Article

Response of *Coffea arabica* L. to the application of organic fertilizers and biofertilizers

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Abstract

Organic coffee is in high demand in the international market and its cultivation is used as a hub for community development. Oaxaca is one of the states where ecological alternatives are implemented in a sustainable way to produce coffee. The objective of the study was to evaluate the effect of organic fertilizers and biofertilizers on the growth dynamics of *C. arabica* L. in plants established in the var. Typica renovated three years ago. The study was carried out at the El Nueve farm, Santa Maria Huatulco, Oaxaca, during 2018. The organic fertilizers evaluated were: Vermicompost (L), Natur-fertilizer® (Na), Bio-Orgamin (Bo) and Bat Guano (Gm). The biofertilizers were based on *Azotobacter* sp. (Az) and *Glomus cubense* (Gc). In addition to their combinations and a control (T), for a total of 17 treatments. Data were subjected to analysis of variance and Tukey tests. The variables evaluated were plant height (Ap), stem diameter (Dt), slenderness index (IE) and number of knots (Nn). The coffee trees responded positively to organic fertilizers and biofertilizers, obtaining significant differences between treatments with a level of significance ($p \leq 0.05$), for Ap, with the combination of Gm+L+Gc, heights of 216 cm were obtained. For Dt, the T showed the highest value with 3.16 cm. As for Nn, the combination of Gm+L+Gc was the one that generated the highest number with 56.33 knots. The use of organic fertilizers and biofertilizers in combination is essential for the good growth of coffee trees in renovated plantations.

Keywords: *Azotobacter* sp., *Glomus cubense*, bat guano, Bio-Orgamin.

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Introduction

Coffee (*Coffea arabica* L.) is grown in more than 80 countries in Latin America, Africa and Asia. It is one of the most important agricultural products in the world in terms of production, commercial, economic and social value for the actors that participate in the agro-productive and food chain (Coutiño *et al*., 2017). It was introduced to Mexico around 1790 (Medina *et al*., 2016) and in recent years production has decreased and in 2016 it occupied the 11th position, which represents 2.1% of world production (FIRA, 2018) is the eighth producer coffee world (OIC, 2014).

Production depends on the family labor force of small producers under traditional management with the use of rustic nurseries for seedling production, shade planting, pruning, etc. (SAGARPA, 2018). There are more than 500 000 coffee growers in 12 states of the country, where 90% of them have areas of less than 5 ha (Flores, 2015).

700 000 ha are cultivated nationwide, with six states concentrating 97.42% of the total supply, for the 2017-2018 cycle, the states of Chiapas (40.7%), Veracruz (24.6%), Puebla (15.9%), Oaxaca (8.27%), Guerrero (4.56%) and Hidalgo (3.26%) stand out (SIAP, 2018). Oaxaca is one of the states where various organizations have been developed that commercialize coffee in market niches such as organic production, fair trade, organic coffees and shade coffee (CEDRSSA, 2018).

The above is thanks to the ideal conditions for cultivation, with mountainous areas, being a plantation with a pre-productive period of approximately three years and a productive life of up to 40 years, in addition, it is cultivated at altitudes ranging from 900 and 1 500 m, with temperatures of 16 to 22 °C and rainfall of 750 to 3 000 mm (Espinosa *et al*., 2016).

Despite this, coffee production and yields have been affected in recent years by up to 50%. According to SAGARPA (2017), the main causes include prices on the world market, the advanced age of coffee plantations and the low content of nutrients in cultivated soils. On the other hand, the abandonment and neglect of the plantations due to low prices, high incidence of pests and diseases that affect quality and yield, especially the presence of broca (*Hypothenemus hampeim* Ferrari) and rust (*Hemileia vastratix* Berkeley & Broome) (Reyes *et al*., 2018).

Despite the effect they cause, the application of technological packages for their prevention and control is almost null, 9.1% of the units use chemical fertilizers, 2.3% use improved seed, 2.5% organic fertilizers, 7% herbicides, 5% insecticides and other type of technology 0.1% (SAGARPA, 2018).

This leads to considering alternatives for coffee production with a greater possibility of implementing ecological and sustainable alternatives (Mosquera *et al*., 2016). The approach is based on the use of agroecological practices; as well as the use of basic techniques used in organic agriculture, which are of vital importance (Aguilar, 2014). Among them, the incorporation of organic fertilizers into the soil stands out to improve its physical, chemical, biological and sanitary characteristics, to increase its fertility (Boudet *et al*., 2015).

The benefits generate vigorous growth of roots, foliage, flowering and fruiting, allowing plants greater resistance against pests and diseases and their rapid recovery after harvest (Aguilar *et al*., 2016). In addition, the insertion of biofertilizers has now been achieved, which by containing live or latent microorganisms (fungi and bacteria, alone or in combination) and when used in crops, stimulates growth and increases in yields, and therefore, production of the coffee plantations (Aguado, 2012).

As well as, they increase the processes of absorption and translocation of nutrients in plants; since these inputs allow to improve the development of the crop when they interact with the plants, creating symbiosis with each other (Moises *et al*., 2015). So the proposed objective was to evaluate the effect of different organic fertilizers and biofertilizers on morphological variables of *C. arabica* L. established in the field.

Materials and methods

Characteristics of the study area

The study was carried out at the El Nueve coffee farm, located in the municipality of Santa Maria Huatulco, Oaxaca, Mexico, located on the banks of the Copalita river basin at coordinates 15° 55’ 57” north latitude, 96° 17’ 08” west longitude, at an altitude of 1 250 m, average annual precipitation of 1 364 mm and an annual temperature of 21 °C.

The farm has an area of 200 ha, 160 ha have a vegetation of medium sub-evergreen jungle and the remaining 40 are organic coffee under an agroforestry system (INEGI, 2019). The farm is administratively included in the Coffee Product System and is associated with the Confederation of Oaxacan Coffee Growers, AC, which allows it to export quality and differentiated coffee (Figure 1).

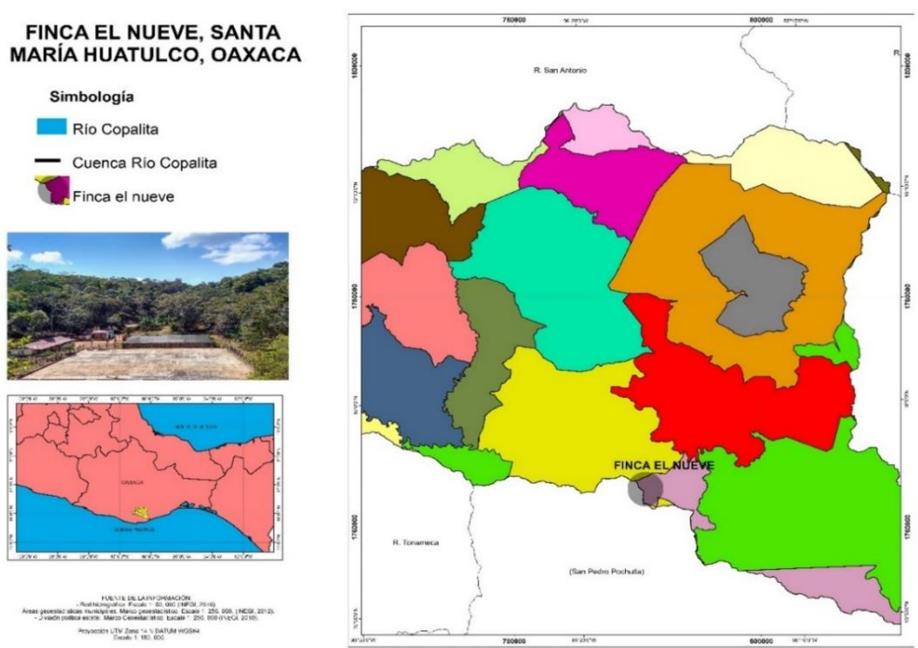

Figure 1. Location of the El Nueve farm, Santa María Huatulco, Oaxaca.

For the establishment of the experiment a typical variety coffee plantation was used, selecting a batch of coffee trees established under a traditional agroforestry system under regulated shade in lands with a great diversity of trees, especially of the *Inga* genus, with average slopes of 30%, with organic fertilization, standardized coffee trees, abundant foliage, good phytosanitary status and renewed four years ago.

Before applying the treatments, soil samples were taken from four sites in the experimental zone, high position (1 297 masl) and low position (1 284 masl) of the slope. According to what is stated in the Official Mexican Standard NOM-021-RECNAT-2000 (SEMARNAT, 2000), the texture was determined by the Bouyocus method, pH by potentiometry in water (ratio 1:2), electrical conductivity (EC) by the conductimeter method, the organic matter content (OM) by the Walkley and Black method, humidity by the gravimetric method; determination of phosphorus (P) by the method of Bray and Kurtz 1, interchangeable bases of calcium and magnesium (Ca, Mg) with 1N ammonium acetate, pH 7 as an extractant solution; interchangeable acidity by the procedure of potassium chloride and total nitrogen (Nt) by using the formula: NT=0.1105CO+0.0116, with the help of obtaining the percentage of organic carbon, so the value was substituted in the formula CO for the percentage value of each sample already analyzed.

A completely randomized design was used. A total of 17 treatments with three repetitions were established, where one plant represents one repetition. The organic fertilizers used were diluted in 8 L of water, leaving them to rest for two hours for their subsequent application at the foot of the plant (*drench*) making a crescent or semicircle at the top of the slope. The biofertilizers were diluted in 1 L of water and applied instantly under the same scheme. The same individual doses were used to prepare the combination treatments (Table 1).

Table 1. List of treatments under study.

Treatment	Organic fertilizers and biofertilizers	Dose plant^{-1}
T1	T	Without application
T2	L	2 kg in 8 L
T3	Na	2 kg in 8 L
T4	Bo	2 kg in 8 L
T5	Gm	2 ml L^{-1}
T6	Az	4 ml L^{-1}
T7	Gc	10 g L^{-1}
T8	Az+Gc	4 ml +10 g L^{-1}
T9	Gm+L	2 ml+2 kg +8 L
T10	Gm+Az	2 ml+4 mL L^{-1}
T11	Gm+Gc	2 ml+10 g L^{-1}
T12	L+Az	2 kg +4 ml+ 8 L
T13	L+Gc	2 kg +10 g + 8 L
T14	Gm+Az+Gc	2 ml+4 ml +10 g+ 8 L
T15	Gm+L+Az	2 ml +2 kg +4 ml + 8 L
T16	Gm+L+Gc	2 ml +2 kg +10 g + 8 L
T17	L+Az+Gc	2 kg +4 ml +10 g+ 8 L

The products used are certified as organic products by the certifying agency CERTIMEX organic product CMX-276-2006-48-48-48 and were purchased at the Oaxaca State Center for Organic Products (CEFO).

Variables evaluated

The application of the treatments began in the first days of March and ended in April 2019. For the evaluation of the response variables, four measurements were made at 90-day intervals, starting one month after the first application (dda) of treatments. The variables evaluated were plant height (Ap) (cm) and stem diameter (Dt) (Cm), at the beginning of production the number of total knots per plant (Nn) was recorded.

Statistical analysis

The experimental design was completely random. The data of the measured variables were subjected to a verification process of variance homogeneity and error normality (Montgomery, 2005). When the tests were negative, the transformations corresponding to log10 (x) were made to comply with the assumptions of normality and homogeneity of variances (Steel and Torrie, 1988). The data were subjected to analysis of variance and comparison of means (Tukey, 0.05). The statistical software used was SAS/STAT® 9.3 (SAS Institute Inc. 2011).

Results and discussion

Physicochemical properties of the experimental study area

Physical-chemical analyzes of the soils were carried out at the site where the experiment was established at four different points, two for each zone of high, low and altitudinal gradient. According to the criteria of NOM-021-SEMARNAT-2000, the textural composition of the soils in the study area varied without following a defined pattern between sandy to loamy-sandy, which indicates that despite the rains there are no problems due to excess water and that there is a strong process of washing of nutrients and susceptibility to erosion by rain.

These textures are similar to those reported by Contreras *et al*. (2019), who found loamy-sandy and sandy textures in a study of agroecological practices and their influence on soil fertility in a coffee community in the state of Puebla. Likewise, Gómez *et al*. (2018), mention that in soils with a high presence of sand, rapid drainage of rainwater is promoted. It should be noted that, to obtain a sustainable coffee production, the soil must have a clayey texture (Aranda, 2010).

According to Palma *et al*. (2007), the unconsolidated soils of fine and medium texture have a strong alteration and washing and are considered as old lands subject to erosion processes. The pH value varied in a range of 4.43 to 4.92, being more acidic in the upper parts, which is logical due to the dragging and leaching of materials due to the effect of the rains.

According to the NOM-021-RECNAT-2000 standard, soils with values <5 are classified as strongly acidic soils. Similar results are reported by Rodríguez *et al*. (2016), when evaluating spatial variability of the chemical attributes of the soil in the yield and quality of coffee, where they report a pH of 4.73. Duicela (2011), reports that the soils suitable for coffee cultivation must have a slightly acidic pH between 5.5 and 6.5 and indicates that acidity values of <5 or above 6.5 hinder the nutrition of the coffee plantations.

The EC values found were 0.04-0.06, which means that they are in the range of a concentration <1, so they are classified as soils with negligible effects on salinity. The results obtained are similar to those reported by Gómez *et al*. (2018), where they mention that in soils that *C. arabica* L. is produced in Chiapas, they have an EC of 0.02 to 0.09 dS m^{-1}. Aranda (2010), indicates that low EC values favor coffee crops. In addition, coffee does not tolerate saline soils, so that when rains are scarce, the concentration of salts increases.

The OM values vary in the range of 2.46 to 5.9%, depending on the gradient of the slope, being low in the upper parts and increasing for the lower parts. This classifies soils with medium values for high sites and with high content for low sites, as they are non-volcanic soils. Noriega *et al.* (2014), reports OM averages in coffee soils of 5.14%, which agrees with data obtained in the study. Cabon (2015); Theriez (2015), mention that coffee plantations with shade trees provide a greater amount of OM.

As for the high values of OM in the lower parts of the farm, it is explained why, being in the low position of the slope, it is a receptor site for organic and mineral materials, presenting a good state of conservation and low intensity of erosion (Zavala *et al*., 2014). In turn, Noriega *et al*. (2014), mention that medium and high OM values, acidity could be limiting the growth of bacteria and limiting the mineralization process.

The soil moisture had values of ≤5%, which indicates a low capacity to retain moisture, so plants can suffer deficiencies in the absence of rain, which occurs in the months of March and April, due to than the rainy season, which usually begins in early May. In this regard, Duarte (2016) points out that sandy soils retain moisture between 7.5 and 20.5%. This soil characteristic is a function of other factors such as texture and structure, they are also shallow soils with high slopes.

This capacity represents the reserve of the plants to absorb the necessary amounts for their energy and nutrient cycles (Villareyna, 2016). The nutritional elements that the coffee tree requires in greater quantity are: N, P and K, and in smaller quantities: Ca, Mg, S, Cl, Zn, Mn, B and Cu. The lack of any of these nutrients affects their growth and development (Duicela, 2011). Percentages were obtained between the values of 0.17-0.39, considered high (0.5-0.25) and very high (0.25) in the total N content, possibly due to the high content of organic matter. Contreras *et al*. (2019), in his study of agroecological practices in coffee plantations reports values of 0.22%, in turn he mentions high yields and productivity.

However, they are considered low values compared to those reported by Larios *et al*. (2014), who found values of 0.5% in systems with agroecological practices and 0.35% in conventional systems. The P contents found were <15 mg kg^{-1}, low values with respect to those required by the crop, coinciding with Galindo (2013), who reported that, in Santander Colombia coffee soils, the levels are very low, <0.4 mg kg^{-1}. Roger *et al*. (2014), indicate that this element has little mobility in the soil.

The Ca contents were practically negligible, being in the range of <2, classified as very low concentration for this element. Gómez *et al*. (2018), mention that in soils where coffee is produced, they found low values of 4.78 mg kg^{-1}, values much higher than those reported, indicating that plants can suffer from the deficiencies of the element in the soil.

Mg has very low levels, <0.5 classifying in a very low class. Jaramillo (2002), indicates that the low contents of N, Ca, P, Mg, are influenced by leaching, which intensifies if the rainfall is intense and prolonged. Likewise, Silva *et al*. (2013), indicate that soils with acidic pH (<5.5) block the absorption of P, Ca and Mg. Since the soils in coffee growing areas have low values, it is for this reason that the use of mycorrhizae is recommended, which improves the absorption of water, phosphate ion and nutrients such as N, K, Ca and Mg. As well as the incorporation of phosphoric rock, mineral source and organic fertilizers (López *et al*., 2019) (Table 2).

Table 2. Physicochemical properties of the sites in the study area.

Sampling points	Texture	pH	EC (dS m^{-1})	OM (%)	Moisture (%)	N (%)	P (mg kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
Site 1 high part	Sandy-loamy	4.36	0.06	2.46	5.09	0.33	2.25	0.00087	0.0023
Site 2 high part	Sandy	4.46	0.04	3.34	2.69	0.22	2.05	0.0016	0.0013
Site 1 lower part	Sandy-loamy	4.92	0.05	2.6	5.18	0.17	nd	0.0025	0.00067
Site 2 lower part	Loam sandy	4.43	0.04	5.9	5.09	0.39	2.08	nd	nd

ND= not detectable.

Plant height

The evaluation results show that in all the treatments they showed significant differences over time. At the end of the evaluation, the maximum Ap value was 216 cm for treatment with the combination of Gm+L+Gc.

These results agree with those obtained by Plaza *et al*. (2015), where they found that the application of organic fertilizers influences the agronomic and productive behavior of *Coffea canephora* plantations, by reporting plant heights of ≤220 cm for low-growing plants, values of ≤300 cm in medium-sized plants and >301 cm for tall plants, evaluated over a period of eight months. The lowest values were for treatments L (120 cm), L+Az (140 cm), L+Gc (133 cm) (Table 3).

The combination of organic fertilizers and biofertilizers generates growth in plants. These results coincide with Roman *et al*. (2013), where they report that the greater the amount of organic matter, the greater the microbial quantity since when applying organic fertilizers, there is a greater possibility of nutrient release and when applied to the soil, the decomposition process continues.

Table 3. Response of organic fertilizers and biofertilizers over time in the height variable.

Bioproducts	Height			
	90 dda	180 dda	270 dda	360 dda
T	182.33 ±13.01 ab	188.67 ±9.01 ab	194 ±6.55 ab	199.3 ±5.85 a
L	104.33 ±17.24 c	111.67 ±13.42 c	116 ±13.07 c	120 ±13.07 a
Na	134.67 ±5.5 abc	139.33 ±4.5 abc	143.67 ±4.04 abc	147.7 ±4.04 a
Bo	135 ±22.91 abc	139.33 ±23.79 abc	143 ±23.25 abc	147 ±23.59 a
Gm	149 ±12.76 abc	153.67 ±12.34 abc	158.33 ±11.93 abc	162 ±11.78 a
Az	167.33 ±46.69 abc	171.33 ±46.49 abc	180.67 ±51.85 abc	184 ±49 a
Gc	167.33 ±16.16 abc	172 ±17.08 abc	177.67 ±16.62 abc	182.7 ±15.63 a
Az+Gc	152.33 ±28.04 abc	156 ±27.73 abc	160 ±27.73 abc	163.3 ±27.13 a
Gm+L	162.33 ±37.09 abc	166.33 ±36.46 abc	170.33 ±36.46 abc	174.3 ±36.46 a
Gm+Az	145 ±6.24 abc	149 ±5.29 abc	153 ±5.29 abc	157 ±5.29 a
Gm+Gc	134.67 ±16.16 abc	137.67 ±16.56 c	141.67 ±16.56 abc	145.7 ±16.56 a
L+Az	129.33 ±14.74 c	132.67 ±15.14 c	136.33 ±14.57 c	140.7 ±14.36 a
L+Gc	122.33 ±7.5 c	126 ±7 c	130 ±7 c	133 ±6.55 a
Gm+Az+Gc	148.67 ±27 6abc	151.33 ±25.65 abc	154.67 ±25.1 abc	157.7 ±25.1 a
Gm+L+Az	144.33 ±33.54 abc	148.33 ±33.54 abc	152 ±33.86 abc	155.7 ±32.29 a
Gm+L+Gc	205.67 ±23.62 a	209.33 ±23.24 a	213 ±22.86 a	216.7 ±22.5 a
L+Az+Gc	135.33 ±23.24 abc	139.33 ±23.24 abc	143.33 ±23.24 abc	480.3 ±592.33a
Cv	3.06	2.97	2.89	6.5

dda= days after application of organic fertilizers and biofertilizers; T= control; L= vermicompost; Na= Natur-Abono®; Bo= Bio-Orgamin; Gm= bat guano; Az= *Azotobacter* sp.; Gc= *Glomus cubense*. Averages with the same letter per column do not differ significantly (Tukey, $p< 0.05$). The mean ± standard error is included; cv= coefficient of variation; **= highly significant ($p\leq 0.01$); ns= not significant.

Generally, the organic fertilizers used as a substrate for the production of plants are relevant agroecological alternatives, since these, in combination with the soil, favor the physical, chemical and biological properties of the substrate and an adequate growth and development of the plants (Aguilar *et al*., 2017). Pérez *et al*. (2002), indicate that the application of HMA in combination with Az have a positive effect on growth and development in plantation.

Stem diameter

It was found that from 180 to 360 dda, there are significant differences between treatments. The highest Dt found was 3.16 cm for T, very different from the combinations of fertilizers and biofertilizers, which were those with the smallest diameters, Gm+Az (2.3 cm), Gm+Gc (2.23 cm), L+Gc (2.16 cm) (Table 4).

Table 4. Response of organic fertilizers and biofertilizers over time in the variable stem diameter.

Bioproducts	Diameter (cm)			
	90 dda	180 dda	270 dda	360 dda
T	2.16 ±0.28 a	2.6 ±0.17 a	2.83 ±0.15 a	3.16 ±0.15 a
L	1.6 ±0.17 a	1.86 ±0.11 ab	2.13 ±0.15 ab	2.36 ±0.11 ab
Na	1.96 ±0.05 a	2.26 ±0.05 ab	2.5 ±0 ab	2.8 ±0 ab
Bo	1.9 ±0.17 a	2.26 ±0.25 ab	2.53 ±0.25 ab	2.76 ±0.25 ab
Gm	1.76 ±0.25 a	2 ±0.2 ab	2.26 ±0.25 ab	2.5 ±0.2 ab
Az	1.73 ±0.25 a	2 ±0.26 ab	2.2 ±0.26 ab	2.5 ±0.26 ab
Gc	7.1 ±9.44 a	1.9 ±0.17 ab	2.16 ±0.15 ab	2.43 ±0.11 ab
Az+Gc	1.26 ±0.46 a	1.83 ±0.57 ab	2.1 ±0.6 ab	2.43 ±0.6 ab
Gm+L	2.1 ±0.17 a	2.36 ±0.11 ab	2.63 ±0.15 ab	2.93 ±0.11 ab
Gm+Az	1.6 ±0.17 a	1.83 ±0.15 ab	2.1 ±0.17 ab	2.3 ±0.17 b
Gm+Gc	1.5 ±0 a	1.76 ±0.05 b	2.03 ±0.05 ab	2.23 ±0.11 b
L+Az	1.76 ±0.25 a	2.1 ±0.3 ab	2.33 ±0.35 ab	2.63 ±0.35 ab
L+Gc	1.36 ±0.23 a	1.6 ±0.17 b	1.86 ±0.15 b	2.16 ±0.15 b
Gm+Az+Gc	1.83 ±0.28 a	2.1 ±0.34 ab	2.3 ±0.34 ab	2.53 ±0.28 ab
Gm+L+Az	2± 0.5 a	2.26±0.55 ab	2.5 ±0.5 ab	2.73 ±0.5 ab
Gm+L+Gc	2.1 ±0.17 a	2.36 ±0.11 ab	2.6 ±0.17 ab	2.9 ±0.17 ab
L+Az+Gc	1.73 ±0.25 a	1.96 ±0.2 ab	2.26 ±0.2 ab	2.5 ±0.17 ab
Cv	61.17	18.21	14.61	11.42

dda= days after application of organic fertilizers and biofertilizers; T= control; L= vermicompost; Na= Natur-Abono®; Bo= Bio-Orgamin; Gm= bat guano; Az= *Azotobacter* sp.; Gc= *Glomus cubense*. Averages with the same letter per column do not differ significantly (Tukey, $p< 0.05$), the mean ±standard error is included; cv= coefficient of variation. **= highly significant ($p\leq 0.01$). ns= not significant.

These results coincide with Plaza *et al*. (2015), who found significant differences in Dt when evaluating organic fertilizers in coffee with values of ≤3 cm, which indicates that good vegetative growth must be ensured to obtain high production levels. In this regard, Adriano *et al*. (2011), mention in their biofertilization research that there is a mutualistic interaction in HMA, the root of plants and Az. Cilas *et al*. (1998), indicate that morphological traits, stem diameter, plant height and number of primary branches, are genetically correlated with yield. Casique *et al*. (2018), mention that the Dt is an indicator that reveals the behavior of the height and defines the production of the plants.

Number of knots

For this variable, the application of treatments did not have the expected effect, that is, no significant statistical differences were found in any evaluation ($p\geq 0.05$). It is attributed to the fact that the crop had possibly formed the reproductive structure from the previous year; however, the highest value was obtained by the combination of two organic fertilizers and a biofertilizer, Gm+L+Gc with 56.33 Nn.

It is evident that when a higher Nn is found, the number of fruits is greater and therefore higher yields (Cascante and Furcal, 2018). The Na obtained the lowest Nn with 12.33. Likewise, these results have an impact on the climatic conditions of each place, so that as rainfall increases, there is a greater probability of node losses at the time of their formation and defoliation of the previous harvest, in addition, the productive knots vary each year to the extreme of the bandola (Duarte, 2016) (Table 5).

Table 5. Response of organic fertilizers and biofertilizers to the number of stem knots.

Treatments	Number of knots			
	30 dda	90 dda	150 dda	210 dda
T	6 ±8.66 a	8.66 ±6.5 a	11.33 ±5.5 a	35.67 ±16.86 a
L	2.66 ±2.08 a	5 ±0 a	9 ±4.35 a	15 ±2.64 a
Na	4 ±2.64 a	6.66 ±2.88 a	13.67 ±6.5 a	12.33 ±4.5 a
Bo	4.33 ±3.05 a	8.33 ±0.57 a	12 ±1.73 a	19 ±5.56 a
Gm	5 ±3 a	8.66 ±2.3 a	19 ±10.58 a	30.33 ±10.4 a
Az	7 ±1 a	10.66 ±1.15 a	17.33 ±4.16 a	41.67 ±28.93 a
Gc	3.66 ±2.08 a	10 ±1 a	36.67 ±21.22 a	49 ±15.39 a
Az+Gc	3.66 ±2.08 a	8.33 ±1.52 a	23.33 ±19.73 a	35.33 ±23.18 a
Gm+L	8.66 ±2.08 a	13 ±1 a	17.67 ±0.57 a	16.33 ±9.71 a
Gm+Az	7 ±2.64 a	11.33 ±3.05 a	25.33 ±15.37 a	33.33 ±3.51 a
Gm+Gc	4.66 ±4.04 a	9.33 ±4.5 a	24.33 ±20.25 a	33 ±9.64 a
L+Az	9.66 ±6.65 a	16.66 ±9.23 a	40 ±24.57 a	43.67 ±40.5 a
L+Gc	5.66 ±07.23 a	8.66 ±7.23 a	15.67 ±16.77 a	16.67 ±19.34 a
Gm+Az+Gc	4 ±2.64 a	7.33 ±6.11 a	15.33 ±12.09 a	27 ±10.14 a
Gm+L+Az	6 ±3 a	10 ±8.66 a	18.33 ±10.21 a	26.67 ±7.76 a
Gm+L+Gc	8.66 ±0.57 a	13 ±3 a	20 ±9.53 a	56.33 ±18.58 a
L+Az+Gc	14 ±14.73	17.33 ±17.03 a	22 ±18.52 a	29.33 ±20.55 a
Cv	85.58	60.34	62.25	57.14

Nn= Number of knots; T= control; L= vermicompost; Na= NaturAbono®; Gm= bat guano; Az= *Azotobacter* sp.; Gc= *Glomus cubense*. Averages with the same letter per column do not differ significantly (Tukey, $p < 0.05$); mean ±standard error is included; cv= coefficient of variation; ns= not significant.

Roman *et al*. (2013), mention that these results are attributed to the fact that, the greater the amount of organic matter, the greater the microbial quantity and when applying organic fertilizers together with biofertilizers, there is the possibility of nutrient release due to the continuous decomposition of organic matter and by the effect of microorganisms in the soil.

Martínez *et al*. (2015), report that the incorporation of biofertilizers is an alternative for the survival of the coffee crop, since they provide beneficial microorganisms that when applied to crops or to the soil, alone or in combination, favor their biological activity, the use of nutrients in association with plants and plant growth, so that yields are maintained or increased.

Conclusions

The incorporation of organic fertilizers and biofertilizers had significant effects between treatments. In the variable Ap the treatment Gm+L+Gc showed the highest values with 213 cm from the 180 dda. For Dt, treatment T showed a value of 3.16 cm. The variable Nn did not find significant differences, with the treatment Gm+L+Gc with 56.33 Nn. Likewise, the incorporation of said inputs generates greater growth and vigor to the plants, on the other hand, improves the soil structure, providing the necessary nutrients for said cultivation.

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