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RESEARCH ARTICLE
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Effects of "*Bokashi*" Organic Fertilizer on Physico-chemical Soil Fertility and the Yield of Cocoa Trees (*Theobroma cacao* L.) in Daloa (Central-Western Ivory Coast)

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ABSTRACT

Most cocoa-growing soils in Côte d'Ivoire are currently of low-quality chemical fertility. This makes it difficult to optimize the development of cocoa trees, and to ensure sustainable cocoa production in Côte d'Ivoire. The aim of this study was to improve soil fertility under cocoa trees and cocoa production in Côte d'Ivoire. The study was conducted in a completely randomized Fisher block design, with three repetitions over two years. The organic fertilizer "*Bokashi*" was applied as follows different doses in the crowns around the cocoa trees. Thus, treatments T0 (treatment control), T1 (2 kg of *Bokashi*), T2 (4 kg of *Bokashi*) and T3 **(**6 kg of *Bokashi*) fractionated in two equal inputs per year were made per cocoa plant. Soil samples were sampled before and after Bokashi application to assess initial fertility and at the end of the study. The fertilizing potential of "*Bokashi*" and cocoa yields fertilized with "*Bokashi*" were evaluated and compared with those of the T0 control treatment. The data collected were subjected to an analysis of variance (ANOVA) using the software SAS 9.4. The results obtained revealed that "*Bokashi*" contains nutrients which improve soil fertility and cocoa yields. The application of "*Bokashi*" has increased the soil's content of elements essential for development and cocoa production. The application of Bokashi has reduced the levels of aluminum, which is toxic plants in high quantity. T2 treatment with a dose of 2 kg of "*Bokashi*" per year and per yields of 1351.05 and potential yields of 1351.05 kg and 1846.8 kg per hectare is the optimum dose for improving fertility soil chemistry and cocoa production.

Keywords: *Bokashi*, Cocoa (*Theobroma cacao*), Fertility, Soils under cocoa trees.

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INTRODUCTION

Since its independence, Côte d'Ivoire's economic development has been based on the agricultural development. The actions undertaken in this sector, particularly in the industrial crops, has led to a sustained growth rate (ICCO, 2015). For more than four decades, Côte d'Ivoire has been one of the world's leading the world's leading producer of cocoa beans, accounting for over 40% of global supply (ICCO, 2015). The cocoa sector is one of the main source for the development of Côte d'Ivoire. Cocoa farming employs a population of more than a million farmers, and around three million people earn their livelihood from income from cocoa (Deheuvels et al., 2003). It also provides many jobs in the secondary and tertiary sectors (ICCO, 2015) and accounts for around 40% of total revenue and contributing to more than 15% of GDP (Gross Domestic Product) (Assiri et al., 2009). However, the existing plantations that have been the basis of the cocoa production in Côte d'Ivoire are senescent (Konaté, 2008). This senescence is accentuated by declining soil fertility (Assiri et al., 2015), unfavorable climate trends in addition to the Swollen shoot disease of cocoa (Koffié et al., 2012), causing low average annual yields of between 260 and 560 kg/ha (Assiri, 2007). In Against this backdrop, Ivorian cocoa production could decline in the coming years. For improve soil fertility and maintain Côte d'Ivoire's cocoa production, fertilizers have been proposed as one of many solutions. However, their high cost makes them almost inaccessible to small-scale producers. What's more, their use is polluting the environment. In this context, the use of fertilizers such as *Bokashi* would be a good substitute for chemical fertilizers, to improve soil fertility and cocoa productivity. This study therefore, improves soil fertility under cocoa trees and increase cocoa yields cocoa trees.

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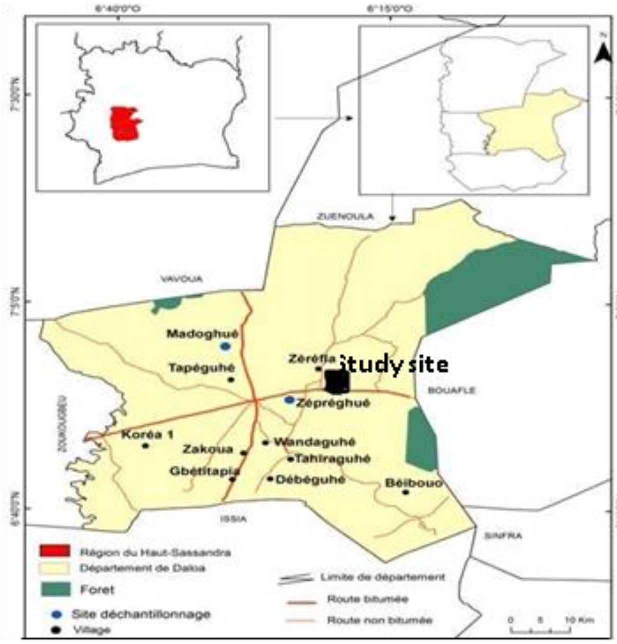

Fig. 1: Location map of study area and site.

MATERIALS & METHODS

Characteristics of the Study Site

The study was carried out in Kouadiokro, a village in the Daloa department (Fig. 1). Daloa, capital of the Haut-Sassandra region, is located in west-central Côte d'Ivoire between 6°30' and 8° North latitude and between 5° and 8° West longitude (Diarra et al., 2016). This region is characterized by two seasons, dry and wet, alternating with high and low temperatures ranging from 24.65 to 27.75°C on average (N'guessan et al., 2014).

June represents the peak of the long rainy season and September the peak of the short rainy season. The forest landscape of the study area varies progressively from semi-dense rainforest to semi- dense coniferous forest deciduous to mesophilic cleared forest. Extensive and shifting cultivation practices and the uncontrolled exploitation of forest species have pushed back the limits of this forest (Sangaré et al., 2009). Soil surveys carried out in the area reveal that the soils are generally moderately leached (or desaturated) ferralitic soils. They have good aptitude for all crop types (Zro et al., 2016). The region's dense hydrographic network is dominated by the Sassandra River. The entire along this river, there are large alluvial plains ideal for vegetable growing off-season. The relief is of little contrast and little variety; it is dominated by plateaux of 200 to 400 m altitude.

Plant Material

The plant material consists of plots of mature cocoa trees in the production phase from raw plant material.

Fertilizing Equipment

The fertilizing material used is "*Bokashi*" organic fertilizer manufactured by "BIOSAVE-CI" structure and marketed under the name "MOAYE" as an organic fertilizer (Fig. 2). *Bokashi* is an organic fertilizer obtained by the degradation of aerobic or anaerobic treatment of materials of plant and/or animal origin with an inoculant with a high degree of humification.

Edaphic Material

The edaphic material consists of soil samples taken from under cocoa trees adults in the production phase (10 to 15 years) in the top 40 cm of soil. These samples were used to determine changes in the physico-chemical properties of these soils.

Technical Equipment

A certain amount of technical equipment was used for the field work, namely :

- a *Munsell* code for determining horizon colors;
- a 2 mm mesh sieve for sieving samples;
- saws, to cut gourmands and dead branches;
- pruning shears to remove parasitic plants (Loranthus);
- picks and shovels for opening pits;
- a Roberval scale, for weighing fertilizer doses;
- a tape measure to measure horizon thickness;
- a knife, for delineating horizons.

Fig. 2: Fertilizer used in the study.

Choice of Plots

The cocoa plots were selected on the basis of the growers' previous work. The plots that have reached their production plateau (between 10 and 15 years of production) and have not fertilized or treated with herbicides during the last three years of production were selected for the study.

Plot Maintenance

Plot maintenance prior to fertilizer application consisted of eliminating gourmands on cocoa trees, dried-out branches that form insect nests and parasitic plants (Loranthus). Sanitary harvesting was also carried out for rid cocoa trees of all sources of disease propagation (dried-out pods, etc.) or rotten). As a result, phytosanitary treatments were carried out to control insects and diseases to achieve satisfactory results.

Morphological Description of Soils

The morphological description of the soils consisted in opening 3 pits (1 m x 1 m x 1.2 m) one (1) pit per block to assess the physical fertility of the soil under cocoa trees. The depth of the pits, capped at 120 cm, varied according to the level of encounter insurmountable constraints. This morphological description of the soils using the Anderson and Ingram (1993) method based on macroscopic observations in the soil pits. Horizons were described according to the morphological characteristics of the soil depth, color, texture, structure, presence of coarse elements, porosity, moisture, compactness, presence of roots, organic matter, boundary and transition between horizons and internal drainage.

Soil Sampling before Application of *Bokashi*

Soil samples were taken from the 0-40 cm horizon using an auger of soils in selected cocoa farms prior to fertilizer application to assess fertility soil chemistry. To do this, 5 soil cores were taken at points randomly selected and blended to form a single composite sample per block. The composite soil samples, each weighing approximately 500 grams, were then air - dried, then sieved using 2 mm mesh sieves and stored in plastic bags and then labelled.

Applied Treatments

The treatments applied consisted of a T0 control treatment (no addition of Bokashi) and 3 doses of *Bokashi* represented by treatments T1, T2 and T3. The trial included a total of 4 treatments:

- **T0** (control): without *Bokashi*;
- **T1**: 2 kg of Bokashi/cacao tree (1 kg in March-April and 1 kg/cacao in August-September);
- **T2**: 4 kg of Bokashi/cacao tree (2 kg/cacao in March-April and 2 kg/cacao in August-September);
- **T3**: 6 kg of Bokashi/cacao tree (3 kg/cacao in March-April and 3 kg/cacao in August-September).

Fertilizer Application Methods

The doses of *Bokashi* were applied to the surface of the cocoa trees in the crown at 60 cm in diameter around the plants (Fig. 3), during the rainy season in two applications per year (March-April and September-October). Before spreading *Bokashi*, dead leaves from cocoa trees have been cleared from the base of the cocoa tree to allow the fertilizers to be in contact with the soil. After spreading, the fertilizers were lightly closed with the dead leaves to reduce the impact of raindrops on fertilizers.

Experimental Set-up

The trial was conducted over a two-year period in a cocoa farm on a one-and-a-half hectare plot (5000 m2) using a Fisher block design. Treatments were repeated 3 times and randomly distributed in blocks arranged parallel to each other following the toposequence. Each block consisted of 4 treatments or elementary plots. In all, the trial comprised 12 elementary plots or treatments (Fig. 4).

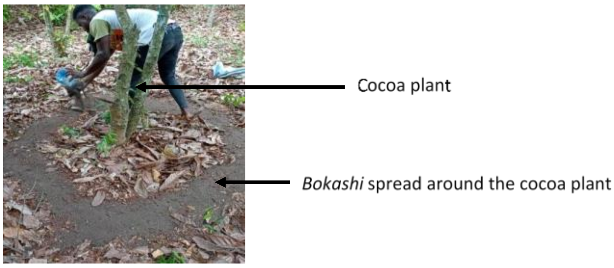

Fig. 3: Spreading *Bokashi* in a ring around the cocoa plant.

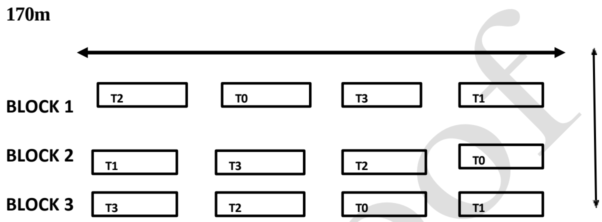

Fig. 4: Experimental set-up and treatment layout.

Physico-chemical Analysis of Soil Samples in the Laboratory

Soil composite samples taken at the beginning and end of the trial after the addition of the fertilizers were analyzed using standard methods (McKeague, 1978) in the "laboratoire des végétaux et des sols (LAVESO)" at the "Ecole Supérieure d'Agronomie (ESA)" in Yamoussoukro. The physical or mechanical analysis focused on granulometry, determined by the sieving method for coarse elements and by densimetry using a pipette of Robinson for fine elements. For chemical analysis:

- soil organic carbon (C) was determined by titrimetry (Walkley-Black method) after oxidation with a mixture of sulfuric acid (H_2SO_4) and sodium dichromate potassium ($K_2Cr_2O_7$)
- total nitrogen was determined by the Kjeldhal method based on oxidation by the wet
- total phosphorus content was assessed colorimetrically after reaction with acid phosphoric acid in the presence of ammonium molybdate and ascorbic acid;
- Assimilable phosphorus (Olsen-Dabin method) was extracted using sodium bicarbonate sodium (NaHCO3) at pH 8.5;
- exchangeable bases (K, Ca, and Mg) were determined using acetate ammonium;
- Cation exchange capacity (CEC) was determined using the saturation method with NH4+ and potassium using a flame photometer;
- calcium and magnesium were determined by flame absorption spectrophotometer atomic ;
- pH (water) was determined using a pH meter after addition of 50ml of 20g ionized water of soil, followed by stirring and settling for 30 minutes.

Statistical Analysis

Data analysis was carried out using descriptive statistics and analysis methods of variance. The data collected were subjected to an analysis of variance (ANOVA) with using SAS 9.4 software. Means were separated using Newman's test and Keuls at the 5% probability threshold.

RESULTS

Soil Physico-chemical Properties before *Bokashi* Application

Physico-chemical properties of soil used as a nursery substrate determined in the laboratory were compared with normative reference values such as shown in Table I below. Soil analysis revealed a low pH (pH=5.3 <6.6-7.3) with a high C/N ratio (C/N=14.63 >9-12). Nitrogen levels, carbon and soil organic matter levels are also very low compared with normative reference values (MO=2.12% <9.6-68.8%; C=1.17% <5.6-10%; N=0.08% <0.3-0.6%). Assimilable phosphorus levels (Pass.=30.5 ppm <50-100 ppm) as well as and cation exchange capacity (CEC=7.69 cmol.kg-1 <10 cmol.kg-1) are very low in relation to normative reference values.

Table I: Physico-chemical parameters of cocoa soils

Parameters	Initial soil substrate contents	*Normative values
pHwater	53	6.6 -7.3
MO (%)	2.12	9.6-68.8
C (%)	1.17	5.6-10
N (%)	0.08	0.3-0.6
C/N	14.63	9-12
Pass (ppm)	30.5	50-100
CEC (cmol.kg)-1	8.31	10-15

*Normative reference values (Duval and Weill, 2011).

Effect of *Bokashi* doses on Changes in Soil Physico-chemical Parameters under Cocoa Trees

Evolution of Acidity (pH), Carbon (N) and Nitrogen (N)

The addition of *Bokashi* to the soil had a significant effect on the evolution of soil acidity and the organic carbon levels under cocoa (Fig. 5). The highest values were obtained in the *Bokashi* treatments compared with the T0 control treatment. pH values ranged from 6 to 6.3. However, treatment T2 (6.3) had the highest pH value. As for carbon, the highest level was obtained in the T3 treatment (1.5 %). On the other hand, *Bokashi* dose additions had no effect on the evolution of nitrogen levels.

Macro-elements Evolution

The addition of *Bokashi* to the soil had a significant effect on the evolution of macroelements (phosphorus, potassium, magnesium, calcium) under cocoa (Fig. 6). In fact, these values vary between 13 and 15 g/kg for phosphorus, 35 and 40 g/kg for magnesium, 15 and 17 g/kg for phosphorus and magnesium for potassium and between 139 and 144 g/kg for calcium.

Aluminium (Al) Evolution

The addition of *Bokashi* to the soil had a significant effect on soil aluminium levels under cocoa (Fig. 7). The lowest values were obtained in treatments based on of *Bokashi* compared with the T0 control treatment (0.19g/kg). These values range from 0.01g/kg and 0.1g/kg.

Evolution of Microelements (B, Cu, Zn, S)

The addition of *Bokashi* to the soil resulted in high values for all the microelements compared to the T0 treatment, with the exception of Boron, where values are (Fig. 8). The highest levels of microelements are observed for Zinc (Zn) and Sulfur (S) in soil. These values range from 1.14 to 1.15 g/kg for Zinc and between 1 and 1.2 g/kg for sulfur.

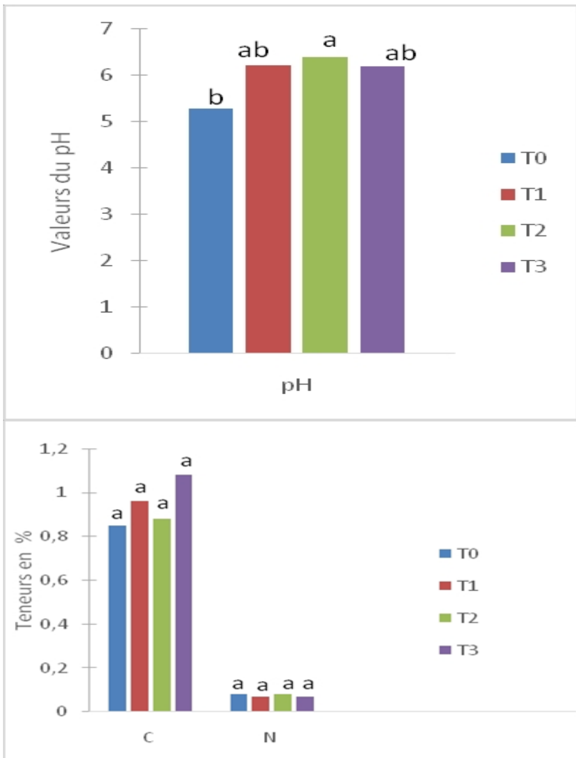

Fig. 5: Changes in pH, carbon and nitrogen levels as a function of *Bokashi* doses.

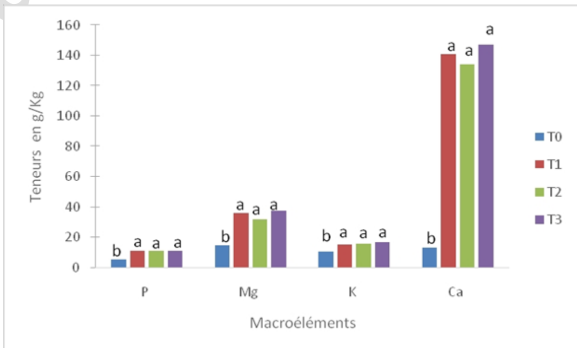

Fig. 6: Changes in soil macro-elements as a function of *Bokashi* doses.

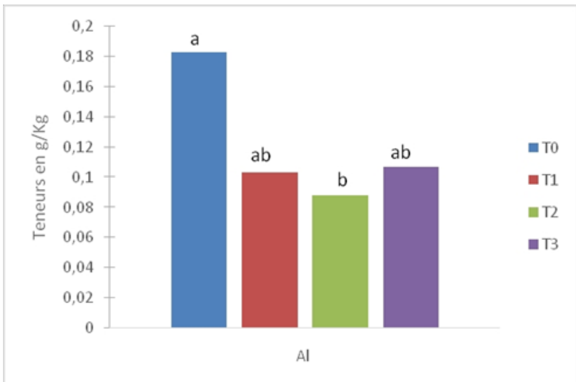

Fig. 7: Changes in soil aluminium content as a function of *Bokashi* doses.

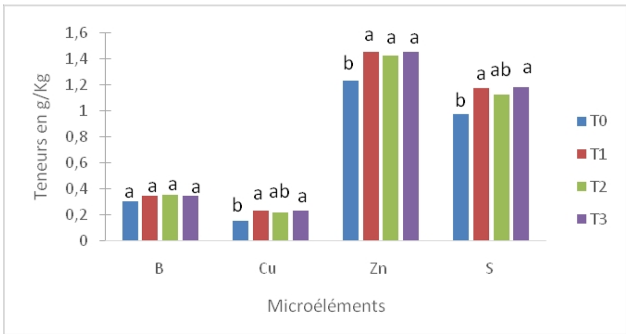

Fig. 8: Changes in soil microelements as a function of *Bokashi* doses.

DISCUSSION

Initial Physico-chemical Characteristics of Soil under Cocoa Trees

The low values of the initial physico-chemical parameters obtained in the soil of the study site compared with normative reference values after soil analyses at the laboratory show the current state of soil poverty under cocoa trees in Côte d'Ivoire, generally characterized by an increased decline in fertility and high acidity (Koko et al., 2009). It is for this reason that Chaussod (2006) asserted that the revival of the cocoa sector requires attention to the chemical fertility of the soil. This poverty could be explained by the nature of the soils under cocoa trees, which are generally tropical soils characterized by high acidity and deficiencies in phosphorus and nitrogen, elements that are essential to growth of most plants (Sahrawat et al., 2001). Indeed, according to Yao-Kouamé (2008), pH levels below 5.5 lead to poor assimilation of nutrients such as nitrogen, phosphorus, potassium and magnesium. According to Toop et al. (2005), soil acidity negatively affects not only physical and chemical parameters, but also the abundance of certain populations of soil decomposers. These results concur with those by Ruganzu et al. (2005), who showed that tropical soils are characterized by low organic matter, high acidity and desaturation with exchangeable cations and slow mineralization of organic matter.

Effects of *Bokashi* doses on Changes in Soil Physico-chemical Properties under Cocoa Trees

The high nutrient content of soils fertilized with *Bokashi is* thought to be related to the *Bokashi* is rich in certain elements that are essential for the proper development of cocoa trees, such as potassium, calcium and magnesium. In fact, calcium plays an important role in the binding of anions to exchange sites, thereby bridging the gap between anions and soil colloids; by occupying the binding sites on the adsorbent complex at the expense aluminum (Al) and iron (Fe) ions, which acidify the soil. High levels of these parameters are also linked to the contribution of organic matter to the soil contained in *Bokashi*, which promote the proliferation of micro-organisms decomposers and the mineralization of elements present in the *Bokashi*. This will increase soil nutrient levels and promote healthy development and growth cocoa production. Indeed, according to Morlat and Gravier (2006), the addition of matter not only increases the mineral content, but also promotes the growth of creation of chemical balances between the elements in the soil, enabling a good cocoa tree development. The low levels of aluminium in the soils obtained from treatments based on *Bokashi*, compared with the control treatment, could be explained by the richness in and the high pH values in the *Bokashi*, which will promote complexation of aluminium in the soil. This will free up binding sites for elements such as exchangeable bases on the adsorbent complex. According to Lompo (2009), in the presence of at high pH levels, the calcium and magnesium contained in organic matter bind the ion aluminium, reducing its content in the soil. High cocoa yields on soils fertilized with *Bokashi*, would be linked to the composition of *Bokashi*, which is partly made up of residues rich in phosphorus and potassium, which are essential for the development of cocoa trees. In fact, according to Kotaix et al. (2021), phosphorus and potassium are recognized as major contributors to the proliferation of flowers, improving fruit quantity and quality. According to Assiri (2010) phosphorus contributes to increasing the flowering intensity of cocoa trees and potassium, to the development of chérelles. These high yields can be explained by adding *Bokashi* to the soil, which, already enriched with microorganisms, will create good porosity and better soil aeration (Ponge, 2004). This, in turn, leads to better mineral nutrition (Kouassi, 2012) and, consequently, good cocoa production having received *Bokashi*. The high values of the soil chemical parameters and the average yield of the cocoa trees obtained by T2 treatment, would be linked to the fact that the mineral elements dose of 2 kg of *Bokashi* per cocoa tree and plant was sufficient for ensure that plants have the essential nutritional requirements needed for good crop production cocoa. This dose would therefore be sufficient to create better habitat conditions for soil fauna to decompose and mineralize the organic matter in the soil.

Conclusion

The study determined the optimal dose of *Bokashi*, likely to improve the soil fertility under cocoa trees. The results obtained revealed that *Bokashi* contains nutrients that can improve soil fertility. The results also showed that the addition of *Bokashi* to the soil has reduced the levels of certain substances in the substrate trace elements such as aluminum, which in very high quantities can be toxic for most plants. T2 treatment with a dose of 2 kg of *Bokashi* per year and per cocoa tree is the most effective optimum dose to improve the chemical fertility of soils under cocoa and the cocoa yield.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

REFERENCES

Anderson, J.M., and Ingram, J.S.I. (1993). Tropical soil biology and fertility: a handbook of methods. 2nd edition. Wallingford-CAB International, 221 p.

Assiri, A. (2007). Identification des pratiques paysannes dans la conduite des vergers de cacaoyers en Côte d'Ivoire. Mémoire de DEA, option agro-pédologie, Université de Cocody-Abidjan, 56 p.

Assiri, A.A. (2010). Étude de la régénération cacaoyère en Côte d'Ivoire : impact des techniques de réhabilitation et de replantation sur le développement et la productivité des vergers de cacaoyers (*Theobroma cacao* L.) en relation avec l'état du sol. Thèse de Doctorat Unique, UFR STRM, Université de Cocody, Abidjan, Côte d'Ivoire, 106 p.

Assiri, A.A., Konan, A., N'Guessan, K.F., Kébé, B.I., Kassin, K.E., Couloud, J.Y., Yapo, A.R., Yoro, G.R., and Yao-Kouamé, A. (2015). Comparaison de deux techniques de replantation cacaoyère sur antécédents culturaux non-forestiers en Côte d'Ivoire. *African Crop Science Journal*, 23(4), 365 – 378.

Assiri, A.A., Yoro, G.R., Deheuvels, O., Kébé, B.I., Keli, Z.J., Adiko, A., and Assa, A. (2009). Les caractéristiques agronomiques des vergers de cacaoyer (*Theobroma cacao* L.) en Côte d'Ivoire. *Journal of Animal & Plant Sciences,* 2 (1), 55- 66.

Chaussod, R. (1996). La qualité biologique des sols : Evaluation et implications. *Etude et Gestion des sols*, 3(4), 261-278.

Deheuvels, O., Assiri, A.A., Pétithuguenin, P., Kébé, B.I., and Flori, A. (2003). Production cacaoyère en Côte d'Ivoire : Etat actuel du verger et pratiques paysannes. *In* Actes de la 14ème conférence internationale sur la recherche cacaoyère (Accra, Ghana, 18-23 octobre 2003), 2, 1157-1166.

Diarra, A., Guy, C.D., and Sékongo, L.G. (2016). Crise de l'eau potable en milieu urbain : cas de la ville de Daloa. *Revue de Géographie de l'Université de Ouaga I,* Pr Joseph KI-ZERBO, 5 (2), 132-151.

Duval, J., and Weill, A. (2011). Guide de gestion globale de la ferme maraîchère biologique diversifiée. Equiterre, Montréal, Québec, 319 p.

ICCO, (2015). What are the effects of intensive commercial production of cocoa on the environnement? Westgate House W5 1YY, United Kingdom. Rapport Annuel ICCO, 25 p.

Koffié, K., Kebe, B.I., Kouassi, N., Anno, A.P., Ake, S., and Muller, E. (2012). Impact de la maladie virale du swollen shoot du cacaoyer sur la production de cacao en milieu paysan à Bazré (Côte d'Ivoire). *Journal of Applied Biosciences*, 43, 2947 - 2957.

Koko, L.K., Kassin, K.E., Yoro, G., N'goran, K., and Yao-Kouamé, A. (2009). Correlations between early aging of cocoa trees and morpho-pedological characteristics in the South-West of Côte d'Ivoire. *J. Appl. Biosci*. 24, 1508-1519.

Konaté, Z. (2008). Etude comparative des pratiques paysannes de plantation ou de replantation cacaoyère en Côte d'Ivoire. Mémoire de DEA. UFR STRM, Université de Cocody-Abidjan (Côte d'Ivoire), 91 p.

Kotaix, A.J.A., Kouadio, K.H., Angu, K.T.P., Kassin, K.E., Gbeuli, T.A., Assi, M.E., Kouamé, N.N., Coulibaly, K., Koko, L.A., and Bakayoko, S. (2021). Les engrais minéraux issus du diagnostic sol améliorent la fertilité chimique et la production cacaoyère à l'Est de la Côte d'Ivoire. *Journal of Animal & Plant Sciences, Vol.47 (1), 8387-8399*

Kouassi, K.G. (2012). Evaluation de différents fertilisants sur la croissance et le développement de pépinières de cacaoyer (*Theobroma cacao* L.) élevées sur différents substrats. Mémoire de fin d'études du Diplôme d'Agronomie Approfondie (DAA), option Agronomie et Productions Végétales, Ecole Supérieure d'Agronomie (ESA) de l'Institut National Polytechnique Houphouet-Boigny, Yamoussoukro, 62 p.

Lompo, F. (2009). Effets induits des modes de gestion de la fertilité sur les états de phosphore et la solubilisation des phosphates naturels dans deux sols acides du Burkina Faso. Thèse de Doctorat d'Etat ès Sciences Naturelles. Université de Cocody, Côte d'Ivoire 214 p.

McKeague J.A. (1978). Manuel de méthodes d'échantillonnage et d'analyses des sols. Soc Can Sci Sol, 2nd Ed. Ottawa, De Kimpe, pp: 114-23.

Morlat, R., and Gravier, J.C. (2006). Effets de divers apports en matière organique sur le sol, la vigne et le vin, dans un essai de longue durée à Chinon (France). 6ème Congrès International sur les Terroirs viticoles: Bordeaux-Montpellier (France) 2 au 8 juillet 2006. 7 p.

N'Guessan, A. H., N'Guessan, K. F., Kouassi, K. P., Kouamé, N. N. and N'Guessan, P. W. (2014). Population dynamics of the cocoa stem borer, Eulophonotus myrmeleon. Felder (Lepidoptera: Cossidae) in the Haut-Sassandra region of Côte d'Ivoire, Journal of Applied Biosciences 83: 7606-7614.

Ponge, J.P. (2004). Effets des composés organiques sur la faune du sol. Perturbation des communautés et recolonisation des substrats pollués. Muséum National d'Histoire Naturelle, CNRS UMR 7179, p. 19.

Ruganzu, V., Bock, L., and Culot, M. (2005). Effets comparés des espèces d'arbustes en jachère sur les propriétés des deux types de sols de Rubona au Rwanda : *African Crop Science Conference Proceedings*, 7, 1095-1101.

Sahrawat, K.L., Jones, M.P., Diatta, S., and Adam, A. (2001). Response of upland rice to fertilizer phosphorus and its residual value in an Ultisol. *Community Soil Science and Plant Annales*, 32, 2457-2468.

Sangaré, A., Koffi, E., Akamou, F., and Fall, C. (2009). État des ressources phytogénétiques pour l'alimentation et l'agriculture. Second rapport national, Ministère de l'agriculture, République de Côte d'Ivoire, 16 p.

Toop, W., Kappes, H., Kulfan, J., and Zach, P. (2005). Distribution pattern of woodlice (Isopoda) and millipedes (Diplopoda) in four primeval forests of the Western Carpathians (Central Slovakia). *Soil Biological Biochemitry,* 38, 43-50.

Yao-Kouamé, A. (2008). Étude des sols brunifiés dérivés des matériaux du complexe volcano-sédimentaire de Toumodi en moyenne Côte d'Ivoire. Thèse de Doctorat d'Etat ès Sciences Naturelles, Université de Cocody-Abidjan, 210 p.

Zro, B.G.F., Guéi, A.M., Nangah, K.Y., Soro, D., and Bakayoko, S. (2016). Statistical approach to the analysis of the variability and fertility of vegetable soils of Daloa (Côte d'Ivoire). *African Journal of Soil Science*, Vol. 4 (4), 328-338.