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Assessment on physical and chemical properties of surface soil and subsoil of coconut cultivated lands located in region of Batticaloa, Sri Lanka

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Abstract

Appropriate physicochemical conditions of soil and fertilizer recommendations for coconut cultivation have been limited in Sri Lanka. A study was conducted to evaluate the status of soils supporting coconut cultivation in Batticaloa. Surface soil (0 – 15cm) and the subsoil (15 – 30cm) of five localities in Batticaloa area were investigated for physiochemical properties and soil fertility. The results showed that most of the soil properties are declined with significant difference ($p > 0.05$) with soil depth, whereas moisture content of soil increase with soil depth with a range from $0.23 \pm 0.01\%$ to $0.23 \pm 0.01\%$. The ranges for the studied soils properties are 2.63 ± 0.02 - 2.49 ± 0.03 for true density (gcm^{-3}), 1.68 ± 0.05 - 1.64 ± 0.03 for apparent density (gcm^{-3}), 36.30 ± 1.41 - 36.30 ± 1.41 for porosity (%), 7.82 ± 0.04 - 8.12 ± 0.06 for pH, 20.4 ± 0.93 - 17.8 ± 1.16 for CEC ($\text{meq}/100\text{g}$), 11.4 ± 0.47 - 8.68 ± 0.56 for TEB ($\text{meq}/100\text{g}$), 56.11 ± 2.29 - 48.82 ± 0.29 for OM (%), 0.39 ± 0.02 - 0.35 ± 0.01 for Nitrogen ($\text{g}/100\text{g}$), 0.043 ± 0.001 - 0.035 ± 0.001 Phosphorous ($\text{g}/100\text{g}$) and 1.12 ± 0.03 - 1.03 ± 0.04 Potassium ($\text{g}/100\text{g}$) respectively. The results showed the samples were not generally ideal for coconut growth and production of best yields because of considerable deviation from acceptable limits. It is recommended that the soils in these area need fertilization and optimum soil management for the highest benefits of coconut cultivation.

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Key words: Coconut; physicochemical properties; fertility elements; surface soil; subsoil.

1. Introduction

Coconut palm, *Cocos nucifera* (L), of the order Arecales and family Arecaceae is widely dispersed in most regions of the tropics. It has generally been accepted that the coconut originated in the Indian-Indonesia region and float-distributed itself around the world by riding ocean currents [1] [2]. According to Food and Agriculture Organization of the United Nations, Sri Lanka is the world's fifth largest producer of coconuts, producing 2,200,000 tons in 2009. Coconut production contributes to the national economy of Sri Lanka. Many cultivated coconut varieties are found in Sri Lanka. Most of them were introduced by the National Coconut Research Institute and they identified these varieties during a coconut germplasm exploration mission in the Southern Province of Sri Lanka [3].

Coconuts are known for their great versatility, as evidenced by many traditional uses, ranging from food to cosmetics [4]. They form a regular part of the diets of many people in the tropics and subtropics. Coconuts are distinct from other fruits for their large quantity of water and when immature, they are known as tender-nuts or jelly-nuts and may be harvested for their potable coconut water. When mature, they can be used as seed nuts or processed to give oil from the kernel, charcoal from the hard shell, and coir from the fibrous husk. The endosperm is initially in its nuclear phase suspended within the coconut

water. As development continues, cellular layers of endosperm deposit along the walls of the coconut, becoming the edible coconut "flesh" [5]. When dried, the coconut flesh is called copra. The oil and milk derived from it are commonly used in cooking and frying, as well as in soaps and cosmetics. The husks and leaves can be used as material to make a variety of products for furnishing and decorating. The coconut also has cultural and religious significance in certain societies, particularly in India, where it is used in Hindu rituals [6].

The coconut, though essentially belonging to the humid regions of the tropics, is a very adaptable palm, which can tolerate a wide range of soil conditions. There are vast areas of coastal land throughout the tropics, which have been and could be used for coconut cultivation. An important factor orienting soil suitability for good coconut growth and high yields is tied up with the fertility status of the soils. Principal factors that play a major role in relation to coconut cultivation; soil moisture, soil nutrients including the major and trace elements, soil air, soil temperature, root space and the presence of injurious substances toxic to plant growth [7]. A high fertility status of the supporting soils is required for high productivity of coconut per unit land area. Coconuts grow better and give higher yields under suitable soil conditions like well drained soils, good soil depth, sandy soil texture, proper layout of land and nutritionally fertile soil [8].

The determination of the baseline data on inherent physical and chemical properties of soil is required so as to know the limit of nutritional requirement for the cultivation of coconut palm. Small scale cultivation of palm is currently undertaken in the selected location and this study aims at evaluating the soil fertility and physiochemical properties states and make appropriate recommendations for an effective large scale production of coconut.

2. Materials and methods

2.1. Study area

Coconut cultivated lands exist in Batticaloa, are located in Low Country Dry Zone (DL) of Sri Lanka. The mean annual rain fall is 2056mm and the mean annual temperature is 28.5°C. Soil samples of soil at different depths from manure circle of palm were collected from five localities of coconut cultivated land in Batticaloa region.

2.2. Preparation of soil sample

The surface soil (0 -15cm) and sub soil (15 – 30cm) samples were collected using soil core sampler (Arborline; 32x100mm) without disturbing the soil. They were placed on drying trays in the drying room for 24 - 48 hours so as to break the lumps and ensure proper drying. After drying, the soil was ground and passed through a 2mm nylon sieve (the materials that did not pass through the sieve were discarded). The fine particles were then placed in containers and labeled before they were subjected of following analytical methods.

2.3. Analysis of properties of soil samples

2.3.1. Soil moisture content

Moisture content of soil samples were determined by oven dry method.

2.3.2. True density, apparent density and pore space

True density, apparent density and pore space were determined by the method proposed by G.C. Aggarwal [9].

$$\text{Pore space (\%)} = (\text{True density} - \text{Apparent density}) / \text{True density} \times 100\%$$

2.3.3. Soil pH

Soil pH was determined as 1:2.5, H₂O extracted with 10g of fine earth shaken with 25ml H₂O for 1hour on a circular shaker, rested for 1hour and with the pH of supernatant then read using an automatic probe.

2.3.4. Soil cation exchangeable capacity (CEC) and total exchangeable base (TEB)

Cation Exchange Capacity (CEC) and exchangeable bases were measured by using ammonium acetate at pH 7 [10].

2.3.4.1. Percentage Base Saturation (PBS)

$$\text{PBS\%} = (\text{TEB/CEC}) \times 100\%$$

2.3.5. Soil total nitrogen

0.2g of the fine ground soil samples was weighed into digestion tubes; 1 tablet of selenium catalyst and 4ml of concentrated sulfuric acid were added. The digestion tubes were placed on the digestion block until the solution became clear and cool. The solution was then filtered into 100ml volumetric flask and made up to the 100ml mark with distilled water. The nitrogen content was then estimated by an auto-analyzer and its reagents with sets of standards [11] [12].

2.3.6. Soil available Phosphorous

50g of the air-dried, fine soil samples was weighed into 150ml plastic bottle and 35ml of L-ascorbic acid was added and shaken manually for a minute. The resultant suspension was filtered and the phosphorus content was estimated calorimetrically using ammonium molybdate as the coloring agent [13].

2.3.6. Soil available potassium

0.5g of the air-dried, fine soil samples were weighed into 250ml plastic bottle. 100ml of neutral ammonium acetate was added and then flask was stoppered and shaken for 30 minutes with a mechanical shaker. The resultant suspension was filtered and the filtrate was estimated for potassium (K) [14].

2.3.7. Soil organic matter content

Organic matter content was determined by the process of oxidation by $K_2Cr_2O_7$ [15].

2.4. Statistical Analysis

The Average mean, SEM were analyzed using ANOVA F test, and the means were compared using Duncan multiple range test at 5% level of significance [16].

3. Results and discussion

3.1. Physical properties of the surface soil and the subsoil

The mean values $\pm$ standard error of mean (SEM) for the selected physical properties of the surface soil and the subsoil of the coconut fields of five localities used in this study are shown in Tables 1 and 2.

Table 1: Physical properties of surface soil (0 – 15cm) of the five localities

Localities	Moisture (%)	True density (gcm^{-3})	Apparent density (gcm^{-3})	Porosity (%)
Eravur	0.32	2.65	1.70	35.85
Mylambaveli	0.35	2.71	1.75	35.42
Thannamnei	0.32	2.59	1.57	39.38
Kommathurai	0.28	2.62	1.79	31.68
Vipulanathapuram	0.26	2.58	1.57	39.15
Mean $\pm$ SEM	0.23 $\pm$ 0.01	2.63 $\pm$ 0.02	1.68 $\pm$ 0.05	36.30 $\pm$ 1.41

Physical and chemical properties of surface soil and subsoil have significant difference at 5% confidence level ($P>0.05$). Moisture content ranged from 0.23 $\pm$ 0.01% to 0.31 $\pm$ 0.02%. Moisture content of subsoil is higher than the surface soil. Subsoil is an important storehouse of moisture, especially since it is usually much thicker than the topsoil and the moisture is not lost as easily by evaporation [17].

True density and apparent density have greater influence to determine the porosity. In this study, porosity is higher in surface soil than subsoil with range from 34.02 $\pm$ 2.03% to 36.30 $\pm$ 1.41%. Theoretically, coconut are well established in sandy rich soils. Sandy soils have relatively high bulk density since total pore space in sands is less than silt or clay soils. Bulk

density typically increases with soil depth since subsurface layers are more compacted and have less organic matter, less aggregation and less root penetration compared to surface layers, therefore contain less pore space [18].

Table 2: Physical properties of subsoil (15 – 30cm) of the five localities

Localities	Moisture (%)	True density (gcm ⁻³)	Apparent density (gcm ⁻³)	Porosity (%)
Eravur	0.22	2.48	1.64	33.87
Mylambaveli	0.25	2.56	1.57	38.67
Thannamnei	0.26	2.49	1.71	31.32
Kommathurai	0.23	2.39	1.72	28.03
Vipulanathapuram	0.19	2.54	1.57	38.19
Mean±SEM	0.31±0.02	2.49±0.03	1.64±0.03	34.02±2.03

True density and apparent density have greater influence to determine the porosity. In this study, porosity is higher in surface soil than subsoil with range from 34.02±2.03% to 36.30±1.41%. Theoretically, coconut are well established in sandy rich soils. Sandy soils have relatively high bulk density since total pore space in sands is less than silt or clay soils. Bulk density typically increases with soil depth since subsurface layers are more compacted and have less organic matter, less aggregation and less root penetration compared to surface layers, therefore contain less pore space [18].

3.2. Chemical properties and nutrient elements of the surface soil and the subsoil

The mean values ± standard error of mean (SEM) for the amount/concentration of basic chemical properties and nutrient elements of the surface soil and the subsoil samples for the coconut fields used in this study are summarized in Table 3,4,5 and 6 respectively. The pH values ranged from 7.82±0.04 to 8.12±0.06 in surface soil and subsoil respectively. The values obtained suggest that the pH of the soil samples were slightly base. The pH values obtained for the various surface soils were found to be slightly higher than that of the surface soil. This means that the subsoil is slightly more basic than the surface soil. Child (1974) observed that the best soils for coconuts are clayed alluvial soils, which are not too acidic and are also rich in nutrients. The soil net ability to hold nutrients and water is higher with increasing pH [19].

Table 3: Chemical properties of surface soil (0 – 15cm) of the five localities

Localities	pH	CEC (meq/100g)	TEB (meq/100g)	PBS (%)
Eravur	7.8	20	10.7	53.5
Mylambaveli	7.7	18	10.2	56.67
Thannamnei	7.8	19	11.9	62.63
Kommathurai	7.9	23	11.3	49.13
Vipulanathapuram	7.9	22	12.9	58.64
Mean±SEM	7.82±0.04	20.4±0.93	11.4±0.47	56.11±2.29

Table 4: Chemical properties of subsoil (15 - 30cm) of the five localities

Localities	pH	CEC (meq/100g)	TEB (meq/100g)	PBS (%)
Eravur	8.1	17	8.4	49.41
Mylambaveli	8.0	15	7.2	48.00
Thannamnei	8.3	16	7.9	49.38
Kommathurai	8.2	20	9.6	48.26
Vipulanathapuram	8.0	21	10.3	49.05
Mean±SEM	8.12±0.06	17.8±1.16	8.68±0.56	48.82±0.29

Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and the soil's reaction to fertilizers and other ameliorants [20]. The term total exchangeable bases refers to the sum of the bases (calcium, magnesium, potassium, and sodium) in exchangeable form in soil. CEC and TEB are linked to determine the percentage of base saturation (PBS). CEC is higher in surface soil (20.4 ± 0.93) than subsoil (17.8 ± 1.16). Likewise, TEB is little bit higher in surface soil (11.4 ± 0.47) compared to subsoil (8.68 ± 0.56). Thus, CEC of the soil will vary with pH [21].

The organic matter in soil derives from plants, animals and microorganisms. Surface soil are more fertile than subsoil, due to having more organic matter and because fertilizers are usually added to the topsoil only. In case of, coconut cultivated land also have high organic matter content and major nutrient element such as N, P, K in surface soil rather than subsoil, which mostly supportive by color variation of surface soil and subsoil. Surface soil are darker in color than subsoil. This results obtained correspond with those reported by Ukpebor *et al* [22]. N, P and K content of surface soil in coconut cultivated land was $0.39 \pm 0.02\%$, $0.043 \pm 0.001\%$ and $1.12 \pm 0.03\%$ respectively, but those are in subsoil $0.35 \pm 0.01\%$, $0.035 \pm 0.001\%$ and $1.03 \pm 0.04\%$ respectively.

Table 5: Organic matter and nutrient concentration of surface soil (0 – 15cm) of the five localities

Localities	OM (%)	N (g/100g)	P (g/100g)	K (g/100g)
Eravur	2.74	0.37	0.038	1.16
Mylambaveli	2.55	0.32	0.046	1.08
Thannamnei	2.94	0.39	0.047	1.14
Kommathurai	2.71	0.43	0.040	1.03
Vipulanathapuram	2.82	0.46	0.042	1.18
Mean $\pm$ SEM	2.75 ± 0.06	0.39 ± 0.02	0.043 ± 0.001	1.12 ± 0.03

Table 6: Organic matter and nutrient concentration of subsoil (15 - 30cm) of the five localities

Localities	OM (%)	N (g/100g)	P (g/100g)	K (g/100g)
Eravur	2.69	0.34	0.032	1.02
Mylambaveli	2.59	0.37	0.038	1.03
Thannamnei	2.72	0.32	0.036	1.01
Kommathurai	2.55	0.38	0.037	0.92
Vipulanathapuram	2.62	0.36	0.034	1.16
Mean $\pm$ SEM	2.63 ± 0.03	0.35 ± 0.01	0.035 ± 0.001	1.03 ± 0.04

4. Conclusion

The results of the present study manifest that the soils supporting the growth of coconut in this area are sandy and having various range of physical and chemical indications. The soil pH, true density, porosity, cation exchange capacity, total exchangeable bases, percentage of base saturation, organic matter content and potassium content of soil declined with soil depth, whereas apparent density and nutritive elements such as nitrogen and phosphorous content are more or less uniformly distributed among the soil depth. However, moisture content of soil increased moderately with soil depth. With the sandy texture and low to moderate fertility status of the studied soils, amelioration of the physicochemical properties of the soil and fertilization especially with nitrogen, phosphorous and potassium carriers are necessary to boost coconut yields in these localities.

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