Assessment of Fertility Status of Soils Supporting Coconut (*Cocus nucifera*) Cultivation in Western and Central Regions of Ghana

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Abstract

Coconut cultivation is mostly practiced in the Western and Central regions of Ghana. Information on the fertility status of the soils on which coconuts are grown and possible fertilizer recommendation is not common. Since coconut yield is generally related to the fertility status of the soil, a study was conducted to evaluate the fertility status of soils supporting coconut in the Western and Central regions. The soils were sampled at three depths, 0–20 cm, 20–40 cm and 40–60 cm at 21 different sites. The soil physical properties do not constitute any major limitation to good coconut growth and yield. Evaluation of the top soil showed that the mean top soil *p*H was very strongly acidic (4.1 $\pm$ 0.12) and far below the acceptable limits for good coconut yield. Mean exchangeable acidity [0.57 $\pm$ 0.06 cmol(+)kg^{-1}] was relatively high while exchangeable basic cations (Ca, Mg and K) were generally very low. Mean effective cation exchange capacity (ECEC) of 3.1 $\pm$ 0.48 cmol (+) kg^{-1} was very low. Mean organic matter status 22.1 $\pm$ 1.9 gkg^{-1} was moderate. Mean available phosphorus of 2.8 $\pm$ 0.56 mgkg^{-1} was very low and one of the major nutrients that will affect coconut yield. Except for soil *p*H, nutrient levels generally showed a decreasing trend in the order top soil > subsoil > sub-subsoil. The evaluation showed that the soils suffer from multi-nutrient deficiency. Nutrient levels of the soils are low to very low, and will not support good coconut growth and yield. Liming to improve the exchangeable basic cations and *p*H of the soils is recommended. Use of rock phosphate is also recommended for raising the levels of both phosphorus and some basic cations. Amendments and fertilizers with high K content must also be considered.

Introduction

Western and Central regions are traditionally known for coconut production in Ghana. Coconut is an important tree cash crop. Hybrids have been introduced after the onset of the Cape St Paul Wilt Disease (CSPWD).

Coconut production had in the past been confined to the coast and a few kilometers inland. Indication from isolated coconut palms far inland shows that the crop can be grown in the forest regions. Generally, climatic and soil conditions are important physical determinants of the suitability of coconut production in an area.

The elements of climate basically required by coconut are rainfall, temperature, humidity and sunlight (Child, 1964). The coconut palm requires a well-distributed rainfall for optimum performance. Rainfall as low as 1000 mm and distributed throughout the year is favourable. The upper limit is 2250 mm per annum. The crop can stand much higher rainfall amounts provided the soil is well-drained. With regard to temperature, coconut thrives best where it is most constantly warm. The optimum mean annual temperature for best performance is between 26 and 28 °C. However, the general temperature range is from 20 to 34 °C. Coconut likes warm and humid conditions. In as much as high humidity is desirable, conditions should not retard transpiration. The coconut palm also requires enough sunlight and does not grow well under shade or in too cloudy regions. Coconut grows on a wide range of soils but there are certain soil conditions that may inhibit growth. These are 1. Poor drainage with prolonged water-logging conditions; 2. Exceedingly porous soil from which water is drained readily, making the soil too dry. Porous soils can be used provided the soil is not dry; 3. Soils with an impermeable hard-pan or rock near the surface (i.e. shallow soils); 4. Very gravely or stony soils, because they are generally sterile and are likely to be dry.

Generally, the coconut palm will grow on many different soil types provided they are reasonably deep and free draining to allow for unrestricted root development and aeration. Examples of major world producing areas indicate that the soils range from coarse sand, which contains up to 97% sand (0.2–2.0 mm) to heavy soils with about 70% clay (Child, 1964). It is also observed that coconut grows very well in lower slopes, piedmont slopes of hills and, most importantly, coastal areas, where sub-surface moisture drains down slope, which makes them to retain moisture for appreciably long periods.

The growth and yield of the coconut palm is highly affected by the fertility status of the soil. The optimum soil *p*H range is 6.4– 7.0. The tree can also thrive under soil *p*H range of 5.5–6.3 and 7.1–7.5. Soil *p*H values below 5.4 or above 7.5 provide marginal condition for the growth of the tree (Child, 1974). The importance of soil nutrients change as the tree grows (Tennakoon, 2004). The order of nutrient requirement for young trees is N > P > K > Mg while that for adult palms (fruit bearing trees) is K > Mg > N > P (Tennakoon 2004). In the coconut belt of south-western Ghana the order of nutrient requirement for restoration of nut yield potential in mature coconut is K > P > N > Mg (Andoh-Mensah *et al*., 2003). According to Tennakoon (2004), Okerih *et al.* (2006) and Hameed *et al*. (1986), coconut palm responds positively to fertilizer, and the response is normally higher when magnesium is included.

Climatic condition in the Western Region is generally suitable for coconut production. It is more favourable in the coastal areas, extending northwards to beyond Tarkwa, where total rainfall is around 2000 mm or more per annum and well-distributed throughout the year. The rainfall decreases northwards and eastwards to about 1400 mm at the fringes. The rainfall distribution also becomes less favourable towards the fringes.

The Central Region, like the Western Region, extends from the coast to far inland. Generally, rainfall is lower in the Central Region. From the coast, total annual rainfall is about 1200 mm, increasing inland to 1400 mm in the forest areas. There is a period of marked dry season from mid-November to mid-March, even though there can be occasional rains. Temperatures are uniformly high throughout the year in both regions, ranging from 25–29 °C. Humidity is also moderately high with influences from the sea and the forest.

Materials and methodology

The study was carried out in four districts, namely Nzima East, Jomoro and Ahanta

West, in the Western Region, and Komenda-Edina-Eguafo-Abirem (KEEA), in the Central Region (Table 1a). Secondary information was obtained from Ahn (1961) and Asamoah (1966). Coconut farms of varying ages were selected in each of the districts. On each farm, the soils were identified, described and sampled at pre-determined depths of 0–20 cm, 20–40 cm and 40–60 cm. Three profiles were dug for detail description. A total of 21 soil samples (Nzima East District , 10 samples; Jomoro District, 2 samples; Ahanta West District, 5 samples; KEEA District, 4 samples) were taken.

Coconut yield estimation

On each farm 10 trees were selected and the potential nut yield estimated. Yield of coconut was determined by counting nuts in bunches of leaf ranks 14, 19 and 24. The average number of nuts in the theee bunches was multiplied by 12 months to obtain nut load/ tree/ year (Santos, 1996). Coconut leaves were also sampled for analysis.

Laboratory analysis

Soil samples were air-dried, ground and passed through a 2-mm sieve. Soil *p*H was measured in a soil to water ratio of 1:2.5 (IITA, 1979). Total nitrogen was determined by the modified Macro-Kjeldahl method (Bremner, 1965). Available phosphorus was extracted with Bray's P_1 solution and measured on a spectrophometer (Bray & Kurtz, 1945). Organic carbon was measured by the method of Nelson & Sommers (1982). Exchangeable bases were extracted with 1.0 *M* ammonium acetate solution.

Sodium and potassium contents in the extract were determined by flame photometry, while calcium and magnesium were determined by atomic absorption spectro-photometry. The method of Thomas (1982) was used for the determination of exchangeable acidity. Effective cation exchange capacity (ECEC) was then calculated as the sum of exchangeable cations (K, Ca, Mg, Na) and exchangeable acidity (Aℓ+H). Particle size analysis was done using the pipette method (Gee & Bauder, 1986). Descriptive statistics was used to analyse data on soil parameters.

Results and discussion

Soil types and their descriptions

The soil types observed in the four districts and their major profile characteristics are presented in Tables 1a and 1b.

Nuba and Boi series. These soils have similar physical characteristics (Table 1b). They are generally deep and sandy, and have no physical limitation. The soils are found in the Nzima East and Jomoro districts both in the Western Region. The sandy nature of these soils allow free drainage under flooding or when rainfall is high. The underlying sandy clay texture prevents excessive drainage leading to droughty condition during the dry season.

Yakasis and Nkwanta series. These soils also have similar physical characteristics (Table 1b). They are deep with many ironstone concretion in the subsoil. The gravelly nature of the subsoil may limit the retention of moisture and nutrients, hence, the trees may suffer from moisture stress during draught periods. The gravels are generally sterile and provide no nutrients to the trees. These soils were observed in the Agona West District in the Western Region.

Nta series. This soil was observed at

TABLE 1a
Soil types and their location

District	*Observed sites*	*Soil name (series)*	*Parent material*
Nzima East	Menzezor, Aiyinase	Nuba	Tertiary coastal sands
	Nyamebekyere	Boi	Lower Birimian phyllite
Jomoro	Agyimavuley	Boi	Lower Birimian phyllite
	Allowuley	Boi	
Agona West	Cape Three Points	Yakasi	Upper Birimian phyllite
	Mmaapehia	Nkwanta	Granite
	Asemko, Agona	Nta	Granite
Komenda-Edina-Eguafo -Abirem	Enyinase	Akroso	Granite
	Ayensudo, Dompoase, Kwahenkro	Nta	Granite

TABLE 1b
Summary of profile characteristics of the soils

Soil series	*Classification (WRB)*	*Profile description*	*Soil limitation (physical)*
Nuba	Haplic Ferralsol	Deep (>150 cm), moderately well-drained, sandy loam topsoil, underlain by sandy loam to sandy clay loam in the subsoil.	None
Boi	Haplic Ferralsol (Ferric)	Deep(>120 cm), moderately well-drained, sandy loam topsoil. The underlying subsoil is sandy clay loam /clay and contains many quartz and ironstone gravel / concretions (10–15%).	Gravelly subsoil
Yakasi	Acric Ferralsol (Ferric)	Deep (120 cm), well-drained and consists of silt loam topsoil. The underlying sub-soil is silty clay containing many ironstone concretions and quartz gravel.	Gravelly subsoil
Nkwanta	Acric Ferralsol	Deep (120 cm) and well drained. The topsoil is sandy loam, which overlies sandy clay loam subsoil containing many (15%) ironstone concretions.	Gravelly subsoil
Akroso	Haplic Acrisol	Deep (120 cm) and moderately well to imperfectly drained. The topsoil is sandy loam. The underlying subsoil is either gravel-free or has only few quartz gravel and stones. The texture ranges from sandy clay loam to sandy clay.	None
Nta	Gleyic Arenosol	This soil is characteristically sandy. It is deep, imperfect to poorly drained. The topsoil is sandy loam. The underlying subsoil coarse sand with single grain loose structure.	Sandy, droughty and poor drainage

Agona West in the Western Region and Komenda-Edina-Eguafo-Abrirem District in the Central Region. It is characteristically sandy, deep imperfectly to poorly drained (Table 1b). The soil may become waterlogged during the raining season or dry during draught periods.

Akroso series. The soil is deep with moderately well to imperfectly drained (Table 1b). Generally, it has no physical limitation and occur in the Komenda-Edina-Eguafo-Abrirem District in the Central Region.

Soil fertility status of the study area

Soil reaction. Mean surface soil *p*H value (4.1) for the whole area is very strongly acidic (Table 2a), ranging from a very strongly acidic value of 3.4 to strongly acidic value of 5.4. Mean *p*H values for all the districts are also very strongly acidic accept KEEA, which gave strongly acidic value. For all the districts over 78% of the topsoil samples had *p*H values below 4.5. This is critical and has a negative influence on the production potential of the crop since *p*H values are below the acceptable range required by th crop. Mean soil *p*H is almost similar with depth (Tables 2ab). Generally, the soil environment is not good for coconut development and yield.

Mean top soil total acidity (TA) is 0.57 cmol(+)kg^{-1} and generally increased with depth. Increasing values of TA, couple with decreasing exchangeable cations, negatively affect root development.

Exchangeable cations. Mean values for exchangeable Ca, Mg, K and Na for the various districts are very low (Tables 2ab). For exchangeable Mg and K, the situation is most critical for Jomoro and Nzima East districts both in the Western Region. Exchangeable Ca, Mg and K values generally decrease with depth, signifying leaching of these nutrients out of the soil or into deeper layers. Exchangeable Na was exceptionally high for KEEA and moderate for Ahanta West districts. Sampling sites for these districts are nearer to the sea, and the effect of sea spray might play a role in the values observed. Mean values for ECEC for the study area is very low. Mean values for KEEA in the Central Region and Ahanta West District are relatively higher.

Organic matter and total nitrogen. Organic matter and total nitrogen are strongly correlated since much of the nitrogen is due to mineralization of organic matter. Mean values for the whole study area is average and range from very low value of 6.7 gkg^{-1} to a high value 41.6 gkg^{-1} (Table 2a.

Available phosphorus. Mean value of available P for the whole area is very low, ranging from almost a trace to a moderate value of 13.6 $mgkg^{-1}$ (Tables 2ab). Available P is another critical element, which is highly deficient. Under very strong soil acidity serious fixation is expected, and partly explains the situation regarding available P.

Soil fertility evaluation for coconut production

Table 3 shows drainage condition and soil *p*H values for optimum coconut growth and yield. Mean top soil *p*H for the study area is very strongly acidic (4.1), which falls far below the minimum soil *p*H value of 5.5 suitable for coconut growth. This clearly shows the extreme conditions under which these coconut trees are growing. Mean topsoil *p*H for the various district are all far

TABLE 2a

Mean soil fertility status of top soil (0-20 cm) for the various districts

District	*Soil* pH	*Org. M.* *g Kg^{-1}*	*Total N*	*Ca*	*Mg*	*K*	*Na*	*TA*	*ECEC*	*Avail. P* *mgkg^{-1}*
					Exchangeable cations [cmolol(+)kg]					
Nzima East	4.0	23.0	2.03	1.3	0.7	0.09	0.03	0.66	2.78	2.4
Jomoro	3.5	18.7	1.9	1.1	0.3	0.06	0.06	0.78	2.30	4.5
Ahanta West	4.4	22.8	1.7	2.4	1.5	0.15	0.14	0.49	4.19	1.6
KEEA	4.6	20.1	1.8	3.3	1.5	0.23	0.32	0.34	5.69	4.6
All Districts	4.1	22.1	1.90	1.96	0.99	0.13	0.12	0.57	3.10	2.8
SE	0.12	1.86	0.13	0.27	0.20	0.02	0.03	0.06	0.48	0.56

TABLE 2b

Mean sub-soil properties for the study area

Depth (cm)	*Soil pH* *g Kg^{-1}*	*Org. M,*	*Total N*	*Ca*	*Mg*	*K*	*Na*	*TA*	*ECEC*	*Avail. P* *mgkg*
				Exchangeable cations [cmolol(+)kg]						
20-40	4.4	15.2	1.38	1.50	0.51	0.11	2.05	0.78	2.87	5.1
40-60	4.1	10.8	1.15	1.15	0.50	0.07	0.10	0.96	2.74	3.7
SE										
20-40	0.42	1.15	1.15	0.19	0.09	0.03	0.03	0.06	0.24	3.0
40-60	0.17	1.02	0.60	0.12	0.09	0.01	0.04	0.10	0.21	2.1

TABLE 3

Some soil factors that influence good coconut growth and high yields

Parameter	*Optimum*	*Moderate*	*Poor condition*
Drainage	*Good*	*Moderate*	*Poor*
Soil p*H*	6.4–7.4	5.5–6.3	5.5 >

Adapted from Child 1964

below the minimum value. While values for total acidity are moderate the very low values for exchangeable cations resulted in the soil *p*H values observed. Low soil *p*H influences the availability of phosphorus and some micro-elements. Mean subsoil *p*H are equally very low and far below the acceptable minimum (Child, 1974).

Mean values for top soil exchangeable cations (Ca, Mg and K) for the study area are very low and will not support good coconut growth and high yield for that matter. Mean values are equally very low for all districts. Exchangeable Na is moderate for the Cape Three Point, Dompoase and Enyinase sites. These sites are near to the sea and may benefit from water particles blown inland. Mean exchangeable cations showed a decreasing trend with depth (Tables 2ab).

With reference to the environmental conditions (high rainfall, temperature and adequate sunshine), mean organic matter content is below the expected value. Broad leaves unlike grass generally decompose very fast (Jenny, 1941) and may be the explanation. Total nitrogen is equally not encouraging. Mean available phosphorus for the study area is very low and generally low for all the districts. With reference to soil fertility, the soils are less capable in supporting good coconut growth and yield. Pragmatic steps need to be taken to improve the fertility status of these soils if better yields are to be achieved.

Evaluation of soil physical properties for coconut production

At Nzima East and Jomoro districts, in the Western Region, the soils generally do not have physical limitations (Table 1b) except a limited out crop of Boi soil series, which has a gravelly subsoils. Soils of Jomoro District and Enyinase site in KEEA District have no physical limitation. At Ahanta West District, however, the Cape Three Point and Mmaapehia sites have gravelly subsoils (Table 1b). The rest of the sites have limitations because of sand/droughty/poor drainage conditions. That is because the soils are sandy and in the valley. During the dry period they become very dry. Generally, it can be said that most of the soils have good soil physical conditions for good coconut growth and yield.

Coconut nut yield. Age of coconut palms at the various sites and their nut loads are presented in Table 4. The mean yield potential of 52.5 nuts/ tree/year for the old West African Tall (WAT) coconut trees observed at the sites was quite unsatisfactory, considering a yield potential of 100 nuts/ tree/ year for WAT coconut trees aged 30–40 years. The low yields could be linked to poor nutritional status of the palms as presented in Table 5. All the WAT coconut plots observed at all the sites except Nyamebekyere II, which had satisfactory yield of 80 nuts/ tree/year, did not meet all the critical leaf values of 0.12% for P, 0.8% for K and 0.15% for Mg.

The strong acidic soils at the sites with low soil properties might be the major contributory factor to the poor nutritional status of the palms with the situation compounded by the fact that fertilizers are normally not applied and agronomic practices are generally poor.

The mean potential yield of 65.2 nuts/ tree/ year for MYD × VTT plots, observed in the Ahanta West and KEEA districts, was very low compared with a yield potential of 150 nuts/tree/year for the hybrid at the age of 6–8 years. However, at Ayensudo (146.0 nuts/ tree/year) and Asemko (109.2 nuts/tree/year) potential yield were good. The yield trends in the MYD × VTT coconut hybrid again could be linked to the poor nutritional status of the young palms as shown in Table 5. All the MYD × VTT coconut plots observed at sites except Ayensudo and Asemko, which had satisfactory yields of 146.0 and 109.6 nuts/ tree/year, respectively, did not meet all the critical leaf values of 0.10% for P, 1.0 % for K and 0.15% for Mg.

Use of appropriate amendments will raise the soil *p*H and, in addition, add some nutrients to the soils. Practices that will improve the fertility status of the soils include 1. Rock phosphate contains adequate amounts of phosphorus, calcium, magnesium and some micronutrients. Application of rock phosphate will improve the acidic condition of the soil and some amount of the nutrients mentioned; 2.

TABLE 4
Nut load/ tree/ year for the various selected sites

Region	*District*	*Town/village*	*Age (years)*	*Nuts/tree/year*	*Remarks*
Western	Nzima East	Menzezor	35	36.4	
		Aiyinase I	20	44.0	
		Aiyinase II	40	41.0	
		Nyamebekyere	40	47.6	
		Nyamebekyere II	40	80.0	
	Jomoro	Allowuley	45	47.2	
		Agyimavuley	40	71.2	
	Ahanta West	Cape Three Point	7	55.2	
		Asemko	6	109.2	
		Mmaapehia	9	28.0	CB*
		Agona	8	35.1	CB
Central	Komenda-Eguafo-Edina-Abirem (KEEA)	Ayensudo	8	146.0	
		Enyinase	8	74.4	CB
		Dompoase	8	66.8	CB
		Kwahenkro	8	95.2	
		Mean old trees		52.5 (36.4–80.0)	
		Mean young trees		76.2 (28–146.0)	
		Mean all trees		65.2 (28–146)	
		SE all trees		8.3	

*CB: Coconut bug attack causing fruit drop

TABLE 5
Leaf N, P, K, Ca and Mg contents of coconut palms

Location	*N %*	*P %*	*K %*	*Ca %*	*Mg %*
Menzezor	1.68	0.13	0.81	0.21	0.17
Aiyinase I	1.96	0.08	0.61	0.23	0.18
Aiyinase II	1.82	0.10	0.74	0.21	0.15
Nyamebekyere	1.82	0.09	0.67	0.24	0.12
Nyamebekyere II	2.24	0.13	1.10	0.32	0.19
Allowuley	1.68	0.10	0.77	0.25	0.08
Agyimavuley	1.96	0.09	0.58	0.22	0.11
Cape Three Point	2.24	0.10	0.76	0.21	0.12
Asemko	2.38	0.13	1.08	0.23	0.14
Mmaapehia	1.96	0.09	0.63	0.28	0.11
Agona	2.10	0.11	0.74	0.31	0.12
Ayensudo	2.10	0.13	1.03	0.42	0.13
Enyinase	1.68	0.08	0.81	0.23	0.12
Dompoase	1.68	0.06	0.58	0.29	0.13
Kwahenkro	1.96	0.10	0.67	0.31	0.11

Agriculture lime is highly soluble. This material will improve the soil *p*H drastically and add large amounts of calcium; 3. Dolimitic lime contains both calcium and magnesium. These elements will be added to the soil in addition to some improvement of the soil reaction; 4. Introduction of leguminous crop (pueraria, etc.) will improve the nitrogen status of these soils; 5. Direct use of mineral fertilizers will surely improve the yield of the crop. This may be practicable when farmers intercrop with cassava, plantain or maize; 6. Examination of fertility status for the various sites showed that Ayensudo (13.6 mg kg^{-1} P) and Asemko (22.2 mg kg^{-1} P) have moderate to high values of available P. Ayensudo soils had the highest exchangeable cations while soil *p*H values for Asemko site was above 5.0. Soil properties of these two sites may partly account for the good yield potentials observed.

Generally, however, the soils have low fertility status and may be the major factor for the general low potential yield. Coconut bug attack resulting in fruit drop may also account for the low potential yield at Agona, Mmaapehia, Dompoase, Enyinase and Kwahenkrom; and Values obtained from foliar analysis are low and within critical levels. Poor soil properties of the study area is the major cause

Conclusion and recommendations

Climatic conditions at all the selected districts are favourable for coconut production. Soil physical properties are generally good. The main problem regarding the soils is the low levels of fertility elements. The soils are strongly acidic particularly those in the Western Region. Exchangeable cations are low with low to very low available phosphorus. Due to the high rainfall regime of the area organic matter is generally moderate, total nitrogen is about average. Drastic improvement of fertility levels of these soils is required for improvement of coconut production in these areas.

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