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Chemical and biological characterization of acid sulphate Kuttanad soils

■ V. ARYA NATH, B. APARNA AND MANORAMA THAMPATTI

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MEMBERS OF RESEARCH FORUM:

Corresponding author :
V. ARYA NATH, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani, THIRUVANANTHAPURAM (KERALA) INDIA
Email: krishna6vnt@gamil.com

Co-authors :
B. APARNA AND MANORAMA THAMPATTI, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani, THIRUVANANTHAPURAM (KERALA) INDIA

Summary

Kuttanad, the rice bowl of Kerala is a unique agricultural tract lying 0.6 to 2.2 m below MSL. The soils of the area are highly acidic, saline and high in organic carbon content. Several parts of this delta have subsoil layers containing pyrites which on oxidation produce severe acidity. Hence, the present study was envisaged to characterize the acid sulphate wet land soils of Kuttanad. For the collection of soil samples, stratified random sampling technique was followed. Surface (0-15 cm) and sub surface (15-30 cm) soil samples were collected from the identified six soil series *viz.*, Ambalapuzha, Kallara, Purakkad, Thakazhi, Vaikom and Thuravoor. From the study it is inferred that the pH of the samples varied between 3.0 -4.0 which is typical for acid sulphate soils. Lab incubation studies also revealed that there was a drastic decline in the pH of the soil with submergence while the EC ranged between 0.1 – 8 dS/m. With regard to the enzyme assay between the locations, subsurface soil samples collected from the wetlands of Thuravoor reported to have the highest value of 76.1 ppm of urea hydrolysed g^{-1} of soil hr^{-1} for urease and surface samples of Thakazhi had the highest of 105.8 µg of p-nitrophenol released g^{-1} of soil hr^{-1} for phosphatase. In the case of respiratory activity, which is an indicator of soil microbial biomass, surface samples from Thuravoor recorded the highest followed by Vaikom.

Key words : Acid sulphate soils, Kuttanad, Enzyme studies, Incubation studies

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Introduction

Kuttanad, the rice bowl of Kerala is a unique agricultural tract lying 0.6 to 2.2 m below the mean sea level on the west coast of India. It has a geographic area of 854 sq. km which represents a deltaic formation traversed by numerous water courses that drain into the Vembanad lake. The soils of the area are highly acidic, saline and high in organic carbon content. Several parts of this delta have subsoil layers containing pyrites which on oxidation produce severe acidity. Depending on the type of soil, the entire wetland area of the region can be classified into Kayal lands (13000 ha), Karappadams (33000 ha) and Kari lands (9000 ha). Kayal lands are reclaimed beds from Vembanad lake and are mainly located in Kuttanad and Kottayam taluks. Karappadams are situated along the waterways and lakes, mainly in the eastern and southern parts of Kottayam district while Kari lands are situated in the taluks of Vaikom, Cherthala and Ambalapuzha.

Acid sulphate soil is the common name for soils that contain metal sulfides. In an undisturbed and waterlogged state, these soils may pose no or low risk. However, when disturbed or exposed to oxygen, acid sulfate soils undergo chemical oxidation, produces sulphuric acid which has led to these soils being called acid sulphate soils. The pH of the soil will be neutral or slightly acid in the field. Upon drainage, the soil becomes strongly acidic, which directly affects the growth of plants as a result of aluminium and iron toxicity and indirectly decreases the availability of phosphorus and other nutrients. Kuttanad showed a declining trend in rice production for the past few decades despite the use of high yielding varieties and modern farming techniques, definitely due to loss of soil health and fall in cropped area. Another major problem is the low inflow into Kuttanad during summer months (February-May) which leads to an increase in salinity, acidity and lack of water. Hitherto several studies have been carried out to characterize the soil chemically and evaluate the health. In contrast, a handful of research has been undertaken to characterize the acid sulphate soils in terms of the biological status which is very important for nutrient cycling and microbiologically mediated transformations. This study will add to the knowledge about the fate of the microflora and agriculturally significant enzymes in severe acidic conditions, which is a serious problem. More over the characterization of enzymes in these soils would provide a database for the future researcher to probe into this field of study.

Kuttanad soils :

Though a handful of works were carried out in Kerala, in depth or focused research on characterization of soil microbiological status have not been undertaken so far. Some of the important works undertaken by the researchers are provided in the following paragraphs.

Chemistry of low productive acid laterite and acid sulphate soils and their amelioration for growing rice was carried out by Kabeerthumma (1975).

Macro, meso and micro morphology and clay mineralogy of the acid sulphate soils of Kerala was carried out by Iyer (1989).

A study was carried out by Sasikumar (1996), for the development of inoculant cultures of *Azospirillum* for Rice (*Oryza sativa* L.) in Kuttanad. *Azospirillum* was isolated from the rice roots from 25 different locations of Kuttanad in order to develop acid and salt tolerant inoculant cultures suited for the locality. The isolates were identified as *A. lipoferum* and *A. brasilense*. All the isolates showed good salt tolerance upto 2 per cent NaCl concentration and good acid tolerance upto pH 5.

An effort was made by Muralidharan *et al.* (1999), to study the phosphorus and iron adsorption characteristics of the acid saline soils of Kuttanad. Themodynamic parameters of phosphorus adsorption also were worked outand was described by Langmuir, Frendilch and Temkin equations.

Sulphur mineralization and oxidation potential was studied in four soil types from Kerala *i.e.*, sandy, red sandy loam, laterite and Kari. In Kari, sandy and laterite soils, the sulphate sulphur mineralization increased upto 40 days after incubation, then reached a plateau after 60 days and subsequently increased after 80 days of incubation. After 6 days of incubation, oxidized sulphur was highest in Kari soils followed by sandy, laterite and red loam soils (Swami *et al.*, 2000). An evaluation on the physical and chemical characters of acid saline rice soils of Kuttanad with special reference to salinity protection by Thanneermukkom regulator was attempted by comparing the present soil properties with that of pre-barrage period. The closure of the regulator during the summer for the past 23 years had altered several soil chemical properties and it was found that most of the physical properties remained unaffected (Thampatti and Jose, 2000).

The presence of pollutants due to the coir retting, salinity due to sea water intrusion and pesticide residues had led to poor quality irrigation water as well as drinking water for the area. There are threats for biologically rich zones of Kuttanad like mangroves and consequent reduction of biodiversity. Improvement of irrigation facility, protection of side bunds of canals and mechanization of agricultural activities can increase crop yield in the area (NBSS and LUP, 2004).

An investigation was carried out at College of Agriculture, Vellayani during 2001-04 by Beena (2005) to delineate acid sulphate soils of Kuttanad and to develop sustainable land use plan for an area based on land evaluation and crop suitability rating with the help of GIS technology. Based on this study the land use models suggested for the area are rotational farming involving paddy, fish and livestock. Detailed investigations were carried out to find out the acidity characteristics of wetland rice soils of Kerala by Usha and Vargheese (2006). From the characterization of acidity in major wetlands of Kerala, maximum exchange acidity was noticed in Kari soils (16.4 cmols).

Yield maximization in rice (*Oryza sativa* L.) in the acid sulphate soils of Kuttanad through 'systematic approach' in fertilizer use was studied by Koruth (2007). The investigation to realize the maximum economic yield in rice has arrived at a reduced optimum ferlizer dose of 90 : 45 : 15 kg NPK/ha for the medium duration rice varieties. Soil micro-organisms play an important role in various metabolic reactions in soils such as mineralization of soil organic nitrogen, decomposition of rice straw and compost applied in soil, thereby supporting rice production as well as maintaining the fertility of paddy soils of Kuttanad (Kikuchi *et al*., 2007).

The biogeochemistry of wetland paddy soils determine the wetland functions like biogeochemical cycles, plant production, microbial transformations, nutrient availability, pollutant removal, heavy metal chemistry, atmospheric exchange and sediment transport (Schoner *et al*., 2009).

Sasidharan and Padmakumar (2012) reported that the rice fields in Kuttanad are underutilized and mostly single cropped. Therefore, there is considerable scope for improvement by farming system approach by growing 2000 fish fingerlings, 300 broiler ducks, 1-2 buffaloes, 20 coconut palms on the bund, 40 banana plants, 20-40 yams/cassava in one acre paddy land. A study was proposed by Smily *et al*. (2012) to determine the changes in soil microflora of paddy fields in relation to the type of farming system. A total of 11 bacterial species were isolated from paddy field soil whereas 15 were obtained from fish-rice rotational farming soil. The highest frequency of occurrence among paddy field isolates was the *Bacillus* spp. followed by *Klebsiella pneumoniae*, *K. oxytoca* and *Pseudomonas* spp.

In a study carried out by Sridevi *et al*. (2013) the bacterial community in both alluvial and acid sulfate flooded rice soils and their biochemical / metabolic activities was measured. Higher number of aerobic heterotrophic bacterial population was observed in alluvial soil than in acid sulfate soils.

So the present study aimed to assess the chemical and biological parameters of the already identified acid sulfate soil series of Kuttanad and to evaluate the biological fertility.

Resource and Research Methods

The present study was conducted in Kari soils of Kuttanad. The soil samples were collected from six representative acid sulfate soil series. The soil series are:

– Ambalapuzha
– Thuravoor
– Vaikom
– Kallara
– Purakkad
– Thakazhi.

The sample collection was done by stratified random sampling technique from both surface (0- 15 cm) and subsurface (15- 30 cm). Ten samples each were collected from both levels. The samples were analysed to estimate soil respiratory activity, enzymes like phosphatase and urease, pH and EC to know the biological fertility status of acid sulphate soils. The urease activity was estimated by following the method described by Broadbent *et al.* (1964). Phosphatase activity was determined by making use of procedure described from Eivazi and Tabatabai (1977). The method proposed by Jenkinson and Powlson (1976) was used to estimate the soil respiratory activity.

Research Findings and Discussion

The present study was undertaken to investigate the dynamics of enzymes in acid sulphate Kuttanad soil and to know the soil fertility status. The study comprised of soil sample collection, incubation studies and analysis of major enzymes. Results based on statistically analysed data pertaining to the experiment conducted during investigation are presented in the following paragraphs.

From Table 1 it is clear that the pH of the analysed soil series were strongly to extremely acidic. The pH ranges varied from 2.4 to 4.8. According to Beena and Thampatti (2013), the Kuttanad soils were found to be extremely acidic showing a range of pH varying from 2.5 to 5.2. In this study the subsurface samples from the Thakazhi series showed high pH value and the lowest value for surface samples of Thuravoor series. The subsurface soil acidity might be also one of the reasons for the extreme acidity in Kuttanad soils. The higher values of pH reported in the Thakazhi soils might be due to the exposure of the subsurface layers to air through drainage or evacuation where the iron sulphides in the soils react with oxygen and water to produce iron compounds and sulphuric acid. This acid might release with the other substances including heavy metals from the soils which destroys the ecological balance. Similar findings were reported by Hinwood *et al.* (2006).

Incubation of soils for one month showed a decline in pH values (Table 2). That helped to confirm the acid sulphate condition in the Kuttanad region. EC values were ranging from 0.185 to 8.752 dS/m. And also the highest EC was shown by Thuravoor surface samples and lowest by subsurface samples of Vaikom. EC values were varied and showed a higher range and it can be attributed to the sea water intrusion in summer months in the Kuttanad region.

From the data presented in Table 3, the activities of two major enzymes like urease and acid phosphatase in the acid sulphate soils of Kuttanad were noticed. Urease activity was the highest for subsurface samples of Thuravoor and the lowest for Thakazhi subsurface soils. While comparing the enzyme activity of both surface and subsurface soils in urease and phosphatase, surface samples had the highest values than respective subsurface soils except in Kallara and Thuravoor in the case of urease and Purakkad in phosphatase. Dick *et al.* (2000) reported that soil fertility and crop production are affected by biological processes,including enzyme activities, and are influenced by pH. Kalembasa and Kuziemska in (2010) opined that organic fertilization has been resulting in significant increase in the activity of phosphatase. It supports the fact that here since the Kuttanad soil have enormous amount of organic deposition, the values for phosphatase shows high range compared to urease activity. Also the dominant enzyme activity in the surface soils might be due to the abundance of microbial population in the surface layers pertaining to the presence of organic matter in those layers.

From Table 4 the soil respiratory activity of Kuttanad kari soils were noticed. The soil respiratory activity was measured by the evolution of carbon dioxide from the

Table 1 : pH and EC of surface and subsurface soils of Kari series of Kuttanad

Soil samples	pH	EC (ds/m)
Ambalapuzha- subsurface	4.0	0.20
Ambalapuzha- surface	4.4	0.73
Purakkad- subsurface	4.0	1.15
Purakkad- surface	4.0	1.71
Thakazhi- subsurface	4.8	0.20
Thakazhi- surface	4.6	0.26
Kallara- subsurface	4.1	0.73
Kallara- surface	4.1	1.26
Thuravoor- subsurface	2.9	7.59
Thuravoor- surface	2.4	8.75
Vaikom- subsurface	4.0	0.15
Vaikom- surface	4.0	0.16
C.D. (P=0.05)	0. 3	0. 99

Table 2 : pH values during incubation studies

Soil samples	pH in first week of incubation	pH in second week of incubation	pH in third week of incubation
Ambalapuzha- subsurface	4.0	3.4	3.3
Ambalapuzha- surface	4.4	3.3	3.4
Purakkad- subsurface	4.0	3.6	3.5
Purakkad- surface	4.0	3.5	3.4
Thakazhi- subsurface	4.8	3.6	3.4
Thakazhi- surface	4.6	3.5	3.3
Kallara- subsurface	4.1	2.9	2.8
Kallara- surface	4.1	2.9	2.9
Thuravoor- subsurface	2.9	1.7	1.6
Thuravoor- surface	2.4	1.8	1.7
Vaikom- subsurface	4.0	3.7	3.5
Vaikom- surface	4.0	3.6	3.5

soil incubated and the evolved carbon dioxide was collected in an alkali kept in a vial. The alkali was then titrated against acid. The soil respiratory activity is an indirect measure for arriving facts about soil biological activity and microbial population. According to Santruckova (1993), it is a strong indicator of soil metabolic and ecological functions. In this study the high values for soil respiratory activity was noticed in subsurface soils of Thuravoor Kari and lowest value was in the subsurface soils of Thakazhi. The urease activity also showed the same trend. It might be due to the abundance of microbes in the Thuravoor Kari than the other series.

From Table 5, it is clear that the available nitrogen content was significant and the highest value was recorded by the Kallara surface samples and the lowest by Purakkad sub surface samples. Regarding the depth, all the sub surface samples reported lower available nitrogen than surface. This might be due to its high organic carbon and organic matter content of this locality. Generally the available nitrogen content from the present study varied from medium to high range. Similar reports of high nitrogen availability in Kallara series among the all acid sulphate series were putforth by Beena (2005). In Kuttanad after harvesting, approximately 30 per cent of the straw remain in the field which later decomposes.

Table 3 : Urease and phosphatase activity in Kuttanad kari soils

Soil samples	Urease activity (ppm of urea hydrolyzed/g/year)	Acid phosphatase activity (ppm of p- nitro phenol released.g/year)
Ambalapuzha- subsurface	52.6	38.6
Ambalapuzha- surface	57.6	51.5
Purakkad- subsurface	56.8	90.9
Purakkad- surface	67.5	82.3
Thakazhi- subsurface	52.5	97.6
Thakazhi- surface	75.7	105.8
Kallara- subsurface	72.3	37.3
Kallara- surface	64.1	34.7
Thuravoor- subsurface	76.1	14.6
Thuravoor- surface	70.5	37.1
Vaikom- subsurface	58.3	31.5
Vaikom- surface	60.8	44.5
C.D. (P= 0.05)	11.5	50.5

Table 4 : Soil respiratory activity in Kuttanad Kari soils

Soil samples	Soil respiratory activity (microg of CO_2 /g)
Ambalapuzha- subsurface	1.1
Ambalapuzha- surface	1.0
Purakkad- subsurface	1.0
Purakkad- surface	1.0
Thakazhi- subsurface	1.0
Thakazhi- surface	1.0
Kallara- subsurface	1.0
Kallara- surface	1.1
Thuravoor- subsurface	1.1
Thuravoor- surface	1.1
Vaikom- subsurface	1.2
Vaikom- surface	1.2
C.D. (P= 0.05)	0.1

Fores and Comin (1987) also suggested that the 50 per cent of straw biomass buried later decomposes to release the nutrients like nitrogen, phosphorus and potassium. Considering the phosphorus availability, the highest value was given by Ambalapuzha surface and lowest by Purakkad surface. The P content varied from low to high and the results are contradictory to the general trend of phosphorus availability in acid sulphate soils. But the phosphorus values are in consent with the reports of Rajasekharan *et al.* (2013), who reported that the present phosphorus status of Kerala is high to extremely high (35 to 100 kg/ha) in 61 per cent of the selected samles from all the districts. High phosphorus levels of soils are usually attributed to aver fertilizing or adding enormous quantity of manures. Repeated application of manures based on nitrogen requirement could have caused phosphorus to accumulate in the soils. Ray *et al.* (2014) also reported available phosphorus ranged from 7.14 to 129 kg/ha in the Kuttanad region. Potassium availability also varied significantly among various locations and the highest availability was reported by the Kallara sub surface and lowest at Thuravoor sub surface. Beena (2005) also reported similar available potassium content who reported that the available potassium content of Kuttanad soils ranged from 142.1 to 326.4 mg/kg. This high values might be due to high incorporation of paddy straw and organic matter deposition in the region. The findings corroborated with findings of Ponnamperuma (1972), who reported that the high potassium content may due to addition of organic manures and amendments

Table 5 : Available nutrient status of the soil (kg/ha)

Samples	N	P	K
Ambalapuzha- subsurface	271.18	11.95	77.28
Ambalapuzha- surface	432.99	78.60	121.93
Purakkad- subsurface	226.69	66.73	75.62
Purakkad- surface	296.94	4.10	142.91
Thakazhi- subsurface	430.30	32.18	77.00
Thakazhi- surface	435.01	37.04	116.18
Kallara- subsurface	663.26	36.78	154.14
Kallara- surface	674.02	9.60	148.49
Thuravoor- subsurface	539.84	22.67	77.71
Thuravoor- surface	626.75	9.33	125.40
Vaikom- subsurface	378.56	19.81	51.87
Vaikom- surface	448.90	11.46	65.40
C.D. (P=0 0.5)	50.91	6.27	50.49

Table 6 : Organic matter and organic carbon content of the soil (%)

Samples	O.C	O.M
Ambalapuzha- subsurface	1.17	2.01
Ambalapuzha- surface	1.93	3.33
Purakkad- subsurface	1.01	1.74
Purakkad- surface	1.28	2.20
Thakazhi- subsurface	1.92	3.31
Thakazhi- surface	1.94	3.35
Kallara- subsurface	2.96	5.10
Kallara- surface	3.01	5.18
Thuravoor- subsurface	2.41	4.15
Thuravoor- surface	2.80	4.82
Vaikom- subsurface	1.69	2.91
Vaikom- surface	2.00	3.45
C.D. (P=0.05)	0.24	0.42

in the soils. The low values in the Thuravoor series might be due to the low pH values.

Table 6 clearly depicts the high organic carbon and organic matter status of the Kuttanad soils and the highest organic carbon and organic matter content was reported by the Kallara surface and lowest at Purakkad sub surface. The reason for the increased organic carbon and organic matter content in acid sulphate soils of Kuttanad can be attributed to the luxuriant growth and decaying of the macrophytes. Similar findings were also reported by Kannan *et al.* (2014) from the Kuttanad soils and reported that the organic carbon content ranges from 2.79 to 7.70 per cent. Waterlogging associated with rice cropping mighy also enhances the accumulation of organic carbon. Stolt *et al.* (2000) explained that hydrologic regime played a role in organic matter accumulation. The highest organic matter of 5.14 per cent reported in Kallara soils might be also due to enrichment of weed biomass and paddy straw in the cultivated fallows (Pillai and Subrahmanyan, 1929 and Fores and Comin, 1987). Beena (2005) also observed highest organic carbon content of 5.35 per cent in Kallara soils.

Conclusion :

From the study it can be inferred that there is a relation between soil enzyme activity and soil respiration as both have relation with soil microbial population and organic matter status of the soil. Also from the study it is again stressed that the pH of the Kuttanad soil is extremely acidic which also has a relation with enzyme activity and all other chemical properties.

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