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Availability of exchangeable potassium due to cocoa pods husk and coffee wastes amended with urea and impact on some other soil physico-chemical properties in a ferralsol of west Cameroon

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ABSTRACT

This incubation trial was carried out to determine the effect of urea amendment of cocoa pods husk (CP) and coffee wastes (CW) on their ability to improve some physico-chemical properties and potassium availability in a Ferralsol of the Western region of Cameroon. It was conducted using a completely randomized design consisting of seven treatments and three replications. Modalities included three doses of urea (0; 0.003 and 0.006g per 100g of dry soil corresponding to 0, 75 and 150 Kg per hectare) combined with 0.225 g corresponding to 5 $t.ha^{-1}$ for each organic residue in addition to the control. The study was conducted under aerobic conditions, at a temperature of 28°C and in darkness for 90 days. The Changes in the studied parameters was taking every 30 days. Compared to the control, the urea amendment of the bio-waste studied reduced the alkalinity and the negative net charge of the soil. On the other hand, it improved organic carbon mineralization and potassium availability (0.81 cmol+/kg with 5 $t.ha^{-1}$ of CP + 75 to 150 $kg.ha^{-1}$ of urea compared to 0.48 cmol+/kg for the control). Urea amendment of cocoa pods husk and coffee wastes can therefore improve the availability of potassium and the mineralisation of organic carbon from these residues in ferralsols.

Contribution/Originality: This study contributes to existing literature that urea amendment of cocoa pods husk and coffee wastes can improve their mineralization and therefore increase their ability to affect some physico-chemical properties and potassium availability in ferralsols.

1. INTRODUCTION

In the West Cameroon region, Ferralsols are the most represented soils [1]. These soils generally have an acidic pH of around 5 and are subject to significant mineralization of organic matter and increased nutrient leaching due to high rainfall and high temperatures. In addition to this, the common practice of farmers is clear cutting and burning to clear the plots. This situation predisposes the soil to degradation, decrease in organic matter, reduction in the amount of nitrogen in the soil, and the rapid depletion of other nutrients such as potassium [2-4]. In agriculture, the most pronounced effects are reduced yields of the main food crops. For example, Sanginga, et al. [5] noted a reduction in cassava yields from 11 $t.ha^{-1}$ to less than 2 $t.ha^{-1}$ for a reduction in the duration of fallow in the humid savannah zones of Nigeria and Benin to less than two years. Despite mineral fertilization, crop yields tend to decrease from one cropping season to the next due to mineral leaching [6]. Hence the need to use amendments such as organic matter to improve the properties of these soils and to make the use of mineral fertilizers profitable [7] as they are expensive and not widely available, are not affordable for most farmers [8].

The main sources of organic matter in agricultural soils are crop residues and root systems, droppings, manure, slurry or recycling of organic wastes from effluents, composts and sludge. When these organic materials are incorporated into the soil, there are three main reactions: CO_2 production, humification and mineralization [9]. Mineralization of organic matter results from its use as an energy source by soil micro-organisms [10]. The organic compounds are then degraded with the production of carbon dioxide. Several studies argue that the presence of exogenous mineral nitrogen in the soil can modify the mineralization rates of organic inputs. Along these lines, Schomberg, et al. [11] have shown that decomposition of nitrogen-rich, lignin-poor plant residues is rapid, whereas decomposition of nitrogen-poor, lignin-rich compounds requires mineral nitrogen that is immobilized by soil microorganisms to satisfy their "thirst for nitrogen". According to Monsanto [12] the carbon to nitrogen ratio (C/N) varies from one plant residue to another, but soil microbes prefer a C/N ratio around 10. Several studies have examined the potential to enhance soil fertility through the use of plant by-products with or without mineral fertilizers [13-16] but the use of cocoa husks and coffee residues with or without urea amendments has not yet been widely studied. These potassium-rich residues [17] which are available in Cameroon [18] are rarely used for soil fertilization. They are generally abandoned in the fields either in pits or in the form of piles, especially in the case of cocoa. This is mainly due to their low decomposition rate and the inoculation of cryptogamic diseases, especially *Phytophtora infestans* infection [19].

Hence the present study, which was conducted to test the effect of cocoa pods husk and robusta coffee wastes amended or not with urea on some physico-chemical properties and potassium in a Ferralsol of West Cameroon.

2. MATERIALS AND METHODS

2.1. Soil Used

The soil used (0-20 cm deep) for this study came from an experimental plot of the Faculty of Agronomy and Agricultural Sciences (FAAS) of the University of Dschang, located in the Western Highland of Cameroon at 5°20'N, 11°45'E and an average altitude of 1410 m above sea level. The area has a Cameroonian equatorial-type climate modified by altitude characterized by monomodal annual rainfall. The dry season runs from mid-November to mid-March and the rainy season runs from mid-March to mid-November with an average annual rainfall of 1500 to 2000 mm. Temperatures vary between 10 and 25°C for an average of 20°C. The soil used was according to the World Reference Base (WRB) 2015 a Mollic Geric Rhodic Ferralsol (Aric, Orthoeutric). Table 1 shows the initial soil characteristics determined at the FASA soil analysis laboratory using the methods described by Pauwels, et al. [20].

2.2. Used Crop Residues and Chemical Fertilizer Material

The crop residues used in this study were cocoa pods husk and robusta coffee wastes (parchment and pericarp) both in the form of grindings (ø < 2mm). The cocoa husks were collected from a family farm in the town of Santchou and the coffee residues were collected from a hulling factory in the same town. Once obtained, we dried these by-products in the open air for two weeks and then dried them in a ventilated oven at 70 °C until a constant mass was obtained. Finally, these residues were crushed and sieved (ø < 2 mm). The chemical characteristics of these waste products were also determined in the soil analysis laboratory of FASA (Table 2). The inorganic fertilizer used in this experiment was urea at 46% nitrogen bought in a phyto-sanitary shop.

2.3. Experimental Design

The trial was conducted using a completely randomized design consisting of seven treatments and three replications. For each waste tested, 0.225 g corresponding to 5 $t.ha^{-1}$ was combined with three doses of urea (0;

0.003 and 0.006g per 100g of dry soil) corresponding to 0, 75 and 150 Kg per hectare. Subsequently, the combinations thus obtained were mixed with soil samples (100 g each) for comparison with an unamended control.

The treatments were as follows:

- T0 : Unamended soil (control) ;
- TA : 0.225 g of cocoa pods husk (5 $t.ha^{-1}$) without urea ;
- TB : 0.225 g of cocoa pods husk (5 $t.ha^{-1}$) + 0,003 g of urea (75 $kg.ha^{-1}$) ;
- TC : 0.225 g of cocoa pods husk (5 $t.ha^{-1}$) + 0,006 g of urea (150 $kg.ha^{-1}$) ;
- TD : 0.225 g of coffee wastes (5 $t.ha^{-1}$) without urea;
- TE : 0.225 g of coffee wastes (5 $t.ha^{-1}$) + 0,003 g of urea (75 $kg.ha^{-1}$);
- TF: 0.225 g of coffee wastes (5 $t.ha^{-1}$) + 0,006 g of urea (150 $kg.ha^{-1}$).

2.4. Conduct of Incubations

The procedure applied in this study was based on those used by Bouajila, et al. [15] and Mboua, et al. [19]. In 125 mL jars, 100 g of dry treated or untreated soil was introduced. Throughout the trial, weekly weigh-overs were used to maintain the moisture content of the mixtures at field capacity. The jars thus formed were also kept in the dark at a temperature of 28°C in a thermo-regulated and ventilated chamber for a period of 90 days. The potassium dynamics and other physico-chemical parameters studied in this experiment were monitored every 30 days after the waste products were added. These were actual acidity, total acidity, net soil charge, organic carbon and electrical conductivity.

2.5. Physico-Chemical Analysis

In this study, grain size was determined by the Robinson-Köhn pipette method and bulk density on undisturbed samples after oven drying at 105 °C taken with metal cylinders. The actual acidity was determined using a sample-distilled water suspension, while the total acidity was determined using a normal potassium chloride (KCl) sample suspension with a ratio of 1/2.5 (w/v). The water holding capacity was determined by the amount of water held in the soil versus the dry weight of soil sample 24 hours after saturation and organic carbon content was determined by Walkley and Black potassium dichromate titration method. Total nitrogen was determined by the Kjeldalh method and available phosphorus by the Bray 2 method. Cation exchange capacity (CEC) and Exchangeable Ca^{2+}, Mg^{2+}, K^+ and Na^+ were determined by the leaching of ammonium acetate method.

2.6. Statistical Analysis

Data entry and diagram design was done using Microsoft EXCEL software. Using SPSS 23 (statistical package for social sciences), the normal residue test (Shapiro-Wilk test) and the one-factor analysis of variance (ANOVA) were performed. This software was also used for multiple comparison tests at the 5% level of significance according to Duncan's model and for the analysis of the correlation between some of the parameters studied.

3. RESULTS AND DISCUSSIONS

3.1. Initial Physico-Chemical Characteristics of the Soil

The initial physico-chemical properties of the soil in this study are shown in Table 1. Analysis of the results showed that the soil was loamy sand with an average clay content of 12.24%. According to Beernaert and Bitondo [21] it was moderately acidic (5.3 < pH < 6) with a negative ΔpH (pH KCl-pH H2O = -0.9) giving it a negative net charge. Its organic carbon content was very high (4.63%) but of very poor quality (C/N > 20) with an average total nitrogen content (0.125 < N < 0.225%). The sum of bases was high and CEC_7 moderate with a high base saturation rate (78.89%). The Ca^{2+} level was low (2 < Ca^{2+} < 5cmol+/kg) while Mg^{2+}, K^+ and Na^+ were high, medium and very low respectively. Finally, the level of available phosphorus was low (7 < Pass < 16 ppm).

Table 1. Some physico-chemical characteristics of the studied soil.

Physico-chemical characteristics	Means and standard deviations
Texture	
Clay (%)	11.71 ± 0.69
Total silt (%)	06.10 ± 1.49
Total sand (%)	82.19 ± 1.76
Textural class (USDA)	LS
Acidity	
pH H_2O	5.4 ± 0.10
pHKCl	4.5 ± 0.20
Organic matter	
Organic carbon (%)	04.63 ± 0.17
Organique matter (%)	07.99 ± 0.08
Total nitrogen (%)	00.18 ± 0.02
C/N ratio	25.36± 1.71
Exchangeable cations	
Calcium (cmol+/kg)	03.68 ± 0.41
Magnesium (cmol+/kg)	05.76 ± 0.18
Potassium (cmol+/kg)	00.58 ± 0.00
Sodium (cmol+/kg)	00.07 ± 0.01
Sum of exchangeable cations (S)	10.09 ± 0.24
Cation exchange capacity	
CEC with 1N ammonium acetate pH7 (cmol+/kg)	12.84 ± 0.43
ECEC (S + exchangeable acidity in cmol+/kg)	11.69 ± 0.07
Saturation rate (%)	78.89 ± 3.58
Assimilable phosphorus « P » Bray 2 (ppm)	07.01 ± 0.54
Electrical conductivity (mS/cm)	00.05 ± 0.01
Bulk density (g/cm³)	01.11 ± 0.03
Field capacity (% of dry soil)	63.44 ± 2.23

Note: Mean ± standard deviation; n=3; USDA: United State department of agriculture; LS: Loamy sand; ECEC: Effective cation exchange capacity.

3.2. Chemical Characteristics of Cocoa Pods Husk and Coffee Wastes

The chemical characteristics of the by-products used in this work are listed in Table 2. The analysis of this table shows that cocoa pods husk has a C/N ratio (23) and a total phosphorus content (0.11%) almost twice as high as those of coffee residues and a similar organic matter content. Also, the potassium contents of these two residual products are high (2.1 and 1.5% respectively) in relation to the contents of calcium, magnesium and sodium.

Table 2. Chemical characteristics of cocoa hulls and coffee residues (g/100g).

Chemical characteristics	Cocoa shells	Coffee residues
Ash (%)	06.60	06.60
Organic carbon (%)	46.70	45.45
Organic matter (%)	80.51	78.36
Total N (%)	02.03	03.57
C/N ratio	23.00	12.73
Total phosphorus (%)	00.11	00.05
Ca (%)	00.68	00.88
Mg (%)	00.56	00.32
K (%)	02.11	01.51
Na (%)	00.23	00.16
CEC pH_7 (cmol+/kg)	22.24	23.04
Fe (ppm)	2035.90	5861.07
Electrical conductivity (mS/cm)	03.19	04.16

Note: Nb: Contents are expressed as a percentage of dry matter (DM).

3.3. Effect of Different Treatments on Soil Acidity and Net Soil Charge

Figure 1 and 2 show, respectively, the results of the effect of the different treatments on actual and total acidity as a function of incubation periods. Analysis of these figures after 90 days of incubation reveals that, compared to the initial state (pH water = 5.4), the actual acidity was lower for soils treated only with plant residues (pH water ≥ 5.50) and higher for soils treated with combined inputs of organic fertilizers and increasing doses of urea (pH water ≤ 5.27). For pH KCl, the general trend was increasing (pH KCl ≥ 4.57) with all treated soils and only the control showed a decrease (pH KCl = 4.40) from the initial state (pH KCl = 4.50). Significant ($P < 0.05$) and highly significant differences ($P < 0.01$) were observed after 60 and 90 days of incubation respectively between the different treatments for actual acidity, whereas only at 60 days of incubation were significant differences ($P < 0.05$) observed between the different treatments for potential acidity.

After 90 days of incubation, the TA modality predominated for actual acidity (pH water = 5.53) and the TB modality predominated for potential acidity (pH KCl = 4.67). In this study, the effects were greatest at 30 and 60 days and the pH values were lowest at 90 days. These results corroborate those of Kaho, et al. [16]; Tabitha, et al. [22] and Nyami, et al. [23] which obtained decreases in pH when increasing rates of mineral fertilizers (especially urea) were applied in combination with biochar, quail manure and *Tithonia diversifolia* leaves. The decrease in pH in soils with increasing doses of urea is thought to be due to the leaching of base cations such as Ca^{2+} and Mg^{2+} and their replacement by acidifying NH_4^+ ions resulting from the decomposition of urea in the clay-humic complex. On the other hand, the increase in pH in soils under the application of crop residues alone would be due to the chelation of toxic cations (Fe and Al) by organic matter which reduces their acidifying power [19, 24].

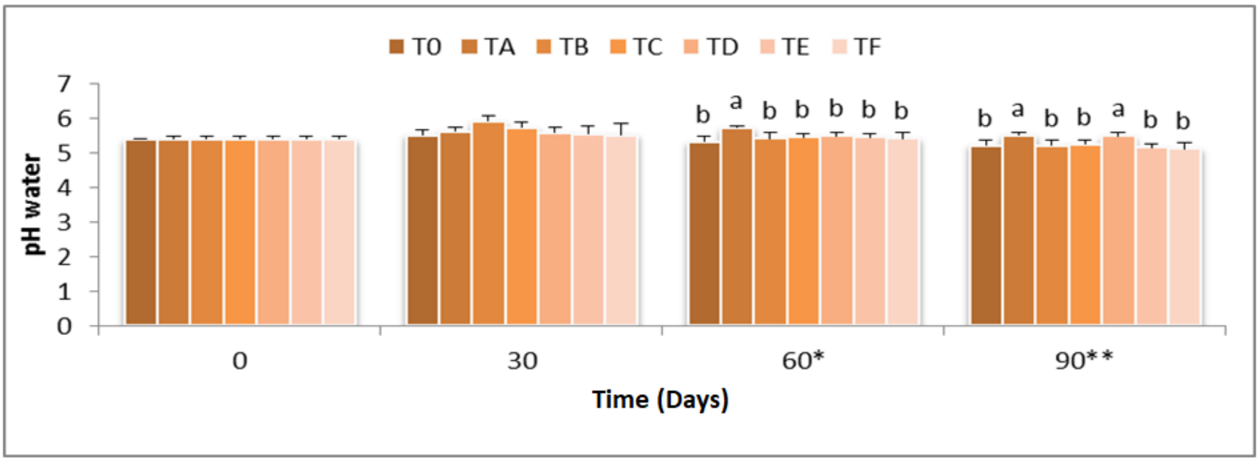

Figure 1. Combined effect of organic fertilizers and urea on actual soil acidity as a function of incubation periods.

Note: * = Significant differences ($P < 0.05$); ** = highly significant differences ($P < 0.01$). T0: Control; TA: 5 $t.ha^{-1}$ of cocoa pods husk without urea ; TB : 5 $t.ha^{-1}$ of cocoa pods husk + 75 $kg.ha^{-1}$ of urea ; TC : 5 $t.ha^{-1}$ of cocoa pods husk + 150 $kg.ha^{-1}$ of urea ; TD : 5 $t.ha^{-1}$ of coffee wastes without urea; TE : 5 $t.ha^{-1}$ of coffee wastes + 75 $kg.ha^{-1}$ of urea ; TF : 5 $t.ha^{-1}$ of coffee wastes + 150 $kg.ha^{-1}$ of urea; a and b: means with the same letters on the same dates are not significantly different

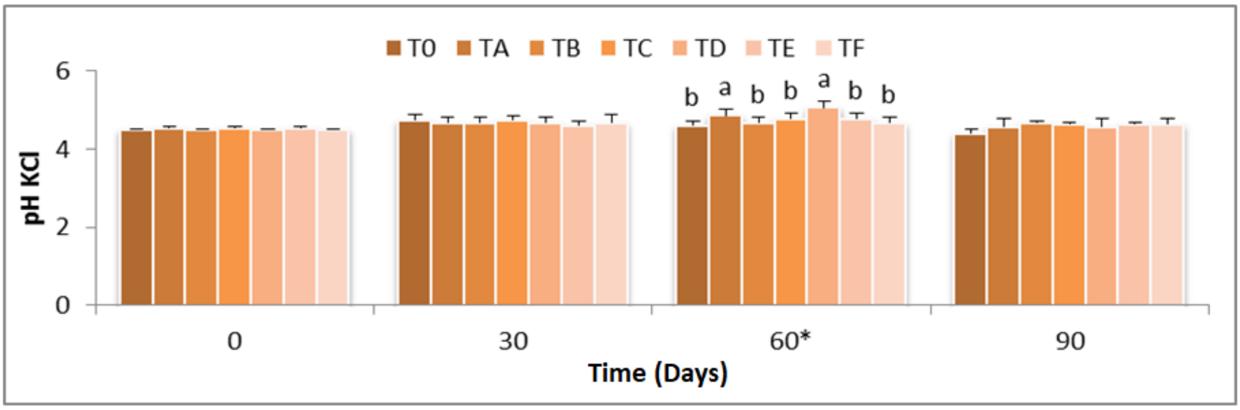

Figure 2. Effect of different treatments on total soil acidity according to incubation periods.

Note: * = Significant differences ($P < 0.05$) ; T0: Control; TA: 5 $t.ha^{-1}$ of cocoa pods husk without urea ; TB : 5 $t.ha^{-1}$ of cocoa pods husk + 75 $kg.ha^{-1}$ of urea ; TC : 5 $t.ha^{-1}$ of cocoa pods husk + 150 $kg.ha^{-1}$ of urea ; TD : 5 $t.ha^{-1}$ of coffee wastes without urea; TE : 5 $t.ha^{-1}$ of coffee wastes + 75 $kg.ha^{-1}$ of urea ; TF : 5 $t.ha^{-1}$ of coffee wastes + 150 $kg.ha^{-1}$ of urea; a and b: means with the same letters on the same dates are not significantly different.

Figure 3 shows the effect of the different treatments on the net soil charge as a function of incubation periods. Throughout the trial, the ΔpH remained all negative, giving a negative net soil charge. After a considerable increase in the negative net soil charge after 30 days, the general trend is towards a decrease in this parameter for all treatments except those based on plant residues alone. It was at 90 days after incubation that highly significant differences were observed between the different treatments. At the end of the incubations, the highest pH difference was obtained with TA (ΔpH = -0.97) and the lowest with TF (ΔpH = -0.5).

Thus, the net charge of all treatments remained negative throughout the trial with a decrease in negativity for the organic treatments and an increase for the organo-mineral treatments. These results corroborate those of Djeke, et al. [25] and can be explained by a higher release of acidifying cations (NH_4^+) from crop residues combined with urea compared to plant residues applied alone [19, 26].

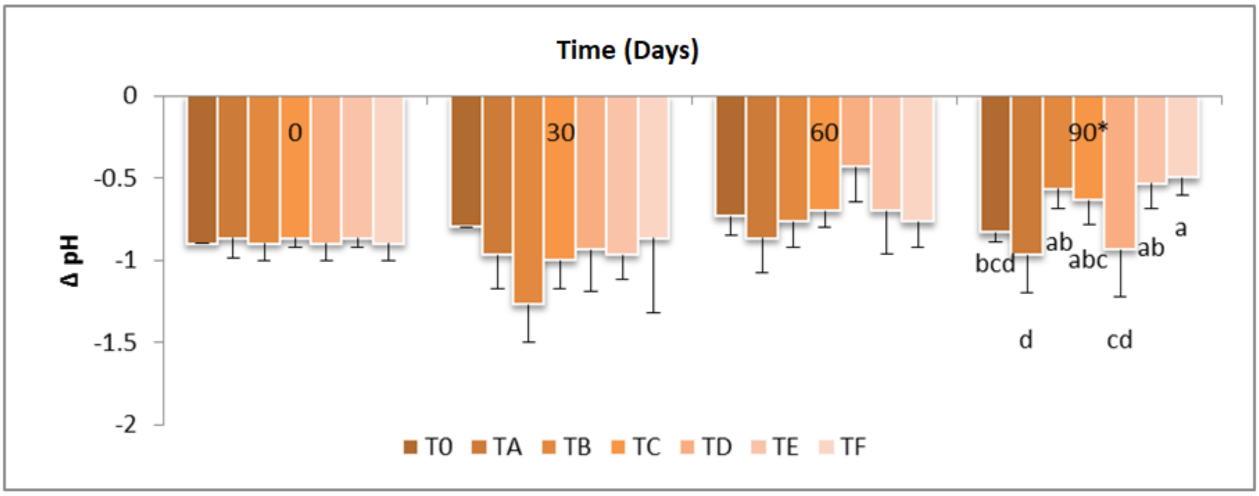

Figure 3. Effect of different treatments on the net soil charge according to incubation periods.

Note: * = Significant differences ($P < 0.05$) ; T0: Control; TA: 5 t.ha^{-1} of cocoa pods husk without urea ; TB : 5 t.ha^{-1} of cocoa pods husk + 75 kg.ha^{-1} of urea ; TC : 5 t.ha^{-1} of cocoa pods husk + 150 kg.ha^{-1} of urea ; TD : 5 t.ha^{-1} of coffee wastes without urea; TE : 5 t.ha^{-1} of coffee wastes + 75 kg.ha^{-1} of urea ; TF : 5 t.ha^{-1} of coffee wastes + 150 kg.ha^{-1} of urea; a, b, c and d: means with the same letters on the same dates are not significantly different.

3.4. Effect of the Different Treatments on the Organic Carbon Content (%) of the Soil

Very highly significant differences ($P < 0.001$) were observed between the different treatments at all incubation periods (Table 3). After 90 days, the organic carbon content was increased in soils treated exclusively with cocoa pods husk (TA = 3.88%) and coffee residues (TD = 3.84%) compared to the control (T0 = 3.74%). This level was rather lower in soils that received combined inputs of organic and mineral fertilizers. Compared to the initial state, the general trend was a decrease in organic carbon content for all treatments after 90 days of incubation. Thus, the greatest rates of decline were recorded between 30 and 60 days. This period would probably correspond to the time when the rate of organic carbon mineralization was at its optimum. Thereafter, between 60 and 90 days, these rates of decline tend to stabilize, reflecting a decrease in the importance of this process.

The changes in organic carbon content observed in this study are in agreement with the results of Nyami, et al. [23] as well as those of Khan, et al. [27] who reported similar observations with the use of increasing doses of mineral nitrogen fertilizers combined or not with crop residues. According to Khan, et al. [27] exclusive nitrogen, phosphorus and potassium (NPK) fertilization as opposed to organic fertilization depletes soil organic matter stocks in the long term despite considerable crop residue inputs. The latter has also shown that the use of increasing rates of nitrogen in the soil is correlated with increases in the rate of humus mineralization. Increases in organic carbon levels for soils treated only with cocoa pods husk and coffee residues corroborate those of Mboua, et al. [19]; Tabitha, et al. [22] and Kabirinejad, et al. [28]. These results show that the exclusive use of these residues led to an increase in more humified compounds in the soil, which according to Hartemink and O'sullivan [29] are likely to slow down decomposition.

Table 3. Combined effect of crop residues and urea on organic carbon content.

Treatments	Organic carbon (%)			
	0 Day	30 Days***	60 Days***	90 Days***
T0	4.24±0.01 (a)	4.15±0.02 (b)	3.95±0.02 (a)	3.74±0.02 (c)
TA	4.26±0.01 (a)	4.23±0.02 (a)	3.93±0.02 (a)	3.88±0.00 (a)
TB	4.24±0.05 (a)	4.14±0.04 (b)	3.24±0.04 (c)	3.11±0.02 (e)
TC	4.22±0.01 (a)	4.04±0.02 (a)	2.64±0.02 (d)	2.53±0.01 (g)
TD	4.24±0.04 (a)	4.12±0.01 (b)	3.94±0.04 (a)	3.84±0.03 (b)
TE	4.25±0.02 (a)	4.16±0.03 (b)	3.25±0.02 (c)	2.95±0.02 (f)
TF	4.29±0.01 (a)	3.73±0.03 (c)	3.35±0.03 (b)	3.15±0.03 (d)

Note: *** = Very highly significant differences (P < 0.001); T0: control; TA: 5 $t.ha^{-1}$ of cocoa pods husk without urea ; TB : 5 $t.ha^{-1}$ of cocoa pods husk + 75 $kg.ha^{-1}$ of urea ; TC : 5 $t.ha^{-1}$ of cocoa pods husk + 150 $kg.ha^{-1}$ of urea ; TD : 5 $t.ha^{-1}$ of coffee wastes without urea; TE : 5 $t.ha^{-1}$ of coffee wastes + 75 $kg.ha^{-1}$ of urea ; TF : 5 $t.ha^{-1}$ of coffee wastes + 150 $kg.ha^{-1}$ of urea; a, b, c, d, e, f and g : means with the same letters in brackets on the same dates are not significantly different.

3.5. Effect of the Different Treatments on the Exchangeable Potassium Content of the Soil

The results presented in Table 4 illustrate the evolution of potassium content in the soil during the trial. They show that there are very highly significant differences ($p < 0.001$) between the different treatments at 60 and 90 days of incubation.

After 90 days of incubation, the treatments resulting from the combination of cocoa pods husk and urea showed the highest levels of exchangeable potassium ($0.75 \leq K \leq 0.81$ cmol+/kg) while the treatments resulting from the combination of coffee residues and urea gave lower and similar levels of potassium ($0.75 \leq K \leq 0.76$ cmol+/kg). The lowest level at the end of the trial (0.48 cmol+/kg) was obtained with the control. Between the dates for each treatment, there was a small increase between 0 and 30 days, then a large increase between 30 and 60 days, and finally stability. Also, between 30 and 60 days, soils treated with amended crop residues showed greater increases in exchangeable potassium than other soils. The highest rate (50%) was obtained with the TC modality, while the lowest rate (0.02%) was obtained with the control.

These results corroborate those of Luciens, et al. [30] and Kaho, et al. [16] who obtained increases in exchangeable potassium contents of soil respectively with poultry manure and *Tithonia diversifolia* leaves combined or not with mineral fertilizers. These observations highlight the improving power of organic matter on soil chemical properties and confirm that it is a source of nutrients for crops [31]. The predominance of urea-combined cocoa pod husk treatments over urea-combined coffee wastes treatments is thought to be related to the higher content of this element in these residues [32].

Table 4. Combined effect of crop residues and urea on exchangeable potassium content.

Treatments	Exchangeable potassium (cmol+/kg of soil)			
	0 Day	30 Days	60 Days***	90 Days***
T0	0.42±0.03 (a)	0.45±0.05 (a)	0.46±0.04 (d)	0.48±0.03 (c)
TA	0.44±0.04 (a)	0.45±0.05 (a)	0.64±0.01 (c)	0.75±0.01 (a)
TB	0.43±0.05 (a)	0.53±0.05 (a)	0.74±0.02 (b)	0.81±0.01 (a)
TC	0.43±0.04 (a)	0.54±0.04 (a)	0.81±0.04 (a)	0.81±0.04 (a)
TD	0.46±0.02 (a)	0.44±0.05 (a)	0.63±0.03 (c)	0.75±0.02 (b)
TE	0.42±0.04 (a)	0.53±0.04 (a)	0.71±0.01 (b)	0.75±0.01 (b)
TF	0.43±0.04 (a)	0.52±0.03 (a)	0.75±0.01 (b)	0.76±0.03 (b)

Note: *** = Very highly significant differences (P < 0.001) ; T0: Control; TA: 5 $t.ha^{-1}$ of cocoa pods husk without urea ; TB : 5 $t.ha^{-1}$ of cocoa pods husk + 75 $kg.ha^{-1}$ of urea ; TC : 5 $t.ha^{-1}$ of cocoa pods husk + 150 $kg.ha^{-1}$ of urea ; TD : 5 $t.ha^{-1}$ of coffee wastes without urea; TE : 5 $t.ha^{-1}$ of coffee wastes + 75 $kg.ha^{-1}$ of urea ; TF : 5 $t.ha^{-1}$ of coffee wastes + 150 $kg.ha^{-1}$ of urea; a, b, c and d : means with the same letters in brackets on the same dates are not significantly different.

3.6. Effect of the Different Treatments on the Electrical Conductivity of the Soil

Table 5 presents the evolution of the soil electrical conductivity during the experiment. Very highly significant differences ($P < 0.001$) were observed between the different treatments throughout the incubations. At the end of the trial, all treated soils showed higher electrical conductivity values than the control (0.08 mS/cm). The highest value was obtained with the TB, TC and TF treatments (0.15 mS/cm) and the lowest value for treated soils was obtained with the TA, TD and TE treatments (0.12 mS/cm). Nevertheless, the values obtained at the end of the incubations were all below the critical value (2 mS/cm) beyond which favorable plant growth is compromised in the study area [20].

These results are in agreement with those of Bryla, et al. [33] as well as those of Antil and Singh [34] who obtained increases in the electrical conductivity of the soil with mineral nitrogen fertilizers combined or not with organic fertilizers. They show that the addition of fertilizers to the soil considerably modifies the extent of solubilization, sorption and mineralization/immobilization processes in the soil. Organic and mineral inputs therefore have a major influence on the quantities of ions that determine the electrical conductivity of the soil [14].

Table 5. Combined effect of crop residues and urea on the electrical conductivity (mS/cm) of the soil.

Treatments	Electrical conductivity (mS/cm)			
	0 Day***	30 Days***	60 Days***	90 Days***
T0	0.05±0.01 (c)	0.07±0.01 (e)	0.07±0.01 (e)	0.08±0.01 (c)
TA	0.06±0.01 (c)	0.09±0.01 (d)	0.09±0.01 (cd)	0.12±0.01 (b)
TB	0.10±0.01 (ab)	0.12±0.01 (bc)	0.14±0.01 (a)	0.15±0.01 (a)
TC	0.11±0.01 (a)	0.15±0.01 (a)	0.11±0.01 (b)	0.15±0.01 (a)
TD	0.06±0.01 (c)	0.08±0.01 (de)	0.10±0.01 (bc)	0.12±0.02 (b)
TE	0.08±0.01 (b)	0.11±0.01 (c)	0.10±0.01 (bc)	0.12±0.01 (b)
TF	0.11±0.01 (a)	0.13±0.01 (b)	0.08±0.01 (de)	0.15±0.01 (a)

Note: *** = Very highly significant differences ($P < 0.001$) ; T0: Control; TA: 5 $t.ha^{-1}$ of cocoa pods husk without urea ; TB : 5 $t.ha^{-1}$ of cocoa pods husk + 75 $kg.ha^{-1}$ of urea ; TC : 5 $t.ha^{-1}$ of cocoa pods husk + 150 $kg.ha^{-1}$ of urea ; TD : 5 $t.ha^{-1}$ of coffee wastes without urea; TE : 5 $t.ha^{-1}$ of coffee wastes + 75 $kg.ha^{-1}$ of urea ; TF : 5 $t.ha^{-1}$ of coffee wastes + 150 $kg.ha^{-1}$ of urea; a, b, c, d and e : means with the same letters in brackets on the same dates are not significantly different.

3.7. Correlation between the Soil Physico-Chemical Properties Studied

Table 6 presents the correlation coefficients of the relationships between the soil physico-chemical properties studied. These coefficients ranged from -0.53 to 0.53, with most of them being less than 0.5. In half of the cases, these correlations were significant ($P < 0.05$) or highly significant ($P < 0.01$). Also, just over half of the correlation coefficients obtained were positive. The highest correlation coefficient values were found between pH H_2O and pH KCL (0.53**), between ΔpH and organic carbon (-0.52**) and between ΔpH and organic matter (-0.53**). Exchangeable potassium and organic carbon were negatively and highly significantly correlated (-0.51**). The lowest correlation coefficient (0.11) was obtained between ΔpH and electrical conductivity.

Table 6. Correlation matrix of the physico-chemical properties of the studied soil.

Soil characteristics	K_{ech}	pH_{water}	pH_{KCl}	ΔpH	CO	Na	EC
K_{ech}	1						
pH_{water}	0.14	1					
pH_{KCl}	0.35	0.53**	1				
ΔpH	0.23	-0.52**	0.38*	1			
CO	-0.51**	0.31	-0.12	-0.53**	1		
Na	0.26	-0.46*	0.05	0.52**	-0.41*	1	
EC	0.38*	0.17	0.38*	0.11	-0.30	0.20	1

Note: * = Significant differences ($P < 0.05$); ** = Highly significant differences ($P < 0.01$); K_{ech} : Exchangeable potassium, OC : Organic carbon, EC: Electrical conductivity; ΔpH : delta pH.

These results are in agreement with those obtained by Tabi, et al. [35] and Kozak, et al. [36] on the correlations between different soil chemical parameters (pH H_2O, pH KCl, CO, MO and K among others) in areas with high nitrogen fertilization. The correlation coefficients between exchangeable potassium and the other soil properties studied were generally less than 0.5 and not significant except with organic carbon, organic matter and electrical conductivity. According to Kozak, et al. [36] potassium is a less important exchangeable cation compared to calcium and magnesium, but soil acidification is the result of the leaching of all exchangeable cations. This therefore justifies the positive correlation between pH and exchangeable potassium. In addition, the increase in soil pH causes the dissociation of H^+ ions from the functional groups of organic matter, which creates negative charges that justify the positive correlation between exchangeable potassium, pH and electrical conductivity.

4. CONCLUSION

The results obtained from this study suggest that urea amendment of cocoa pods husk and coffee wastes may be a solution to increase mineralization of organic matter, potassium availability and electrical conductivity of the soil. On the other hand, the organo-mineral combinations tested decreased alkalinity and the negative net charge of the soil. In addition, the exchangeable potassium content of the soil was positively correlated with pH H_2O, pH KCl, ΔpH, sodium and electrical conductivity. Our results finally indicated that exchangeable potassium content was negatively correlated with organic carbon content of the soil.

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