12	0.52	0.31	Trace
		18″–48″	20.30	5.00	0.19	Trace	0.10	0.41	0.01	,,
		48″–72″	18.9	6.8	0.15		0.10	0.57	0.02	
VII	Thottapally	0 - 9"	57.4	4.3	0.77	0.01	0.31	0.12	0.21	0.54
	Porakkad	9″–24″	67.2	5.5	0.81	Trace	0.34	0.12	0.24	0,34
		24″–45″	74.2	5.4	0.85	,,	0.45	0.11	0.25	0.41

TABLE IV

Changes in acidity and sulphate content on drying.

(Cl. & SO, expressed as percentage)

	Initial			Two weeks			Four weeks		
	PH	Cl.	SO_4	pH	Cl.	SO_4	pH	Cl.	SO_4
Thottapally top soil	6.5	2.7	1.1	3,2	3.8	3.1	2.,7	2.7	3.4
sub s.il	5.2	2.3	1.5	3 1	2.3	2.4	I 9	2.2	3.1
Porakkad top soil	5.9	2.4	3.2	4,4	2,4	3.4	2 7	2.3	3.7
Mannakal padam sub soil	5.7	2.1	2.1	2.9	2.1	3.1	2. 1	2.0	3.4
Kainakari top soil	6.7	1.2	0.91	6.2	1.3	1.2	5, 1	1.3	1.5
sub soil	5.9	0.9	0.70	3.3	1.1	1.3	3.5	1.1	2.1
Kayal top soil	6.9	0.21	0.12	6. /	0.22	0.13	6.7	0.22	0.13
sub soil	6.4	0.32	0.13	6 0	0.34	0.19	6, 2	0.34	0.29

found on the surface of exposed soils as a yellowish white inflorescence. This is directly related to the presence of oxygen as can be seen from Table I \ The increase in acidity when the soils are exposed to air is a character exhibited by most of the soils in the area even though it varies in degree from place to place. The presence of a toxic sub-soil layer is a source of permanent danger to crops as the acid salts can enter the permeable layer with the rise of ground water.

The distribution of different forms of sulphur in the surface and sub-surface soils as well as in wood fossils were determined in the following manner. The total sulphur was determined by Eschoka mixture method (A.O.A.C. 1946). Inorganic sulphur compounds were extracted with Hydrochloric acid. Organic and free sulphur were determined by extraction with carbon di-sulphide. The results are given in Table V.

TABLE V.

Distribution of Sulphur (Percentage)

Sample	Total sulphate	Free sulphur	Organic sulphur	HC1 extractable	water extractable
Surface soil	1.92	Trace	Trace	1.84	1.41
Sub soil	3.13	1.21	0.12	0.02	1.04
Fossil	6.10	3.20	1.51	1.81	1.40

Inoculation of the samples in the respective sulphur media showed the presence of sulphur oxidising and reducing bacteria. The occurrence of sulphides provides additional evidence to the existence of sulphur microbial cycle ''. Sulphur being the chief source of toxicity, the nature of its occurrence and transformation in situ assume great significance. It is not possible just yet to prove conclusively the precise origin of sulphur in the types of soils and fossil.

TABLE VI.

Composition of some ground waters in the cultivated fields

Particulars of Samples	pH	Total soluble salts mg./litre.	In percent of ignited residue				
			CaO	Fe_2O_3	Al_2O_3	SO_4	Cl.
Thottapally Manakal, Porakad.	2.1	2102.1	2.3	4.9	3.1	12.1	1.4
Kanji Padam, Ambalapuzha.	2.9	1720.3	1,2	3.3	1.9	10.4	1.2
Kaupanam	3.1	82.0	7.4	2.1	1.2	7.2	0.41
From H. block kayal	4.6	3675	1.X	1.9	0,7	4.7	3.1
Mundar estate Vaikom	2.2	1921	0.7	3.9	1.1	7.1	1.42

It can be noted from the above table that water flowing out of the fields which are exposed to air gives an acid reaction and contains greater percentages of iron and aluminium sulphates. Further the formation of free H_2SO_4 (as has been proved in an earlier work of the author (1948) contributes to the unfavourable influence on crops. Considerable variation is found in the chloride content. It is well known that chlorides can also be toxic but this depends on the stage of development of the plant, the chloride content and the nature of the soil. Again it has been found that in fields having a permeable sub-soil a slight rise in the salt content in the irrigation water proves toxic to the paddy in the field. The fact that salinity shifts towards the coast during the rainy season is responsible for the phenomenon known as '' Makarakal '' (a disease where the roots rot and the plants wilt).

Summary and conclusions.

From the foregoing studies, it is seen tha' the chief source of toxicity in the area are extreme acidity, solubility of iron and presence of a large amount of soluble salts especially chlorides and sulphates.

The results show that the improvement in hydrological condition is of primary importance for proper crop growth. The great majority of crop failures is due to the insufficient drainage.

The rain water must be conserved and be utilised fully to improve the soil. Surface ploughing may be beneficial as deep ploughing may set free toxic salts from below.

Based on the studies the following lines of cultivation practices are suggested for crop improvement.

(1) Change in the period of cultivation.

(2) Application of heavy doses of lime to the fields.

(3) Provision for proper ring bunds.

(4) Use of acid resistant varieties of seeds.

(5) Provision of high bunds to protect against floods.

Acknowledgements.

Grateful acknowledgements are recorded of the assistance and advice given by Professor Brito-Mutunayagam and Dr. P. V. Nair former Director Research, University of Kerala in the execution of this work.

LITERATURE CITED

A. O. A. C. (1946) Official and tentative methods of analysis.

Hoagland, D. R. (1919) Jour. Agrl. Research 18–73–117.

Mltra, S.K. & Phukan L.N. (1929) The Agri. Jour. of India 24.

Truog, E. (1930) Ameri. Nat. 64. 300-313.

Villa, T. (1928) The Phillipine Agriculturist.

Wijik, C. L. (1951) Contribution of gen. Agric. Res. Stn. Bogor. Indonesia No. 23.

Money, N. S. (1948) M. Sc. Thesis University of Travancore.