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Characterization of Acidity in Acid Saline hydromorphic Soils of Southern Kerala

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ABSTRACT: The acid saline soils of the State are characterized as highly saline (EC>4), EC during summers range between 2.00-21.00 dSm^{-1} and potential acidic while post monsoon soils are These soils suffer from severe acidity and the presence of detrimental concentrations of Fe, Al, and S, which typically limit crop production and crop choice in these soils. As a result, characterization of soil acidity is most warranted here in order to create a suitable acidity amelioration/management technique. The acidity attributes of acid saline soils of Southern Kerala, known as Orumundakan were studied for two crop growing season in two phases of monsoon by collecting surface soil samples from 200 sampling sites of 17 panchayaths that belong to saline hydromorphic soils. The soils reactions ranged from ultra-acid to very strongly acid showing a pH (H_2O) range of 3.09 to 4.49 in saline pre-monsoon phase and ranged between 5.01-5.62 in non-saline post-monsoon rice growing season. Lowest pH of 3.09 in saline phase was observed in Devikulangara panchayath of Alappuzha and highest of 5.62 in Muthukulam. Exchangeable acidity ranged between 1.30 to 5.10 cmol kg^{-1}. The potential acidity of soils ranged from 19.40 to 35.80 cmol kg^{-1}. The contribution of hydrolytic acidity to potential acidity ranged from 82.93 % to 95.89 % in pre-monsoon phase while in post-monsoon phase it ranged between 85.06 % to 96.61 %. Exchangeable Al^{3+} contributed greatly than exchangeable H^+ to exchangeable acidity.

Keywords: Acid saline soils, exchangeable acidity, potential acidity, hydrolytic acidity, Orumundakan.

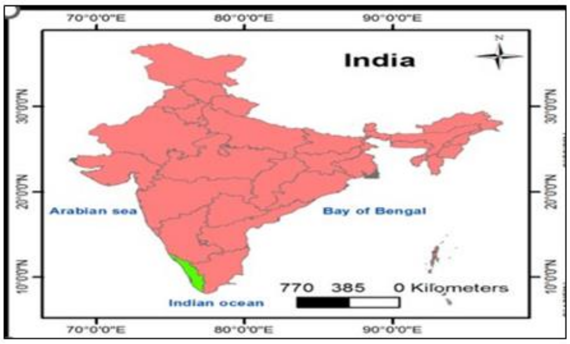
INTRODUCTION

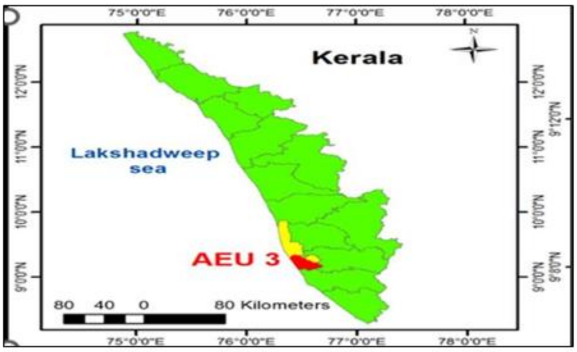
One of the primary restrictions to crop yield in tropical soils is soil acidity. Acidic soils cover over half of all arable land on the planet, and the problem of soil acidification has gotten worsened in many agricultural systems in recent years (Dai *et al.*, 2017). Kerala soils have intrinsic physical and chemical constraints owing to the geographical location and climatic conditions of the state. Acid saline soils developed from alluvial and colluvial deposits with tidal influence and found at or below sea level, located between coastal sand and midland laterite of the state have unique existence (Goulding, 2016). High seasonal variability is observed resulting in accumulation or build-up of some essential nutrient to toxic levels during summer while same nutrients is limited after monsoon shower. These soils are affluent in terms of available nutrients, but they are limited by salinity, acidity, iron and aluminium toxicity.

Because of tidal influence and rainfall pattern, nutrients such as nitrates (NO_3^-), potassium (K^+), magnesium (Mg^{2+}), and boron (B) exhibit high seasonal variations. During the summer months, high tides cause the deposition of sodium, potassium, and magnesium salts, primarily as chlorides and sulphates, resulting in severe salinity. Once salinity is washed off by monsoon acidity limits the crop production of this tract. Declining rice cultivating area and thus productivity of the state enforce to manage the potential but constrained lowlands to meet the food requirement of the state and also these lowlands/coastal wetlands are the lifeline of the state. Salinity constrains of these coastal ecosystems are mainly seasonal but acidity and presence of Fe, Al and S in toxic levels usually limit the crop production and even the choice of crop in these soils (Yadav *et al.*, 2017). The knowledge of the most serious soil condition, soil acidity, is critical for managing and sustaining rice production and soil health in these soils (Mathew *et al.*, 2022). According to recent research, pH-dependent and hydrolytic acidities comprise about 86 to 99 and 77 to 97 percent of total potential acidity and total acidity, respectively, with exchangeable acidity contributing only 0.8 to 22.6%. In high-acid soils, exchangeable acidity ranges from 0.79 to 7.61 cmol (p+) kg^{1} and is largely made up of exchangeable Al^{3+} (Gangopadhyay *et al.*, 2016). The characterization of soil acidity is of particular importance here in order to develop a proper acidity amelioration/management method. Though numerous studies on characteristics of acid sulphate and other acid saline soils of the state were done, no work as been done so far for characterization of acidity of this tract. The current research discusses the contribution of different acidity components to potential acidity, which will aid in determining the best appropriate method for regulating acidity in these hydromorphic soils.

MATERIALS AND METHODS

Acid saline soils of Onattukara sandy plain (AEU 3) are Orumundakan soils. Onattukara is a fluvial and marine sand area of Kerala state covering an area of 67, 447 ha (1.74 %) of state. AEU 3 is spread over 43 panchayaths under eight blocks and two municipalities and three major taluks *viz*., of Kollam and Alappuzha districts. Onattukara sandy plain experiences a tropical humid monsoon type. The mean annual temperature and rainfall are 27.6 c and 2492 mm respectively. The probability of annual moderate drought is negligible. Soil moisture is adequate for crops from 2nd week of April to 2nd week of December. This tract experiences a soil moisture deficit for around four months. Pyrites, pyrolites, jarosite, goethite, and quartz are the major minerals in these soils. A semi-detailed soil survey to assess the seasonal variation in nutrient status of rice-grown acid saline soils of Onattukara sandy plain (AEU3) was conducted. Exchangeable acidity, exchangeable Al^{3+}, exchangeable H^{+}, potential acidity, hydrolytic acidity was determined as per standard procedures described by Page *et al*. (1982); Hesse (1971). Nutrient status of the soils including primary, secondary, micronutrients and beneficial elements were studied.





RESULTS AND DISCUSSION

The study area was confined to the saline hydromorphic condition of Southern Kerala. Though numerous research has been done on soils of similar characteristics in the state no or little is known about the soils of this tract. Potentially productive but nutrient constrained lowlands of Southern Kerala need to be studied for identification of limiting factors. Though the soils are subjected to sea water ingression during summers acidity remain dominated throughout the growing season.

Acidity characteristics of surface samples. The seasonal variation in soil acidity characteristics are given in Fig. 1-6. The lowest and highest pH was recorded as 3.09 and 4.49 respectively. Of the 200 post-monsoon soil samples, 93.5 per cent were very strongly acidic and the remaining 6.5 per cent of soils were moderately acidic. The lowest increase in soil reaction following monsoon was observed as 5.01 and the highest pH attained was 5.62. The overall change in mean soil reaction was from 3.98 inthe saline phase to 5.18 in the non-saline phase.

The transition from a saline to a non-saline environment caused a significant drop in potential acidity. Potential acidity ranged between 19.40 cmol kg^{-1} to 35.80 cmol kg^{-1} with a mean of 30.83±2.61 $cmol^{-1}$ in saline soils. Post-monsoon value of potential acidity ranged from 13.00 cmol kg^{-1} to 23.80 cmol kg^{-1} with a mean of 19.54±2.04 cmol kg^{-1}. Exchangeable acidity varied between 1.30 cmol kg^{-1} and 5.10 cmol kg^{-1} in pre-monsoon soils with a mean value of 2.96±0.84 cmol kg^{-1}. Post-monsoon soils exhibited lower values ranging from 0.60 cmol kg^{-1} to 3.80 cmol kg^{-1} and a mean of 1.77±0.62 cmol kg^{-1} was perceived. Observations on hydrolytic acidity were similar to exchangeable and potential acidity. Hydrolytic acidity of pre-monsoon soils ranged between 17.00 cmol kg^{-1} and 32.20 cmol kg^{-1} with a mean value of 27.87±2.59 cmol kg^{-1}. The decline in hydrolytic acidity following the transition of soil environment caused a drop in values and hydrolytic acidity ranged from 11.30 cmol kg^{-1} to 22.80 cmol kg^{-1} and a lower mean of 18.14±2.11 cmol kg^{-1} was recorded. The potential acidity comprised of exchangeable acidity and hydrolytic acidity, with hydrolytic acidity being the major contributor to total acidity. The contribution of hydrolytic acidity to potential acidity ranged between 88.77 % and 91.13 % in saline phase while higher vales between 90.18 % and 94.50 % was observed in post-monsoon phase. The contribution of exchangeable acidity to potential acidity was very merge. Exchangeable Al^{3+} had comparatively major share in contributing to exchangeable acidity.

Table 1: Seasonal variation in soil reaction (pH).

District	Panchayath	Pre-monsoon pH (dS m^{-1})		Post-monsoon pH (dS m^{-1})	
		Range	Mean ± SD	Range	Mean ± SD
	Neendakara	3.32-4.44	**4.10±0.43**	5.11-5.35	**5.23±0.11**
	Chavara	3.27-4.48	**3.92±0.48**	5.01-5.53	**5.22±0.17**
	West Kallada	3.12-4.21	**3.69±0.46**	5.11-5.51	5.25±**0.14**
	Panmana	3.39-4.38	**4.02±0.35**	5.01-5.53	5.21±**0.15**
	Alappad	3.19-4.49	**3.93±0.43**	5.01-5.55	5.17±**0.15**
	Karunagapally	3.39-4.48	**4.06±0.46**	5.12-5.53	5.23±**0.16**
Kollam	Kulasekharapuram	3.38-4.49	**4.12±0.28**	5.02-5.25	5.11±**0.08**
	Thazhava	3.27-4.49	**4.00±0.52**	5.03-5.21	5.11±**0.05**
	Clappana	3.31-4.45	**3.98±0.41**	5.02-5.31	5.13±**0.09**
	Ochira	3.32-4.49	**4.11±0.46**	5.03-5.55	5.14±**0.14**
	Devikulangara	3.09-4.43	**3.94±0.54**	5.05-5.55	5.17±**0.10**
	Muthukulam	3.22-4.37	**3.97±0.43**	5.01-5.62	5.19±**0.19**
Alappuzha	Arattupuzha	3.28-4.38	**3.95±0.45**	5.13-5.61	5.18±**0.16**
	Cheppad	3.39-4.49	**3.97±0.45**	5.11-5.61	5.28±**0.20**
	Chingoli	3.21-4.49	**4.12±0.46**	5.01-5.33	5.14±**0.09**
	Karthikapally	3.22-4.46	**3.88±0.47**	5.01-5.33	5.17±**0.11**
	Thycattussery	3.24-4.41	**3.90±0.49**	5.06-5.26	5.15±**0.08**
	Average	**3.09-4.49**	**3.98 ±0.44**	**5.01-5.62**	**5.18±0.13**

Table 2: Acidity parameters of surface samples of Acid saline soils of Southern Kerala during saline phase.

Sample location	Exchangeable acidity (Cmol kg^{-1})	Potential acidity (Cmol kg^{-1})	Hydrolytic acidity (Cmol kg^{-1})	Contribution to pot. AcidityEx. Acid Hy. Acid (Cmol kg^{-1})		Contribution to Hyd. AcidityEx. Al Ex. H^{+} (Cmol kg^{-1})	
Neendakara	2.61	30.08	27.47	8.73	91.27	1.58	1.01
Chavara	2.97	30.36	27.39	9.85	90.15	1.71	1.25
West Kallada	2.75	30.20	27.45	9.25	90.75	1.72	1.03
Panmana	3.09	29.68	26.59	10.50	89.50	1.79	1.30
Alappad	2.81	31.98	29.17	8.87	91.13	1.65	1.16
Karunagapally	2.74	29.72	26.98	9.31	90.69	1.60	1.14
Kulasekharapuram	2.79	31.81	29.03	8.88	91.12	1.53	1.25
Thazhava	3.08	31.58	28.50	9.76	90.24	1.47	1.61
Clappana	2.99	31.50	28.51	9.47	90.53	1.51	1.48
Ochira	2.77	29.84	27.07	9.22	90.78	1.43	1.34
Devikulangara	2.95	30.64	27.69	9.57	90.43	1.75	1.21
Muthukulam	2.91	30.56	27.65	9.52	90.48	1.70	1.21
Arattupuzha	3.13	31.20	28.07	10.06	89.94	1.80	1.33
Cheppad	2.95	30.11	27.15	9.81	90.19	1.78	1.17
Chingoli	2.88	30.44	27.56	9.35	90.65	1.77	1.11
Karthikapally	3.51	31.63	28.11	11.23	88.77	1.95	1.57
Thrikkunappuzha	3.46	33.20	29.74	10.48	89.52	1.92	1.53
Average	2.61-3.51	29.68-33.20	26.59-29.74	9.64 90.36		1.69	1.28

The acidic pH of the soil might have been attributed mainly due to the presence of acidic parent material, presence of large quantities ofsulphide which under dry condition have oxidize to produced sulphuric acid. Heavy use of fertilizers with residual acidity and infrequent lime applications to neutralize the acidity produced may be the prime causes of the development of significant acid conditions in the soil as per KSPB report (2013). The subsequent increase in soil pH following submergence in acid soils is due to soil reduction (Ponnamperumal *et al.*, 1972). When the nitrateproduced by the nitrification of ammonium ion is removed from the soil, acidification takes place (Marschner, 2012). High rainfall of humid tropical regions results in intense weathering and leaching leading to the formation of ferruginous soils characterized as low in basic cations and accumulation of acid forming ions like H^{+} and Al^{3+} leading to development of soil acidity. Under submergence high concentration of CO_2 builds in soils along with limited organic matter decomposition and low redox potential. Soil organic matter has a variety of functional groups that contain H^{+} ions and contribute to various types of acidity.

Table 3: Acidity parameters of surface samples of Acid saline soils of Southern Kerala during non-saline phase.

Sample location	Exchangeable acidity (Cmol kg^{-1})	Potential acidity (Cmol kg^{-1})	Hydrolytic acidity (Cmol kg^{-1})	Contribution to pot. Acidity Ex. Acid Hy. Acid (Cmol kg^{-1})		Contribution to Hyd. Acidity Ex. Al Ex. H$^+$ (Cmol kg^{-1})	
				Ex. Acid	Hy. Acid	Ex. Al	Ex. H$^+$
Neendakara	1.61	20.72	19.32	7.98	93.11	6.23	2.39
Chavara	1.67	19.36	17.94	8.61	92.64	17.94	2.85
West Kallada	1.70	19.66	18.34	8.72	93.24	6.85	2.54
Panmana	1.88	19.78	18.37	9.62	92.81	7.15	3.33
Alappad	1.65	20.84	19.66	8.18	94.26	6.31	2.46
Karunagapally	1.52	19.75	18.67	7.73	94.50	6.02	2.18
Kulasekharapuram	1.68	20.69	19.45	8.19	93.89	5.46	3.32
Thazhava	1.74	18.55	17.11	9.43	92.21	6.03	4.25
Clappana	1.76	19.52	17.89	9.05	91.58	5.83	4.14
Ochira	1.59	19.74	18.45	8.08	93.42	5.04	3.66
Devikulangara	1.80	20.59	19.15	8.65	93.05	6.51	2.95
Muthukulam	1.69	19.52	18.17	8.67	93.09	6.53	2.85
Arattupuzha	1.91	19.69	18.16	9.67	92.26	7.12	3.50
Cheppad	1.84	18.65	17.15	9.86	91.89	7.45	3.39
Chingoli	1.76	18.30	16.89	9.66	92.22	7.49	3.15
Karthikapally	2.19	17.24	15.57	12.90	90.18	9.73	4.68
Thrikkunappuzha	2.14	20.00	18.29	10.86	91.33	7.87	4.10
Average	1.77	19.56	18.15	9.17	92.69	7.39	3.28

It was observed that pH dependent acidity values were greater than exchangeable acidity values as pH-dependent acidity increased linearly with organic carbon, and free Fe and Al oxides. The very low contribution of exchangeable acidity to total acidity is consistent with the findings of many other researchers (Thampatti& Jose 2000). The proportion of exchangeable acidity in total acidity varies with soil type and base saturation. H+ and Al^{3+} are not the only ions that contribute to soil acidity; Fe and Mn, the principal hydrolysable ions in soil complex exchange sites, also contribute to soil acidity, which has gone unaccounted for on the basis of these two types of acidity. 92 % of total state soil is acidic with pH range between 2.9 and 7.0 with lowest value is recorded in acid saline Pokkali soils (dried samples) (Bhindhu *et al*., 2018). Reduction of basic cations during biomass harvesting and leaching of base cations during monsoon will significantly contribute to soil acidification (Marcar & Khanna 2008).

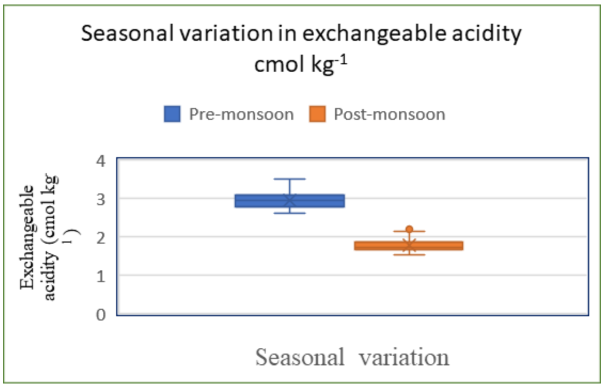


Fig. 1. Seasonal variation in exchangeable acidity (cmol kg^{-1}).

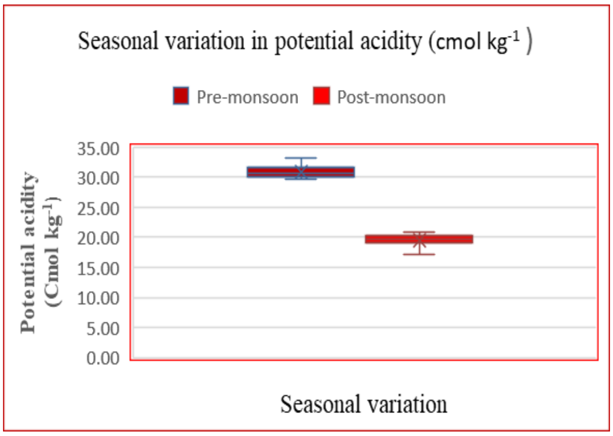


Fig. 2. Seasonal variation in potential acidity (cmol kg^{-1}).

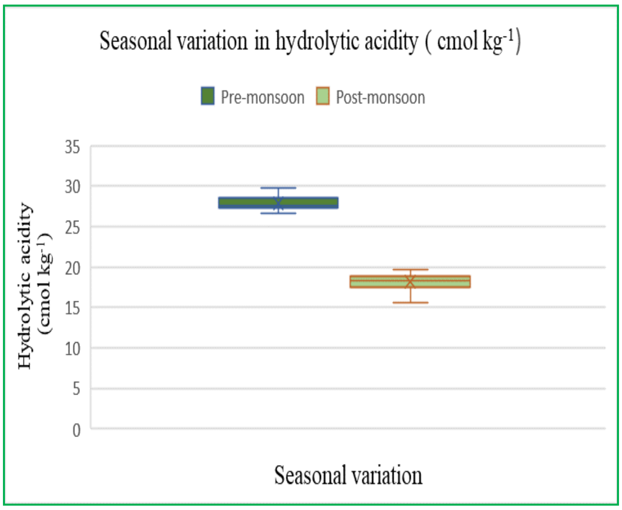


Fig. 3. Seasonal variation in hydrolytic acidity (cmol kg^{-1}).

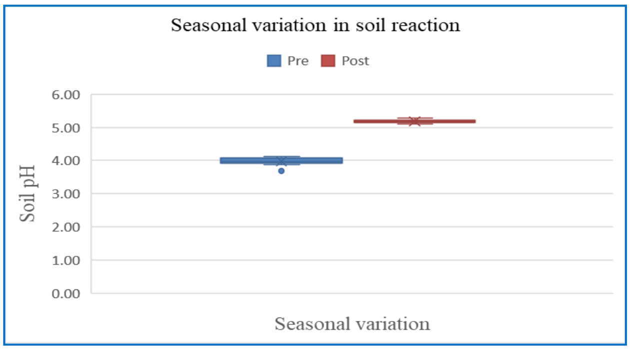


Fig. 4. Seasonal variation in soil reaction.

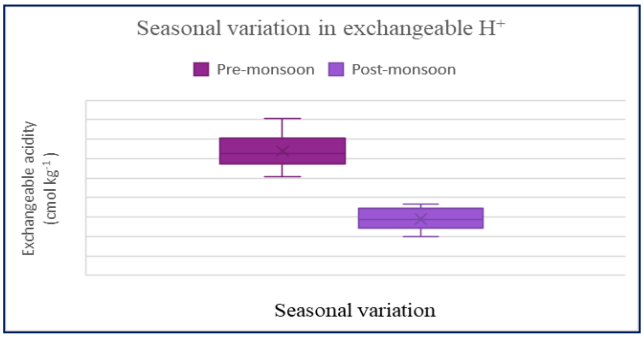


Fig. 5. Seasonal variation in soil exchangeable H^{+}.

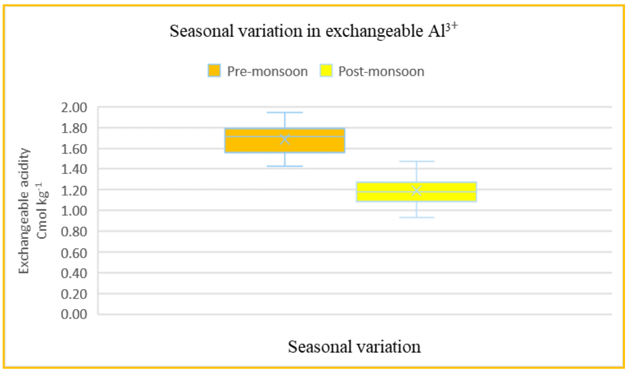


Fig. 6. Seasonal variation in soil exchangeable Al^{3+}.

The low contribution of exchangeable acidity to total acidity might be due to the saline water intrusion even for a short period was able to remove a significant amount of exchangeable acidity from the soils. According to Van Mensvoort *et al*. (1991), in acid sulphate soils, Al^{3+} can be substituted by Na^{+} and Mg^{++} in salt or brackish water which aids in lowering acidity caused by these ions ow exchangeable acidity could be attributed to the effective recycling of exchangeable sites with basic cations. Also, the alkalinity of soil amendments, followed by decarboxylation of organic anion and ammonification of organic N, could be key explanations for the low E_a, albeit nitrification of mineralized N could generate protons to some extent (Cai *et al*., 2016).

CONCLUSIONS

Seasonal variation caused significant fluctuation in soil properties. The acid saline soils of Orumundakan tract recorded very low pH of 3.09 in saline phase which increased to a maximum of 5.62 in post-monsoon phase. The increase in soil reaction and reduction in acidity attributes following monsoon can be due to substitution of acidic ions such as H^{+} and Al^{3+} with basic cations. The potential acidity was very high compared to exchangeable acidity. Understanding of soil reaction is of prime importance for nutrient management and thus the agriculture production depends on soil reaction and acidity attributes. Liming and flushing out of salt, intermittent water stagnation, subsurface drainage can reduce surface acidity. The acidic, low- fertile and poor nutrient and water retention capable soils of Kerala need soil test-based, site-specific and crop-specific nutrient management strategiesfor sustainable crop production.

FUTURE SCOPE

We advocate a good soil management strategy that reduces surface and subsurface acidity as well as the harmful amount of metals found in low-pH soil. Again, for the best results in terms of biomass production and economic crop yields, management of soil acidification should be followed by adequate plant nutrient inputs.

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Conflict of Interest. None.

REFERENCES

Dai, Z., Zhang, X., Tang, C., Muhammad, N., Wu, J., Brookes, P. C. & Xu, J. (2017). Potential role of biochar in decreasing soil acidification-a critical review. *Science of the Total Environment*, *581*, 601-611.

Bhindhu, P. S., Sureshkumar, P., Abraham, M. & Kurien, E. K. (2018). Effect of liming on soil properties, nutrient content and yield of wetland rice in acid tropical soils of kerala. *International Journal of Bio-resource and Stress Management*, *9*(4), 541-546.

Cai, Z., Wang, B., Xu, M., Zhang, H., He, X., Zhang, L. & Gao, S. (2015). Intensified soil acidification from chemical N fertilization and prevention by manure in an 18-year field experiment in the red soil of southern China. *Journal of Soils and Sediments*, *15*, 260-270.

Gangopadhyay, S. K., Nayak, D. C. & Singh, S. K. (2016). Characteristics of tea growing soils in relation to soil acidity in upper Brahmaputra valley of Assam. *Journal of the Indian Society of Soil Science*, *64*(4), 341-350.

Goulding, K. W. T. (2016). Soil acidification and the importance of liming agricultural soils with particular reference to the United Kingdom. *Soil use and management*, *32*(3), 390-399.

Hesse, P. R. (1971). A Textbook of Soil Chemical Analysis. William Clowes & Sons. London, UK.

KSPB [Kerala State Planning Board]. 2013. Soil Fertility Assessment and Information Management for Enhancing Crop Productivity in Kerala. Kerala State Planning Board, Thiruvananthapuram, 514p.

Marcar, N. E. & Khanna, P. K. (1997). Reforestation of salt-affected and acid soils. *Management of soil, nutrients and water in tropical plantation forests*, 481-525.

Marschner, P. (2012). Rhizosphere biology. In Marschner's mineral nutrition of higher plants (pp. 369-388). Academic Press.

Mathew, J., Haris, A. A., Indhuja, S., Krishnakumar, V., Nair, K. M., Bhat, R. & Kumar, K. A. (2022). Effectiveness of site-specific management practices on the amelioration of soil acidity in the coconut growing entisol and ultisol of humid tropics. *Journal of Soil Science and Plant Nutrition*, 1-14.

Page, A. L., Miller, R. H. & Keeney, D. R. (1982). Methods Of Soil Analysis, Part 2-Chemical and Microbiological Properties, /Soil Science Society of America.

Ponnamperuma, F. N. (1972). The chemistry of submerged soils. *Advances in agronomy, 24,* 29-96.

Thampatti, K. M. & Jose, A. I. (2000). Characterization of acid saline rice-based wetland ecosystems of Kuttanad, Kerala, and their salinity protection by Thanneermukkom regulator. *Agropodology, 10,* 111-115.

Van Mensvoort, M. E. F., Van Ni, D. & Schans, J. (1991). Improvement of acid sulphate soils by leaching with salt or brackish water.

Yadav, P. I., Manu, C. R. & Abraham, N. (2017). Silicon nutrition for sustainable rice production in iron toxic laterite soils of Kollam District in Kerala. *Journal of Krishi Vigyan, 5*(2), 150-153.

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