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Pedological Investigation of Soil Quality Indicators in *Tapioca* Growing Soils

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ABSTRACT

Background: *Manihot esculenta*, the most important tropical root crop which supply dietary staple food for about 800 million populations worldwide. Twenty soil profiles that represent the soil Pedology and soil quality are similar in their concept in relation to soil formation. In this regards, soil quality can be considered as part of the science of pedology. Significant differences in yield of Tapioca (*Manihot esculenta*) with selected soil properties and subsequent interpretations as influenced by land use are explained.

Methods: Soil samples were taken from designated pedogenic horizons for physico-chemical properties in the laboratory. Soil textural class, saturated hydraulic conductivity, Cation Exchange Capacity, Base Saturation Percentage, soil organic carbon, exchangeable cations, available N, P, K content and available micronutrients were analysed. The general fertility of the soils in the area is discussed highlighting their potentials and constraints.

Result: A comprehensive analysis of soils in the study area showed that shallow soil depth of <47 cm and more clay of 44% with high bulk density of 1.4 gcc^{-1}, low hydraulic conductivity of 0.12 $cmhr^{-1}$, low base saturation percentage of 77%, more exchangeable sodium percentage of 7.96% with low available N, P and K of 110, 10.75 and 142.25 kg ha^{-1}, respectively in low yielding soils are the major constraints in the tract might behind the yield differences in Cassava.

Key words: Chemical properties, *Manihot esculenta*, Soil physical, Yield categories.

INTRODUCTION

Soil is the product of rocks with interaction of Pedogenic process. A detailed characterization of soils earmarked as “Benchmark soils” to find the yield variation in Cassava (Fabio *et al.,* 2021). Soil survey plays a crucial role in defining sustainable management practices and also for harnessing the potential of varied agro-ecological regions for commercial commodity production (Obasi *et al.,* 2021). In order to suggest both current and upcoming potential land users on how to use land in the best possible way, a good data bank on soil properties and related site characteristics are essential.

Evaluation of the potentials and limitations of the soil for different land uses provides the basis for formulating the appropriate management strategies which target specific management problems to improve crop production and soil and water conservation. This information is generated by a detailed biophysical characterization of soil (Maneesh Kumar *et al.,* 2021). Grouping of soils based on similarities in their textural, taxonomic and/or structural properties has broad applications to pedology, hydrology and soil science (Behzad and Bandon, 2021).

Even the study area hold second rank in *Manihot esculenta* area of cultivation and production in Tamil Nadu, detailed information on soil morphology, mineralogy and physico-chemical were not studied properly. Behind this insight, pedological investigations were conducted in tapioca growing soils of Namakkal, Tamil Nadu to find out soil problems related to yield reduction.

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MATERIALS AND METHODS

Geographical and geomorphological features of studied location

The study area of Paramathy block covered 19,149 ha and it is situated in Namakkal district of Tamil Nadu, India. It falls within 11°N longitude and 78°E latitude approximately. The mean annual rainfall is 637 mm and located in 170 m above Mean Sea Level (MSL). The tapioca growing soils of Paramathy block falls under *ustic* soil moisture and *iso-hyperthermic* temperature regime. The average temperature ranges from 27 to 33°C. The famous Sithampoondi anorthosite complex which is known for its complex geology and occurrences of platinum group of elements. Hornblende, feldspar and biotite gneiss are the oldest rocks and iron ore deposits associated with quartz feldspatic gneiss and granetiferous quartz gneiss are occurred in Tapioca tract of Namakkal district.

Benchmark sites

The study area contains 23 revenue villages and were divided into three categories based on yield data of over a period of last 15 years as Tapioca high yielding soils (12-15 t/ac), Tapioca medium yielding soils (8-12 t/ac) and Tapioca low yielding soils (<8 t/ac). The detailed soil survey was carried out with cadastral map using 1: 5,000 scales. The area was traversed and 49 benchmark sites were finalized. Profiles were excavated at 20 different sites and minipit was used for remaining locations. Profiles were excavated at dimension of 2×2 m^3 with depth up to parent material or 2 m based on georeferenced points (Fig 1).

Determination of soil physical, physico-chemical and chemical properties

The soil samples were collected and analysed using standard procedure. Soil colour was determined by Munsell colour chart (Pendleton *et al.,* 1951), particle size was determined using the International Pipette method (Piper, 1966) with sodium hydroxide as dispersing agent. Water holding capacity like hydraulic conductivity, infiltration rate was determined by the procedure given by (Dakshinamoorthy and Gupta, 1968). Available N was estimated using Alkaline permanganate method (Subbiah and Asija, 1956), Available P by colorimetric method using 0.5 N $NaHCO_3$ of pH 8.5 (Olsen, 1954) and Available Na and K by Flame photometer by neutral normal ammonium acetate (Stanford and English 1949). Soil organic carbon was determined using Chromic acid wet digestion method (Walkley and Black, 1934). Exchangeable bases (Ca, Mg, Na and K) such as Ca and Mg was determined using versenate method (Jackson, 1973). Micronutrient was estimated by DTPA extractant method using Atomic Absorption Spectroscopy.

RESULTS AND DISCUSSION

The pedon characteristics were studied in the profile itself and soil samples were collected and analysed for their properties by adopting standard analytical procedures. Correlation studies were worked out among the closely related properties for each series by IBM SPSS 25 (Table 1). The results of soil characteristics with respect to yield is discussed here.

Soil textural characteristics

The clay content ranged from 15.5% in high yielding tapioca growing soils to 44.3% in low yielding tapioca growing soils. The increased clay content with depth is significant enough to qualify as argillic horizon and pattern of clay illuviation. The total sand content varied from 5.0% in low yielding tapioca growing soils to 32.7% in high yielding soils. The highest totals and content observed in high yielding tapioca growing soils series documented minimum profile development, due to less pronounced effect of weathering and pedogenic process (Swarnam *et al.,* 2004).

Soil densities and its correlation

The bulk density ranged from 1.12 Mg m^{-3} of high and medium yielding tapioca growing soils to 1.4 Mg m^{-3} in low yielding tapioca growing soils. An increased free Fe_2O_3 content in argillic horizons favouring crusting, cementation of particles and compaction as inferred by (Ramprakash and Rao, 2002). The lowest bulk density content explains minimum aggregation of soil particles and encourages rapid

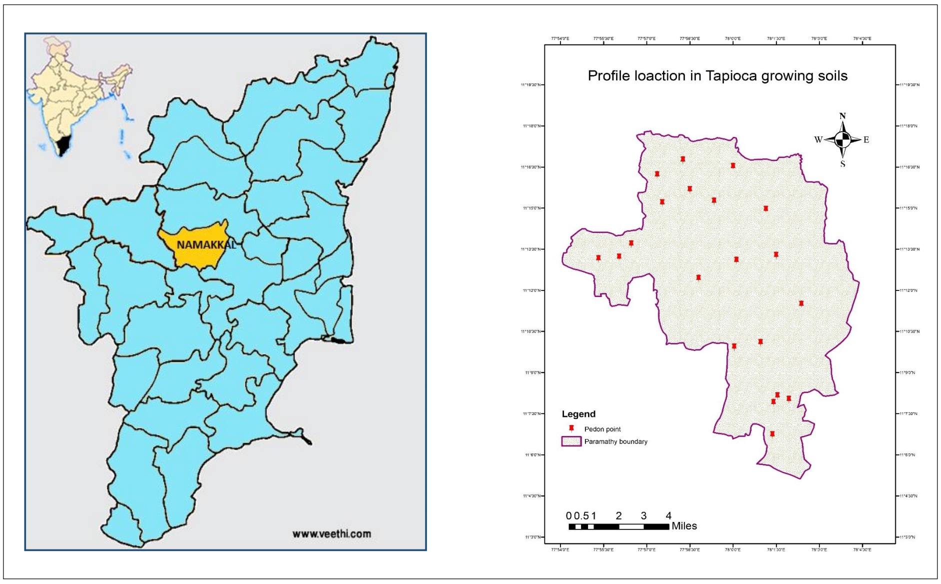

Fig 1: Location of the study area.

Table 1: Correlation between inter-related soil properties of tapioca growing soils.

	Sand	Silt	Clay	$CaCO_3$	CEC	BSP	pH	OC	Avail. N	Avail. P	Avail. K	Avail. Fe	Avail. Zn	Avail. Cu	Avail. Mn
Sand	1														
Silt	-930**	1													
Clay	-887**	.656**	1												
$CaCO_3$	-0.340	0.266	0.367	1											
CEC	-817**	.645**	.874**	0.269	1										
BSP	0.078	-0.177	0.066	0.113	0.076	1									
pH	-0.027	-0.088	0.165	-.516*	0.303	-0.055	1								
OC	-0.075	0.142	-0.020	-0.147	0.251	-0.225	-0.043	1							
Avail. N	0.143	0.075	-0.391	-0.175	-0.132	-0.175	-0.029	.689**	1						
Avail. P	-0.031	0.111	-0.076	0.020	0.075	-0.178	-0.137	.544*	.591**	1					
Avail. K	0.167	0.085	-.455*	-0.158	-0.277	-0.278	-0.054	0.407	.868**	0.406	1				
Total N	0.224	-0.081	-0.360	-0.190	-0.150	-0.007	0.003	.615**	.786**	.627**	.500*				
Total P	-0.382	0.319	0.387	0.194	0.431	0.073	-0.354	.475*	0.087	.647**	-0.153				
Total K	-0.049	0.226	-0.187	-0.257	-0.087	0.131	0.046	0.209	.557*	0.132	.710**				
Avail. Fe	0.262	-0.153	-0.349	-.567**	-0.249	-0.298	0.035	0.242	0.189	-0.178	0.198	1			
Avail. Zn	0.432	-0.249	-.577**	-.747**	-.489*	-0.285	0.204	0.138	0.338	-0.198	.479*	.787**	1		
Avail. Cu	.456*	-0.298	-.568**	-.672**	-.499*	-0.332	0.202	0.010	0.249	-0.109	0.343	.763**	.856**	1	
Avail.Mn	0.274	-0.128	-0.408	-.717**	-0.375	-0.237	0.156	-0.022	0.100	-0.259	0.172	.813**	.832**	.874**	1

**: Correlation is significant at the 0.01 level (2-tailed).

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

Table 2: Mechanical analysis and water movement related properties of tapioca growing soils.

Pedon no.	Depth of the pedon (cm)	Sand	Silt (%)	Clay (%)	Bulk density (Mg m^{-3})	FC (%) (33 kPa)	PWP (%) (1500 kPa)	AWHC (%)	Saturated hydraulic conductivity (cm hr^{-1})	Infiltration rate (cm hr^{-1})
High yielding pedons										
P1	54^+	11.0	42	34.6	1.3	23.9	14.60	9.33	0.22	0.19
P2	70^+	30.0	20.6	18.7	1.3	24.9	16.90	9.10	0.40	0.25
P3	52^+	32.15	18.25	15.55	1.2	25.7	18.20	7.49	0.40	0.52
P4	95^+	28.5	23.9	17.6	1.3	24.4	15.60	8.80	0.50	0.61
P5	54^+	28.5	17.75	23.85	1.1	27.8	18.35	9.48	0.33	0.39
P6	54^+	28.8	17.2	23.65	1.1	26.3	16.95	9.35	0.41	0.37
P7	85^+	7.50	40.40	40.47	1.3	27.2	15.27	11.6	0.26	0.28
P8	70^+	32.7	11.9	21.3	1.2	26.2	17.00	9.20	0.60	0.50
Medium yielding pedons										
P9	55^+	22.8	24.0	28.3	1.2	23.0	12.8	10.2	0.20	0.29
P10	52^+	30.7	13.9	23.2	1.2	23.2	15.4	7.80	0.40	0.31
P11	43^+	31.5	16.70	19.00	1.1	23.8	17.4	6.50	0.30	0.32
P12	75^+	10.2	46.33	31.83	1.2	21.2	12.4	8.80	0.22	0.21
P13	70^+	19.6	31.35	28.9	1.3	24.1	13.6	10.4	0.25	0.25
P14	55^+	30	17.07	22.57	1.2	23.8	16.7	7.07	0.30	0.28
Low yielding pedons										
P15	90^+	22.3	14.6	39.6	1.2	26.3	15.33	11.0	0.23	0.27
P16	65^+	29.1	13.03	18.30	1.2	24.9	18.30	6.67	0.35	0.29
P17	47^+	28.3	13.9	27.95	1.2	25.8	17.40	8.45	0.36	0.30
P18	65^+	22.2	22.1	33	1.2	23.3	13.20	10.1	0.32	0.29
P19	95^+	12.02	32.77	42.27	1.3	29.2	15.77	13.4	0.33	0.38
P20	110^+	5.0	44.80	44.33	1.4	28.5	14.78	13.8	0.18	0.28

permeability. The total clay content was significantly and positively correlated with bulk density and CEC (0.874**). The total sand content was significantly and positively correlated with hydraulic conductivity, silicon dioxide (0.715**) and negatively correlated with clay, bulk density and CEC.

Water holding capacity of soil

The available water holding capacity ranged from 6.5% of medium yielding tapioca growing soils to 13.8% of low yielding tapioca growing soils. The saturated hydraulic conductivity ranged from 0.12 of low yielding series to 0.6 cm hr^{-1} of high yielding tapioca growing soils. The infiltration rate ranged from 0.19 to 0.61 cm hr^{-1} of high yielding tapioca growing soils (Table 2).

Soil chemical parameters

The cation exchange capacity varied from 9.5 cmol (p^+) kg^{-1} in high yielding soils to 29.6 cmol (p^+) kg^{-1} in high and low yielding tapioca soils. The high cation exchange capacity of low yielding cassava growing soils might be due to the influence of high organic matter, smectite type of clay mineral and illuviation process (Merumba *et al.,* 2020). The base saturation percentage varied from 77.1% of low yielding soils to 94.3% of high yielding tapioca growing soils. The exchangeable sodium percentage ranged from 1.73% to 7.96 % in low yielding tapioca growing soils (Table 3).

The pH varied from 6.9 of low yielding soils to 8.4 in medium yielding tapioca soils. The available nitrogen content ranged from 110 kg ha^{-1} in low yielding tapioca growing soils to 254 kg ha^{-1} of high yielding tapioca growing soils. The available nitrogen was significantly and positively correlated with organic carbon. The available N had significant positive correlation with available K (0.868**).

The available phosphorus content ranged from 10.75 kg ha^{-1} in medium yielding tapioca growing soils to 21.0 kg ha^{-1} of high yielding tapioca growing soils. The available phosphorus content of tapioca growing soils were found to be low to medium the reason might be due to confinement of crop cultivation to the rhizosphere and supplementing the depleted phosphorus by external source and the low P may be due to fixation of released P by clay minerals and oxides of Fe^{2+} and Al^{3+} (Merumba *et al.,* 2020).

The available potassium content varied from 142.25 kg ha^{-1} in low yielding tapioca growing soils to 319.33 kg ha^{-1} of high yielding tapioca growing soils (Table 3). The available potassium content of high yielding and medium yielding soils

Table 3: Exchangeable properties and available nutrients of tapioca growing soils.

Pedon no.	Depth of the horizon (cm)	Exchangeable bases (cmol (p^+) kg^{-1})				CEC [cmol (p+) kg^{-1}]	BSP (%)	ESP (%)	pH	EC (dSm^{-1})	Available nutrients (kg ha^{-1})		
		Ca^{2+}	Mg^{2+}	Na^+	K^+						N	P	K
High yielding soils													
P1	54^+	14.97	9.86	0.88	1.62	29.60	93.7	3.02	7.90	0.14	254.33	14.77	319.33
P2	70^+	7.31	4.18	0.61	0.78	14.00	92.0	4.36	7.55	0.13	189.75	19.40	222.50
P3	52^+	4.30	3.20	0.55	0.88	9.50	94.0	5.79	7.30	0.16	195.00	20.95	245.00
P4	95^+	6.25	4.05	0.34	0.90	13.40	86.1	2.54	7.33	0.20	145.33	19.10	219.67
P5	54^+	8.75	4.47	0.56	0.81	17.70	82.4	3.16	7.45	0.14	159.50	18.60	212.00
P6	54^+	7.50	5.38	0.69	0.31	16.52	84.0	4.18	7.85	0.16	142.50	15.25	240.00
P7	85^+	11.40	5.39	0.59	0.64	22.12	81.5	2.67	7.70	0.16	205.33	21.00	273.00
P8	70^+	6.47	2.76	0.60	0.74	11.48	92.1	5.23	7.53	0.16	180.67	18.90	236.00
Medium yielding soils													
P9	55^+	9.05	4.59	0.85	0.60	17.13	88.1	4.96	7.73	1.11	220.67	16.17	270.00
P10	52^+	6.75	3.73	0.29	1.13	14.32	83.1	2.03	7.25	1.19	165.50	20.65	235.00
P11	43^+	6.47	3.44	0.79	0.37	13.55	81.7	5.83	7.80	0.92	174.00	14.83	232.33
P12	75^+	9.57	4.84	0.49	0.72	20.40	76.6	2.40	7.37	0.19	204.00	16.23	239.00
P13	70^+	14.95	8.44	1.05	0.55	27.97	89.3	3.75	8.35	0.24	203.00	10.75	224.00
P14	55^+	7.10	4.60	0.55	0.91	14.25	92.4	3.86	7.40	0.10	164.33	20.07	221.67
Low yielding soils													
P15	90^+	14.73	6.77	2.13	0.26	26.76	89.3	7.96	8.27	0.19	110.00	13.67	220.67
P16	65^+	6.85	3.14	0.23	1.06	13.32	84.7	1.73	6.93	0.12	144.67	16.83	207.00
P17	47^+	8.50	4.31	0.88	0.60	15.93	89.7	5.52	7.80	0.17	190.50	11.50	206.00
P18	65^+	10.60	5.40	0.92	0.50	19.68	88.5	4.67	7.80	0.21	148.50	11.35	151.50
P19	95^+	14.30	9.67	0.89	0.70	27.11	94.3	3.28	7.40	0.20	117.00	17.37	198.33
P20	110^+	14.18	6.61	1.71	0.32	29.60	77.1	5.78	7.98	0.19	115.25	11.18	142.25

Table 4: Available micronutrient status of high yielding tapioca growing soil series.

Pedon no.	Depth of pedon (cm)	Free $CaCO_3$ (g kg^{-1})	OC (%)	pH	Available Micronutrients ($mgkg^{-1}$)			
					Fe	Zn	Mn	Cu
High yielding soils								
P1	54^+	1.53	0.56	7.90	3.70	1.13	1.73	1.10
P2	70^+	0.02	0.32	7.55	3.70	1.25	2.02	1.60
P3	52^+	0.20	0.33	7.30	3.55	1.65	2.30	1.50
P4	95^+	0.70	0.23	7.30	4.40	1.60	2.50	2.20
P5	54^+	0.06	0.55	7.45	4.55	1.20	2.05	1.80
P6	54^+	0.07	0.40	7.85	2.60	1.10	1.65	1.20
P7	85^+	1.60	0.36	8.00	4.00	1.00	2.00	2.00
P8	70^+	Nil	0.25	7.80	3.10	1.20	1.20	1.10
Medium yielding soils								
P9	55^+	1.11	0.33	7.73	2.23	1.40	1.90	1.63
P10	52^+	0.07	0.31	7.25	5.55	1.70	2.35	1.70
P11	43^+	2.07	0.32	7.80	3.03	1.17	1.90	1.57
P12	75^+	2.87	0.36	7.37	4.53	1.53	2.03	1.60
P13	70^+	10.03	0.34	8.35	8.35	1.34	1.35	1.50
P14	55^+	2.17	0.29	7.40	4.50	1.40	2.27	2.10
Low yielding soils								
P15	90^+	7.43	0.24	8.27	1.77	0.44	1.07	0.66
P16	65^+	0.08	0.28	6.93	5.33	1.47	2.77	2.03
P17	47^+	0.07	0.35	7.80	3.05	1.10	1.70	1.10
P18	65^+	Nil	0.22	7.80	2.85	1.05	1.95	1.45
P19	95^+	1.06	0.39	7.40	4.60	1.17	2.13	1.27
P20	110^+	3.10	0.14	7.98	1.70	0.49	1.68	0.75

were medium in K status might be due to more intense weathering, release of liable K from organic residues, application of K fertilizers and upward translocation of K from lower depth along with capillary raise of ground water (Devi *et al.,* 2015).

Soil micronutrient

The available iron content varied from 1.7 ppm in low yielding soil series to 5.5 ppm in high yielding soils. The tapioca high yielding soils had sufficient iron status due to presence of more iron bearing minerals and continuous supplement of organic matter content forming a organo-metallic complex favours easy availability of iron to crops with external fertilizer source (Patil and Kumar, 2014).

The available zinc content varied from 0.4 ppm in low yielding tapioca soils to 1.7 ppm of medium yielding tapioca growing soils. The relatively highest amount of zinc might be due to $ZnCO_3$ formation and less complexing of zinc with easy desorption from soil particles (Merumba *et al.,* 2020).

The available copper content ranged from 0.6 ppm in low yielding tapioca growing soils to 2.2 ppm of high yielding tapioca growing soils. Available copper was highly sufficient in high and low yielding soils due to parent material composition and optimum organic carbon level and more retention of Cu by clay, but more clay reduces the cassava yield in low yielding soils due to high bulk density and hindrance in tuber growth as compared with high yielding and medium yielding soils. The available manganese content varied from 1.07 ppm to 2.7 ppm in low yielding tapioca soils (Table 4). The available iron content was significantly and positively correlated with pH, available zinc, available copper, available manganese (0.813**). The available zinc content was significantly and positively correlated with pH, available potassium, available copper (0.856**). The available copper content had significantly positive correlation with sand, available manganese (0.874**). The available manganese content was significantly positive correlation with available iron, available copper (0.874**).

CONCLUSION

The shallow depth with less compacted soils are suitable for growing tuber crops. The relatively coarser textured nature of high yielding tapioca growing soil series with poor water retentivity and rapid permeability requires frequent irrigation. Mixing of soil with 50 to 100 tonnes of clay will enhance the water and nutrient retentivity. The low CEC of high yielding soil series suggested to increase the number of splits and high CEC of high and low yielding tapioca soil demands only minimal number of splits during fertilizer application.

The low organic carbon content in medium and low yielding tapioca growing soil series accent the need for application of higher organic matter like coir pith, FYM and crop wastes. Owing to the low status of available micronutrients in the soils especially manganese emphasis the need for application of fertilizers as chelated form or foliar application. Integrated application of fertilizer along with organic manure releases the organic acids during decomposition, makes the soil reserve micronutrient into available form for higher uptake.

A comprehensive analysis of soils in the study area showed that soil depth was one of the major constraints for all the soil series. The platy structure, clayey texture, high bulk density, low hydraulic conductivity, low infiltration rate, low base saturation percentage, more exchangeable sodium percentage, low available macro nutrients, very low Zn and Cu contents abridged the yield but Sgp, Npr, Cnp, Jnp, Vlp and Kup series are marginally and moderately suitable for growing tapioca. The structure and textural characters play a major role in restricting tuber yield over and above the fertility constraints.

Conflict of interest

All authors declared that they don’t have any conflict of interest.

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