

CHEMICAL SOIL FERTILITY DIAGNOSIS FOR COTTON CROPPING IN NORTHERN COTE D'IVOIRE

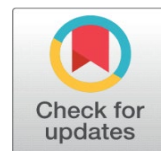


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ABSTRACT

The work was conducted in the north of Cote d'Ivoire, central pivot cotton production savannah area, to make the diagnosis of soil fertility for cotton cropping. Cotton cropping, the mainstay of the savannah's economy, suffered from low productivity in relation to the soil's chemical properties. Prior cultivation, soils samples were collected at a depth of 0 to 30 cm, collecting 32 simple samples to generate a complete sample. The samples were sent to the soil laboratory to measure the pH unities, CEC, nitrogen, phosphorus, potassium, calcium, magnesium, sodium, iron, zinc, copper and manganese contents. In order to facilitate the interpretation of analysis results, the nutrients critical level recommended for optimum production of cotton were used. Results showed that soils had pH ranging from 4.4 to 6.4. On the other hand, the need to add nitrogen, magnesium and phosphorus to the soils and to augment the low carbon, calcium and potassium content. There is the need to search for fertilizer formulations with nitrogen, magnesium phosphorus and calcium for the Cote d'Ivoire cotton belt.

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1. INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is the third most important industrial crop of Côte d'Ivoire after cocoa (*Theobroma cacao* L.) and coffee (*Coffea arabica* L.). this is a cash crop of global importance especially, to the economies of producing in savannah's smallholder farmers who depend on cotton for their livelihoods. Cotton cropping is one of the main sources of income of the Ivorian economy [A. E. Aiwa, 2015](#). It counts for less than 10% of the export incomes. Cotton is the third most important cash crop of the country after cocoa and coffee. Cotton cropping is the main economic resource in the savannah area although it has little relative importance at the national level. The fiber production average 100.000 tons per annum, of which 90% are exported [F. Berti, J.P. Pabanel, E. 2006](#). In on socio-economic hand, cotton production development increases the farmer agricultural incomes in savannah's zone, in particularly, women incomes.

In Côte d'Ivoire, during the 2015-2018 season, cotton covered approximately 357.061 ha, producing 350.280.513 tons'grain, representing 7% [S. Y. Koffi, 2013](#) of the total annual crop surface with a mean yield of 981 kg ha⁻¹ [COIC, 2021](#). During the 2020-2021 season, Ivorian Scientists developped a large, high-throughput genetics centre of cotton seedling. In despite of the varieties of high-yielding, such Gouassou (4,000 kg / ha), Sicama (4,000 kg / ha) and BLT (3,000



kg / ha), new germoplants had produced 1.700 kg ha⁻¹, 1,400 kg ha⁻¹ and 1,200 kg ha⁻¹, respectively. Considering the large amounts of fertilizers and pesticides used, this performance is relatively low compared with major African countries [S. Kanté, 2001](#).

Several reasons have been reported to account for the low cotton productivity on smallholder farms in Côte d'Ivoire. These include low soil fertility as the major cause of yield decline. Low productivity of agriculture in cotton zones still constitute real concerns for the cotton belt economic development. However, accessible information cannot help to distinguish between possible causes such as fertile savannah soils, in areas. To increase these low yields, cotton cropping requires a practical basis into macronutrients (nitrogen, phosphorus and potassium), secondary nutrients (calcium and magnesium) and micronutrients (zinc, iron, manganese, copper and boron). Furthermore, understanding nutrient concentrations is a very useful in assessment of nutrient levels in soils. However, although large fertilization rates have been increasing in north Côte d'Ivoire for the past 10 years, in many cases, this has not resulted in a proportional increase in crop yields [FAO, 2015](#). On the one hand, [Diomandé, L. B. K. Brahima, V. T. Etienne, B.T. Tié, A. Yao-Kouamé, 2014](#) reported that in the savannah zone of Côte d'Ivoire there are mainly acidic soils, where on low pH soils may occur nutrient deficiencies, in particular, among the microelements, copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) deficiency is the most widespread problem in cashew tree fields, mostly related to acidic soils and soils.

On the other hand, soil fertility status may be diagnosed using chemical procedures in laboratory. Based upon diagnostic results, preliminary recommendations would be formulated. Therefore, it is important to provide to the farmer appropriate in savannah's zone, good recommendations in soil conditions [A. Delaunois, 2013](#)., e.g., on a practical basis into macronutrients, secondary nutrients and micronutrients. Based upon soil diagnostic results suggest that cotton yields would be increased if an adequate soil fertility study is implemented. However, there is a lack of information about the nutrient status of soils to facilitate the implementation of better applying fertilizer practices, such as N-P-K-S-B and urea [O. G. Ochou, E. N'Guessan, E. Koto, N. Kouadio, Y. Ouraga, K. Téhia et Y. Touré, 2006](#), [FIRCA, La Filière du Progrès-La filière anacarde, 2018](#) The main aim of this study was to carry out a diagnostic of soil fertility for cotton crop.

2. MATERIALS AND METHODS

2.1. SOIL ANALYSIS

Prior the tillage, surface (0 – 30 cm) soil samples were collected into a grid size of 10-acres using auger. Sampling areas were carried out in Nielle 10.12 Nord and 5.38 W), Dassoungbo (9.23 N and 5.46 W) and Niakaramandougou. For all data sets, samples were located purposively and subjectively to represent soil and cotton cropping land use. Soil samples were bulked, air-dried and 2mm-sieved for analysis. Samples were also collected over each treatment plot. Organic matter (OM) was determined using wet dichromate method, total N by Kjeldahl method, available P by molybdenum blue colorimetry. Exchangeable K, Ca and Mg were extracted using ammonium acetate, K was read on flame photometer and Ca and Mg on atomic absorption spectrophotometer. These samples were also analyzed for plant available Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn) following

Diethylenetriamine Penta-Acetate (DTPA) extraction methodology. Quantification was carried out by Flame Atomic Absorption Spectroscopy (AAS).

2.2. FIELD EXPERIMENT

Field experiments were conducted in 2021 at region of Korhogo, central pivot cotton farm in savannah area, Nielle and Dassoungbo (sandy clay) and clay loam soil of Niakaramandougou. Soils were Ferralsols and Gleysols (Nielle and Dassoungbo) L. B. Diomandé, A. Yao-Kouamé, et B. 2016 and Cambisols and Gleysols in the savannah zone of northern Cote d'Ivoire. Sites were cultivated to cotton with application of fertilizer N-P-K-S-B and urea for many years.

2.3. STATISTICAL ANALYSIS

Statistical data analysis was performed for the whole range of samples including 30 samples and analyses were carried out in the R environment, R Core Team [12, 13]. Descriptive statistics were computed on all soil variables at each location.

3. RESULTS

The soil chemical properties used for the present work are shown in Table 1, Table 2, Table 3. The nutrient critical level recommended for optimum production of cotton in Cote d'Ivoire are also shown D. Arrouays, V. Antoni, M. Bardy, A. Bispo, M. Brossard, C. Jolivet, C. Le Bas, M. Martin, N. Saby, N. Schnebelen, E. Villanneau, P. Stengel, Fertilité 2012, A. Assa, 2005.

Table 1 Initial Soil Ph Units, Organic Matter (OM), Total Nitrogen (NT) And Available Phosphorus (Pav.) Properties									
		Nielle (n = 10)							Satisfactory nutrient values in CI
Vars		mean	sd	Min	Max	Range	skew	Kurtosis	
pH	Units	5.59	0.81	4.40	6.40	2.00	-0.26	-1.92	6,5 < pH < 7,5
OM	g.kg ⁻¹	1.34	0.45	0.80	1.98	1.18	0.19	-1.84	8.6 < OM < 12.9
NT	mg.kg ⁻¹	0.14	0.05	0.08	0.21	0.13	0.29	-1.64	1 < NT < 1,5
Pav.		38.00	7.57	30.00	55.00	25.00	1.19	0.00	25 < Pav. < 50
		Dassoungbo (n = 10)							Satisfactory nutrient values in CI
Vars		mean	sd	Min	Max	Range	skew	Kurtosis	
pH	Units	6.14	0.23	5.80	6.50	0.70	0.38	-1.30	6,5 < pH < 7,5
OM	g kg ⁻¹	0.92	0.20	0.65	1.30	0.65	0.40	-1.11	8.6 < OM < 12.9
NT	mg kg ⁻¹	0.09	0.02	0.06	0.12	0.06	0.30	-1.05	1 < NT < 1,5
Pav.		43.70	29.39	30.00	127.00	97.00	2.24	3.47	25 < Pav. < 50
		Niakaramandougou (n = 10)							Satisfactory nutrient values in CI
Vars		mean	sd	Min	Max	Range	skew	Kurtosis	

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pH	Units	6.00	0.16	5.80	6.30	0.50	0.14	-1.14	6,5 < pH < 7,5
OM	g.kg ⁻¹	0.92	0.28	0.45	1.32	0.87	-0.11	-1.40	8.6 < OM < 12.9
NT	mg.kg ⁻¹	0.08	0.03	0.04	0.12	0.08	-0.26	-1.30	1 < NT < 1,5
Pav.		26.20	6.66	18.00	40.00	22.00	0.75	-0.65	25 < Pav. < 50
TOTAL (n = 30)									
pH	Units	5.91	0.53	4.40	6.50	2.10	-1.49	1.31	6,5 < pH < 7,5
OM	g kg ⁻¹	1.06	0.38	0.45	1.98	1.53	0.92	0.16	8.6 < OM < 12.9
NT	mg kg ⁻¹	0.10	0.04	0.04	0.21	0.17	1.17	0.90	1 < NT < 1,5
Pav		35.97	18.83	18.00	127.00	109.00	3.71	15.33	25 < Pav. < 50

Table 2 Summary statistics showing mean values of basic cations (Ca⁺⁺, Mg⁺⁺, K⁺ and Na⁺) and CEC with the three sites

		Nielle (n = 10)							Satisfactory nutrient values in CI
Vars		mean	sd	Min	Max	Range	skew	Kurtosis	
CEC	cmol _c kg ⁻¹	10.5	4.09	5	17	12	0.18	-1.63	12
Ca ⁺⁺		4.07	2.33	1.3	7.4	6.1	0.09	-1.75	7.5
K ⁺		0.84	0.21	0.6	1.2	0.6	0.4	-1.38	0.25
Mg ⁺⁺		0.34	0.19	0.1	0.6	0.5	0.27	-1.82	1.33
Na ⁺		0.12	0.06	0.1	0.3	0.2	2.28	3.57	Na
Dassoungbo (n = 10)									
CEC	cmol _c kg ⁻¹	7	2	4	10	6	0	-1.57	12
Ca ⁺⁺		1.42	0.43	1	2.2	1.2	0.69	-1.04	7.5
K ⁺		0.87	0.17	0.7	1.2	0.5	0.54	-1.18	0.25
Mg ⁺⁺		0.1	0	0.1	0.1	0	-	-	1.33
Na ⁺		0.05	0.05	0	0.1	0.1	0	-2.19	Na
Niakaramandougou (n = 10)									
CEC	cmol _c kg ⁻¹	7.3	4.27	1	14	13	-0.16	-1.52	12
Ca ⁺⁺		2.75	1.53	0.7	4.8	4.1	-0.3	-1.71	7.5
K ⁺		0.77	0.32	0.3	1.3	1	-0.05	-1.17	0.25
Mg ⁺⁺		0.14	0.13	0.1	0.5	0.4	2.28	3.57	1.33
Na ⁺		0.2	0.16	0.1	0.5	0.4	1.1	-0.64	Na
TOTAL (n = 30)									
CEC	cmol _c kg ⁻¹	8.27	3.83	1	17	16	0.28	-0.44	12
Ca ⁺⁺		2.75	1.92	0.7	7.4	6.7	0.89	-0.31	7.5
K ⁺		0.83	0.24	0.3	1.3	1	-0.16	-0.13	0.25
Mg ⁺⁺		0.19	0.17	0.1	0.6	0.5	1.5	0.64	1.33
Na ⁺		0.12	0.12	0	0.5	0.5	2.03	3.96	Na
Na : Satisfactory values not available; CI: Cote d'Ivoire; SD: Standard deviation									

Table 3 Critical limits of extractable iron, manganese, copper and zinc and their relative content in cotton cropping of three savanah's zones.

Vars	Nielle (n = 10)							Adequate nutrient values in CI
	mean	sd	Min	Max	Range	skew	Kurtosis	
Fe	105.1	11.37	88	119	31	-0.17	-1.78	>4.5
Mn	356.6	123.75	214	514	300	0.00	-1.99	>2.0
Cu mg.kg ₁	34.5	6.26	27	43	16	0.43	-1.66	>0.50
Zn	137.0	16.51	114	157	43	-0.09	-1.91	>1.0
Dassoungbo (n = 10)								
Fe	74.3	12.88	56	90	34	-0.01	-1.77	>4.5
Mn	200.1	5.61	189	208	19	-0.44	-0.90	>2.0
Cu mg.kg ₁	33.9	6.57	22	41	19	-0.70	-1.17	>0.50
Zn	60.0	43.93	31	145	114	1.26	-0.39	>1.0
Niakaramandougou (n = 10)								
Fe	60.8	9.62	50	82	32	0.98	-0.23	>4.5
Mn	200.4	16.03	185	232	47	0.68	-1.16	>2.0
Cu mg.kg ₁	37.3	4.76	29	44	15	-0.41	-1.28	>0.50
Zn	27.6	4.65	17	34	17	-0.76	0.26	>1.0
TOTAL (n = 30)								
Fe	80.07	21.82	50	119	69	0.33	-1.28	>4.5
Mn	252.37	102.28	185	514	329	1.60	0.87	>2.0
Cu mg.kg ₁	35.23	5.91	22	44	22	-0.39	-0.86	>0.50
Zn	74.87	53.55	17	157	140	0.44	-1.72	>1.0

4. DISCUSSIONS

The [Table 1](#) summarized the Chemical properties of soils in relation with soil pH, organic matter, nitrogen and available phosphorus. pH values varied from 4.40 to 6.50 with an average value of 5.91 ± 0.53 ([Table 1](#)). The pH of soils was acidic due to the indigenous parent material. Low organic matter was observed. The observation of Granite weathering biotite alteration to give iron chlorites and the presence of manganese gravels and pebbles on the soil surface strongly argue in favor of such an acidic soil [Diomandé, L. B. S. Soro, D. Koné et K. D. P. 2021](#). The original composition of biotite has a strong influence on the alteration products [Diomandé, L. B. K. Brahima, V. T. Etienne, B.T. Tié, A. Yao-Kouamé, 2014](#). Organic matter content varied from 0.45 to 1.98 g kg⁻¹ with mean value of 1.06 ± 0.38 ([Table 1](#)). 100 % soil samples had poor SOM content.

The main reason for low organic matter in the area is sudanese temperature which exceeds to 35°C due to which rate of decomposition is amplified [Koné, B. S. Diatta, S. Oikeh, Y. Gbalou, M. Camara, D. D. Dohm, et A. Assa, 2015](#). Available total nitrogen (N) contents ranged from 0.04 to 0.21 mg kg⁻¹ with the mean value of 0.10 ± 0.04 . According to criteria suggested ([Table 1](#)), 100 % samples were found low.

Plant available phosphorous content was deficient in 20 % of the analyzed samples, while 80% was categorized in satisfactory range [L. B. Diomandé, O. F. Akotto, C. Kanko, V. E. Tia, and A. Yao-kouamé, 2015](#). Phosphorous content ranged from 18.00 to 127.00 mg kg⁻¹ with mean value of 35.97 ± 18.83 . Low organic matter in soils of surveyed area is the main reason for deficiency of nitrogen. Phosphorous deficiency in acidic soils developed from sandstone pH approaches 6, precipitations as calcium compounds begins, at pH 6.5 the formation of insoluble calcium salt is a factor in rendering the phosphorus unavailable [T. V. Ouattara, K. E. Kassin, L. J. Koko, G. N. Tah, M. E. Assi, G. Amari, E. Dick, et M. 2017](#).

This is the place to draw attention to the fact that in an acidic soil, phosphorus, potassium, calcium, magnesium, sulfur and molybdenum are less easily available, while iron, manganese, boron, copper and zinc will be more. It is also known that most plants have optimal growth when the soil pH varied from 6 to 7 (majority of nutrients are available in this pH zone).

Results of mean values of basic exchangeable cations (Ca⁺⁺, Mg⁺⁺, K⁺ and Na⁺) and CEC their standard deviation (SD), are shown in table 2. Soil samples are shown low values of exchangeable Ca⁺⁺ and Mg⁺⁺ are recorded at the locations. Possible reasons for low values could be that the parent material on which soil has developed is poor in bases and the low pH values in these soil types [Quesada, C. A. J. Lloyd1, L. O. Anderson, N. M. Fyllas, M. Schwarz, C. I. Czimczik, 2011Kopittke et Menzies, 2005](#). High value of exchangeable K⁺ was recorded at the locations. Cation exchange capacity of soil is a total sum of exchangeable cations that it can adsorb at a specific pH. Results are shown low Soil CEC with an average value of 8.27 ± 3.83 ([Table 2](#)). At the three locations it is observed that the values of CEC are relatively low in relation to the of basic exchangeable cations Ca²⁺ and Mg²⁺, specially, soil texture is one of the parameters that have great influence on CEC values [Tomašić, M. J. Zgorelec, A. Jurišić, I Kisić, 2013](#).

Results showed Fe content ranged from 50 to 119 mg Fe/ Kg soil with mean value of 80.07 ± 21.82 mg Fe/Kg ([Table 3](#)). Manganese concentration ranged from 185 to 554 mg Mn/Kg soil with mean value of 252.37 ± 102.28 ([Table 3](#)). Plant available Cu ranged from 22 to 44 mg Cu/ Kg soil with mean value of 35.23 ± 5.91 . Zinc concentration ranged from 17 to 157 mg Zn/ Kg soil with mean value of 74.87 ± 53.55 ([Table 3](#)). All soil samples (100%) were in adequate category. The possible reason of adequate availability of Zn in the study area could be the normal nature of its soils. The soils of Korhogo are free from sodicity problem. Soil pH is in acidic range and did hamper micronutrients availability [B. Koulibaly, 2011](#). This acidic pH reduces the solubility of micronutrients in soil solution resultantly micronutrients precipitate and become unavailable to cotton plants.

5. CONCLUSIONS AND RECOMMENDATIONS

In this investigation, it is observed that the values of Organic matter, CEC, nitrogen, phosphorus, potassium, calcium, magnesium are very low. However, in this investigation a very high concentration had recorded for iron, zinc, copper and manganese contents. pH for all examined soils was acid. pH had an impact on soil depending on acidity. The level of organic matter in the soil is relatively low, and its rapid mineralization, in a context of predominantly sandy soil, does not always make available the nutrients that plants need at certain critical phases of their development. It is recommended to have an organic matter content of at least 5%. It is therefore necessary to add, in several batches, about 25Kg / m² of compost in order to approach 5%.

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