

Effect of feather compost on soil chemical indicators in CCN-51 cocoa plantation (*Theobroma cacao* L.)¹

Nelino Florida-Rofner², José Dolores Levano-Crisóstomo³ y Santos Jacobo-Salinas⁴

Abstract

Introduction. Organic management of cocoa accounts for 60% of production in Peru and large amounts of compost prepared with different inputs are used, in order to improve the quality of the soil and cocoa yields. **Objective.** Evaluated the effect of the application of chicken feather compost on the main soil chemical indicators in a cocoa plantation CCN-51 un the Town of Nuevo Progreso, province of Padre Abad in the Ucayali-Peru region was evaluated. **Materials and methods.** A randomized complete block design was used, with four treatments and four repetitions where: FC1 was an absolute witness, FC2 feather compost at a rate of 2,000 kg. ha⁻¹, FC3 feather compost at a rate of 4,000 kg. ha⁻¹ and FC4 feather compost at a rate of 6 000 kg. ha⁻¹. The main chemical indicators of soil quality were evaluated: hydrogen potential

(pH), organic matter (OM), total nitrogen (N), available phosphorus (P), potassium (K⁺), calcium (Ca²⁺), magnesium (Mg²⁺), aluminum (Al³⁺), available cadmium (Cd²⁺), changeable acids (AC) and cation exchange capacity (CEC). **Results.** The results showed a decrease in exchangeable aluminum and changeable acidity and increases in organic matter, nitrogen, phosphorus, and potassium, depending on the proportion of compost applied, these indicators presented significant differences (p < 0.05); The pH, calcium and cadmium available did not show significant differences (p < 0.05). **Conclusion.** Feather compost (FC) significantly improved the levels of OM, N, P and K⁺, indicators that define soil quality and reduce aluminum levels, the latter of utmost importance in acidic soils.

Keywords: aluminum, biocomposts, soil quality, organic production.

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2 Ing., M. Sc. en Agroecología. Profesor Investigador de Ingeniería en Conservación de Suelos y Aguas. Universidad Nacional Agraria de la Selva. Correo: nelinof@hotmail.com. ORCID: 0000-0002-8751-4367.

3 Ing. M. Sc. en Suelos. Profesor de Ingeniería en Conservación de Suelos y Aguas. Universidad Nacional Agraria de la Selva. Correo: joselevano@hotmail.com, ORCID: 0000-0002-8102-9897

4 Ing. Dr. Agrónomo. Profesor de la escuela profesional de ciencias agrícolas. Universidad Nacional Hermilio Valdizan. Correo: salinasjacobob@hotmail.com. ORCID: 0000-0002-5984-1766

Autor para correspondencia: Nelino Florida Rofner, correo: nelinof@hotmail.com

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Efecto del Compost de plumas sobre indicadores químicos del suelo en plantación de cacao CCN-51 (*Theobroma cacao* L.)

Resumen

Introducción. El manejo orgánico del cacao representa el 60 % de la producción en el Perú y se utilizan grandes cantidades de compost preparado con diferentes insumos, en busca de mejorar la calidad del suelo y los rendimientos del cacao. **Objetivo.** Se evaluó el efecto de la aplicación de compost de plumas de pollo sobre los principales indicadores químicos del suelo en una plantación de cacao CCN-51, en el poblado de Nuevo Progreso, provincia Padre Abad en la región Ucayali-Perú. **Materiales y métodos.** Se utilizó un diseño de bloques completo al azar, con cuatro tratamientos y cuatro repeticiones en donde: CP1 fue testigo absoluto, CP2 compost de plumas a razón de 2 000 kg. ha⁻¹, CP3 compost de plumas a razón de 4 000 kg. ha⁻¹ y CP4 compost de plumas a razón de 6 000 kg. ha⁻¹. Se evaluaron los principales indicadores químicos de calidad del suelo: potencial de hidrogeno (pH), materia orgánica (MO), nitrógeno total (N), fósforo disponible (P), potasio (K⁺), calcio (Ca²⁺), magnesio (Mg²⁺), aluminio (Al³⁺), cadmio disponible (Cd²⁺), ácidos cambiante (AC) y capacidad de intercambio de cationes (CIC). **Resultados.** Los resultados mostraron disminución del aluminio intercambiable y ácidos cambiante e incrementos de la materia orgánica, nitrógeno, fósforo, y potasio, según la proporción de compost aplicado, estos indicadores presentaron diferencias significativas (p<0.05); el pH, calcio y cadmio disponible no presentó diferencias significativas (p<0.05). **Conclusión.** El compost de plumas (CP) mejoró significativamente los niveles de MO, N, P y K⁺, indicadores que definen la calidad del suelo y reducen los niveles de aluminio, este último de suma importancia en suelos ácidos.

Palabras clave: aluminio, biocompostos, calidad del suelo, producción orgánica

Efeito do composto de penas sobre indicadores químicos do solo na plantação de cacau CCN-51 (*Theobroma cacao* L.)

Resumo

Introdução. O manejo orgânico do cacau representa 60% da produção no Peru e grandes quantidades de composto preparado com diferentes insumos são utilizados, a fim de melhorar a qualidade do solo e os rendimentos do cacau. **Objetivo** Foi avaliado o efeito da aplicação de composto de penas de galinha nos principais indicadores químicos do solo em uma plantação de cacau. CCN-51 na cidade de Nuevo Progreso, província de Padre Abad, na região de Ucayali-Peru. **Materiais e métodos.** O delineamento experimental utilizado foi o de blocos completos casualizados, com quatro tratamentos e quatro repetições, sendo: CP1 testemunha absoluta, CP2 composto de penas a uma taxa de 2 000 kg. ha⁻¹, CP3 composto de penas a uma taxa de 4 000 kg. ha⁻¹ e CP4 a uma taxa de 6 000 kg. ha⁻¹. Os principais indicadores químicos de qualidade do solo foram avaliados: potencial hidrogênio (pH), matéria orgânica (MO), nitrogênio total (N), fósforo disponível (P), potássio (K⁺), cálcio (Ca²⁺), magnésio (Mg²⁺), alumínio (Al³⁺), cádmio disponível (Cd²⁺), ácidos mutáveis (AC) e capacidade de troca catiônica (CEC). **Resultados.** Os resultados mostraram uma diminuição do alumínio trocável e dos ácidos trocáveis e aumento da matéria orgânica, nitrogênio, fósforo e potássio, dependendo da proporção de composto aplicado, esses indicadores apresentaram diferenças significativas (p <0,05); O pH, cálcio e cádmio disponíveis não mostraram diferenças significativas (p <0,05).

Conclusão. O composto de penas (CP) melhorou significativamente os níveis de MO, N, P e K, indicadores que definem a qualidade do solo e reduzem os níveis de alumínio, este

último de extrema importância em solos ácidos.

Palavras-chave: alumínio, biocompostos, qualidade do solo, produção orgânica

Introduction

75% of Peruvian exports correspond to fine or flavored cocoa, ranking third as the world's producer of fine cocoa or flavored; The Ucayali region contributes 8% of the national cocoa production and is one of the three fastest growing regions in recent years (Ministry of Agriculture and Irrigation-MINAGRI, 2016). Therefore, organic cocoa management accounts for approximately 60% of production in Peru and large quantities of compost fertilizers, prepared with different inputs, are used to develop sustainable production that improve soil and cocoa quality, improving its export potential.

Currently, pen-based compost (FC) is not applied or produced; however, research notes that feather-based compost is a bio-bone with excellent characteristics for its high content of organic matter and nitrogen (Florida and Reategui, 2019) and that it shows great potential to be used in agriculture (Florida, 2019), particularly in crops that require low but constant amounts of nitrogen, as evidenced in organic tobacco (Bennett et al., 2018; Vann et al., 2017) and cocoa that responds negatively to excess fertilization (Puentes et al., 2014) could show positive results regarding the application of this bio-fertilizer.

There is evidence that its application in agriculture functions as semi-slow release fertilizer of its components, in particular nitrogen (Adetunji et al., 2012), significantly improve water retention capacity (Tamreihao et

al., 2019), the pH, OM, N, P and K⁺ (Bhange et al., 2016) and about population of hydrolyzing cellulose bacteria and proteolytics, favoring the breakdown of organic matter (Esmailzadeh and Gholamalizadeh, 2014). In this context, the research assessed the effect of the application of compost made with 30% broiler chicken feathers on the main chemical indicators of the soil in a CCN-51 cocoa plantation.

Material and methods

Location and weather conditions

The project was developed between September 2018 and July 2019, at the Florida & Cárdenas foundation facility in the town of Nuevo Progreso, located at coordinates UTM 445638 E and 9015391N; (8°54'23.08"S y 75°29'34"O) Politically belongs to the Padre Abad district and province Ucayali-region Peru. The climatic conditions in which this project was developed have an average annual rainfall of 2,500 mm and 26.5 °C, with a bimodal regime; The highest rainfall occurs between September–April and the minimums between May–August. The experimental area is located at an altitude of 288 meters above sea level and is located in the Omagua ecoregion, or low jungle according to the classification of Pulgar (2014).

Installation of the experimental area

The area has a plantation of Creole cocoa grafted with buds of the CCN-51 clone, five

years of installation, the estrangement between rows and plants is 3 m, the terrain has a soft slope of about 2-5%, of the medium terrace Non-floodable with a strongly acidic soil characteristic of subtropical areas (Table 1). The experimental units are 9 x 6 m, include 6 cocoa plants and an area of 54 m² make a total of 16 units and an area of 1 287 m².

Compost application

Compost has been made with 70% beef manure and 30% feathers as recommended produced by Florida and Reategui company O&D Innovation Sustainable EIRL and applied in three partial doses (September and December 2018 and April 2019); the total applied by treatment was: FC1 absolute witness, FC2 compost of feathers at a rate of 2,000 kg. ha⁻¹, FC3 compost of feather at a rate of 4,000 kg. ha⁻¹ and FC4 compost of feather at a rate of 6,000 kg ha⁻¹. The criterion of the amount applied had as references Florida et al. (2018), Alvarado (2016) and Puentes et al. (2014).

Characterization of compost and soil

The characterization of the FC (Table 2) was carried out in the soil laboratory of the National Agricultural University of the forest (a sample before each application), the parameters for both feather compost and soil samples were: N_t with the Kjendhal method (Bremmer 1965), pH by electrometric method (1: 2.5), dry base OM (for compost) by the acid digestion method and in soil by Walkley and black; P by Metavanadate and UV-Visible spectrum and Ca⁺², Mg⁺², K⁺ and Al³⁺ by extraction with ammonium acetate (Bazán, 2017); for available soil cadmium was used as an extractant EDTA 0.05 M, following mite's methodology (2010), the readings were performed on atomic emission spectrum with inductively coupled plasma ICP OES (HORIBA, Ultima Expert).

Experimental design and statistical analysis

It corresponds to an experimental design, with DBCA arrangement consisting of four treatments (FC1, FC2, FC3 and FC4) and four repetitions with a total of 16 experimental units. Variance analysis with a significance level $p < 0.05$ was performed using general linear model procedures to determine significant differences between treatments, with the help of statistical software (IBM SPSS 22-2015). The results of the chemical indicators are shown as the average of each treatment for the comparison of mean treatments. The Duncan test was used, with a significance level of $p < 0.05$.

Results

Table 1, shows the results of the soil analysis of the experimental field at the start of the experiment according, to Bazán (2017) and SAGARPA (2012) presents: pH strongly acid, mean content in OM, N, P, K⁺, Mg²⁺ and low in Ca²⁺ and CEC. In addition, it has a changeable acid (CA) and a very high level of Al³⁺, levels considered to be toxic for most crops.

Table 1. Soil characterization at the start of the experiment

Indicators	Concentration
pH	4.15
OM %	2.86
N %	0.14
P µg. g ⁻¹	8.5
K µg. g ⁻¹	137
Ca Cmol. kg ⁻¹	2.58
Mg Cmol. kg ⁻¹	1.5
Al Cmol. kg ⁻¹	4.91
CEC Cmol. kg ⁻¹	9.64
CA %	57.68
Cd µg. g ⁻¹	0.23

Source: elaborated by the authors

Table 2 shows the results of the FC analysis made with 70% beef manure and 30% chicken or broiler feathers, according to the recommendations by the company M&F Organics, made prior to each application of the compost (three applications), it shows a pH slightly alkaline, high OM and N content, the other indicators evaluated are considered normal according to the Colombian Technical Standard-NTC 5167 (2011).

Table 2. Characterization of feather compost, average of three applications

Indicators	Concentration
pH	7.9±0.19
OM %	46.71±3.18
N %	4.35±0.42
P ₂ O ₅ %	0.65±0.11
K %	1.3±0.24
Ca %	1.53±0.08

Indicators	Concentration
Mg %	0.78±0.1
Na %	0.46±0.04
Cu µg. g ⁻¹	39±5.84
Fe µg. g ⁻¹	3080±69.47
Mn µg. g ⁻¹	196±12.49
Zn µg. g ⁻¹	82±7.91

Source: elaborated by the authors

The general results of the effect of the treatments are described in Table 3, there is a decrease in the exchangeable aluminum (Al³⁺), changeable acids (CA) and the cation exchange capacity (CEC) and increase in organic matter (OM), nitrogen total (N), phosphorus (P), and potassium (K⁺), according to the proportion of compost applied, these indicators presented significant differences ($p < 0.05$); the pH, Ca²⁺, Mg²⁺ and available cadmium did not present significant differences ($p < 0.05$).

Table 3. Effect of treatments on soil chemical indicators

Indicators	Treatments				Statistics	
	FC1	FC2	FC3	FC4	MSE	p
pH	4.02±0.186 ^a	4.09±0.16 ^a	4.22±0.07 ^a	4.09±0.12 ^a	0.02	0.274
OM %	3.05±0.16 ^a	4.31±0.16 ^c	4.55±0.18 ^c	3.72±0.2 ^b	0.03	< 0.001
N %	0.16±0.01 ^a	0.22±0.01 ^c	0.23±0.012 ^c	0.19±0.013 ^b	0.00	< 0.001
P µg. g ⁻¹	7.5±0.22 ^a	8.06±0.27 ^{bc}	7.78±0.1a ^b	8.2±0.24 ^c	0.047	0.003
K µg. g ⁻¹	187±5 ^b	183±3.42 ^{ab}	190±6.24 ^b	179±2.58 ^a	20.563	0.029
Ca Cmol. kg ⁻¹	1.43±0.17 ^a	1.3±0.08 ^a	1.28±0.15 ^a	1.15±0.17 ^a	0.022	0.129
Mg Cmol. kg ⁻¹	0.48±0.1 ^a	0.48±0.1 ^a	0.53±0.1 ^a	0.48±0.1 ^a	0.009	0.844
Al Cmol. kg ⁻¹	5.14±0.01 ^b	6.15±0.02 ^c	4.62±1.03 ^b	3.34±0.52 ^a	0.329	< 0.001
CEC Cmol. kg ⁻¹	8.53±0.58 ^b	10.27±0.43 ^c	8.34±1.26 ^b	5.81±0.42 ^a	0.571	< 0.001
AC %	77.75±1.5 ^b	82.71±1.34 ^b	77.86±5.16 ^b	71.93±4.82 ^a	13.45	0.011
Cd µg. g ⁻¹	0.197±0.04 ^a	0.227±0.03 ^a	0.2±0.02 ^a	0.21±0.03 ^a	0.001	0.527

FC1 = absolute control (without compost), FC2 = feather compost at 2000 kg. ha⁻¹, FC3 feather compost at the rate of 4000 kg. ha⁻¹ and FC4 feather compost at a rate of 6000 kg. ha⁻¹. The means followed by the same letter on the line do not differ from each other by Duncan's test, $p < 0.05$. MSE mean square error.

Source: elaborated by the authors

Table 4 shows the multiple comparisons to determine the effect of the treatments with respect to the control treatment. For this, the honest significant difference Tukey's HSD was used; the test suggests that the FC2 treatments presented the greatest differences with respect to the control in the available cadmium in the soil, the FC3 treatment in the content of OM and N, Mg²⁺ and Ca²⁺ and the FC4 treatment in the content of P, K⁺, Al³⁺ and CEC.

Table 4. Multiple HSD Tukey comparisons

Indicador	Tratamientos		Sig.
OM	FC1	FC2	< 0.001
		FC3	< 0.001
		FC4	0.001
N	FC1	FC2	< 0.001
		FC3	< 0.001
		FC4	0.006
P	FC1	FC2	0.015
		FC3	0.309
		FC4	0.003
K ⁺	FC1	FC2	0.611
		FC3	0.745
		FC4	0.143
Mg ²⁺	FC1	FC2	1
		FC3	0.879
		FC4	1
Al ³⁺	FC1	FC2	0.113
		FC3	0.598
		FC4	0.004
CEC	FC1	FC2	0.03
		FC3	0.983
		FC4	0.001
CA	FC1	FC2	0.273
		FC3	0.1
		FC4	0.167
Cd ²⁺	FC1	FC2	0.504
		FC3	0.993
		FC4	0.967

FC1 = absolute control (without compost), FC2 = feather compost at 2000 kg. ha-1, FC3

feather compost at the rate of 4000 kg. ha-1 and FC4 feather compost at a rate of 6000 kg. ha-1.

Source: elaborated by the authors

Discussion

Response of chemical Indicators

According to Table 3, no significant differences were found between the different treatments for pH, Ca²⁺, Mg²⁺ and Cd²⁺ indicators; This result is partially related to some works such as that of Florida et al (2018) who point out that the application of cowure compost showed no significant effects for Ca²⁺, Mg²⁺ and Cd²⁺, but found differences for pH, producing an increase, Although this does not change the critical level (strongly acidic). Also, Firme et al. (2014) point out that the application of organic amendments significantly improves the pH. However, Torres (2018) applying hen and vacancy found significant increases in pH values (from 4.58 to 4.83); also, Ramírez et al. (2015) with the application of worm humus found the same behavior. Therefore, the means found in this work show an increase from 4.02 FC1 to 4.22 in FC3 with the application of pen compost, although no significant difference was found and the critical level of strongly acidic pH did not vary, evidence, which has the same effect as a compost produced with other inputs as indicated by the references cited.

The results (Table 3) show increases in organic matter (MO), nitrogen N, phosphorus P, potassium(K) and CEC, depending on the proportion of compost applied, these indicators had significant differences and can be explained taking into account the high levels of OM and N according to the proximal analysis of the FC (Table 2). These high levels of OM and N are consistent with what is reported by Florida and Reategui (2019); in addition, according to

Bhange et al. (2016) the application of the FC significantly improves the soil OM, N, P and K levels are not high in proximal FC analysis, their decomposition resistance noted by Hadas and Kautsky (1994) and its semi-slow release of its components (Adetunji et al., 2012) promote and adequate incorporation into the soil and increase the levels of some nutrients such as P, K and others. Also, its high OM content may be increasing exchange sites and forming stable complexes (Cortes et al., 2016; Firme et al., 2014), favoring the retention and increase of the main interchangeable cations.

In general, the application of compost based on different inputs has similar effects as the FC on the soil, as well Firme et al. (2014) found significant differences in OM and CIC. Also, Alvarado (2016) showed significant effect on organic matter and phosphorus; Ramírez et al. (2015) with worm humus and manure, found a positive effect and increased the contents of OM, P and K⁺; Gracia (2012) found changes in the content of OM, macro and micronutrients; Orozco and Muñoz (2011) with chicken increased OM and CEC. Therefore, the results found show great potential for FC for use in agriculture.

Reducing interchangeable aluminium

The soils of the experimental area correspond to strongly acidic soils (Table 1), typical of sub-tropical soils of high rainfall in which the levels of aluminum toxicity are high. about this, Carreño and Chaparro (2013) they point out that aluminum toxicity is the first factor that limiting crop production in acidic soils, because 50% of the potentially arable soil is acidic, particularly soils with warm and humid conditions of the tropical southern belt in which Peru is located; in these types of soils acidity is mainly a consequence of interchangeable aluminum (Castro and Munevar, 2013), because under conditions of acidic soil at pH less than

5.5, Al³⁺ aluminum ions are solubilized and can penetrate root cells, which inhibits root growth and hinders the absorption of water and essential nutrients such as phosphorus and calcium (Carreño and Chaparro, 2013)

The results in Table 3 show a sustained trend of Al³⁺ reduction from 5.14 FC1 to 3.34 Cmol. Kg⁻¹ in FC4, reducing by 35.01% on average, this behavior is attributable to the capacity to complex inorganic materials by OM (Martínez et al., 2008), reducing mobility factors by producing an increase in exchange sites, forming stable complexes, mineral precipitation and ion exchange (Cortes et al., 2016; Firme et al., 2014). These interactions improve the availability of P, block potential reaction sites with Fe, Al and Ca (Martínez et al., 2008) and increase the retention capacity of different soil metals (Firme et al., 2014). There is limited information on the capacity of different types of compost in reducing aluminum, however, Orozco and Thienhaus (1997) found trends in Al³⁺ decline and signal the potential of compost to improve this chemical soil indicator. Therefore, pen compost feather performs better compared to traditional compost to reduce aluminum toxicity levels in acidic soils, thus showing its great potential and differentiation with other types of compost.

Conclusions

Significant differences (p <0.05) were found between the treatments applied in levels of organic matter, nitrogen, phosphorus, potassium, aluminum, cation exchange capacity and changeable acids. The pH, calcium, magnesium and available cadmium significant differences for p <0.05.

Treatments showed increases in organic matter, nitrogen, phosphorus, and potassium and decrease acids changeable and interchangeable

aluminum; the latter showed a reduction from 5.14 FC1 to 3.34 Cmol. Kg⁻¹ at FC4, reducing by 35.01% on average.

The Feather based compost, at a rate of 4,000 to 6,000 kg. ha⁻¹ showed positive effects similar to traditional compost on chemical indicators that define soil quality, however, it presented comparative advantages in reducing aluminum levels. This result shows feather compost with advantages over compost made with other materials and can be used to improve some fertility indicators and reduce toxic levels of aluminum in acidic soils, typical of the tropics.

Recommendations

To carry out proper management, under the criteria of organic production, it is recommended to:

- Improve fertility indicators by applying feather compost, with a maximum ratio of 30% chicken feathers, higher percentages reduce the pH of final compost and can have negative effects on soils and plants.
- 4 000 kg ha⁻¹ is an adequate amount, higher amounts offer the same benefits and preferably in soils with high levels of aluminum, to reduce the toxic effects on plants.

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