An Appraisal of Fertility Status of Problem Soils of Tiruchirappalli district in Cauvery Delta Zone, Tamil Nadu

ABSTRACT:

Soil fertility is an important factor for plant growth and has a global impact on both developed and developing countries. The present investigation was carried out on soil fertility status of farm in ADAC&RI, Trichy which comes under the Cauvery Delta Zone of Tamil Nadu. The pH value indicates that ADAC&RI farm soils are very strongly alkaline in nature. The rating of electrical conductivity was normal with values ranging from 0.16 – 0.72 dS m^{-1}. The farm soil was low in available nitrogen, medium to high in available phosphorus and potassium. The average organic carbon content was low in the farm soil with values of 4.09 and 4.33 g kg^{-1} in A and D block, respectively. The available sulphur content of the farm was recorded as sufficient. This study clearly shows that, most of the soil nutrients in the ADAC&RI, farm was found to be low and need proper management practices to improve the soil quality for better crop production. The present investigation reveals the effect of sodicity on the status of available nutrients in soil.

Keywords: Nutrient index, available nutrients, physico-chemical properties, soil fertility status, soil productivity

1. Introduction

The main issues related to land degradation that limit crop yield are soil salinity and sodicity. Managing salt-affected soils is a global concern because they are not limited to arid and semi-arid regions; they can also develop in humid, sub-humid, and coastal areas. 6.73 million hectares (M ha) of salt-affected soils are found in India, of which 3.77 Mha are sodic soils and 2.96 Mha are saline soils (Choudhary and Yaduvanshi, 2016) [7]. These soils are characterised by high concentrations of carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), chloride (Cl^-) and sodium (Na^+), ions. The inherent fertility status of these soils is generally poor due to low organic carbon and nitrogen, medium to high phosphorus and high potassium content (Dargan *et al*., 1982) [9]. Several factors lead to salt accumulation in the soil profile such as saline irrigation water, capillary rise of saline ground water, seawater intrusion and indiscriminate use of chemical fertilizers (Lakhdar *et al.,* 2009), [15] weathering of rocks (Rengasamy, 2010) [29] besides poor quality irrigation water (Ghasemi *et al*., 1995), [10] and shallow groundwater table and poor drainage condition (Smedema and Shiati, 2002; Brinck and Frost, 2009) [33, 3]. The osmotic stress under saline soil conditions and ion toxicity and unfavourable pH under sodic conditions may inhibit crop and microbial growth (Rietz and Haynes, 2003) [27] due to poor acquisition of nutrients by plant roots (Grattan and Grieve, 1992) [11]. The salt-affected soils are considered as the most degraded type of soils which adversely affects plant growth and limits crop yield (Rengasamy, 2002) [28]. Periodical assessment and monitoring of soil quality is critical for evaluating the sustainability of soil health in terms of fertilizer and crop management practices. Therefore, the current research was undertaken to assess the fertility status of salt affected soils of Anbil Dharmalingam Agricultural College and Research Institute, Navallur Kuttapattu, Trichy as influenced by the nutrient management and cropping sequence in increasing the productivity and sustainability of soil.

2. Materials and methods

The study was carried out at Anbil Dharmalingam Agricultural College and Research Institute, Navallur Kuttapattu, Trichy district in Tamil Nadu. It is located at 10°45’N latitude and 78°36’ E longitude, at an altitude of 85 metres above mean sea level. The study area is characterized by excessively hot summer with a mean annual maximum temperature of 34.6℃ and a mean annual minimum temperature of 23.8℃. The mean annual rainfall received was 1669.9 mm during the study period (2022). The farm is divided into two major blocks *viz.*, A and D blocks which comprises of 21 and 12 fields, respectively. The soil texture varies from loam to sandy clay loam in A block and loam to clay loam in D block.

Representative surface soil samples (0-15 cm) were collected randomly with GPS (geographical positioning system) locations from 21 fields in A block and 12 fields in D block in ADAC&RI farm, Trichy. All the samples were air dried in shade and powdered gently using a wooden mallet and sieved through 2.0 mm sieve. The processed samples were analysed for pH and electrical conductivity (EC) from saturated paste extract as per procedure described by Jackson (1973) [13] using a pH and EC meter. Soil textural analysis was performed by international pipette method (Piper (1966) [20]. Bulk density, particle density, pore space was determined by 100 ml measuring cylinder (Piper, 1966) [20]. Organic Carbon was determined by wet oxidation method (Walkey and Black,1947) [40]. Available nitrogen was estimated by alkaline permanganate method (Subbiah and Asija, 1956) [34], available phosphorus was extracted by 0.5 M sodium bicarbonate solution as described by Olsen *et al.* (1954) [17] and measured using Spectrophotometer. Available potassium by flame photometer method using neutral normal ammonium acetate solution (Jackson, 1973) [13] and available sulphur by turbidimetric method (Wiiliams and Steinberg, 1969) [41].

2.1 Parker's Nutrient Index (NI)

The Nutrient Index was computed using the following formula given by Parker *et al*., 1951) [18]:

$$\text{Nutrient Index} = \frac{(1 \times A) + (2 \times B) + (3 \times C)}{\text{Total number of samples}} \quad \text{where,}$$

A = Number of samples in low category; B = Number of samples in medium category; C = Number of samples in high category. Nutrient Index was introduced in order to compare the soil fertility of one area with another by obtaining a single value for each nutrient

Table 1. Soil fertility index (Parker index)

Low	< 1.67

Medium	1.67 to 2.33
High	> 2.33

Source: Ramamoorthy and Bajaj (1969) [12]

3. RESULTS AND DISCUSSION

3.1Soil texture

Soil textural analysis of soil samples drawn from 33 fields of ADAC & RI farm revealed that most soils were loamy (18 fields), followed by sandy clay loam (7), clay loam (7) to sandy clay (1) in nature. The texture was mainly moderately coarse textured (sandy clay loam to loam) to fine textured (clay loam to sandy clay). The soils of D block were equally fine and moderately coarse while the soils of A block were predominantly of moderately coarse texture (loam to sandy clay loam). The textural analysis (Table 2) for particle size fraction of soils of ADAC & RI farm showed that the sand fraction was high with a mean value of 43.17 % followed by silt (34.19 %) and clay (21.13 %).

Table 2. Soil textural properties in ADAC&RI farm, Trichy

Statistical parameter	Sand (%)	Silt (%)	Clay (%)	Soil texture
A block				
Range	36.55-58.70	12.50-42.50	13.40-33.40	Moderately coarse texture (loam to sandy clay loam)
Mean	46.63	30.95	21.14	
SD	5.86	7.92	7.63	
CV	12.57	25.59	36.09	
D block				
Range	33.00-44.50	27.50-42.50	13.40-30.90	Equally fine (clay

Mean	39.71	37.43	21.11	loam to sandy clay) and moderately coarse (sandy clay loam to loam)
SD	3.22	3.96	5.81	
CV	8.11	10.58	27.52	

3.2 Soil pH

pH is an important soil property that decides the fertility status of soil as it decides the availability of plant nutrients. The solubility of nutrients is governed by soil pH as nearly fourteen of the seventeen essential plant nutrients comes from soil. The solubilization of nutrients is influenced by soil pH as it decides the amount of nutrients in the soil solution which is readily available for plant uptake. The soil reaction (pH) varied from neutral to very strongly alkaline with values ranging between 7.85 to 9.90 in A block and 7.63 to 10.17 in D block and the average pH value was 8.92 and 9.00 in A and D block (Table 3), respectively. Such variations in soil pH were reported by Polara *et al*. (2006) [21] which may be the result of applied fertilizers which facilitates the exchange and retention of basic cations on soil colloids which causes soil alkalinity. Similar observations were reported by Sharma *et al*. (2008) [31] for soils of Amritsar district, Punjab and by Vijayakumar *et al*. (2013**)** [39] in salt-affected soils of Ongole division, Prakasam district, Andhra Pradesh. The results revealed that 33.33 % of soil samples analyzed were moderately alkaline while 52.39 % of soils were strongly alkaline and 9.52 % soils were very strongly alkaline in nature. The high pH values may be due to presence of exchangeable and soluble sodium along with bicarbonate ions which precipitates as calcium and magnesium carbonates on evaporation. The alkaline nature of farm soils can also be attributed to the inherent calcareous parent material along with typically low soil organic matter (Brady and Weil, 2005) [2].

3.3 Electrical conductivity

It is a measure of the soluble salts in the soil and is generally influenced by quality of irrigation water, land use and choice of fertilizers. It is an important property as higher concentrations of soluble salts may hinder nutrient uptake by plant roots due to excessive osmotic stress or due to antagonistic effect of nutrients (Rehman *et al*, 2010) [26]. The EC of farm soils varied from 0.29 to 0.72 dS m^{-1} and 0.16 to 0.31 dS m^{-1} (Table 3) in A block and D block, respectively. The electrical conductivity was observed to fall under normal category and hence found suitable for crop production. The low EC values of farm soils may be attributed to the moderately coarse texture of soil dominated by sand fraction which might have leached down the excessive salts to lower layers of soil profile (Singh *et al*., 2016) [32]. These results were in accordance with the findings of Vijayakumar *et al*. (2013) [39].

3.4 Soil organic carbon

The soil organic carbon content is an index of the fertility status of soil. It not only supplies plant nutrients but also ensures its retention and cycling, improves physical properties such as soil structure, aeration, movement and retention of water besides serves as reservoir of food for the micro flora and fauna in soil (Johnston, 2007) [14]. It is an indirect measure of the nitrogen content in soil (Cooke, 1982) [8]. The OC content of farm soils were low to medium in status. In A block the values varied between 1.8 to 6.6 g kg^{-1} (Table 3), of which, 61.90 per cent soil samples were found to be low and 38.09 per cent of the samples were medium in status. Similarly in D block, the organic carbon content ranged between 1.2 to 6.9 g kg^{-1} with 66.67 per cent samples in low category and 33.33 per cent in medium category (Table 4).

Table 3. Soil physico-chemical properties of ADAC&RI farm, Trichy

Statistical parameter	**pH**	**EC (dSm^{-1})**	**OC (g kg^{-1})**
A block			
Range	7.85-9.90	0.29-0.72	1.80-6.60
Mean	8.92	0.37	4.09
SD	0.64	0.18	1.50

CV	7.17	48.65	36.67
D block			
Range	7.63-10.17	0.16-0.31	1.20-6.90
Mean	9.00	0.26	4.33
SD	0.84	0.04	1.86
CV	9.33	15.38	42.96

Table 4. Soil organic carbon rating

OC rating	A block		B block	
	No. of samples	% samples	No. of samples	% samples
Low (< 5 g kg^{-1})	13	61.90	8	66.67
Medium (5 -7.5 g kg^{-1})	8	38.09	4	33.33
High (> 7.5 g kg^{-1})	0	0.00	0	0.00

From the data it was clear that most of the soils in ADAC&RI farm were low in soil organic carbon content. The low OC in soils could be ascribed to the semi-arid climatic conditions due to rapid decomposition and mineralization of organic matter. Suribabu *et al*. (2002) [35] also reported similar results for A. Konduru mandal in Krishna district of Andhra Pradesh. The alkaline pH and poor biomass turn over in salt-affected soils may be some of the reasons for the low OC content.

3.5 Available macronutrients

The concentration of available nitrogen content varied between 168.0 to 221.6 kg ha^{-1} in A block, while in D block the values ranged between 162.8 to 229.9 kg ha^{-1} (Table 5). This indicates that 100 per cent of the soil samples recorded low available nitrogen content in ADAC&RI farm and there is a need to apply more nitrogen fertilizer based on soil test to enhance the crop productivity. The low levels of available nitrogen may be attributed to a number of factors, including low OC from poor vegetation and high pH, which favors higher losses from volatilization (Chaudhary *et al*., 2006) [4]. The correlation analysis (Table 8) revealed that soil available N was negatively correlated with pH (r = - 0.976), while it was significantly and positively correlated with electrical conductivity (r = 0.593**). Soil available N had significant and positive correlation with OC (r = 0.713**) 0.710**). Nitrogen requirements are usually based on the nitrogen released by mineralization of soil organic matter (Cooke, 1982). The positive correlation between OC and available N clearly indicated the poor status of both OC and available N in soil.

Alkali soils are rich in extractable phosphorus though deficient in organic matter and available nitrogen (Chhabra, 2002) [6]. The available phosphorus in A block and D block ranged between 12.69 to 22.40 kg ha^{-1} and 11.95 to 32.85 kg ha^{-1}, respectively (Table 5). It showed that 100 per cent of the soil samples in A block were found to be medium in fertility status. In case of D block 75% of the samples were found to be medium and 25% high in fertility status (Table 4). This clearly shows that most of the soil samples have sufficient available phosphorous content. Pathak (2010) reported that available phosphorus in India range from medium to high category. Similar results were also reported by Singh *et al.* (2016) in sodic soils of Kapurthala district of Punjab. The increase in available P may be due to mobilization of non-available soil P because of localized reduction in pH caused by the organic acids released by plant roots. This is mainly because Na_2CO_3 and $NaHCO_3$ present in these soils react with native apatite to form soluble Na_3PO_4 which are then converted to H_2PO_4 ions when they come in contact with the plant roots in the rhizosphere region and meet crop needs. However, the available P decreases with time which may be due to leaching of soluble P as Na_3PO_4 (Chabbra *et al*., 1981; Swarup, 1986) [5, 36] and sometimes due to adsorption of phosphorus on $CaCO_3$ (Ilyas, 1990) [12]. Similar results were observed by Qadir *et al*. (1997) [22]. Santhi *et al*. (2018) [30] reported high available P status in alkaline soils of Villupuram district. Vijayakumar *et al*. (2013) [39] observed medium to high available phosphorus (P) in salt-affected soils of Ongole division, Prakasam district, Andhra Pradesh. Adequate phosphorous availability in 87.5 % of the farm soils may also be attributed to build up of soil phosphorus due to continuous application of phosphate fertilizers. Similar findings were also reported by Thangaswamy *et al*. (2005) [38], Rajeswar and Khan (2007) [23] and Sharma *et al*. (2008) [31]. The correlation analysis (Table 8) showed that available P was negatively correlated with pH (r = -0.946) and was positively and highly significantly correlated with organic carbon (0.770**) and available nitrogen (r = 0.808**).

The overall rating of available K showed 80.36 % samples under medium status and 19.64 % under high status. The available potassium content in A block ranged between 172.14 to 306.8 kg ha^{-1} and 155.4 to 362.9 kg ha^{-1} in D block, respectively (Table 5). 85.72% of the soil sample in A block was found to be medium in fertility status and remaining 14.29% falls under high (Table 6). The medium to high K status of farm soil may be attributed to the presence of potash rich micaceous and feldspar minerals containing parent rocks. Similar findings were reported by Ravi Kumar *et al*. (2007**)** [25] and Sharma *et al*. (2008) [31]. Singh *et al.* (2016) also reported high available K in soils of Punjab. Very high available K content was reported in alkali soils of Indo-Gangetic plains (Agarwal *et al*. 1979, Swarup and Chhillar 1986) [1, 37]. The results revealed that the soils of ADAC & RI farm were adequate in available potassium (medium to high status). The correlation analysis revealed that the available K was negatively correlated with pH (r = -0.960) and positively and significantly correlated with EC (r = 0.392*). The correlation data (Table 8) also revealed positive and highly significant relation between available K and OC (r = 0.804**), available N (r = 0.915**) and available (r = 0.959**).

The available sulphur content in the farm soils of ADAC & RI farm was found to be high in status (Table 7). It ranged from 48.50 to 122.58 and 66.25 to 92.58 mg kg^{-1} (Table 5), respectively. The high sulphur content observed in the farm soils may be due to continuous addition of sulphur containing fertilizers mainly through gypsum, super phosphate etc. to supplement the crop needs. Similar results were documented by Sharma *et al*. (2008) [31] in

Amritsar district in Punjab and by Nega *et al*. (2001) [16]. Another reason for high sulphur content may also be due to presence of appreciable amounts of sulphur in irrigation water leading to its accumulation in soils (Pasricha *et al*., 2001). The available sulphur was found to be negatively correlated with pH. It was positively and highly significantly correlated with EC (0.557**), available N (0.807**), available P (0.521**) and available K (0.632**) (Table 8).

Table 5 Soil available nutrients of ADAC&RI farm, Trichy

Statistical Parameter	**Av. N (kg ha^{-1})**	**Av. P (kg ha^{-1})**	**Av. K (kg ha^{-1})**	**Av. S (mg kg^{-1})**
A block				
Range	168.0-221.6	12.69-22.40	172.1-306.8	48.5-122.6
Mean	193.6	17.58	236.8	82.1
SD	15.99	3.43	39.15	16.38
CV	8.26	19.51	16.53	21.51
D block				
Range	162.8-229.9	11.95-32.85	155.4-362.9	66.3-92.6
Mean	194.43	19.10	244.4	82.0
SD	22.29	7.18	65.68	8.57
CV	11.49	37.61	26.87	10.46

Table 6. Soil available nutrient rating

Nutrients	**Low**	**% Sample**	**Medium**	**% Sample**	**High**	**% Sample**
A block						
Nitrogen	< 280	100	280 – 450	Nil	> 450	Nil
Phosphorus	< 11	Nil	11 – 22	100	> 22	Nil
Potassium	< 118	Nil	118 - 280	85.72	> 280	14.29
D block						

Nitrogen	< 280	100	280 – 450	Nil	> 450	Nil
Phosphorus	< 11	Nil	11 - 22	75	> 22	25
Potassium	< 118	Nil	118 - 280	75	> 280	25

Table 7. Soil available nutrient rating for sulphur

Nutrient	**Deficient**	**% Sample**	**Sufficient**	**% Sample**
Available S (mg kg^{-1})	< 10	Nil	>10	100

Table 8. Correlation matrix between pH, EC, OC and available nutrients

	pH	**EC**	**OC**	**Av. N**	**Av. P**	**Av. K**	**Av. S**
pH	1.000**						
EC	0.449**	1.000**					
OC	-0.772	-0.560	1.000**				
Av. N	-0.976	-0.495	0.839**	1.000**			
Av. P	-0.935	-0.441	0.754**	0.930**	1.000**		
Av. K	-0.961	-0.472	0.834**	0.982**	0.959**	1.000**	
Av. S	-0.289	-0.495	0.335**	0.294**	0.207**	0.225**	1.000**

Correlation matrix between pH, EC, OC and available nutrients

***and ** significant at 5% and 1% respectively**

3.6 Parker's Nutrient Index (Parker *et al.*, 1951) [15]

$$\text{Parker's Nutrient index (PNI)} = \frac{(X1 \times 1 + X2 \times 2 + X3 \times 3)}{\text{Total number of samples}}$$

X1 = Number of ‘low’ samples; X2 = Number of ‘medium’ samples; X3 = Number of ‘high’ samples

Table 9. Nutrient index values (Parker index) for OC and available N, P, K and S

Available nutrient	NIV	Rating
Organic carbon	1.0	Low
Nitrogen	1.0	Low
Phosphorus	2.12	Medium
Potassium	2.18	Medium
Sulphur	> 2.33	High

The nutrient supplying power of soil is indicated by the nutrient index value. The nutrient index of SOC and available N was 1.0 and rated as low across all the sampled spots in the farm (Table 9) while the PNI values for available P and K was 2.12 and 2.18 and rated as medium. The farm soils recorded high nutrient index values (> 2.33) with respect to available S considering the critical limit of sulphur as 10 mg kg^{-1}.

4. Conclusion

The study revealed that soils of Anbil Dharmalingam Agricultural College and Research Institute farm were alkaline in reaction, low in organic carbon and available nitrogen, medium to high in available phosphorus and potassium and high in available sulphur content. The EC of the farm soils were at safe levels. The low organic carbon and low available nitrogen in the farm soils of ADAC&RI indicated poor soil fertility status due to alkaline soil pH. Though available phosphorus was adequate there are chances for the non-availability of P due to its conversion to unavailable forms at higher pH. Hence, there is a need for efficient nutrient management particularly soil nitrogen and soil organic carbon through regular organic matter additions and use of green manure crops. Besides reclamation of these sodic soils with inorganic amendments such as gypsum or pyrite is essential. An integrated use of organic and inorganic amendments will ensure improved physical, chemical and biological properties of soil for sustaining the soil health and increasing the productivity. So, there is a need to follow proper management practices for better crop production.

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