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Appraisal of soil nutrient status in rice ecosystem using nutrient index in Thondamuthur Block, Coimbatore

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Abstract
Geo referenced soil survey was undertaken in rice growing areas of Thondamuthur Block, Coimbatore district of Tamil Nadu. The main aim of this study was to carry out the evaluation of soil fertility and fertilization practices being followed by the rice growing farmers of the selected villages in Thondamuthur block. Soil samples (50 Nos) were collected from with an auger from a depth of 0-15 cm and analyzed for pH, electrical conductivity, organic carbon, available macro and micro nutrients using standard analytical methods. These data were used to spot the range of critical soil available nutrient and the relationships among the soil fertility parameters. Based on the results obtained, soil reaction was neutral to alkaline in nature. With respect to salinity, 16 % of the soils from Muttathuvayal village alone were slightly saline and remaining 84 % of the soil samples were non saline. Almost 80 per cent of the villages fall under the medium category of soil organic carbon content. Results indicated that 54 percent of the samples are low to medium in available nitrogen; for Olsen P, it was 90 percent in high status; and about 80 per cent of the samples were medium in NH_4OAc – K. Except Cu, other micronutrients were deficient. From the nutrient index, Cu was above sufficiency range, P and Fe were found to be adequate and the other elements were deficit in soil.

Keywords: Rice, Nutrient index, macro and micro nutrients, Thondamuthur block

Introduction

In the back drop of food crisis gripped India during 1960's the concept of green revolution was commenced to meet human need of fast growing population. Agriculture production was attentively considered as a main target to satisfy food constraints among the raising population. Traditional farming methods gave way to farming with high yield seeds, fertilizers and pesticides. Subsequently India has achieved a remarkable growth in agriculture, increasing food grain production from 83 mt in 1960-61 to about 252.23 mt in 2015-16. To augment food grain production, fertilizer consumption raised abruptly from 1 million tonnes (1960) to 25.6 million tonnes in 2016-2017.

First of all, chemical fertilization was already crucial in the first half of the 1950s for the replenishment of soil nutrients. Without it soil nutrient balance would have been negative for both N and P although it would have remained positive for K. According to FAI (Fertilizer Association of India), the NPK ratio in India altered *viz.,* 4.6:2:1 in 2008-09, 4.3:2:1 in 2009-10, 6.5:2.9:1 in 2011-12, 8.2:3.2:1 in 2012-13 and 7.8:3.2:1 in 2015-2016 against the ideal ratio 4:2:1. Excessive use of fertilizers and associated chemical pesticides escort erosion of soil fertility, build up of toxicity, loss of nutrients and deprivation of beneficial microbes.

Rice is the most important food crop around the world; in spite of its high domestic consumption. At present rice is grown in 158 million hectares throughout the world. China and India account for 55 percent of world rice production. In Thondamuthur block of Tamil Nadu, rice is grown under larger area. Presently, fluctuation in productivity and yield reduction is a flattering problem amongst farmers. Continuous cropping for enhanced yield removes substantial amounts of nutrients from soil in addition to that imbalanced use of chemical fertilizers, improper irrigation and various cultural practices also affect the soil quality rapidly (Medhe *et al.,* 2012) [21]. Inorganic fertilizer in improving fertility has been reported as futile owing to certain limitation such as decline in soil organic carbon, inappropriate use of chemical fertilizers, monocropping systems and reduction in beneficial microbial activity in soil (Shen *et al.,* 2010) [44].

Hence soil fertility fluctuates throughout crop growing season each year due to alteration in quantity and availability of nutrients added by fertilizers, manure and compost. Evidence for rapidly changing nutrients in different ecosystems has also been reported (Bellamy *et al.*, 2005) [6]. It was estimated that about 4.17 million tonnes of nitrogen, 2.13 million tonnes of phosphorus and 7.42 million tonnes of potassium are removed annually by agricultural cropping in India (Biswas and Mukerjee, 2001) [49], thus affecting the soil nutrient availability (Zargar 2009) [60]. This has been aggravated by the negative nutrient balances of most cropping systems. Similar is the case with micronutrients like Zn, Fe, Cu and Mn deficiency can cause nutritional imbalance in the soils which may results in significant reduction in productivity (Wani *et al.*, 2014) [56]. Therefore, variation in soil properties should be continuously monitored and studied to understand the effects of different management systems on soils. The importance of reliable and timely information on soils cannot be overlooked in order to acquire spatial information of the soil properties, such information are necessary in the implementation of effective management strategies for sustainable agricultural production (Denton *et al.*, 2017) [18]. So, based on these views the survey has been conducted to assess the availability of the soil nutrient status in rice growing areas in Thondamuthur Block, Coimbatore district of Tamil Nadu.

Materials and Methods

Fertilizer packages followed in sampled area

Based on the collected information, the fertilizer practice for rice followed in Thondamuthur block revealed that nitrogen was being used (25 kg N ha^{-1}) lesser than the recommended dose. With regard to phosphorus, more than 90 percent of the farms received excess dose (80-140 kg of P_2O_5 ha^{-1}) and regarding potassium, 70 percent of the farms were using higher dose of K (75 kg ha^{-1}). Requirement of micronutrients is met through the micronutrient mixtures.

Physicochemical analysis of soil samples

Totally fifty soil samples were collected randomly with soil auger from a depth of 0-15 cm in Thondamuthur block which belongs to the Irugur and Palladam soil series. The soil physico-chemical parameters *viz.*, pH, electrical conductivity (EC), organic carbon, available nitrogen, phosphorus, potassium and DTPA Fe, Zn, Mn and Cu were analyzed by using standard analytical methods. Soil pH was measured in a 2:1 water/soil ratio with a shaking time of about 30 minutes (ELICO – LI615 pH meter). Salinity was determined by measuring the electrical conductivity of the saturated soil extract given by Jackson (1967) EC (ELICO CM 180 Conductivity meter). Organic carbon was estimated by Chromic acid wet digestion method given by Walkley and Black (1934) [54]. Available N in soil was determined by alkaline permanganate method (Subbiah and Asija, 1956) [48] and available P was analysed by 0.5 M $NaHCO_3$ (pH 8.5) Colorimetric with ascorbic acid reduction method by (Olsen 1954). Exchangeable K was estimated by flame photometer following soil extraction with Neutral Normal NH_4OAc (Standford and English, 1949) [47]. Sulphur ($CaCl_2$ method), Boron (Hot water soluble method) and Micronutrients (DTPA extract and Atomic Absorption Spectrometry method, Jackson (1973) [24] were analysed.

Nutrient availability index (NAI)

To appraise the fertility status of soils in the study area, different soil properties affecting nutrient availability including pH, electrical conductivity, organic carbon, available N, P, K, iron, manganese, zinc and copper were included. Here the nutrient index was worked out based on the formula given by Bajaj and Ramamurthy *et al.* (1969) [5]. The nutrient index with respect to organic carbon, available N, P, and K, S, B, and micronutrients were used to evaluate the fertility status of soils in the 18 villages.

Nutrient Index Value = (per cent samples in low category x 1 + percent samples in medium category x 2 + per cent samples in high x 3) /100

Table 1: Ratings followed for calculating the nutrient index

Soil Properties	Unit	Range		
Soil pH	pH	<6.5 (Acidic)	6.5-7.5 (Neutral)	>7.5 (Alkaline)
EC	dS m^{-1}	Upto1(Non saline)	1.1-3.0 (Slightly saline)	>3 (Saline)
Organic Carbon	%	<0.5 (Low)	0.5-0.75 (Medium)	>0.75 (High)
$KMnO_4$-N	Kg ha^{-1}	<280 (Low)	280-450 (Medium)	>450 (High)
Olsen –P	Kg ha^{-1}	< 11 (Low)	11-22 (Medium)	>22 (High)
NH_4OAc – K	Kg ha^{-1}	< 118 (Low)	118-280 (Medium)	>280 (High)
DTPA-Fe	mg kg^{-1}	<3.7 (Deficient)	3.7-8.0 (Moderate)	>8.0 (Sufficient)
DTPA-Mn	mg kg^{-1}	<2.0 (Deficient)	2.0-4.0 (Moderate)	>4.0 (Sufficient)
DTPA-Zn	mg kg^{-1}	<1.2 (Deficient)	1.2-1.8 (Moderate)	>1.8 (Sufficient)
DTPA-Cu	mg kg^{-1}	<1.2 (Deficient)	1.2-1.8 (Moderate)	>1.8 (Sufficient)

Sulphur Availability Index (SAI)

Sulphur Availability Index is derived as a key to assess the available S status in soils (Basumatary and Das, 2012).

SAI = (0.4 × $CaCl_2$ extractable SO_4^- in mg kg^{-1} soil) + % organic matter

Table 2: Based on SAI value, the soils were grouped into three categories

Value	Interpretation (Sulphur availability)
<6.0	Low
6.0 to 9.0	Medium
>9.0	High

Using statistical software package the statistical analysis and correlation studies were executed for soil samples and Pearson correlation matrix was used to locate the relationship between the two variables. Guildford's thumb rule was taken for the interpretation of the Pearson product moment correlation.

Results and Discussion

Soil fertility status of study area

The data of physico-chemical parameters of soil samples are presented in Table 1.

Soil reaction (Soil pH)

The pH of the soils ranged from 6.04 to 8.82 which mean the soil was slightly acidic to alkaline in nature. The overall mean pH value was recorded as 7.33 with standard deviation of 0.71. Narasipuram soils were found to be alkaline amongst other villages. Boluvampatti, Madampatti, Ikkarai and Muttathuvayal soils showed the neutral to slightly alkaline nature of soil reaction. Twenty percent of the soils were alkaline (>8.0), 26% were slightly acidic to neutral (6.0 -7.0) and 54% of the soil samples were found as neutral to slightly alkaline. Plant nutrients availability and accordingly soil fertility are affected by pH. Nutrient solubility varies in response to pH, which predominantly affect the accessibility of nutrients by plants (Clark and Baligar, 2000) [14]. According to Brady and Weil (2005) [9], alkalinity problem in soils arised due to indigenous calcareous parent material with typical low organic matter content.

Among the three major nutrients, N (urea) is being excessively used than P and K. In spite of ammonium based fertilizer (urea), undeniably there might be a chance of fertilizer induced acidification (Mustafa *et al.*, 2018) [33]. However urea fertilization seemed to generate more significant change in soil pH in acid paddy soil than in alkaline paddy soil (Hong *et al.*, 2018) [23]. The study areas have near neutral to alkaline condition with mean pH values of 6.5 to 8.8. Consequently, a change in pH was observed as urea was applied surplus than the actual plant requirement. Also acid and base forming cations influences the soil pH to a great extent (Reuss, and Johnson, 2012) [41]. In this case, added urea possibly results in base forming cations (NH_4^+) which upon hydrolysis increases alkalinity through the discharge of OH- ions into soil solution. As a result, the effects of excess urea application could cause the effects by changing soil pH in acid paddy soil than the alkaline soil along with that base forming cations also responsible factor for maintaining such alkalinity even towards the long time application of excess N.

Electrical conductivity (EC)

The electrical conductivity indicates degree of salinity, and its excessive soluble salts in soil solution creates pessimistic impacts on uptake process either by imbalance in ion uptake, antagonistic effect between the nutrients or excessive osmotic potentials of soil solution or a combination of the three effects (Visconti *et al.*, 2010) [52]. EC measured in soil samples collected from the Thondamuthur block falls between 0.59-2.92 dS m^{-1}. The highest EC was observed in Muttathuvayal (2.92 dS m^{-1}) and Boluvampatti village recorded the lowest EC value of 0.59 dS m^{-1}. With respect to salinity, 16 % of the soils from Muttathuvayal village alone were slightly saline and remaining 84 % of the soil samples were non saline. Soil electrical conductivity is a measurement that correlates with soil properties that affect productivity, including cation exchange capacity (CEC), drainage conditions, organic matter level, salinity, and subsoil characteristics (Corwin and Lesch, 2010) [16]. Generally phosphorus fertilizers have the tendency to raise the EC level of soil.

Soil organic carbon (OC)

Soil is known as the largest terrestrial carbon pool on earth where soil organic matter (SOM) constitutes the important biologically active form (Bhattacharyya *et al.*, 2013). Role played by organic carbon is vital for agricultural soils which supplies plant nutrients, improves soil structure, improves water infiltration and retention, feeds soil micro flora and fauna, and augment retention and cycling of applied fertilizer.

The organic carbon content in the Thondamuthur block ranged from 3.5 to 8.1 g kg^{-1}. The average value of the soil organic carbon was 5.4 g kg^{-1} with the standard deviation of 1.17 g kg^{-1}. Madampatti village was recorded with high organic carbon values and Muttathuvayal village was found to be deficient. In the study area, 20 % of the soil samples were deficient in organic carbon (>5.0 g kg^{-1}) and the remaining soils were medium with organic carbon content (5.0 – 7.5 g kg^{-1}).

The maintenance of SOM is desirable for long-term land use because of the manifold beneficial effects of organic matter on nutrient status, water holding capacity and physical structure (Alekhya *et al.* 2015; Shukla *et al.*, 2004) [1, 45]. Thus majority of rice grown areas are medium in organic carbon. According to Kavitha and Sujatha (2015) [28], high levels of organic matter not only provides part of the N requirement of crop plants, but also enhance nutrient and water retention capacity of soils and create favourable physical, chemical and biological environment. It minimizes negative environmental impacts, and thus improves soil quality (Farquharson *et al.*, 2003) [20].

Paddy soils has the tendency to accumulate SOM (Pan *et al.*, 2004) and represent an important carbon pool due to their high capacity for carbon sequestration under inundated soil conditions. Investigation on SOM accumulation in paddy soils revealed that organic carbon (OC) contents in paddy soils was significantly raised compared to non-inundated agricultural soils (Kalbitz *et al.*, 2013; Wissing *et al.*, 2013) [7, 57], which was ascribed to the OC buildup by the paddy silt- and clay-sized fractions (Wissing *et al.*, 2011) [58]. Additionally, it has been suggested that these higher OC contents in paddy soils are attributable to a plant residue or stubbles (Lehndorff *et al.*, 2014) [30] in combination with the slower rates of OM decomposition that occur under inundated anaerobic soil conditions (Lal, 2002; Sahrawat, 2004; Zhang and He, 2004) [29, 43, 62]. It has similarly been suggested that continuous wetland rice cultivation would enhance the accumulation of lignin residues in topsoils (Olk *et al.*, 2002) [36] because they are highly resistant to degradation under anaerobic conditions (Colberg, 1988) [15]. Thus rice is cultivated continuously for more than decades in the study area, which might have added considerable quantity of plant residues and stubbles after every harvest of crop and thus on decomposition of the same would have contributed and maintained medium status OC in the soil.

Available nitrogen (N)

Available N content in the sampling area was ranged from 152 to 656 kg ha^{-1}. The lowest N content was recorded in Muttathuvayal and the Madampatti village recorded highest available N. Among the villages, 14% of the soils were in deficient status, 46% of the soils are high and 40 % of the soils were medium in available nitrogen status. The average value of the available N was 406 kg ha^{-1}

N was considerably the nutrient with larger flow in the agro ecosystem topsoil. The available nitrogen content ranged from 140 to 300 kg / ha. Even though N was applied in excess, the build of N in soil was unseen. Most of the farms had given excess N than recommended level, and its interaction may have antagonistic effect over the other nutrients. Denitrification can be major loss mechanism of NO_3^--N when the soil is under saturation. Buresh and Datta (1990) [11] reported that denitrification has long been considered a major loss mechanism for N fertilizer applied to lowland rice (*Oryza sativa* L.) Also continuous and intensive cultivation leads to high crop removal together with insufficient replenishment might be the reason for the high degree of nitrogen deficiency in soils Amara *et al.* (2017) [3]. The medium status OC content of the soil may be attributed to low level of N in the soil.

Available phosphorus (P)

Compared to N, phosphorus had only negligible nutrient flow in cropping system. P is a unique ion essential for root development, energy storage and transfer of nutrients, get entered into soil solution all the way through mineral fertilizers or mineralization of organophosphates. Plants can take up P ion by and large in the form of $H_2PO_4^-$ which was available at pH 7.2.

The available P in the major study area was found to be high and the range was between 14 and 210 kg ha^{-1}. The overall mean value of the available P was 47 kg ha^{-1} with notable standard deviation of 30.13 kg ha^{-1}. Based on the percentage of sampling, 90% of the soils were high in available P content. The highest P content was recorded in Narasipuram village and the lowest available P content was observed in Madampatti village. Only 5% of the total soil samples were deficient in available P status. A high proportion of soil samples were medium in available phosphorus (15-22 kg/ha), which may be due to the sufficient contribution of phosphate fertilizers over a period of time. Nye and Bertheux (1957) [35] reported that mineralization of organic P is a concomitant reaction with the oxidation of organic matter which contribute 12 kg per ha of available P to the surface layers and also declining reserves of organic matter during subsequent cropping periods however, could not restore concentration of inorganic P at levels high enough to maintain adequate yields. Application of recommended dose of P coupled with P addition through the process of decomposition of organic manure may be attributed to high level of P in the rice soil.

Available potassium (K)

The maximum available K content of 753 kg ha^{-1} was recorded in Narasipuram village followed by Muttathuvayal village (665 kg ha^{-1}). The average value of the soil available K was 352 kg ha^{-1}. More heterogeneity was observed as the standard deviation and standard error recorded as 177 and 25 kg ha^{-1} respectively. In the study area merely 8% of the samples were deficient in available K content and 30% of the samples were medium and 62% of the soil samples were high in available K content. Almost all the farmers apply muriate of potash as source of K. Input application of K was not in accordance with recommended level for rice. Most of the rice farms were applied with higher quantity of K. The leaching condition brought in by rainfall does not permit retention of potassium on the soil exchangeable complex which might be the probable reason for the low potassium status (<280 kg ha^{-1}) of these soils (Pulakeshi *et al.*, 2012) [38]. The low available N recorded in this present study may be attributed to have lesser exchange with potassium on the soil exchange complex and thus potassium was maintained in medium status.

Conclusion

The study revealed that analysis of rice growing soils in Thondamuthur block was neutral to alkaline and non saline in nature. Organic carbon content ranged from low to high across the locations. Majority of soils were high in phosphorus and potassium and medium to low in nitrogen.

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