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RESEARCH ARTICLE
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Impact of Humic Acids and Biofertilizers on Yield and Sensory Quality of Organic Coffee Varieties in Peruvian Plantations

Silvera-Pablo CC [1], Julca-Otiniano A [2], Rivera-Ashqui TA [3] and Silva-Paz RJ [1]*

[1]Departamento de Ingeniería, Universidad Nacional de Barraca, Barranca 15169, Peru
[2]Departamento de Fitotecnia. Facultad de Agronomía. Universidad Nacional Agraria La Molina, Lima 14, Peru
[3]Facultad de Ingeniería y Arquitectura Universidad Peruana Unión, Lima 14, Peru
*Corresponding author: rsilva@unab.edu.pe

ABSTRACT

In the last two years, Peruvian coffee production has been affected by the high cost of fertilizers. In the Selva Central region, 25% of coffee plantations are organic. To explore new technologies, a study was conducted to evaluate the effect of humic acids and biofertilizers on the yield and sensory quality of two coffee varieties: Castillo and Catuaí. The study used an AxB factorial design with 10 repetitions, resulting in 8 treatments. All treatments received lime (200g dolomite/plant) and organic soil fertilization (120N-80P2O5-150K2O kg/ha) using Isla guano and potassium sulfate. The variables evaluated were nodes/plant, number of cherry trees/node, cherry tree yield/plant, dry parchment coffee yield (qq/ha), yield percentage, and sensory quality. The results showed that humic acids positively influenced all evaluated variables in both varieties, with the Castillo variety performing better. Castillo had 12.78 nodes/branch, 20.56 fruits/node, 3.2kg cherry/plant, 53.38qq dry parchment/ha, and 76.13% yield. Catuaí had similar responses, with 9.00 nodes/branch, 14.33 fruits/node, 2.1kg cherry/plant, 35.07qq dry parchment/ha, and 76.93% yield. *Trichoderma* positively influenced the weight of 100 cherry trees and yield percentage in both varieties. Sensory quality scores ranged from 81 to 84 points, with the highest scores for Castillo (83.67) and Catuaí (83.58) when treated with humic acids. The lowest values in both yield and sensory quality were obtained without biofertilizer. In conclusion, organic fertilization complemented with humic acids is a promising technology for improving coffee production and quality in organic plantations.

Keywords: Organic coffee; Fertilizers; Humic acids, Biofertilizers, Quality.

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INTRODUCTION

Coffee is one of the most important crops worldwide, with a significant impact on the economy and culture of many regions. In particular, in the central jungle of Peru, specifically in Chanchamayo, coffee production is a fundamental activity for the agricultural community. In this context, the use of biofertilizers and humic acids has emerged as a promising alternative to improve the yield of coffee crops, while promoting sustainable and environmentally friendly agricultural practices. Coffee cultivation in Peru is currently the main source of income for approximately 225 thousand families, generating more than 2 million jobs. Peru is the world's leading exporter of organic coffee (MIDAGRI, 2021). Of the 425 thousand hectares existing to date, the high costs of fertilizers, the inadequate management of crop nutrition at the field level, the lack of knowledge of the nutritional management of the soil, has promoted continuous degradation in addition to little access to new technologies that promote the efficiency of use of the applied fertilizers, has reduced the useful life of the plantation, as a consequence the low productivity of the plantations, increasing production costs and forcing the coffee grower to abandon their plantations. Every fertilization plan for production must consider all other requirements such as water, an essential input for the absorption of nutrients from the soil solution, organic matter and favorable climate (Sadeghian, 2021).

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It is essential to adopt sustainable agricultural practices to meet food demand and reduce soil degradation and water pollution (Cristofano et al., 2021). Plant biostimulants, such as amino acids and humic acids, are highly effective for this purpose (Souri & Hatamian, 2019; Amiri Forotaghe et al., 2022; Najarian et al., 2022).

Among the new technological alternatives to improve production quality in coffee cultivation are biofertilizers and humic acids. Humic acids are a component of soil organic matter, applied at low concentrations, they positively influence plant physiology, soil fertility, as well as optimizing the absorption of soil nutrients, benefiting the plant with greater growth rate, quality yield and tolerance to abiotic stress (Magaña et al., 2015). Various authors report that these substances have several beneficial effects: indirect, on the physical properties of the soil and direct, on the various physiological and biochemical processes of the plant, stimulating plant growth and improving the levels of yield and quality of the crop (Cesco et al., 2002; Chen et al., 2004; Pedranzani et al., 2015). Regarding humic substances, Rodríguez et al. (2014) states that they have beneficial effects on the physical, chemical and biological properties of the soil, especially on those that present limitations due to some physical-chemical factor, which make crop production difficult. Its influence lies in promoting the growth of plants; in the mobility of organic compounds, nutrients, among others. Another technological alternative is arbuscular *Mycorrhizae*, present in the soil, which form associations with more than 80% of plants. In current coffee growing in various countries, *Mycorrhizae* are used in order to reduce the use of chemical fertilizers (Berruti et al., 2016). These fungi, in symbiosis with plants, increase the absorption of nutrients from the soil, especially immobile elements such as phosphorus, zinc and copper, in addition to other nutrients present in forms not available to plants. The use of *Mycorrhizae* does not imply that edaphic fertilization is suppressed, what is sought is to improve the efficiency of fertilizer use and allow chemical fertilization to be reduced by between 50 to 80% in the medium term (Pérez and Gómez 2000; Jaramillo, 2011).

In Peru to date, its commercialization is little widespread, and commercial products are generally presented in consortium with species such as *Glomus intraradices, Glomus mosseae, Glomus aggregatum, Pisolithus tinctorius, Suillus granulatus, Scleroderma cepa, Rhizopogon rubesce* and *Scleroderma Citrine*. Regarding the benefits of *Mycorrhizae*, Coral (2015) states that the main species are related to the nutrition of plants, due to their propagation in conditions of low nutrient availability, such as the case of P. In addition, another bioinput used is *Trichoderma,* a microorganism that in recent years has gained relevance in agricultural production, is an anaerobic fungus that naturally inhabits the soil, characterized by saprophytic or parasitic behavior. Among the best-known species are *T. harzianum, T. viride, T. koningii, and T. hamatum.* These strains, due to their high reproductive capacity, favor their function as biological control agents, among them, 1) the ability to survive in unfavorable conditions, 2) high efficiency in the use of nutrients, 3) capable of modifying the rhizosphere, 4) promote growth and induce plant defense mechanisms, among others (Castro & Rivillas,, 2012). Likewise, Benítez et al. (2004) states that roots colonized by *Trichoderma* play roles as a promoter of vegetative development, increasing growth, development, crop productivity, resistance to abiotic stress and increasing the uptake and use of nutrients. It has been shown that the productivity of a crop in the field can increase by more than 300% after application, attributed to the production of phytohormones such as auxins, cytokinins and ethylene.

The components of yield and physical quality, independent of the variety, nutritional management, harvest and benefit, are factors that can influence these parameters; however, in sensory quality, altitude is the determining factor (Fajardo and Sanz, 2003). The quality of coffee is the result of the influence of several factors, such as the genotype (variety), the climate (altitude, T°, etc.), in addition to post-harvest practices: such as the maturity of the fruit, pulping, removal of mucilage, washing, drying, roasting and preparation of the drink (Osorio et al., 2021). Likewise, quality measurement can be determined through four approaches: physical quality, sensory quality, chemical composition and safety (Pabón & Osorio, 2019). The Specialty Coffee Association (SCA) developed a total scoring system, specialty description and coffee classification. It is called specialty coffee when it has a score "between" 80 to 100, being described as Very good (80-84.99), Excellent (85-89.99) and Exceptional (90-100). Also, it is classified as non-specialty coffee when it is described below special quality by obtaining a score of less than 80, allowing a good specialty coffee to be differentiated from other coffees (SCA, 2003). The SCAA (2015) mentions that the protocol to evaluate the sensory quality of coffee is independent of the variety, since its purpose is to describe its sensory attributes, flavors, intensity, presence of defects, and thereby define if the coffee is bad, regular, average, good, very good or outstanding, being determined by score. These attributes are: fragrance, referring to the aromatic aspects defined by the coffee smell of the dry ground sample; the flavor, which represents the main characteristic of coffee, and is related to the fragrance; The residual flavor is the duration of the positive qualities that are perceived in the back of the palate at the time of tasting. Acidity, which is the sensation on the tongue that makes you salivate and which can occur in two cases: "bright" when it is favorable or "sour" when it is unfavorable; body, a quality that is based on the sensation of heaviness of the liquid in the mouth and finally the balance or balance, which is the result of the complement or contrast of the different aspects of the coffee flavor such as acidity, residual flavor and body. Aspects that are also referred to by Duicela et al. (2003) and Gast et al. (2013). As can be seen, there are some experiences with the use of microorganisms and humic acids in coffee cultivation, however, the responses in production fields in the Castillo and Catuaí varieties are unknown, so this research may contribute to determining the effect of these bioinputs on the described parameters and be a possible alternative for the organic production of coffee cultivation under the conditions of Chanchamayo and Selva Central. Various previous research has shown that biofertilizers, derived from beneficial microorganisms, and humic acids, organic compounds that improve soil structure and nutrient availability, can positively influence the growth and development of plants. However, there is a need for specific studies that evaluate the effect of these inputs on local coffee varieties under field conditions, especially in regions such as Chanchamayo, where climatic and pedological conditions can vary considerably.

In this context, the main objective of the present study is to investigate the effect of the application of biofertilizers and humic acids on the performance of two coffee varieties grown in Chanchamayo, evaluating the parameters of yield, coffee quality, in order to contribute to the knowledge scientist on sustainable agricultural practices and improving the productivity of coffee plantations in this region and the scientific community.

MATERIALS & METHODS

Experiment Location

The experiment was carried out in the province of Chanchamayo, at the "La Esperanza del Ensueño" Farm located in the Los Olivos Sector, Perene district, Junín department, located at 1250 meters above sea level, average temperature of 27°C and an annual rainfall of 3300 mm (SENAHMI, 2021).

Biological Material and Characteristics of the Treatments

Two cultivation plots of coffee varieties were used: Castillo and Catuaí, each consisting of 400 plants in production, whose ages fluctuated between Castillo (10 years) and Catuaí (7 years). The treatments evaluated in this study are described in Table 1, where two factors (AxB) are worked on: Variety (Factor A) with two levels (Castillo and Catui) and Type of biofertilizer (Factor B) with four levels (Acids Humic 15%, *Mycorrhizae*, *Trichoderma* and without biofertilizer). A total of eight treatments were obtained based on combinations of both factors.

Table 1: Description of the statistical design of the treatments.

Treatments	Factor A	Factor B
T1	Castillo	Acids Humic 15%,
T2	Castillo	*Mycorrhizae*
T3	Castillo	*Trichoderma*
T4	Castillo	Without biofertilizer
T5	Catui	Acids Humic 15%,
T6	Catui	*Mycorrhizae*
T7	Catui	*Trichoderma*
T8	Catui	Without biofertilizer

Installation and Management of the Experiment

The characteristics of the soil are presented in Table 2, this type of soil was found within that recorded by USDA (1999). The plots were located in June 2022, at the end of the harvest, the Catuaí and Castillo plantations were conditioned for the experiment, tissue management was carried out in July of the same year and application of the dolomitic amendment at a rate of 200g/plant 45 days before fertilization (pH < 4.0). The microorganisms and humic acids were applied 30 days after liming. 15 days later, soil fertilization was carried out based on island guano and potassium sulfate, which was applied in 2 moments. Throughout the process, weed and phytosanitary control was carried out in a timely manner.

Table 2: Characteristics of the soils under study

Parameters	Variety Castillo	Variety Catuaí
pH $_{(1:1)}$	3.88	4.01
CE $_{(1:1)}$	0.14	0.07
MO %	3.98	3.27
P ppm	21.7	43.2
K ppm	170	213
Textural Class	Fr. Ar.	Fr. Ar
CIC (cmol/kg)	20.0	18.56
Ca^{+2}(cmol/kg)	1.45	1.72
Mg^{+2}(cmol/kg)	0.50	0.72
K^{+}(cmol/kg)	0.42	0.58
Na^{+}(cmol/kg)	0.19	0.21
Al^{+3} + H(cmol/kg)	4.90	4.00
% Exchangeable Acidity	65.7%	55.3%

Inoculation and Fertilization of Treatments

The application of biofertilizers, humic acids and soil fertilizer, was carried out as follows: i) *Mycorrhizal* complex: 25g/plant was applied, diluted in 100mL of water, 30 days after liming, ii) *Trichoderma*: 20g was added / 20L of water, applying the dose of 150mL/plant, iii) 15% humic acid: 100mL of HA was diluted in 20 liters of water, applying the dose of 150mL/plant, in two moments, 15 days before of the first edaphic fertilization, and 15 days before the second edaphic fertilization, iv) The edaphic fertilization was carried out for all treatments, the fertilization dose being 120N- 80P2O5- 150K2O kg/ha, divided into two applications: 1st (October 2022) and 2nd (January 2023). The inputs used were: Island guano and potassium sulfate, supplemented with micronutrients B and Zn.

Methodology

Starting 150 days after flowering, the harvest began (March 14, 2023) and culminating in the second week of June (June 9-11, 2023), a total of 4 harvests were carried out.

Physical Analysis

a) Number of nodes/branch: The number of nodes/branch was counted in 4 well-developed branches of the middle third of the plant and then the average was taken.
b) Number of fruits/nodes: To do this, the number of fruits per node was counted in 4 well-developed branches of the middle third and then the average was obtained.
c) Weight of 100 cherry trees: At the time of harvest, 20 mature cherry trees/plant were randomly weighed, using a precision scale, projecting the weight of 100 cherry trees.
d) Weight of cherry trees/plant: At the time of harvesting a total of 10 plants per treatment, the harvest was carried out and weighed, using a precision scale.
e) Harvest/dry parchment ratio: It was determined by the proportion of the cherry coffee in relation to the weight of the dry parchment, with the data obtained from the physical performance.

Sensory Analysis

To determine the sensory characteristics of the coffee, the parchment beans from the treatments obtained after harvest were taken to the QUIMICAFE laboratory in Bajo Pichanaqui, which was analyzed by tasters from Qarabica Grader, where the attributes were analyzed and the differences were determined. sensory (% Exportable, % By-product, % Minor mesh 14, % Shell, Fragrance, Flavor, Residual flavor, Acidity, Body, Balance, Uniformity, Cleanliness in the cup, Sweetness, General appearance and Score in the cup) between the varieties and treatments.

Experimental Design

A complete Random factorial design was used, obtaining eight (08) treatments with 10 repetitions, making a total of 8 experimental units. Each treatment was made up of a total population of 100 plants, distributed in 5 lines of 20 plants each. The analysis of variance was applied at 95% confidence and for the comparison of means the Tukey Test at 5% was used (P=0.05), using the XLSTAT-2023 statistical package.

RESULTS & DISCUSSION

Physical Analysis

The results of the physical analysis of the different treatments show significant differences (Table 3). It was observed that there is a significant influence of the Variety*Biofertilizers interaction on all the variables studied. When comparing the results with the other treatments, the humic acids in the castle variety (T1) present significant differences with respect to the other treatments in terms of the number of nodes x branch, number of fruits/nodes, weight of cherry/plant (g) and yield cps/ha (qq). Therefore, the effect of 15% humic acid favors these variable responses. The Castillo and Catuaí varieties to the edaphic application supplemented with humic acids shows a significant effect between the treatments, agreeing with what was recorded by Álvarez et al. (2023), who implemented the nutrition strategy with organic fertilization and foliar application where humic acid had a positive effect on the productive parameters in Borboun variety coffee, increasing between 15 and 56.5%. Ramírez-Iglesias et al. (2021) indicated that fertilization and the application of bio-stimulants increases the weight of the fruits in the tomato crop in Zamora Chinchipe- Ecuador. Montes and Anaya (2019) described that fertilization with 4% aerobically fermented organic liquid fertilizer positively influences the yield of coffee crops, exceeding conventional management by 44.6%. Regarding each variety treated with *Mycorrhizas*, *Trichoderma* and without biofertilizers, it did not influence the number of nodes, cherry/plant weight (g) and yield cps/ha (qq), however, between each variety they showed different significance. For the number of fruits/nodes (Fig. 1) and the weight of 100 cherry trees, this trend was not observed.

The response of the varieties to the addition of humic acids to the soil shows significant differentiation, being superior to the other treatments, which could be attributed to the fact that this bio input at low concentrations positively influences the physiology of the plant, as well as the optimization of the absorption of nutrients from the soil. The Castillo and Catuai varieties to the edaphic application supplemented with *Mycorrhizae* had a non-significant effect, similar to that reported by Vallejos-Torres et al. (2019) who indicated that the effectiveness of *Mycorrhizal* consortia depends on their origin. Narro (2007) and Castillo (2005) point out that humic acids promote the transfer of nutrients from the roots to the aerial part and from the outside of the leaves to the places of accumulation, as well as the activation of some enzymes which could help in promoting plant structures.

The Castillo variety has a greater number of nodes/branch (12.78), differentiating itself from the treatment without biofertilizer (8.11 nodes/branch). Similar results are reported in other species in the growth of shoots, such as corn (Eyheraguibel et al., 2008; De Moura et al., 2023), pepper (Cimrin et al., 2010), cucumber (Mora et al., 2010), and wheat (Tahir et al., 2011), and influencing the performance of *Phaseolus vulgaris L.* by up to 200% (Benavides, 2019). Regarding the predominance of No. of fruits/node and No. of nodes/branch, of the Castillo variety coffee tree, compared to the Catuaí variety (Fig. 1), it could be influenced by several factors, such as: Characteristics of the variety (genotypic, resistance to diseases), environmental conditions, agronomic and nutritional management, as well as the production system (Arcila et al., 2007; Orozco et al., 2011; Gast et al., 2013).

For the weight of 100 cherry trees, it was significantly greater in the castle variety with *Trichoderma* compared to the other treatments. This could be attributed to the fact that the *Trichoderma fungus*, in addition to fulfilling the function of bioprotective of the plant root, can influence the health of the fruit, achieving a better weight of 100

Table 3: Physical analysis data of the different varieties with and without biofertilizer.

Treatments	Variety	Biofertilizers	Number of node x branch	Number of fruit/nodes	Weight of 100 cherry trees	Cherry/plant weight (g)	Performance cps /ha (qq)
T1	Castillo	Acid Humino 15%	12.778±0.509^{a}	20.556±0.694^{a}	177.88±3.59^{b}	3202.5±221.4^{a}	53.38±3.69^{a}
T2	Castillo	*Mycorrhizas*	8.889±0.192^{b}	13.333±0.667^{bc}	174.25±2.96^{b}	2284.1±202.3^{b}	38.07±3.37^{b}
T3	Castillo	*Trichoderma*	8.889±0.192^{b}	12.778±0.694^{bcd}	189.75±3.81^{a}	2288.3±123.1^{b}	38.138±2.051^{b}
T4	Castillo	Without biofertilizers	8.111±0.192^{bc}	11.44±1.95^{cd}	167.25±3.57^{c}	2134.6±113.7^{b}	35.577±1.895^{b}
T5	Catuaí	Acid Humino 15%	9±0.333b	14.333±0.667^{b}	143.25±1.34^{e}	2104.3±99.8^{b}	35.072±1.663^{b}
T6	Catuaí	*Mycorrhizas*	7.667±0.333^{c}	10.778±0.77^{d}	131.13±1.81^{f}	1683±135.5^{c}	28.05±2.258^{c}
T7	Catuaí	*Trichoderma*	7.778±0.509^{c}	10.889±0.192^{cd}	153.5±2.19^{d}	1774.3±112.4^{c}	29.572±1.874^{c}
T8	Catuaí	Without biofertilizers	7.222±0.509^{c}	10.444±0.385^{d}	131.13±2.08^{f}	1658.5±83.4^{c}	27.642±1.389^{c}
				Factor			
Variety			<0.05	<0.05	<0.05	<0.05	<0.05
Biofertilizers			<0.05	<0.05	<0.05	<0.05	<0.05
Variety*Biofertilizers			<0.05	0.001	<0.05	<0.05	<0.05
r^2			95.140	92.430	98.21	90.28	91.36

cherry trees, compared to the other treatments. Shoresh et al. (2010), mention the ability of *Trichoderma* to control plant pathogens that attack roots, foliage and fruits. Likewise, some authors such as Martínez et al. (2011) have shown that *Trichoderma* interacts positively with other classes of beneficial organisms, causing the plant better responses in growth and performance. The Castillo and Catuai varieties to soil fertilization supplemented with *Trichoderma harzianum* had a minimal significant effect on yield, however, on fruit size and quality, it had positive effects. Bacusoy and Fienco (2023) indicated that the application of *T. harzianum* in rice cultivation, as an environmentally friendly organic precursor agent, allows improving performance in height, number of tillers and productivity. Likewise, González et al. (2019) mentions that *T. Harzianum* is a potential biofertilizer that could improve fruit quality control, reducing the attack of fungal diseases.

Sensory Analysis

Tables 4 and 5 present the results of the sensory analysis carried out by the Qarabica Grader tasters. Regarding the descriptive analysis (Table 4), significant differences were found for % Exportable, %By-product and %Husk, although no significant differences were observed for % Minor mesh 14.

In the sensory evaluation, it was observed that of the eleven sensory attributes evaluated (Table 4), four showed significant differences (fragrance, balance, general appearance and cup score), the rest of the attributes did not show significant differences (flavor, residual flavor, acidity, body, uniformity, cup cleanliness and sweetness). In the evaluated samples of both varieties, the sensory characteristics with the best evaluation were: uniformity, clean cup and sweetness, where the scores were similar in all treatments (10 points); regarding the attribute of acidity, in both varieties no influence of biofertilizers was observed, however, slight differences are observed with the application of humic acids. The results of the sensory analysis indicate that the varieties under study, the score has fluctuated from 81 to 84 points, considered as special coffee, however, it was lower than the minimum score (85) required to compete in the cup of excellence (SCAA, 2015). Likewise, a slight variation is observed in the exportable yield, the influence being greater with *Trichoderma*, in both varieties.

The results of the descriptive sensory attributes added by the Qarabica Grader tasters (Table 5), show of the 16 additional attributes, four did not show significant differences (Potato notes, pea notes, herbal notes and cortex). The attributes of panela, brown sugar, cocoa, red fruits, citrus, caramel, malta background, cedar notes, dried

Table 4: Sensory analysis data results.

Treatments	T1	T2	T3	T4	T5	T6	T7	T8
				Descriptive analysis				
% Exportable	76.13±0.15^{abc}	75.83±0.31^{abc}	76.93±0.25^{a}	75.23±0.15^{bc}	75.86±0.15^{abc}	74.93±0.87^{c}	76.17±0.12^{ab}	75.37±0.66^{bc}
%By-product	7.01±0.25^{ab}	7.06±0.38^{ab}	5.92±0.31^{b}	7.12±0.56^{ab}	6.75±0.44^{ab}	7.48±0.50^{a}	6.42±0.31^{ab}	7.15±0.69^{ab}
% Minor mesh 14	0.95±0.17^{a}	1.05±0.173^{a}	1.08±0.20^{a}	1.27±0.32^{a}	1.07±0.24^{a}	1.39±0.31^{a}	1.29±0.26^{a}	1.40±0.31^{a}
% Husk	15.90±0.00^{b}	16.05±0.13^{ab}	16.06±0.16^{ab}	16.38±0.12^{a}	16.31±0.05^{a}	16.19±0.20^{ab}	16.13±0.16^{ab}	16.08±0.21^{ab}
				Sensory analysis				
Fragrance	7.75±0.00^{ab}	7.50±0.00^{abc}	7.67±0.14^{abc}	7.42±0.14^{bc}	7.83±0.13^{a}	7.67±0.14^{abc}	7.67±0.13^{abc}	7.33±0.14^{c}
Taste	7.67±0.14^{a}	7.50±0.00^{a}	7.75±0.00^{a}	7.47±0.14^{a}	7.67±0.14^{a}	7.67±0.29^{a}	7.67±0.14^{a}	7.33±0.13^{a}
Residual flavor	7.66±0.14^{a}	7.33±0.14^{a}	7.67±0.1443^{a}	7.25±0.00^{a}	7.66±0.14^{a}	7.50±0.25^{a}	7.67±0.13^{a}	7.33±0.14^{a}
Acidity	7.75±0.00^{a}	7.50±0.00^{a}	7.66±0.14^{a}	7.50±0.00^{a}	7.66±0.14^{a}	7.66±0.14^{a}	7.58±0.13^{a}	7.50±0.00^{a}
Body	7.50±0.00^{a}	7.33±0.14^{a}	7.50±0.00^{a}	7.25±0.00^{a}	7.58±0.14^{a}	7.58±0.13^{a}	7.58±0.14^{a}	7.33±0.14^{a}
Balance	7.67±0.14^{a}	7.33±0.14^{ab}	7.58±0.13^{ab}	7.25±0.00^{b}	7.58±0.14^{ab}	7.58±0.14^{ab}	7.58±0.13^{ab}	7.41±0.14^{ab}
Uniformity	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}
Clean cup	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}
Sweetness	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}	10.00±0.00^{a}
General appearance	7.67±0.14^{a}	7.41±0.14^{ab}	7.58±0.14^{b}	7.25±0.00^{b}	7.58±0.13^{ab}	7.50±0.25^{ab}	7.58±0.14^{b}	7.25±0.00^{ab}
Cup Score	83.66±0.38^{a}	81.91±0.52^{abc}	83.42±0.14^{a}	81.33±0.14^{c}	83.58±0.804^{a}	83.17±1.15^{ab}	83.33±0.63^{a}	81.50±0.50^{bc}

Table 5: Data recording of sensory attributes and qualitative descriptors.

Treatments	T1	T2	T3	T4	T5	T6	T7	T8
				Additional attributes				
Panela	3.00^{a}	0.00^{b}	3.00^{a}	0.00^{b}	0.00^{b}	2.00^{a}	0.00^{b}	2.00^{a}
Potato notes	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	1.00^{a}
Pea notes	0.00^{a}	0.00^{a}	0.00^{a}	1.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	1.00^{a}
Brown sugar	3.00^{a}	3.00^{a}	3.00^{a}	2.00^{a}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}
Cocoa	0.00^{b}	3.00^{a}	0.00^{b}	3.00^{a}	0.00^{b}	0.00^{b}	0.00^{b}	1.00^{b}
Herbal notes	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	2.00^{a}	0.00^{a}	1.00^{a}
Red fruits	1.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	3.00^{a}	1.00^{b}	3.00^{a}	0.00^{b}
Citrus	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	3.00^{a}	1.00^{b}	3.00^{a}	0.00^{b}
Caramel	2.00^{a}	0.00^{b}	3.00^{a}	0.00^{b}	3.00a	1.00^{b}	2.00^{a}	0.00^{b}
Malta background	3.00^{a}	3.00^{a}	3.00^{a}	1.00^{b}	0.00^{b}	2.00^{a}	0.00^{b}	1.00^{b}
Cedar notes	0.00^{b}	3.00^{a}	0.00^{b}	3.00^{a}	0.00^{b}	0.00^{b}	0.00^{b}	2.00^{a}
Dried herbs	0.00^{b}	3.00^{a}	0.00^{b}	3.00^{a}	0.00^{b}	0.00^{b}	0.00^{b}	2.00^{a}
Cortex	0.00^{a}	1.00^{a}	0.00	2.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	2.00^{a}
Vanilla	3.00^{a}	0.00^{b}	3.00^{a}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}
Honey base	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	3.00^{a}	2.00^{a}	3.00^{a}	0.00^{b}
Clean finish	3.00^{a}	0.00^{b}	3.00^{a}	0.00^{b}	2.00^{a}	1.00^{b}	3.00^{a}	0.00^{b}
				Qualitative descriptors				
Acidity	High	Medium	High	Slight	High	High	High	Medium
Coffee body	Medium	Soft	Medium	Soft	Medium	Medium	Medium	Soft

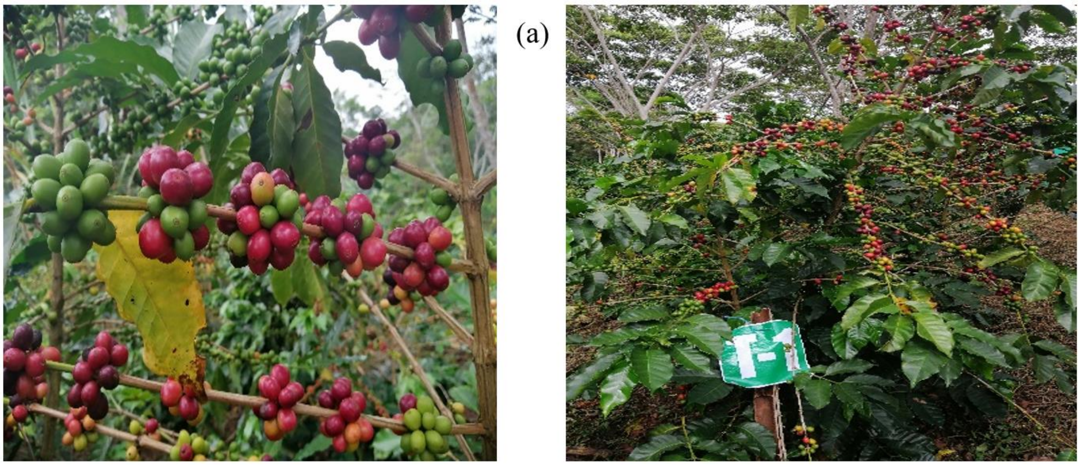

Fig. 1: Number of nodes/plant (a) and fruits/node (b) in the Castillo variety applying humic acid treatment.

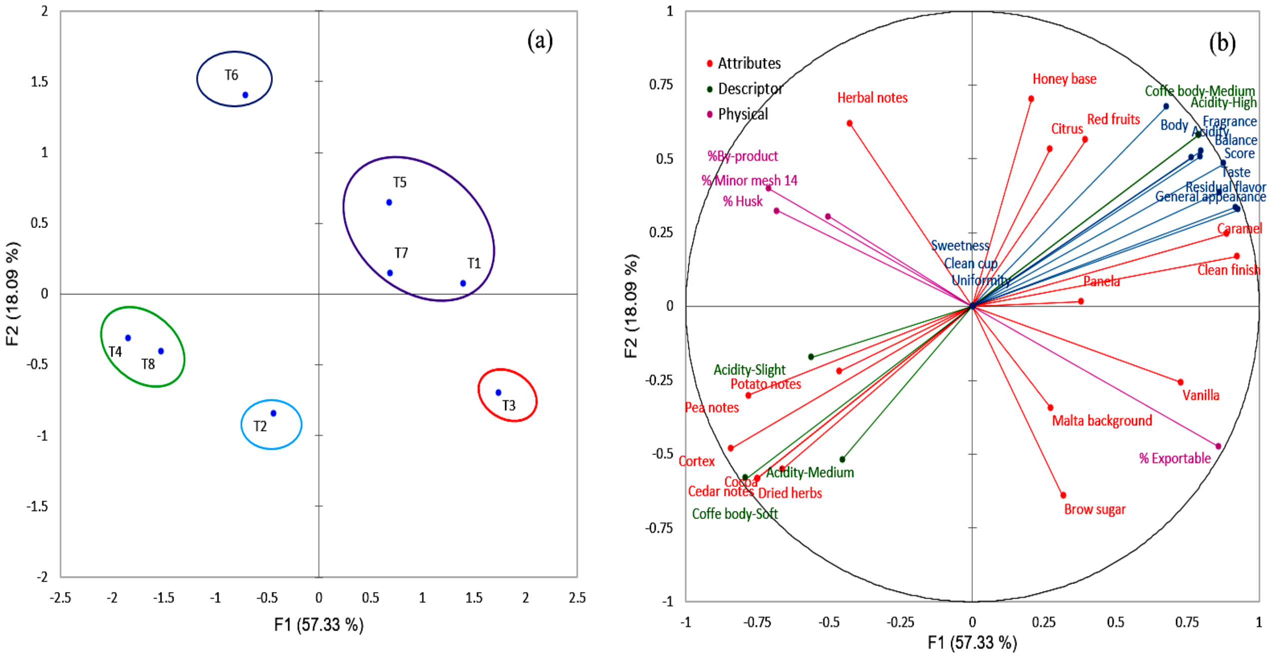

Fig. 2: Multifactorial analysis of the samples (a) and physical-sensory tests (b).

herbs, vanilla, honey base and clean finish were significantly different. In addition, through the qualitative descriptors, differences in description were observed based on the variety and type of biofertilizer. The results obtained indicate that despite sensory quality and additional descriptors in the perception of coffee, these are classified as Very Good (SCAA, 2003), that is, there is no direct influence by the management system, possibly these variations depend on altitude, factor described by various authors who report that the quality of the cup depends on factors such as variety, agroclimatic conditions (Buenaventura, 2002; Duicela et al., 2003).

The multifactorial analysis presents the different treatments with all the variables studied (Fig. 2). The two-dimensional map explains 75.43% of the total variability in the data. In Fig. 2(a), the formation of five groups is observed, the first group consisting of treatment T1, T5 and T7, the second group for T4 and T8, the third, fourth and fifth group for T2, T3 and T6, respectively. Regarding Fig. 2 (a), the descriptors of each group are presented based on the study variables. The first group is characterized by having a clean finish, caramel, citrus, red fruits, body, fragrance, acidity, balance, residual flavor, general appearance, medium coffee body, high acidity and good cup score. The second group is described as cortex, pea notes, potato notes and slight acidity. The third group like dried herbs, cedar notes, cocoa, coffee with a soft body and medium acidity. The fourth group was described as vanilla, base malt and % exportable and the fifth group was characterized by herbal notes, % by-product, % minor mesh 14 and % Husk.

Conclusion

Under the conditions of the present study, edaphic fertilization in coffee cultivation, complemented with humic acids applied via soil, has a positive influence on the different performance components in the Castillo and Catuaí varieties, increasing productivity by 33.34% for the Castillo and Catuaí varieties. 21.6% in the Catuaí variety, compared to yields obtained without application of biofertilizer. The use of *Trichoderma* in coffee plantations in production has a positive influence on the size and weight of the cherry tree, which, when included in the nutritional program with soil fertilization, could improve the % yield, its influence being greater in the Castillo variety. In sensory quality, under the conditions of the present study, the treatments under study had no significant influence on the Castillo and Catuaí varieties. pH correction, timely fertilization, complemented with humic acids, is a technological alternative that could be considered in nutritional programs for coffee plantations in production.

Author Contributions

This study was a collaborative effort among all authors. Silvera-Pablo contributed to the study design and data analysis. Julca-Otiniano conducted the laboratory experiments. Rivera-Ashqui and Silva-Paz analyzed the data, interpreted the results, and drafted the manuscript. All authors reviewed and approved the final manuscript.

Conflict of Interest: The authors declare there is no conflict of interest.

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Data Availability Statement: The primary data is accessible with the corresponding author and can be shared upon reasonable request.

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