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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(7): 913-918

www.thepharmajournal.com
Received: 24-04-2023
Accepted: 29-05-2023

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A customized nutrient formulation for saline hydromorphic soils of southern coastal wetlands (AEU 3) of Kerala based on the weighted average method of nutrient status evaluation

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Abstract
The acid-saline soils of Kerala are unique in their origin and existence. These soils are known for the special saline farming practices or the varieties followed locally as Pokkali, a geographically indicated acid and saline-tolerant rice cultivar and Kaipad, which is a saline-prone and naturally organic tract of northern Kerala. Orumundakan soils constitute acid saline soils of agroecological unit 3 of the state, unlike the similar acid saline soils found in the southern and northern districts, these soils are nutrient-poor and lack water and nutrient retention. A semi-detailed soil survey was conducted to characterise the 200 geo-referenced soil samples in the pre-growing season (September) and soil was analysed for its major primary, secondary, micro and beneficial nutrients. The mean nutrient status of blocks was determined considering the area thus deriving the nutrient status of this special agroecological Unit by the weighted average method. It can be more meaningful and reasonable at arriving the formulation composition recommendation for rice fields in this AEU. Based on the weighted average data of 17 panchayaths spanning in 6 blocks of AEU revealed that the soils of AEU had a soil reaction of 5.05, soluble salt content expressed as the electrical conductivity of 1.39 dS m^{-1}, OC- 0.69, soil available nitrogen- 251.64 kg ha^{-1}, Phosphorus and potassium content of 40.93 and 194.72 kg ha^{-1}, secondary nutrients of Ca-163.64 ppm, Mg and S of 50.24 and 72.98 ppm. Available micronutrients – Fe- 622.88 ppm, Mn- 10.19 ppm, Cu-0.19 ppm, Zn-0.25 ppm and B-0.27 ppm. Beneficial elements of silicon, sodium, Aluminium and chlorine were recorded at 31.45, 674.07, 107.49 and 169.91 ppm respectively. Based on results obtained revealed that soils were deficient in major nutrients except for phosphorus, iron, manganese and sulphur. The nutrient mixture was formulated with the composition of N- 1.60%, K- 12.5%, Ca- 1.88%, Mg- 5.05%, Mn- 0.16%, Cu- 0.70%, Zn- 1.20%, and B- 2.31% specific for rice growing acid saline soils of AEU 3.

Keywords: Agroecological unit, customized fertilizers, nutrient management, nutrient status, weighted average

Introduction

Kerala is a land with highly diversified physical features and agroecological conditions. Soils are subjected to humid tropical climatic conditions, periodic floods, drought, seawater intrusion, and major chemical processes. This coastal state has potentially highly productive lowlands, but nutritional constraints limit rice cultivation. Kerala's acid-saline soils comprise rice-growing soils of Pokkali, Kaipad and Orumundakan. Soils by genesis are acid and periodic seawater ingression causes seasonal salinity and its associated nutritional constraints. These fields are naturally connected to the Arabian Sea through backwaters and canals. Renowned wetlands and the backwater ecosystem of Kerala are potential areas of paddy production. The imprint of marine sediments depicted the formation of coastal sandy and acid sulphate saline soils. Soil-related constraints of the state are responsible for the stagnation and decline of productivity in the state, despite the widespread adoption of agrotechnology associated with the green revolution (Rajasekharan *et al*., 2014) [13]. Sandy soils of this tract are frequently deficient in micronutrients Zn, Cu and B hence, foliar application of micronutrient mixtures helps in the quick correction of deficiency symptoms and sustains yield (Mathew, 2007) [10].

Single-season rice cultivation of this tract commences in August after the onset of monsoon showers in the low-to-medium saline phase. Strong tidal currents and daily twice tidal flaws result in high salinity build-up during the summer months.

However, salts are not fully washed off by the monsoon showers which causes this tract to maintain comparatively higher EC. The mean nutrient status of each soil property of all the panchayath under each block and considering the area of the panchayat forms the basis of deriving the weighted average fertility status of the soil of the AEU. For optimum yield realization and sustained consumption of fertilizers especially when fertilizers are subjected or prone to losses due to soil properties realistic fertility evaluation considering the losses and general crop requirement can reduce nutrient imbalances. Moreover, the use of weighted average data can lead to the optimum use of chemical fertilizers thereby reducing the cost of cultivation as well as prevent build up nutrients in toxic levels (Anju *et al.*, 2020) [1]. Soil and crop-specific inputs especially soil amendments and customized fertilizers to delineate both soil and plant hunger and to sustain crop productivity and environmental health are inevitable. Rice-cultivating soils in general have shown lower soil health in terms of nutrient status and beneficial microbes even in irrigated areas due to the application of an inadequate and unbalanced quantity of fertilizers (Sharma *et al*., 2008) [14]. Inadequate and imbalanced supply of fertilizers and a lack of distinct fertilizer recommendations for specific agro-systems results in low yield or yield gap. The balance nutrient supply for crops resulted in optimum yield acquisition with minimum environmental hazards (Hegde *et al*., 2007) [5]. This study was undertaken to assess the nutritional status of the problematic agroecological unit 3 of the state soil to identify the limiting nutrients and thus formulate a multi-nutrient mixture.

Materials and Methods

Geographical location

Orumundakan tract is coastal wetlands spread over about 2000 hectares of southern districts of Kollam and Alappuzha in the southwest coast of Kerala near the Arabian Sea and surrounded by backwaters and river banks. This tract is located approximately 8.93° N 76.54 E, 9.29°N 76.40 E.

Agro-ecological unit (AEU 3)

Onattukara forms a peculiar agroecological zone with specific soil and climatic condition. This sandy plain of the Alappuzha and Kollam districts comprised of Chavara, Sasthamcotta, Ochira, Karunagapally blocks of Kollam and Muthukulam, Harippad, Bharanickavu, Mavelikkara and Ambalappuzha blocks of Alappuzha districts, covers an area of 40495 ha. This region lies in the lowland tract between 8°55’44” to 9 °21’09” N latitude and 76°23’13” to 76°41’16” E longitude. The average rainfall is about 2700 mm. The temperature varies from 19.2 to 33.7 °C. Onattukara soil is coarse textured with low nutrient and water retention capacity. Now problems due to micronutrient deficiencies have been reported in many parts of this region (KSPB, 2013) [9].

Ecosystem

The southern and northern synonyms of this tract namely the pokkali of Ernakulam districts and Kaipad of Kannur districts differ from this tract’s soils. Soils of Pokkali are clay in texture and organic by origin while soils of Kaipad and Orumundakan contain coarser fractions. Pokkali and Kaipad soils maintained lower salinity for the single crop season of August- January while, the Orumundakan tract retained higher salt content despite leaching with rainwater.

Methodology

The weighted average data was calculated on chemical parameters *Viz*., pH, EC, OC, N, P, K, Ca, Mg, Fe, Mn, Cu, Zn and B. The total area of the block was calculated by summing the area of the respective panchayats. The mean value of each chemical parameter of the panchayath by summing the value of the parameters of individual farmers and the block by summing the panchayaths. Soils from 6 blocks constituting 17 panchayaths were collected and analysed for 13 chemical parameters. The agroecological unit 3 is shown in Fig. 2.

Soil analysis

Surface-collected soil samples were processed before being subjected to various chemical analyses. Textural analysis was done by the international pipette method. Soil reaction and soluble salt content were determined following standard procedures (Jackson, 1973) [7]. Organic carbon was determined using Walkley and black method developed by Walkley and Black (1934) [18]. Available nitrogen estimation using the alkaline permanganate method (Subbiah and Asija, 1956) [17]. Available phosphorus, using the Bray extractant (Jackson, 1973) [7]. Available potassium using neutral normal ammonium acetate and readings were recorded in ppm using a flame photometer (Jackson, 1973) [7]. 0.15 percent $CaCl_2$ solution was used for the extraction of available sulphur, and turbidity developed using $BaCl_2$ was measured using a spectrophotometer at a wavelength of 420 nm (Jackson, 1973) [7]. Available Calcium and magnesium were extracted using ammonium acetate and determined by titration method (Hesse, 1971) [l]. Available micronutrients in this acid-saline soil were estimated using 0.1 N HCl and readings were obtained using atomic absorption spectrophotometer (Sims and Johnson, 1991) [15]. Available boron was recorded using hot water extraction and estimated using a spectrophotometer (Azomethane H method, Gupta 1972) [4].

The weighted average of each nutrient was calculated for each panchayath constituting the block and the summation of all blocks under the agroecological unit forms the basis of formulating the constituents of the customized mixture. The sequence of steps is given below

Collection, processing and analysis of 200 geo-referenced soils samples from farmer's fields covering 17 panchayaths, 6 blocks under AEU 3 for soil properties pH, EC, OC, N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, B and silicon

⇩

Determination of the mean value of each of the chemical parameters of the panchayath by summing and dividing by the number of farmer fields under each panchayath.

⇩

Determination of the mean value of each chemical parameter for the block (Summation of panchayath)

⇩

Determine the total area of the block

⇩

Determine the total area of AEU

$$\text{Determination of \% area of the block under AEU} = \frac{\text{Total area of the block}}{\text{Total area of the AEU}} \times 100$$

Determination of the weighted average of the chemical parameter for the block = Mean value of the chemical parameter of the block × % area of the block /100

Fig 1: Determination of the weighted average of soil properties of AEU 3

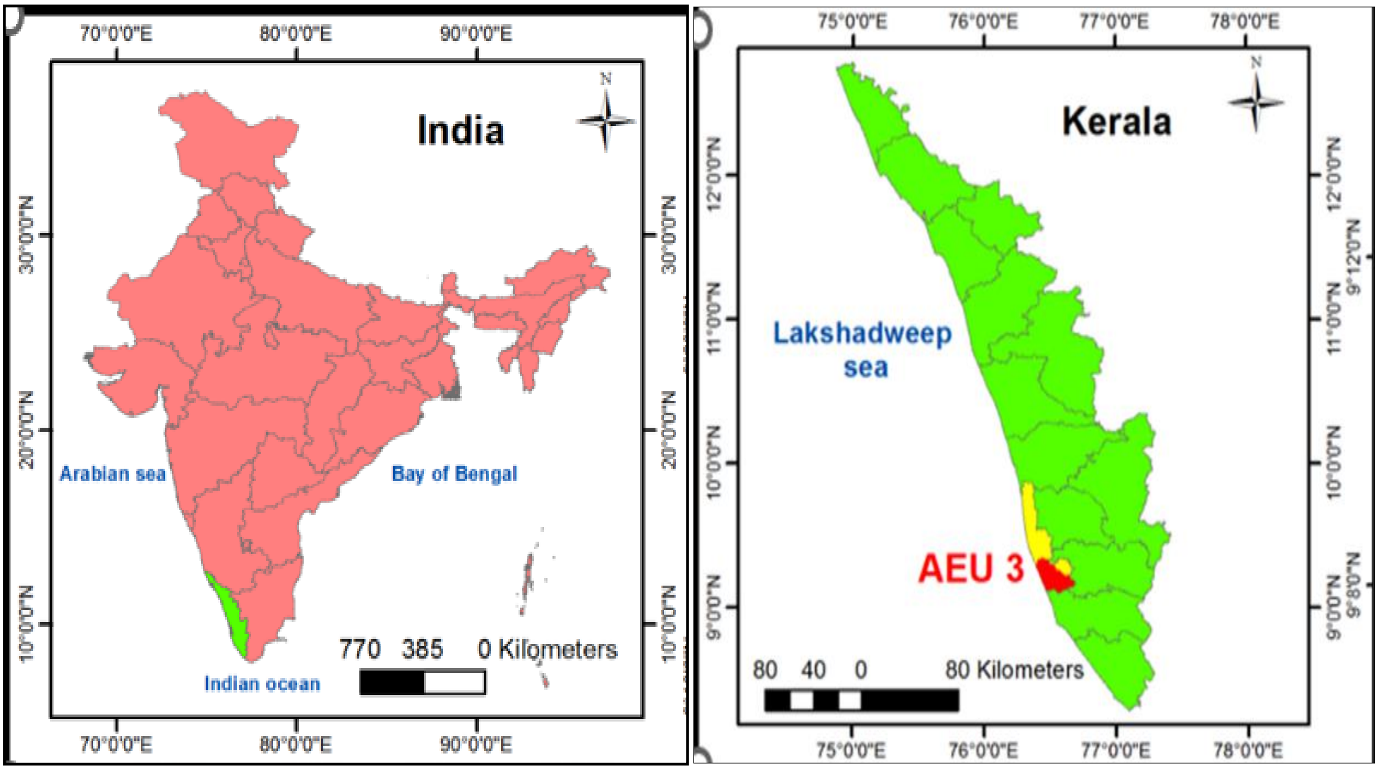

Fig 2: Agroecological unit 3

Result and Discussion

As the methodology followed soil samples from 200 sampling sites were analysed and calculated the overall mean values. The soil results are shown in Table 2. Weighted average data of the location for AEU 3 covering 6 blocks and 17 panchayaths is depicted in table 3

Nutrient status evaluation on 200 geo-referenced soil collected before the growing season revealed that these soils are strongly acidic (5.0- 5.5) and with the presence of salt, despite leaching with monsoon rains the soil maintained an electrical conductivity value of 1.39 dS m^{-1}. Soils had medium organic carbon content (0.5-0.75%). The mean nutrient status of the soils revealed that these soils have low levels of essential nutrients. Among primary nutrients, the soil was critically deficient in available nitrogen (256.27 kg ha^{-1}), rich in phosphorus (40.35 kg ha^{-1}), and medium in available potassium (222.60 kg ha^{-1}). Soils were extremely deficient in secondary nutrients of calcium, magnesium and surplus of available sulphur. The available calcium content recorded was 165.65 mg kg^{-1} which was far below the critical range of 300 mg kg^{-1}. Available magnesium was 51.52 mg kg^{-1} and available sulphur was 72.88 mg kg^{-1}. Acid-extracted micronutrient content revealed that except for available iron and manganese-these soils were deficient for all the essential micronutrients of Zn, Cu, and B. Iron and manganese was present in toxic levels of 618.21 ppm and 10.22 ppm while, copper (0.19 pp), zinc (0.24 ppm), boron (0.28) and silicon (31.38 mg kg^{-1}) deficient ratings were observed.

The weighted average data of soil properties are shown in table 3. The weighted average on soil reaction was 5.05, electrical conductivity was 1.39 dS m^{-1}, available nitrogen (251.6 kg ha^{-1}), available p (40.93 kg ha^{-1}), available k (194.7 kg ha^{-1}), available secondary nutrients (Ca- 163.6 ppm, Mg- 50.24 ppm, S-72.98 ppm), micronutrients content of 622.98 ppm Fe, 10.19 ppm Mn, 0.19 ppm of Cu, 0.24 ppm Zn, 0.27 ppm boron and 31.45 ppm silicon.

About 90 percent of the soils of Kerala are acidic among this 50 percent of soils are strong to extremely acidic in reaction. Acidic parent material and the sub-tropical humid climate prevailing in the state contribute to soil acidity and related soil constraints. The Onattukara plain elected for the present investigation forms one of the problematic coastal ecosystems with marine sand deposits with lowlands subjected to daily tidal inflows. Alternate drying and wetting of these fields caused rapid oxidation of organic marine and crop residue during summers and accumulation with partial oxidation during submergence after the monsoon. High tidal inflows during summer make this tract extremely saline with salinity recorded up to 21 dS m^{-1}. These soils built up high content of available nutrients during the pre-monsoon saline phase while post-monsoon soils show deficiency of these nutrients as these soils get partially or completely leached with rain and water bodies surrounding the lowland rice ecosystems.

The low soil reaction of these soil can be mainly attributed to the closeness of lowlands to the Sea and estuaries. Soil acidification is a major constraint in this region 94 percent of soils are acidic and 77 percent of them are strong to extremely acidic (Mini and Usha, 2015) [11]. The continuous use of acid-producing fertilizers with poor liming practices can also contribute to soil acidity. The comparatively higher electrical conductivity of these soils can be due to the incomplete washing of salts during monsoon and tidal inflows to the field. A low level of essential nutrients is attributed to the low organic matter and sandy texture of these soils permitting excess percolation and infiltration losses of these nutrients to the lower horizons of the profile. The organic matter status of sandy belts is critically low (John and Suresh Kumar, 2015) [8]. The biological transformation of N is very much restricted under submergence and low pH. Under low pH conditions, the activity of microbes responsible for nitrification is adversely affected by toxic levels of Al, Mn and Fe (Ganeshamurthy *et al*., 2012) [3]. Kerala soils in general show low status of basic cations especially K, Ca, Na and Mg. The tropical humid climate prevailing in the state (receives 200-300 cm rainfall) causes the leaching of these cations thereby resulting in highly acidic soils with low content of these nutrients (Nair *et al*., 2013) [12]. The use of the complex fertilizer factomphos (N:P: K:S @ 20:20:0:13) manufactured and widely consumed in Kerala resulted in sufficient S and P status in Kerala soils. Heavy rainfall triggers and accelerates the leaching of all basic cations including K; there is low retention of K by the dominant low-activity kaolinitic clay fraction (Rajashekharan *et al*., 2014) [13]. The toxicity of iron and aluminium elements is anticipated in flooded anaerobic rice ecosystems. Upon flooding, the above forms get solubilized and the reduced forms of iron (Fe^{2+}) and manganese (Mn^{2+}) compete with the other cations for plant uptake and this leads to the induced deficiencies of K, Ca, Mg, and Zn (Fageria *et al.*, 2011) [2]. In coarse-textured soils with low organic matter (sandy and lateritic soils of Kerala), having low pH, boron is lost down the profile by leaching when the rainfall is high. 85 percent soils of Onattukara are deficient in available boron (Mini and Usha, 2015) [11].

Table 1: Rating of nutrients considered for the study

Parameters	Low	Medium	High
Organic carbon (%)	<0.5	0.5-0.75	>0.75
Available N (kg ha^{-1})	<280	280-560	>560
Available P	<11	11-22	>22
Available K	<118	118-280	>280
Available secondary nutrients			
Deficiency limit Sufficiency limit			
Available Ca (mg kg^{-1})	<300	>300	
Available Mg (mg kg^{-1})	<120	>120	
Available S (mg kg^{-1})	<5	5-10	
Available micronutrients (mg kg^{-1})			
0.1N HCl -Fe	<5.00	>5.00	
0.1N HCl -Mn	<1.00	>1.00	
0.1N HCl -Cu	<0.12	>0.12	
0.1N HCl -Zn	<0.60	>0.60	
Hot water extracted Boron	<0.50	>0.50	

Table 2: Overall mean nutrient status of the location under AEU 3

Parameters	value
pH (1: 2.5)	5.02
EC (d Sm^{-1})	1.39 dS m^{-1}
Texture	Sandy loam
Bulk density Mg m^{-3}	1.31
Organic carbon (%)	0.69
Available nitrogen kg ha^{-1}	256.27
Available Phosphorus kg ha^{-1}	40.35
Available potassium kg ha^{-1}	222.60
Available calcium (mg kg^{-1})	165.65
Available magnesium (mg kg^{-1})	51.52
Available sulphur (mg kg^{-1})	72.88
Available iron (mg kg^{-1})	618.21
Available manganese (mg kg^{-1})	10.22
Available Zinc (mg kg^{-1})	0.24
Available Copper (mg kg^{-1})	0.19
Available boron (mg kg^{-1})	0.28
Available silicon (mg kg^{-1})	31.38

Blocks	Area (km^2)	No of panchayats	% of area	B mg kg^{-1}	Si mg kg^{-1}
Chavara	38.93	3	16.36	0.05	5.42
Sasthamcotta	13.36	1	5.61	0.01	1.95
Karunagapally	33.17	2	13.94	0.04	4.96
Ochira	70.68	4	29.69	0.08	9.21
Muthukulam	60.62	5	25.47	0.07	7.11
Haripad	21.26	2	8.93	0.02	2.80
AEU 3	238.02	17		0.27	31.45

Table 3: Weighted average data of the chemical parameters of AEU 3

Blocks	Area (km^2)	No of panchayats	% of area	pH (1:2.5)	EC dS m^{-1}	OC %	(Kg ha^{-1}) N	P	K	mg kg^{-1} Ca	Mg	S	Fe	Mn	Cu	Zn
Chavara	38.93	3	16.36	0.81	0.21	0.09	37.56	7.27	29.74	27.23	9.26	11.41	95.22	1.60	0.03	0.04
Sasthamcotta	13.36	1	5.61	0.28	0.08	0.04	11.51	2.44	10.05	9.14	2.32	3.85	29.95	0.58	0.01	0.01
Karunagapally	33.17	2	13.94	0.70	0.19	0.09	32.16	5.47	30.37	21.58	5.53	9.34	81.23	1.23	0.03	0.03
Ochira	70.68	4	29.69	1.51	0.46	0.18	78.70	11.70	58.03	48.52	15.85	23.77	203.60	3.20	0.05	0.07
Muthukulam	60.62	5	25.47	1.29	0.34	0.23	69.01	10.09	51.23	42.71	12.49	18.66	160.78	2.69	0.05	0.07
Haripad	21.26	2	8.93	0.46	0.11	0.06	22.70	3.51	15.30	14.46	4.79	5.95	52.10	0.89	0.02	0.02
AEU 3	238.02	17		5.05	1.39	0.69	251.6	40.93	194.7	163.6	50.24	72.98	622.88	10.19	0.19	0.24

Conclusion
General recommendations of fertilizers fail to meet crop requirements, especially in problematic soils. New and improved attempts to customize nutrient management are critical in fighting food and nutritional security. Customized nutrient management based on soil-test for major cropping systems in different agro-eco regions of the country helps in boosting crop yields and arresting soil degradation due to indiscriminate and disproportionate fertilizer use. Mere soil characterization for fertility evaluation fails to meet the specific requirements of plants. The area of the panchayats /Blocks or AEUs were considered to arrive at the weighted average data of the AEU instead of the usual methodology of taking the average of the nutrients. Evolving the mean nutrient status of the AEUs is more realistic and meaningful for providing fertilizer recommendations.

Acknowledgement
Authors gratefully acknowledge Kerala Agricultural University for financial support in the form of a Senior Research Fellowship for the entire period of study of the PhD. Scholar.

Disclosure
The authors declare there was no known conflict of interest between us in the entire study period to influence the work reported in this paper.

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