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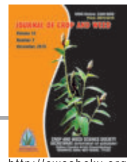

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Physico-chemical and biological properties of soils in Northern Kole land of Thrissur district in the post-flood scenario

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ABSTRACT

The physical, chemical and biological characteristics of soils in Northern Kole lands of the Thrissur district were evaluated in post-flood scenario to assess the fertility and productivity of the soils. Ten soil samples collected from various locations were analyzed for texture, pH, organic carbon, available potassium, available phosphorus, available secondary nutrients, available micronutrients, and exchangeable cations. The soils under study were loamy sand in texture. The soil was strongly acidic with pH range of 5.22 - 5.59. It had a higher available sulfur (12.73-33.13 Kg ha^{-1}), medium available potassium (124.08- 238.24 Kg ha^{-1}), and phosphorus (10.56-13.38 Kg ha^{-1}). The soils were adequate in available calcium (421.31 – 553.94 mg kg^{-1}) but the available iron (1156.09 - 4013.11 mg kg^{-1}) and exchangeable aluminum (50.82 to 125.21 mg kg^{-1}) were in the toxic range. The presence of significant organic matter in the soil with an organic carbon content (2.11- 2.87 %) enriched it with a diverse population of bacteria (2-6x10^{6}), fungus (2-4x10^{4}), and actinomycetes (5-8x10^{4}).

Keywords: Acidity, available calcium, available iron, exchangeable aluminium, Kole land, pH

Kole land is one of the largest wetlands of Kerala. It exists between 10°20' and 10°40'N latitudes and 75°58' and 76°11'E longitudes and spreads an area of 13,632 hectares over Thrissur and Malappuram district, extending from the northern bank of Chalakkudy river in the south to the southern bank of Bharathapuzha river in the north (Fig. 1) (Sujani and Sivaperuman, 2008).

The Kole land is a flat low-lying area, with rich alluvium deposits. On the eastern and western sides, it is bordered by laterite hills. Throughout the South west monsoon, the water level reaches up to 5.5 meters. The area is considered as one of the most fertile lands in Kerala due to the cyclical nutrient recharging throughout the flood season (Johnkutty and Venugopal, 1993).

In Kole land, a peculiar type of paddy cultivation is practiced. From June to October, *i.e.*, for almost six months, a portion of this land lies submerged under water. In summer months, farmers dewater and bund the fields for the cultivation of rice. The main season is mundakan raised between October/November and February/March (Sivaperuman and Jayson, 2000).

It is reported that Kole land soils are acidic with pH varying from 4.9 to 6.1 (Thomas *et al.*, 2003). In addition to this, soils are more prone to Fe and Al toxicity, which in turn affect the plant root system. These are major soil factors limiting the productivity of rice. In order to rectify these problems under cultivation and thereby stabilize food security, it is necessary to study the chemistry of the soil.

Kerala, was exposed to a devastating flood in August,2018 owing to a huge rainfall of nearly 2346.6 mm, against the normal value of 1649.5 mm. Safnathmol (2020) reported that the flood inundation adversely affected the Kole lands of the Thrissur and Malappuram districts and the characteristics of the soil were highly changed. This necessitated a site-specific study in flood-affected areas of Kole lands to suggest post-flood management strategies.

MATERIALS AND METHODS

The study was confined to the Mullasseri block in the Northern Kole lands of the Thrissur district. Random soil samples were collected during May 2019 in the post-flood time from different Padashekharams where the problem of acidity was maximum. The preliminary sample details and the measured pH are presented in Table 1. The area was with a pH range of 4.02-5.06. Among the Padashekharams, 'Pavutai', with extreme acidity (pH of 4.26- 4.44) and toxicity of Fe and Al, was selected for the study.

As part of the study, soils were sampled at a depth of 0 to 30 cm during post-monsoon season, October 2019 from ten selected locations of the Padashekharam before the cultivation of the crop. Kavitha (2018) observed extreme acidic conditions in Kole lands. The high acidity of land may be due to the occurrence of an organic peat layer on the sub-surface layer of the soil profile (Thomas *et al.*, 2003).

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The details of the GPS coordinates of the site of sampling and the corresponding moisture percentage are specified in Table 2. The soil samples were collected in polythene bags and labeled with the name of each site and sample number. These were brought to the College of Agriculture, Vellanikkara and stored in clean airtight containers.

Soil analysis

The moisture percentage of the fresh samples was determined gravimetrically. Then wet analysis was performed to characterize the soil for major physical and chemical properties.

The textural analysis, pH, electrical conductivity, organic carbon, available P, K, Ca, Mg, S, Fe, Zn, Cu, Mn, B, and exchangeable cations (K, Na, Ca, Mg, Fe, Mn, Zn, Cu, Al) and cation exchange capacity were estimated using the standard procedures. The procedures followed for the analysis are elaborated below (Table 3).

Microbial population

Culturable microflora was enumerated using serial dilution pour plate method for bacteria, fungi, actinomycetes. The bacterial population were determined by using nutrient agar media with a dilution of 10^{-6} .Viable fungi were determined by using rose bengal agar with a dilution of 10^{-4} and that of actinomycete by using the Kenknight & Munaier's agar medium with a dilution of 10^{-4}.

Data analysis

Data obtained from the laboratory analysis were undergone descriptive statistics using Microsoft-excel. The mean value was used as primary estimate of central tendency and standard deviation, minimum and maximum values were used to describe the degree of variability in soil physical and chemical properties (SAS Institute Inc., 2002). Data were also analyzed using OPSTAT SOFTWARE to show the correlation of estimated parameters and the scatter diagram was plotted using Microsoft-excel.

RESULTS AND DISCUSSION

Textural property of the soil

The textural analysis of the soil showed that sand had the highest value ranging from 79.22 to 83.87 %. Clay content was low with a range being 7.33 to 9.87 %. The silt was varying from 7.89- 10.38 % (Table 4). The studied soils were loamy sand in texture (Table 4).

Electrochemical properties

The soil reaction of samples collected from ten different locations of Pavutai Padashekharam in Thrissur Kole land during post-monsoon was ranging from pH 5.22 to 5.59 with an average of 5.42. It indicated that the sampling area was strongly acidic in reaction just before cultivation (October). Washing away of active acidity during monsoon and continuous submergence during cropping season might have resulted in the change from extremely acidic to strongly acidic conditions.

The electrical conductivity of the soil samples ranged between 0.32 and 0.60. The low salinity (< 1 dS m^{-1}) of the study area may be caused by the restricted entry of seawater through barrages and weirs (Thampatti and Jose, 2000). Irene (2014) reported that electrical conductivity of Kole lands before cropping season had a mean value of 0.39 dS m^{-1}.

Organic carbon

The organic carbon percentage of the soil samples varied from 2.11 to 2.87 per cent. The high organic carbon status of the sampled locations may be due to the incomplete decomposition under anaerobic conditions and the deltaic deposition of organic matter (Bhindu, 2017). Muraleedharan (1984) and Amritha and Durga Devi (2017) found that organic carbon content in Kole lands varied from 0.85 to 2.47 per cent.

Available phosphorus

The available phosphorus content in the soil samples of Kole land ranged from 10.56 to 13.38 kg ha $^{-1}$ with a mean of 12.24 Kg ha^{-1} (Table 5). Despite high phosphorus fixation by Fe and Al in acid soils, 90 percent of the sampled soils were confined to medium range of available phosphorus (10- 24 Kg ha^{-1}). This suggests the considerable increase of nutrient in soil owing to the indiscriminate use of phosphatic fertilizers and higher availability of phosphorus when analyzed on the wet basis which maintains an anaerobic condition in the field (Ponnamperuma, 1972). Gallardo (2003) and Amery and Smolders (2012) found that flooding increased the phosphorus availability due to the release of phosphorus bound to iron while the reduction of Fe (III) to Fe (II).

Available potassium

The average available potassium content of the sampled locations was found to be 205.14 Kg ha^{-1} with a range of 124.08 to 238.24 Kg ha^{-1} (Table 5). It indicated that the study area was with medium range available potassium (115- 275 Kg ha^{-1}). This may be the result of the incorporation of paddy stubbles into the soil after paddy cultivation or due to variation in mineral composition (Bhindu, 2017).

Available secondary nutrients

Among the secondary nutrients, calcium was dominating over magnesium, followed by sulfur. Though the sampled locations were acidic, were

Table 1: Area, location coordinates and soil reaction of different Padashekharams under Mullasseri Block

S.No	Name of Padashekharam	Area (ha)	North latitude	East longitude	pH
1	Ponnamutha	121	10.281565	76.548118	4.47-4.65
2	Elamutha	121	10.544800	76.282930	4.65-4.85
3	Mathukkara Thekk	86	10.525630	76.116466	4.63-4.72
4	Pavutai	16	10.544060	76.109493	4.26-4.44
5	Parappadam Kizhakk	5	10.543308	76.104931	4.20-4.31
6	Parappadam	14	10.544053	76.102563	4.02-4.23
7	Penakam	42	10.545548	76.108946	4.55-4.76
8	Elavathur	44	10.547121	76.111881	4.67-4.96
9	Cherrotha Akkarappadam	32	10.569162	76.114945	4.83-5.03
10	Peruvallur Padav	40	10.558948	76.094631	4.43-4.67
11	Kaniyamthuruth	40	10.570113	76.104106	4.58-4.99
12	Annakkara Chirakkal	20	10.569363	76.108954	4.22-4.47
13	Annakkara Vadak	10	10.556235	76.114941	4.08-4.222
14	Thanneerkkayal	86	10.528801	76.080076	5.06-5.34
15	Pulipandi	10	10.534048	76.066501	4.11-4.43

Table 2: Location details of the sampling sites in Pavutai Padashekharam and the soil moisture

S. No	North latitude	East longitude	Soil moisture (%)
1	10.323987	76.632840	53.29
2	10.324046	76.632357	46.19
3	10.324068	76.631341	46.44
4	10.324024	76.630467	44.72
5	10.323975	76.629725	42.11
6	10.323910	76.629855	43.18
7	10.323796	76.630152	50.35
8	10.323789	76.629687	42.72
9	10.323744	76.630922	49.16
10	10.323930	76.633175	49.33

sufficient in available Ca. It varied from 421.31 to 553.94 mg kg^{-1} with a mean value of 486.51 mg kg^{-1} (Table 5). This may be due to the calcium mineral deposition.

Available magnesium content over the sampled locations ranged from 90.32 to 129.45 mg kg^{-1} with an average of 117.14 mg kg^{-1} (Table 5). It indicated that 80 percent of the study area was sufficient in magnesium content (>120 mg kg^{-1}) owing to the naturally occurring parent material with high magnesium.

Available sulphur varied from 12.73 mg kg^{-1} to 33.13 mg kg^{-1} with an average of 20.49 mg kg^{-1} (Table 5) which was in high range. The sufficiency of sulphur in Kerala soils is due to excess application of sulphur fertilizers in fields. Irene (2014) observed an average of 34.28 mg kg^{-1} of sulphur in Kole lands before cropping season and no sulphur deficiency was reported. Sureshkumar and Sandeep (2015) stated that soils with high organic matter provide a sufficient level of sulphur.

Available micronutrients

The micronutrients (Fe, Mn, Zn and Cu). in soil samples show very high values of iron. The available iron content ranged from 1156.09 to 4013.11 mg kg^{-1} with an average of 2374.31 mg kg^{-1} (Table 5). Available Fe content was very high in all the sampled locations, which was supported by the findings of Muraleedharan (1984), who reported iron toxicity in Kole lands. He reported that Kole land was generally acidic with Fe and Al toxicity that may cause serious problems in crop production. Fageria *et al.* (2011) observed that submergence occurred by flooding increased the Fe content in soil by its reduction. A hike in Fe concentration (up to 500 mg kg^{-1}) and development of bronzing symptom in rice was also observed by Sahrawat (2004) under submergence.

Table 3: Analytical procedures adopted for soil analysis

S. No.	Parameters	Method	Reference
1.	pH	pH meter	Jackson (1958)
2.	EC	Conductivity meter	Jackson (1958)
3.	Organic carbon	Chromic acid wet digestion method	Walkley and Black (1934)
6.	Textural analysis	International pipette method	Robinson (1922)
8.	Available. P	Bray extraction and photoelectric colorimetry	Jackson (1958)
9.	Available. K	Neutral normal ammonium acetate extraction and Flame photometry	Pratt (1965)
10.	Available. Ca	Neutral normal ammonium acetate extraction and Atomic absorption spectroscopy	Jackson (1958)
11.	Available. Mg	Neutral normal ammonium acetate extraction and Atomic absorption spectroscopy	Jackson (1958)
12.	Available. S	Distilled water extraction, Turbidimetry and Photoelectric colorimetry	Massoumi and Comfield (1963)
13.	Available. Zn	0.1 N HCl Extraction and Atomic absorption spectroscopy	Emmel *et al*. (1977)
14.	Available. B	Hot water extraction and Photoelectric colorimetry	Bhingham (1982)
15.	Available. Fe	0.1 N HCl Extraction and Atomic absorption spectroscopy	Sims and Johnson (1991)
16.	Available. Cu	0.1 N HCl Extraction and Atomic absorption spectroscopy	Emmel *et al*. (1977)
17.	Available Mn	0.1 N HCl Extraction and Atomic absorption spectroscopy	Sims and Johnson (1991)
18.	Exchangeable cations & CEC	0.1 M $BaCl_2$ extraction and Inductively coupled plasma emission spectrometer	Hendershot and Duquette (1986)

Table 4 : Texture and particle size distribution of the soils

S. No.	Sand. (%)	Silt (%)	Clay. (%)	Texture
1	82.19	9.21	8.55	loamy sand
2	83.87	7.89	7.33	loamy sand
3	82.57	8.89	8.52	loamy sand
4	81.72	9.50	8.52	loamy sand
5	82.28	9.39	8.21	loamy sand
6	82.15	9.08	8.71	loamy sand
7	79.22	10.38	9.87	loamy sand
8	83.09	8.89	7.94	loamy sand
9	81.83	9.24	8.68	loamy sand
10	83.65	8.38	7.92	loamy sand

Available manganese content of the sampled locations varied from 33.19 to 49.42 mg kg^{-1} with a mean value of 40.54 mg kg^{-1} (Table 5). Available Mn status was found sufficient in soils. This may be due to the release of available Mn during the flood. Amarawansha *et al*. (2015) claimed that available manganese content increased due to flood. During flooding Mn^{4+} is reduced to Mn^{2+} and this leads to increased solubilization of manganese in the soil.

Available copper content varied from 1.03 to 4.09 mg kg^{-1} with a mean value of 2.11 mg kg^{-1} (Table 5). The increased availability of copper might be due to the effect of flooding. During flooding, the reduction of hydrous oxides of Fe and Mn and the production of organic complexing agents would have increased the solubility of copper. This corroborated the findings of Sahrawat (2004) and Akpoveta *et al*. (2014).

Available zinc ranged from 4.07 mg kg^{-1} to 9.24 mg kg^{-1} with an average of 6.39 mg kg^{-1} (Table 5). The sufficiency in zinc availability might be because of low pH and high amount of organic matter in the soil. Flooding might have increased organic matter content in soil by deposition carried from higher elevations. This is in agreement with the findings of Robertson and Lucas (1981).

Table 5 : Descriptive statistical values of important soil chemical properties

S. No.	Parameter	Mean	Range		Standard deviation
			Min	Max	
1	pH	5.42	5.22	5.59	0.12
2	EC	0.49	0.32	0.60	0.09
3	OC (%)	2.56	2.11	2.87	0.22
4	Available .P (Kg ha^{-1})	12.24	10.56	13.38	0.96
5	Available.K (Kg ha^{-1})	205.14	124.08	238.24	36.38
6	Available Ca (mg kg^{-1})	486.51	421.31	553.94	47.89
7	Available Mg (mg kg^{-1})	117.14	90.32	129.45	12.73
8	Available S (mg kg^{-1})	20.49	12.73	33.13	7.16
9	Available Fe (mg kg^{-1})	2374.31	1156.09	4013.11	1070.07
10	Available Mn (mg kg^{-1})	40.54	33.19	49.42	5.05
11	Available.Cu (mg kg^{-1})	2.11	1.03	4.09	1.10
12	Available.Zn (mg kg^{-1})	6.39	4.07	9.24	1.47
13	Available B (mg kg^{-1})	0.89	0.52	1.26	0.32
14	Moisture (%)	45.16	41.17	49.32	2.82

Table 6 : Descriptive statistical values of exchangeable cations and CEC of soils under study

S.No.	Parameter	Mean	Range		Standard deviation
			Min	Max	
1	Exchangeable K (mg kg^{-1})	232.08	212.08	257.22	12.39
2	Exchangeable Na (mg kg^{-1})	112.67	85.03	142.13	17.55
3	Exchangeable Ca (mg kg^{-1})	721.28	637.34	776.94	47.99
4	Exchangeable Mg(mg kg^{-1})	130.02	111.29	140.67	10.26
5	Exchangeable Fe (mg kg^{-1})	6.88	5.14	9.72	1.68
6	Exchangeable Mn (mg kg^{-1})	29.19	21.05	37.51	6.3
7	Exchangeable Cu (mg kg^{-1})	0.48	0.20	0.71	0.1
8	Exchangeable Zn (mg kg^{-1})	5.60	4.34	7.07	0.85
9	Exchangeable Al (mg kg^{-1})	77.42	50.82	125.21	28.85
10	CEC (C mol (p^{+}) Kg^{-1})	7.09	6.08	7.79	0.45
11	PBS (%)	81.03	71.99	95.97	6.8

Table 7: Correlation (r) of important chemical parameters of the soil samples

	pH	EC	OC	Av. P	Av. K	Av. Ca	Av. Mn	Av. Cu
pH	1							
EC		1						
OC			1					
Av. P	0.687*			1				
Av. K	0.655*			0.638*	1			
Av. Ca	0.716*				0.752*	1		
Av. Mg			0.685*		0.847**	0.738*		
Av. S								
Av. Fe	-0.821**			-0.741*				
Av. Mn							1	
Av. Cu		0.675*						1
Av. Zn								0.643*
Av. B							-0.692*	
Moisture	-0.731*							

Table 8: Correlation (r) of important chemical parameters and exchangeable cations in the soil samples

	pH	EC	Av.P	Av.K	Av.Ca	Av.Mg	Av.Fe	Av.Zn	Av.B	moisture
CEC						0.644*				
Exch. K	0.654*	-0.794**		0.653*	0.811**	0.681*				
Exch. Na									-0.699*	
Exch. Ca	0.716*			0.866**	0.789**	0.904**				
Exch. Mg				0.665*	0.779**	0.881**				
Exch. Cu		0.747*								0.763*
Exch. Al	-0.810**						0.704*	0.698*		0.739*

**Correlation is significant at 0.01 level (2-tailed)
*Correlation is significant at 0.05 level (2-tailed)

Table 9: Correlation (r) of exchangeable cations, CEC and PBS in the soil samples

	CEC	Exch. K	Exch. Ca	Exch. Mg
CEC	1			
PBS	-0.788**			
Exch. Ca	0.700*	0.671*	1	
Exch. Mg	0.708*	0.760*	0.883**	1

Table 10: Soil microbial population

S.No.	Microbe	Mean	Range		Standard deviation
			Min	Max	
1	Bacteria (10^6 c.f.u. g^{-1})	4	2	6	1.25
2	Fungi (10^4 c.f.u. g^{-1})	2.8	2	4	0.78
3	Actinomycetes (10^4 c.f.u. g^{-1})	6.1	5	8	1.1

Available boron varied from 0.52 to 1.26 mg kg^{-1} with a mean of 0.89 mg kg^{-1} and 60 % of the soil samples were sufficient (Table 5). It points directly to the high organic matter content which retains boron in organically complexed form and hence when pH gets reduced, available B was higher (Santhosh, 2013). But the acidic reaction in soil coupled with excessive leaching during flooding increased boron deficiency. This was reported by Rajasekharan *et al*. (2014) and Kavitha *et al*. (2019). According to them, Kerala soils were highly deficient in available boron content due to the acid leaching environment of Kerala soils. This may cause the deficiency of B in 40 % of the soils.

Exchangeable cations, cation exchange capacity and percentage base saturation

The exchangeable cations Ca, Mg, Na, K, Fe, Mn, Cu, Zn, and Al were determined by extracting the samples with 0.1 M $BaCl_2$. The CEC was computed as the sum of cations extracted by 0.1 M $BaCl_2$. The CEC of the samples varied from 6.08 to 7.79 Cmol (+) kg^{-1} with an average of 7.09 Cmol (+) kg^{-1} (Table 6). According to Kirk *et al*. (2003) and Favre *et al*. (2004), flooding increased CEC owing to strong reducing conditions. It was due to the excess iron, aluminium and hydrogen ions in exchangeable sites. The exchangeable potassium, sodium, calcium and magnesium were averaged with values of 232.08, 112.67, 721.28 and 130.02 mg kg^{-1}, respectively. Similarly exchangeable iron, manganese, copper and zinc were ranged from 5.14-9.72, 21.05-37.51, 02-0.71 and 4.34 -7.07 mg kg^{-1} with an average value of 6.88, 28.19, 0.48 and 5.60 mg kg^{-1}, respectively (Table 6).

The exchangeable aluminium widely varied from 50.82 to 125.21 mg kg^{-1}, with a mean value of 77.42 mg kg^{-1} (Table 6) which showed a toxicity in the soil. Brady (1990) suggested that these cations are adsorbed on the negatively charged soil colloids and the exchangeable aluminium ions contribute to soil acidity through hydrolysis. Abraham (1984) reported that a very high content of exchangeable aluminium is present in the rice soils of Kerala, whose pH value is less than 6.0.

Calcium was found to be the dominant on the exchange complex followed by magnesium, potassium, sodium, aluminium and manganese. Fe, Zn and Cu showed very low values and contributed less to the exchange surface.

It was reported that the soils of the Kole area had a cation exchange capacity ranging from 6.08 to 7.79 C

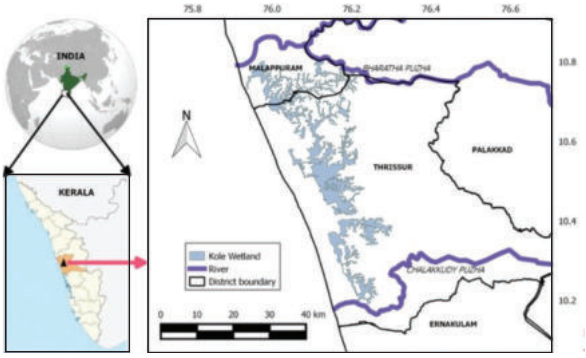

Fig. 1 : Map of Kole land

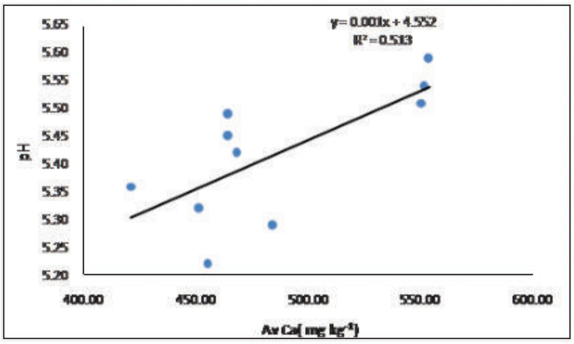

Fig. 2: Relationship between soil pH and Available Ca (mg kg^{-1})

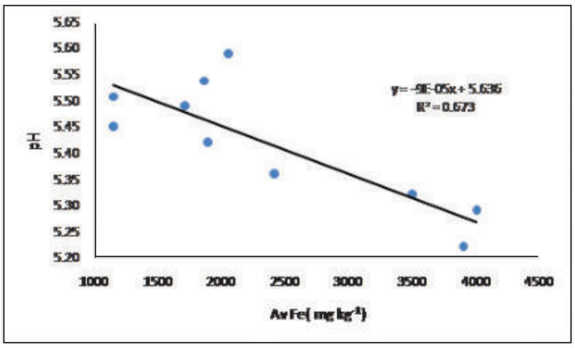

Fig. 3: Relationship between soil pH and Available Fe (mg kg^{-1})

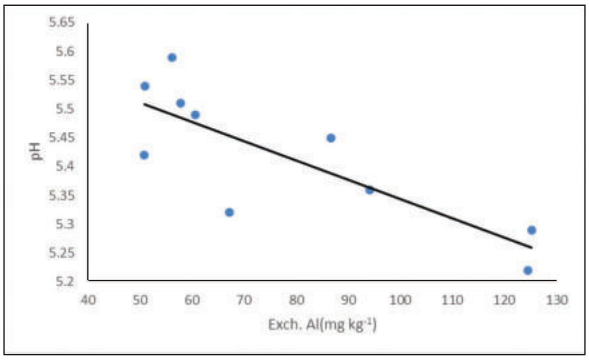

Fig. 4: Relationship between soil pH and Exchangeable Al (mg kg^{-1})

mol/kg. The clay content and organic matter were higher for the surface layer and hence also the CEC and calcium is predominant in exchangeable bases (Johnkutty and Venugopal, 1993).

Percent base saturation, indicated as the percentage of CEC occupied by the basic cations (Ca^2, Mg^{2+}, K^+& Na^+), varied from 71.99 to 95.97 percent with mean content of 81.03 % (Table 6).

Correlation between important soil chemical properties

The data in Table 7 shows the correlation coefficients between important soil properties. Soil pH was found to have a significant positive correlation with Av. Ca (0.716*) (Fig.2) and a week positive correlation with Av. K (0.655) and Av. P (0.687). At the same time, it showed a significant negative correlation with Av. Fe (-0.821**) (Fig. 3), Ex. Al (-0.81**) (Fig. 4) and moisture (-0.731*). A significant negative correlation was observed between Av. Fe and Av P (-0.741*) and a significant strong positive correlation (0.704*) between Av. Fe and Ex Al (Table 7 and 8). Abraham (1984) indicated the negative correlation of exchangeable Al and available Fe with soil pH. Konsten *et al.* (1994) reported that Aluminum toxicity along with Fe toxicity, is a major problem for wetland rice production in acid sulfate soils, which do not experience the usual increase in pH during submergence owing to lack of soil reduction.

Electrical conductivity (EC) had a significant negative correlation with Av Cu (0.675*) and Ex. Cu (0.747*), and weak negative correlation with Ex. K (-0.794*) (Table 7 and 8). Similarly organic carbon had a significant positive correlation with Av. Mg (0.685*) (Table 7).

A significant positive correlation was found between Av K and Av. Ca (0.752*). In addition, Av. K showed a significant positive correlation with Av. Mg (0.847**), Av P (0.638*), Ex. K (0.653*), Ex. Ca(0.866**) and Ex. Mg (0.665*) (Table 7 and 8). In the study conducted by Bhindu (2017), a significant positive correlation of Av. K with Av. Ca and Av. Mg was noticed.

Av. Ca was found to have a strong, significant positive correlation with Av. Mg (0.738*), Ex. K (0.811**), Ex. Ca(0.789*) and Ex. Mg (0.665*). Similarly, Av. Mg showed a significant correlation with OC (0.685*) and Av. Ca(0.738*) (Table 7 and 8). Moreover, there exists a significant positive correlation between Av. Zn and Av. Cu (0.643*) (Table 7). Av. B showed a negative correlation with Av. Mn (-0.692*) and Ex. Na (-0.699).

Among exchangeable cations, Ex. Ca and Ex. Mg were positively correlated with CEC (0.700** and

0.708*) and PBS was negatively correlated with CEC significantly. A strong positive significant correlation was observed between Ex Ca and Ex. Mg (0.883**). Ex. Mg showed a significant positive correlation with Ex. K (0.76*)(Table 9). Bailey *et al.* (2004) observed that high Ex. Ca along high Ex. Mg concentration. This is attributed to similar factors like soil minerals, pH and CEC influencing the distribution of both Ex. Ca and Ex. Mg in soils.

Microbial analysis

As shown in Table 3, the soil samples registered higher bacterial population followed by actinomycetes and fungi. The bacterial count ranged from 2×10^6 CFU/g soil to 6×10^6 CFU/g soil, fungal count ranged from 2×10^4 CFU/g soil to 4×10^4 CFU/g soil and actinomycetes population varied from 5×10^4 CFU/g soil to 7×10^4 CFU/g wet soil, respectively under rice ecosystem (Table 10). Athira (2021) reported that abundance of bacterial genera *Desulfobacca, Thermoanaerobaculum, Thioalkalispira, Anaerolinea, Ktedonobacter, Gemmatimonas, Puedolabrys, Sulfuricurvum, Syntrophobacter, Haliangium, Geobacter and Syntrophorhabdus* were observed in the Kole land rice rhizosphere samples of Thrissur and many of these genera are involved in geo-cycling of nutrients like Fe, S and Mn.

CONCLUSION

The study of northern Kole land soil in the post flood scenario revealed that the soil was loamy sand with high fertility. The strong acidity in the area causes toxicity of available Fe and Exchangeable Al. Owing to inherent properties, the soil had a medium range of available P and K, a high available S and adequate Ca and Mg. The high organic matter presents enriched the soil with bacteria, fungi and actinomycetes.

REFERENCES

Abraham, A. 1984. The release of soluble aluminium in soils under submerged conditions and its effect on rice. Ph. D Thesis. Kerala Agricultural University. 204p.

Akpoveta, V. O., Osakwe, S. A., Ize-Iyamu1, O. K., Medjor, W. O. and Egharevba, F. 2014. Post flooding effect on soil quality in Nigeria: The Asaba, Onitsha experience. *Open J. Soil Sci*., **4**: 72-80.

Amarawansha, E. A. G. S., Kumaragamage, D., Flaten, D., Zvomuya, F. and Tenuta, M. 2015. Phosphorus mobilization from manure-amended and unamended alkaline soils to overlying water during simulated flooding. *J. Environ. Qual.,* **44**: 1252-1262.

Amery, F. and Smolders, E. 2012. Unlocking fixed soil phosphorus upon waterlogging can be promoted by increasing soil cation exchange capacity. *Eur. J. Soil Sci.,* **5**: 1-8.

Amritha, K. and Durga Devi, K. M. 2017. Effect of pre and post emergence herbicides on microbial biomass carbon and dehydrogenase activity in soils. *J. Trop. Agric*., **55**(1): 114-118.

Athira, K. L. R. 2021. Metagenomic analysis of bacterial diversity in the rice rhizosphere of kole lands of Thrissur. M.Sc. (Ag) Thesis. Kerala Agricultural University. 108p.

Bailey, S. W., Horsley, S. B., Long, R. P. and Hallett, R. A. 2004. Influence of Edaphic factors on sugar maple nutrition and health on the Allegheny plateau. *Soil Sci. Soc. Am. J*., **68**: 243-252.

Bhindu, P. S. 2017. Chemistry and transformations of calcium and magnesium in tropical acid soils of Kerala. Ph. D. (Ag.) Thesis. Kerala Agricultural University. 283p.

Bhingham, F.T. 1982. Boron. In: *Page, A.L., Ed., Methods of Soil Analysis Part-2 Chemical and Mineralogical Properties*, American Society of Agronomy, Madison. pp. 431-448.

Brady, N. C. 1990. The nature and properties of soils. (10th Ed.). MacMillan publ. Co., N.Y. pp. 7-16.

Emmel, R. H., Soter, J. J. and Stux, D. L. 1977. Atomic absorption method manual, Vol. l, Standard condition for flame operation. Instrumentation Laboratory Inc., Analytic Instrument Division, Wilmington, MA.

Fageria, N. K., Carvalho, G. D., Santos, A. B., Ferreira, E. P. B. and Knupp, A. M. 2011. Chemistry of lowland rice soils and nutrient availability. *Commun. Soil Sci. Plant Anal.,* **42**: 1913-1933.

Favre, F., Jaunet, A.M., Pernes, M., Badraoui, M., Boivin, P. and Tessier, D. 2004. Changes in clay organization due to structural iron reduction in a flooded Vertisol. *Clay Miner*., **9**: 123-134.

Gallardo, A. 2003. Spatial variability of soil properties in a floodplain forest in Northwest Spain. *Ecosystems,* **6**: 564-576.

Hendershot, W.H. and Duquette, M. 1986. A simple barium chloride method for determining cation exchange capacity and exchangeable cations. *Soil Sci. Soc. Am. J.,* **50**: 605-608.

Irene, E. J. 2014. Wet analysis for nutrient prescription in paddy soil. M. Sc. (Ag) Thesis. Kerala Agricultural University, Thrissur. 254p.

Jackson, M. L. 1958. Soil Chemical Analysis. Prentice Hall, Englewood Cliffs, NJ. 341p.

Johnkutty, I. and Venugopal, V. K. 1993. Kole Lands of Kerala. Kerala Agricultural University, Vellanikkara, Thrissur. 77p.

Kavitha, C., Sujatha, M. P. and Royal, T. 2019. Spatial variations in soil micronutrients as influenced by agroecological conditions in a tropic humid region. *Trop. Ecol*. **37**: 1-17.

Kavitha, C. 2018. GIS based soil fertility mapping in agro-ecosystems of Thrissur district, Kerala. Ph. D Thesis. Cochin University of Science and Technology, Kerala. 78p.

Kirk, G. J. D., Solivas, J. L. and Alberto, M. C. 2003. Effects of flooding and redox conditions on solute diffusion in soil. *Eur. J. Soil Sci.,* **54**: 617-624.

Konsten, C. J. M., van Breemen, N., Suping, S., Aribawa, I. B. and Groenenberg, J. E. 1994. Effects of flooding on pH of rice-producing, acid sulfate soils in Indonesia. *Soil Sci. Soc. Am. J*., **58**: 871-883.

Massoumi, J. and Cornfield, A. H. 1963. A rapid method for determination of sulphate in water extracts of soils. *Analyst,* **88**: 321-322.

Muraleedharan, P. K. 1984. Economics of Kole (paddy) cultivation in Thrissur district. Ph.D. Thesis, University of Calicut, Malappuram. 62p.

Ponnamperuma, F. N. 1972. The chemistry of submerged soils. *Adv. Agron.,* **24**: 29-96.

Pratt, P. F. 1965. Potassium. In : '*Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties'. (Ed. Black, C. A.)*, American Society of Agronomy,: Madison, Wisconsin. pp. 1023-1031.

Rajasekharan, P., Nair, K. M., John, K. S., Sureshkumar, P., Kutty, M. C. N. and Nair, A. R. 2014. Soil fertility related constraints to crop production in Kerala. *Indian J. Fert*., **10**: 56-62.

Robertson, L. S. and Lucas, R. E. 1981. Zinc: an essential plant micronutrient. *Geoderma*, **98:** 123-12.

Robinson, G. W. 1922. A new method for the mechanical analysis of soils and other dispersions. *J. Agri. Sci.,* **12**: 306-321.

Sahrawat, K. L. 2004. Iron toxicity in wetland rice and the role of other nutrients. *J. Plant Nutr.,* **27**: 1471-1504.

Santhosh, C. 2013. Chemistry and transformation of boron in soils of Kerala. Ph.D. (Ag.) Thesis. Kerala Agricultural University, Thrissur. 257p.

Safnathmol, P. 2020. Assessment of soil quality in the post flood scenario of aeu 6 in Thrissur and malappuram districts of Kerala and mapping using GIS techniques. M.Sc. (Ag) Thesis. Kerala Agricultural University, Thrissur, 112p.

Sims, J. R. and Johnson, G. V. 1991. Micronutrient soil tests. In: *Mortvedt, J. J., Cox, F. R., Shuman, L. M. and Welch, R. M. (Eds), Micronutrient in Agriculture (2nd Ed.)*. Soil Science Society of America, Madison, USA, pp. 427-476.

Sivaperuman, C. and Jayson, E. A. 2000. Birds of Kole wetlands, Thrissur, Kerala. *Zoos Print J.,* **15**: 344-349.

Sujani, K.A. and Sivaperuman C. 2008. Preliminary studies on flora of Kole wetlands, Thrissur, Kerala. *Indian Forester,* **134**: 1079-1086.

Sureshkumar, P. and Sandeep, S. 2015. Secondary nutrients in soils and their management. In: *Rattan, R. K., Katyal, J. C., Dwivedi, B. S., Sarkar, A. K., Bhattacharyya, T., Tarafdar, J. C., and Kukal, S. S. (eds), Soil Science: an Introduction.* Indian Society of Soil Science, New Delhi. pp. 601-623.

Thampatti, K.C. M. and Jose, A. I. 2000. Characterization of acid saline rice based wetland ecosystems of Kuttanad, Kerala and their salinity protection by Thanneermukkom regulator. *Agropedology,* **10**: 108-115.

Thomas, K. J., Sreekumar, S. and Cheriyan, J. 2003. Muriyad wetlands: Ecological changes and human consequences. Kerala Research Programme on Local Development, Thiruvananthapuram. 83p.

Walkley, A. and Black, T. A. 1934. An examination of the Degt. Jarett method for determination of soil organic matter and a proposed modification of cromic acid titration. *Soil Sci.,* **37**: 29-38.