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Evaluation of edaphic fertilizers on physical and organoleptic characteristics of the fruit of the hybrid Sarchimor 4260 (*Coffea arabica* L.) in three processing methods.

Evaluación de fertilizantes edáficos sobre características física y organoléptica del fruto del hibrido Sarchimor 4260 (*Coffea arabica* L.) en tres métodos de beneficio

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Abstract: The research objective was to determine the incidence of edaphic fertilization on the physical and organoleptic quality of Sarchimor 4260 coffee (*Coffea arabica* L.) in three different processing methods; wet (BH), dry (BS) and semi-humid (SH). A randomized complete block design was applied with a factorial arrangement of 3^2 with three replications, where the factors under study were a) mycorrhizal fertilizers (M), humus (H) and urea (U), and b) the beneficiation methods. The results determined that in the variables length, diameter and thickness of the fruit, all treatments were equal; regarding the percentage of empty kernels, T5 (H BS) was the best performing with 3%; in terms of snail kernels, the highest percentage was recorded by the treatment T6 (H SH) with 13.5%. The granulometric analysis determined statistical differences between treatments only in sieve 14, where treatments T5 (H BS) and T1 (M-BH), reached the highest percentage; while T6 (H-SH) was the lowest in sieve 15; the best performance is T2: (M BS) and sieve 17 the best is T8 (U BS). The evaluation of fruit characteristics such as fruit color and shape, disk shape and presence of limbo in the calyx, did not present significant statistical differences, and the sensory tests determined that the best cup score was obtained in the sample of T6 (H - SH) with 82.75 points, corresponding to the wet benefit.

Key words: biostimulants, granulometry, tasting, benefits, humus.

Resumen: El objetivo investigativo, fue el determinar la incidencia de la fertilización edáfica sobre la calidad física y organoléptica del café Sarchimor 4260 (*Coffea arabica* L.) en tres diferentes métodos de beneficio; húmedo (BH), seco (BS) y semi húmedo (SH). Se aplicó un diseño de bloques completos al azar con arreglo factorial de 3^2 con tres repeticiones, donde los factores en estudio fueron a) fertilizantes micorriza (M), humus (H) y urea (U), y b) los métodos de beneficios.

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Los resultados determinaron que en las variables longitud, diámetro y grosor del fruto, todos los tratamientos son iguales; en lo que respecta al porcentaje de granos vanos, el T5 (H BS) resultó ser el de mejor comportamiento con un 3%, en cuanto a granos caracolí, el mayor porcentaje lo registró el tratamiento T6 (H SH) con 13,5 %. El análisis granulométrico determinó diferencias estadísticas entre tratamientos solo en la zaranda 14, donde los Tratamientos T5 (H BS) y T1 (M-BH), alcanzaron el mayor porcentaje; mientras el T6 (H-SH) fue el menor en el tamiz 15; el mejor comportamiento lo tiene el T2: (M BS) y tamiz 17 el mejor es el T8 (U BS). La evaluación de características de fruto como color y forma de fruto, forma de disco y presencia de limbo en el cáliz, no presentaron diferencia estadística significativa, y las pruebas sensoriales determinaron que el mejor puntaje en taza lo obtuvo en la muestra del T6 (H - SH) con 82,75 puntos, correspondiente al beneficio húmedo.

Palabras clave: Bioestimulantes, granulometría, catación, beneficios, humus.

Introduction

Latin America's coffee industry has a 61% share of world production, the largest on the planet, and this production is led by far by Brazil, who produced in the 2022/2023 harvest, around 62 million bags of 60 kilos; in Latin America Ecuador ranks 11th with 35,000 bags, well below Colombia and Peru, as well as Central American countries (en.statista.com/statistics/, 2024). In many Latin American countries, plantations are combined with trees that provide shade, capture carbon dioxide (CO2) and protect the soil, becoming one of the main forms of land use in the tropical forest (Larios *et al*., 2016), which is exploited by small producers, who depend economically on what they produce on their farms (Godínez Bazán, 2023).

According to the records of the National Ecuadorian Coffee Association "ANECAFE" in Ecuador, the number of cultivated hectares in 1983 was 346,971 (obest.uta.edu.ec, 2020), in this context Vera-Velásquez *et al*. (2023) mentions that in the province of Manabí, Ecuador, the coffee sector is of relevant economic, social and ecological importance. The economic impact of coffee cultivation lies in its contribution of foreign

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exchange to the State and the generation of income for the families involved.

Alarcó Alicia (2011), citing the National Coffee Council "COFENAC", mentions that coffee in Ecuador is grown in all regions, including the Galapagos, and is of significant social importance, generating at least 105,000 jobs for families in the rural sector, and generating some 700,000 additional jobs through marketing, value added and exports. It also adds that this crop has edaphic importance due to its adaptability to the different ecosystems of the country. Venegas Sánchez *et al.* (2018) points out that production is concentrated in the provinces of Manabí, particularly in the canton of Jipijapa, and in the province of Loja, the latter located in the foothills of the western Cordillera of the Andes. In this context Labrada (2022) mentions that Ecuador has approximately 199,215 hectares of coffee plantations, of which an important portion, around 38.6%, is located in the Canton of Jipijapa, province of Manabi. In addition.

Two genetic lines of Sarchimor were introduced to Ecuador in 1985: C-1669 and C-4260, selected at the Agronomic Institute of Campiñas in Brazil; both showed good adaptation, mainly in the dry zones of Manabí, El Oro and Loja. It is a low-growing hybrid with bronze-colored shoots, high production, low fruit loss and resistance to rust (Amores *et al*., 2004).

The use of chemical fertilizers and organic fertilizers in crops is necessary, since the original nutrient content of soils is generally insufficient for crop growth and development (Avila and Sansores, 2003). Soil fertility is fundamental for agricultural production, since it depends on the capacity of the cropland to produce food in optimal conditions and quantities. Organic fertilizers act indirectly and slowly, with the advantage of improving soil texture and structure, increasing nutrient retention capacity, making assimilation by the plant more efficient, as well as improving water storage capacity (Ayon *et al*., 2023).

Regarding the physical characteristics of coffee, this is closely related to the quality and therefore is subject to the controls that are implemented from the management of the coffee plantation, the harvesting of the fruits, the processing and preparation for export, in this context lies its importance, since it will influence cup quality. The physical characteristics of the bean are related to the shape, size, color, uniformity, humidity, density and defects of the bean (Duicela *et al*., 2010; Cañarte *et al*., 2021); on the other hand, Vázquez Osorio *et al*. (2020), indicate that the soil, environment, climate, altitude, storage, as well as preparation, are factors that influence the quality of the cup.

In this context, the objective of this research work is to "determine the incidence of ecological fertilizers on the physical quality of the bean of the hybrid Sarchimor 4260 (*Coffea arabica* L.) in three processing methods", in order to contribute to the coffee sector with soil fertilization alternatives that favorably affect cup quality.

Methodology

The present investigation was carried out in the experimental farm of the State University of southern Manabi, which is located at km 4.5 of the road that connects the canton Jipijapa with the Noboa parish of the canton 24 de mayo, in the province of Manabí, between Geographic coordinates located at 378 masl with a georeferencing of 17M 0551229 and UTM 9851068 (Holguín Flores, 2029), with predominantly dry warm climate in the West zone, warm humid with dry seasons in the East zone, with an average temperature 24° C. (PDOT, Jipijapa, 2015)..

The Jipijapa canton is located in the south of the province of Manabí and because it is a historical reference in the production of coffee in Ecuador, it was baptized by popular slang as the Sultana del Café (Sultan of Coffee). According to Ponce *et al*, (2022) coffee was cultivated for the first time in 1830 in the canton of Jipijapa, achieving excellent productivity due to its agro-edaphic qualities. Jipijapa is located in the extreme southwest of the Province of Manabí, 403 km from Quito, the capital of Ecuador.

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The experiment on coffee cultivation was carried out on a 6-year-old coffee cultivar, in which 500 coffee plants of the Sarchimor 4260 hybrid were planted.

Data collection variables

Some important characteristics of the ripe fruit were evaluated, as well as some metric aspects of the bean, in both cases the coffee descriptors proposed by the International Plant Genetic Resources Institute "IPGRI" were used as a guide; and for the granulometric evaluation and identification of the proportion of the bean, the sieves number 14, 16 and 17 were used.

The processing, whether dry, semi-dry or wet, was carried out in a canopy measuring 7 by 4 meters, covered with transparent polyethylene plastic sheeting, with beds of plastic mesh arranged in 3 rows. The coffee was stored once a humidity of 11.5% was determined, the storage time was two months, after this time the coffee was piled and then weighed, establishing samples of 500 grams.

Before taking the samples to the tasting laboratory of Solubles Instantáneos, the metric characteristics of the seeds were evaluated, taking measurements of length (mm), width (mm) and thickness (mm), from which the data of 10 seeds per treatment were averaged, using a digital vernier calibrator.

Regarding the physical characteristics of the grain, the following variables were taken into account: proportion of "snail" grains (%) and weight of snail grains; for this calculation, 200 ripe fruits were taken and by observation the rounded or snail-shaped grains were identified.

A sieving test was carried out according to NTE INEN 290 , using the procedure of granulometric analysis or the determination of the proportions of the beans, according to their sizes in a representative sample of green coffee of 300 grams. Table 1 describes the orifices of the sieves number 14, 16 and 17, used for the granulometric analysis according to ISO 4150.

Table 1. *Description of the sieves*

N° Sieve	Hole size (mm)	
	Nominal diameter	Tolerance

14	5,6	± 0,07
15	6,0	± 0,08
17	6,7	± 0,08

Physical defects

An evaluation of the physical defects of green coffee in a sample of 300 grams was carried out using a table for the evaluation of defects according to the NTE INE285:2006 standard. Table 2 below shows the types of defects evaluated. A sample of 300 grams of green coffee was taken for each treatment; the decision is determined based on a maximum of 30 defects, less than this number implies that the coffee complies with the required technical specifications.

Table 2. *Assessment of physical defects of green coffee*

Type of defect	Estimate	Conversion				Quantity of defective grains and/or foreign matter (C)	Defect value (V/D) x(C)
		Defect (D)	Vale (V)	Factor (V/D)			
Black grain	Primary	1	1	(1/1)	1	x	X
Partially black grain	Primary	2	1	(1/2)	0,5	x	X
Fermented grain	Primary	1	1	(1/1)	1	x	X
Amber grain	Primary	2	1	(1/2)	0,5	x	X
Moldy grain	Primary	2	1	(1/2)	0,5	x	X
Large stick or stone	Primary	1	5	(5/1)	5	x	X
Medium stick or stone (o)	Primary	1	2	(1/2)	2	x	X
Stick or small stone	Primary	1	1	(1/1)	1	x	X
Empty grain	Secondary	5	1	(1/5)	0,2	x	X
Immature grain	Secondary	5	1	(1/5)	0,2	x	X
Abnormal or deformed grain	Secondary	5	1	(1/5)	0,2	x	X
Crystalline or glassy grain	Secondary	5	1	(1/5)	0,2	x	X
Grain veined	Secondary	5	1	(1/5)	0,2	x	X
Opaque grain	Secondary	5	1	(1/5)	0,2	x	X

entrosur e-ISSN:2706-6800
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Stained grain	Secondary	10	1	(1/10)	0,1	x	X
Pale or semi-pale grains	Secondary	5	1	(1/5)	0,2	x	X
Brocaded or chopped grain	Secondary	5	1	(1/5)	0,2	x	X
Crushed grain	Secondary	5	1	(1/5)	0,2	x	X
Bitten grain	Secondary	5	1	(1/5)	0,2	x	X
Broken grains	Secondary	5	1	(1/5)	0,2	x	X
Broken grain	Secondary	5	1	(1/5)	0,2	x	X
Ears and or shells	Secondary	5	1	(1/5)	0,2	x	X
Bola seca (dried cherry)	Secondary	1	1	(1/1)	1	x	X
Large shell fragment	Secondary	1	1	(1/1)	1	x	X
Medium shell fragment	Secondary	2	1	(1/2)	0,5	x	X
Small shell fragment	Secondary	5	1	(1/5)	0,2	x	X
Grain with parchment	Secondary	2	1	(1/2)	0,5	x	X
Large fragment of Parchment	Secondary	1	1	(1/1)	1	x	X
Medium fragment of Parchment	Secondary	5	1	(1/5)	0,2	x	X
Small fragment of Parchment	Secondary	10	1	(1/10)	0,1	x	X
Total, of physical defects in the green coffee sample							Xx

Source: Líder Figueroa.

Density of coffee

The density of the beans was determined using the "weight/liter" method proposed by Becker and Freytag (1992), the procedure involves weighing beans contained in the measure of one liter. Current crop" coffee is characterized by a denser bean structure compared to "old crop" coffee. The interpretation determines that mass densities exceeding 650 grams/liter represent a high density of coffee beans.

Qualitative variables

Five qualitative variables were considered for the analysis, which were organized and data were collected according to the recommendations of the "IPGRI" coffee descriptors;
Fruit: five observations: Fruit color: observed on ripe fruit, 1 Yellow, 2 Yellow orange, 3 Orange, 4 Reddish orange, 5 Red, 6 Purple red, 7 Purple, 8 Purple violet, 9 Violet, 10 Black, 11 Other (specify in descriptor Notes 6.5)
Fruit shape (average of five ripe non-fleshed fruits), 1 Rounded, 2 Ovoid, 3 Oval, 4 Elliptical, 5 Oblong, 6 Other
Absence/presence of ribs on fruit, 0 Absent, 1 Present.
Fruit disk shape (found at the end of the kernel), 1 Not marked, 2 Marked, but not prominent, 3 Prominent (cylindrical), 4 Beaked (contracted apex in the shape of a bottleneck), presence of calyx blade: 0 No, 1 Yes

Statistical design

For the analysis of the quantitative variables, parametric statistics were applied, and considering the factors involved in the trial, it was decided to apply a randomized block design with a factorial arrangement of 3^2 , which resulted in 9 treatments with three replications, giving a total of 27 experimental units. Factor A was the type of combinations of organic fertilizers (mycorrhiza, humus, urea) and factor B the methods of processing, as shown in Table 3 below.

Table 3. *Description of the treatments under study*

	Factor A soil fertilization	**Factor B Types of benefits**
T1	Fertilization with mycorrhizae (M)	Wet processing (BH) (anaerobic fermentation)
T2	Fertilization with mycorrhiza (M)	dry processing (BS) (natural coffee).
T3	Fertilization with mycorrhiza (M)	Semi-wet processing (SH) (yellow honey).
T4	Fertilization with humus (H)	Wet beneficiation (BH) (anaerobic fermentation).

entrosur e-ISSN:2706-6800
INSTITUTO TECNOLÓGICO CORPORATIVO EDWARDS DEMING

T5	Fertilization with humus (H)	Dry processing (BS) (natural coffee).
T6	Fertilization with humus (H)	Semi-wet processing (SH) (yellow honey).
T7	Fertilization with urea (U)	Wet beneficiation (BH) (anaerobic fermentation).
T8	Fertilization with urea (U)	Dry processing (BS) (natural coffee).
T9	Fertilization with urea (U)	Semi-wet processing (SH) (yellow honey).

To determine the differences between treatment means, Tukey's 5% significance test was applied.

For the analysis of qualitative variables, the non-parametric chi-square test was applied, trying to find statistical differences between two correlated variables, or otherwise describe the phenotypic characteristics analyzed, among which are considered: fruit color, shape, fruit ribbing, disk shape and presence of limb in the calyx. supported by programs such as InfoStat and the statistical software SPSS Statistics 26.

Results

The Shapiro-Wilk test ($P<0.05$) (Table 1), showed that the data for the variables evaluated were not significant and the coefficients of variation were within the range allowed for this type of research (CV from 17% to 32%). This suggests that the data were normally distributed. Likewise, Levene's test showed that all the variables were not significant at $P<0.05$ probability, with the exception of the stamen length variable (LDE), so the data of the evaluated variables showed homogeneity of variances. These results suggest the continuity of the analysis of variance.

Evaluation of the physical characteristics of the grain of Coffea arabica, Sarchimor 4260

Prior to the statistical evaluation of the results, an analysis of the metric data was carried out, establishing that they have a normal distribution and homogeneous variance, which justified the use of parametric statistics. The analysis of variance of grain morphometry determined that there were significant statistical differences at the level of interaction between factors (Table 4), however, differences were observed at the level of the fertilizer factor, where differences in the width and thickness of the grains were evident, but not in the length; the best performing treatment was urea with dry beneficiation.

Analysis of variance (ANOVA) of physical characteristics of grain 1, related to defects and size.

Treatment	Variables		
	Length	Width	Thickness
T1 (M-BH)	15,42±0,12 (1,4)	14,05±0,23 (2,87)^{ab}	12,14±0,4 (5,71)^{ab}
T2 (M-BS)	15,36±0,38 (4,26)	14,37±0,02 (0,21)^{ab}	12,28±0,08 (1,17)^{ab}
T3 (M-SH)	15,34±0,41 (4,62)	14,47±0,24 (2,84)^{ab}	12,10±0,25 (3,53)^{ab}
T4 (H-BH)	15,69±0,34 (3,76)	14,66±0,09 (1,11)^{ab}	12,86±0,03 (0,47)^{ab}
T5 (H-BS)	14,95±0,44 (5,07)	13,86±0,25 (3,18)^{b}	11,87±0,16 (2,37)^{b}
T6 (H-SH)	15,19±0,11 (1,2)	14,32±0,31 (3,73)^{ab}	12,27±0,16 (2,33)^{ab}
T7 (U-BH)	15,54±0,07 (0,8)	15,79±0,12 (1,33)^{a}	13,69±0,08 (1,97)^{a}
T8 (U-BS)	15,03±0,39 (4,53)	15,11±0,6 (6,85)^{ab}	13,13±0,44 (5,77)^{ab}
T9 (U-SH)	15,72±0,48 (5,26)	15,39±0,41 (4,58)^{ab}	13,98±0,25 (3,08)^{ab}
p- Fertilizer value	0,868^{ns}	<0,05*	<0,01**
p-value Benefit	0,332^{ns}	0,196^{ns}	0,055^{ns}
p-value F vs B	0,696^{ns}	0,264^{ns}	0,075^{ns}

Note. a,b, for each control, least-squares means differ significantly ($p < 0.05$) between groups: *significant; **highly significant;^{ns} not significant.

Evaluation of phenotypic characteristics of *Coffea arabica* bean, Sarchimor 4260

For the analysis of the qualitative variables of the fruit (color, shape, ribbing, disk shape and presence of limb in the calyx), the non-parametric chi-square statistic was applied. The results determined that there were no statistical differences in any of the variables analyzed, establishing that, in terms of fruit color, the most frequent colors are red and purple red; in terms of the presence of a calyx blade, the most common in the treatments is the unmarked, and to a lesser extent the marked, but not prominent; in terms of fruit shape, all of them are rounded, and in all treatments there is an absence of ribbing.

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Table 5. *Evaluation of the qualitative physical characteristics of the coffee fruit.*

Treatments	FRUIT COLOR		PRESENCE OF LIMBO IN THE CALYX	
	Red	Purple red	Not marked	Marked but not prominent
T1 (M-BH	2	1	2	1
T2 (M-BS)	0	3	2	1
T3 (M-SH)	2	1	3	0
T4 (H-BH)	3	0	2	1
T5 (H-BS)	1	2	3	0
T6 (H-SH)	1	2	3	0
T7 (U-BH)	2	1	3	0
T8 (U-BS)	2	1	3	0
T9 (U-SH)	2	1	3	0
Total	15	12	24	3
P value	$0,42^{ns}$		$0,56^{ns}$	

Note: P-value> 0.05 there is no relationship between variables.

Analysis of caracol grains

When evaluating the presence of snail grains, it was observed that treatment T6 (Humus + Semi-humid beneficiation) presented the highest percentage (13.5%), indicating a higher incidence of this type of grain. This was followed by treatment T1 (Mycorrhizae + humid beneficiation) with 10%. In relation to the weight of snail kernels, treatment T8 (Urea + Semi-wet beneficiation) showed the best performance, reaching 3%, and the proportion of snail kernels was significantly higher in this treatment. T6, with an average weight of 17 grams. On the contrary, treatments T1 and T2 presented the lowest weight of snail kernels, with 11 grams each. Detailed percentages and weights of empty fruit and snail kernels for all treatments are shown in Table 6.

Table 6. *Proportion of empty fruit and snail kernels*

Variables	**Treatments**								
	T1 (M-BH)	T2 (M-BS)	T3 (M-SH)	T4 (H-BH)	T5 (H-BS)	T6 (H-SH)	T7 (U-BH)	T8 (U-BS)	T9 (U-SH)
Percentage of empty fruits (%)	4	3,5	4	4	3	4,5	4	4	5
Weight of empty fruits (g)	12	12,5	12	13	12,9	13	15	15,4	16
Percentage of "caracoli" grains (%)	10	10,5	10	13	12	13,5	12,5	13	12,5
Weight of "caracoli" grains (g)	11	11	11,5	14	13	14	15,5	17	15

Note: T: Treatment; M-BH: Mycorrhiza + Wet Benefit; M-BS: Mycorrhiza + Dry Benefit; M-SH: Mycorrhiza + Semi-Humid Benefit; H-BH: Humus + Wet Benefit; H-BS: Humus + Dry Benefit; H-SH: Humus + Sub-Humid Benefit; U-BH: Urea + Wet Benefit; U-BS: Urea + Dry Benefit; U-SH: *Urea* + Semi-Humid Benefit.

screening test according to NTE INEN 290 standard

When analyzing the sieving of the grains (sieves 14, 15 and 17), we found that the treatments applied, as well as their combinations, had a highly significant influence on the results obtained (Table 7). In sieve 14, highly significant statistical differences were identified at the level

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of the fertilizer factors and the type of beneficiation, as well as in the interaction of both factors, with the T6 treatment (H-SH) and the T5 treatment (H-BS) having the lowest and highest percentages. Regarding sieve 15 between treatments, no statistical differences were found; regarding sieve 17, highly significant differences were observed, treatment T2 (M-BS) and treatment T8 (U-BS) resulted in the lowest and highest percentages successively. These results determine that the best treatment is the one containing urea with dry beneficiation, and the treatments with mycorrhiza in all types of beneficiation are the smallest grains.

Table 71. *Screening analysis according to standard NTE INEN 290*

Treatment	Variables		
	Sieve 14	Sieve 15	Sieve 17
T1 (M-BH)	11,33±0,0,49 (7,5)[a]	63,43±0,3 (0,81)	21,3±0,58 (4,69)[cd]
T2 (M-BS)	9,67±0,88 (15,8)[ab]	71±0,4 (0,99)	16,57±0,3 (3,1)[d]
T3 (M-SH)	8,43±1,11 (22,7)[b]	69,67±1 (2,5)	17,57±1,11 (10,9)[cd]
T4 (H-BH)	7,77±0,23 (5,2)[b]	57,33±0,52 (1,58)	32,1±0,67 (3,59)[a]
T5 (H-BS)	12,23±0,29 (4,11)[a]	59,57±0,13 (0,39)	24±0,68 (4,91)[bc]
T6 (H-SH)	7,1±0,1 (2,44)[b]	52,10±14,40 (47,87)	24,30±0,58 (4,12)[bc]
T7 (U-BH)	7,23±0,62 (14,91)[b]	60±1,08 (3,11)	29,43±1,04 (6,13)[ab]
T8 (U-BS)	7,90±0,42 (9,13)[b]	49,8±0,1 (0,35)	36±3,51 (16,90)[a]
T9 (U-SH)	7,43±0,3 (6,90)[b]	66,43±0,81 (2,11)	23,2±0,95 (7,12)[bcd]
p- fertilizer value	<0,01**	<0,05*	<0,01**
p-value Benefit	<0,01**	0,7612[ns]	<0,01**
p-value F vs B	<0,01**	0,1338[ns]	<0,01**

*Note. a,b,c for each control treatments F vs B interaction, least squares means differ significantly (p < 0.05) between F vs V interaction groups : *significant; **highly significant; ns not significant.*

Analysis of residues, physical defects and density.

Coffee density is the weight of a coffee bean in proportion to its volume. Taking as a reference the value of 650g/L, the density of the beans in each treatment was determined. All treatments exceeded the reference value, therefore, it is concluded that the coffee evaluated has a good density. Treatments T1 and T3 presented the highest density with 860 grams/liter, while the lowest density treatment was T4 with 810 grams/liter. Table 17 shows the densities recorded for each of the treatments.

With respect to the evaluation of the physical defects of green coffee, it was determined that there is no significant statistical difference between treatments and replicates with respect to the number of physical defects, with an average of 15.4 defects and a coefficient of variation of 27.5%, which indicates that the average mean is representative.

Within this variable, mathematically, the treatment with the lowest defects was T7 with 11.63 % of defects, while in the opposite direction is T8 with 20.87 defects being the highest scoring, both treatments with only urea application.

Regarding the residue variable, the results indicate that only the interactions between treatments have a highly significant statistical effect. In the samples of 300 grams of green coffee sieved, it was determined that T3 (mycorrhiza + semi-humid processing) obtained a residue of 4.33%, in contrast to T6: Humus + Sub-humid Processing, which obtained 1.49% residue. The means and significance of the variable residue, according to the Tukey test at 5%, applied to the interactions of the factors under study, are presented.

Table 8. *5% Tukey test performed on grain size, related to the interactions of the factors: fertilizers and type of beneficiation and the variable residue.*

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INSTITUTO TECNOLÓGICO CORPORATIVO EDWARDS DEMING

Treatments	Density (g/L)	Physical defects	Residues (average)
T1	860	14,97 ^{a}	3,89 ^{ab}
T2	827	15,27 ^{a}	2,78 ^{ab}
T3	860	15,6 ^{a}	4,33 ^{a}
T4	810	18,67 ^{a}	2,79 ^{ab}
T5	825	15,4 ^{a}	4,20 ^{a}
T6	849	12,9 ^{a}	1,49 ^{b}
T7	848	11,63 ^{a}	3,34 ^{ab}
T8	820	20,87 ^{a}	2,98 ^{ab}
T9	850	12,9 ^{a}	2,92 ^{ab}

Note: Means with a common letter are not significantly different ($p > 0.05$).

Organoleptic analysis of *Coffea arabica* bean, Sarchimor 4260 with different sources of fertilization and different types of processing .

The sensory analysis was carried out by specialists tasters of the company Solubles Instantáneos, the results are presented in table 9, in which it can be seen that all treatments thanks to good management exceed the score of 80 in their attributes, so they are considered coffees of excellence, expressing sweetness, cleanliness of rate, uniformity, balance, body, acidity, balance and flavor.

The treatments with the highest scores are T6 humus with semi-humid benefit (yellow honey) with 82.75; and the treatment T7 urea with humid benefit (BH) (anaerobic fermentation) with a score of 87.25.

Table 10. *Results of organoleptic attributes of samples of Coffea arabica, Sarchimor 4260 with different sources of fertilization and different types of processing.*

Treatments	ATTRIBUTES	Total

	Fragrance Aroma	Taste	Residual Flavor	Acidity	Body	Balance	Uniformity	Clean Cup	Sweetness	Taster Score	defects	
T1 (M-BH)	7,3	7,5	7,5	7,5	7,3	7,3	10	10	10	7,5	0	81,75
T2 (M-BS)	7	7,3	7	7,5	7,3	7,3	10	10	10	7	0	80,25
T3 (M-SH)	7,5	7,3	7	7,8	7,3	7,5	10	10	10	7,3	0	81,5
T4 (H-BH)	7,5	7,3	7,3	7,5	7,3	7,3	10	10	10	7,3	0	81,25
T5 (H-BS)	7,5	7,3	7,5	7,5	7,3	7,5	8	10	10	7,5	0	80
T6 (H-SH)	7,8	7,5	7,8	7,5	7,3	7,5	10	10	10	7,5	0	82,75
T7 (U-BH)	7,5	7,5	7,5	7,5	7,25	7,5	10	10	10	7,5	0	82,25
T8 (U-BS)	7,3	7,3	7,3	7,5	7,3	7,3	10	10	10	7,3	0	81
T9 (U-SH)	7,5	7,3	7,3	7,5	7,3	7,3	10	10	10	7,5	0	81,5

Source: Instant Solubles Laboratory

The characteristics of the best treatments were: for T6 (H-SH): dark chocolate, panela; citric flavor, lime, light herbal; short residual flavor, light astringent; medium malic acidity; medium body; balanced; the coffee has many characteristics that are maintained when cold; and for T7 (U-BH): citric fragrance, sweet, chocolate; pleasant light citric flavor; short residual flavor, pleasant; medium citric acidity; medium-low body; balanced; the coffee maintains its characteristics when cold and remains pleasant. The other treatments lose their attributes when cold or present an astringent residual, characteristics that are not very desirable.

Conclusions

The present research work has demonstrated that agroecological fertilizers have positive effects on *Coffea arabica* plantations; agreeing in this sense with the work carried out by (Aguilar, 2016), where it is stated that coffee responds well to the association with mycorrhizae with which it establishes a natural association. The microorganisms associated with coffee plants play a critical role in the physiology, production and final quality of the coffee bean. Mycorrhizal fungi,

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specifically arbuscular mycorrhizal fungi, form symbiotic associations with coffee plants, supplying nutrients that would otherwise be inaccessible to the roots. This supply of nutrients can affect the quality of the coffee bean. Therefore, the diversity of microorganisms associated with coffee fruits is crucial for understanding the interactions, metabolic pathways, and production of microbial metabolites that serve as sensory precursors of high quality coffee beverages (Rojas *et al*., 2024).

Duicela (2017) in research conducted in agroforestry systems Altitudes of cultivation areas in Ecuador, where 40 samples of coffee of the varieties Tipica, Caturra, Bourbon and Sarchimor, taken in the provinces of El Oro, Loja and Manabi were analyzed. The type of processing was by wet fermentation in water with a time of 12 to 24 hours; the score obtained ranged from 80.95 to 82.27 points, a lower result than that obtained in this research where 82.75 was obtained with the wet processing and the cultivation with the application of worm humus, the points obtained place these coffees as specialty coffees.

Maldonado *et al*. (2024) in research carried out on types of post-harvest coffee processing, indicates that the processing methods can influence the organoleptic quality of coffee; in their study they analyzed forms of fermentation in Arabica coffees IPR 98, CATUCAI and IAPAR 59, leaving with mucilage from 12 to 18 hours in three types of solutions; water, milk and yogurt, obtaining this last solution as the best treatment with a score of 84.7 in cup, while in the ferment in water it reached 81.3 points.

In the evaluation of the sieves, highly significant statistical differences for the factors and their interactions were found in sieve number 14, with an average of 7.1% to 12.23%, the highest being the coffee obtained by dry milling, and the lowest the wet milling, both fertilized with worm castings; these results are similar to the results observed by Bravo and Giler, (2018) who conducted granulometric tests on three varieties of coffee, and although they did not find significant differences in their treatments, they observed that in the Sarchimor varietal, in the sieve 14 they obtained an average of 11.42% of grains. Regarding the dentition, Bravo and Giler obtained an average of 668 grams/liter, a value lower than the average of 830 grams/liter of the research carried out. The same author identified an average of 22 physical defects in the coffee beans, being seven points higher than the present research where an average of 15 defects were found.

Coffee bean size is significantly influenced by soil fertilizers, as evidenced by several studies. Nutrient ratios, in particular the balance of calcium and magnesium and nitrogen and phosphorus, are crucial in determining bean size; an increase in calcium relative to magnesium correlates with larger beans (Abebe *et al*., 2019). In addition, different levels of fertilization have been shown to affect coffee bean size, with higher fertilization leading to a higher proportion of larger beans in specific cultivars (Bruno *et al*., 2007).

Controlled-release fertilizers also improve growth and yield, indicating that the type and timing of fertilizer application can optimize grain size (De Carvalho *et al*., 2024). In addition, the integration of organic and inorganic fertilizers has been recommended to maximize yield and growth, which indirectly influences grain size (Obsa, 2021). In general, careful management of soil nutrients through appropriate fertilization strategies is essential to improve coffee bean size and quality.

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