Vegetative, productive, and nutritional parameters of coffee plants as a function of management systems in Minas Gerais

Parâmetros vegetativos, produtivos e nutricionais de cafeeiros em função de sistemas de manejo em Minas Gerais

Parámetros vegetativos, productivos y nutricionales de las plantas de café en función de los sistemas de manejo en Minas Gerais

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Abstract
The use of management practices that reduce the application of phytosanitary products and guarantee sustainability to the production process has been increasingly used in coffee farming. The objective of this work was to evaluate the vegetative, productive and nutritional parameters of coffee plants as a function of management systems. The experiment was set in 2018 in Monte Carmelo, Minas Gerais. The experimental design was in randomized blocks with four treatments and five blocks. The treatments were composed of doses of organic compost applied in topdressing: (T1): 150 g plant^{-1} (1.7 t ha^{-1}); (T2): 300 g plant^{-1} (3.4 t ha^{-1}); T3: 500 g plant^{-1} (5.7 t ha^{-1}); and T4 (control: standard management of the farm). The conventional management provided an increase in the number of internodes in the plagiotropic branch of the coffee tree and in the productivity of the first crop of the plantation. The management

systems did not influence the format and size of the coffee beans. The use of organic fertilization and absence of phytosanitary products allowed the production of specialty coffees, besides accelerating the maturation process of the fruits. The management with organic fertilization was efficient in keeping the pH, organic matter, base saturation, effective CEC, phosphorus, sulfur, calcium, copper, iron, manganese and zinc levels in the soil at satisfactory levels. The foliar levels of phosphorus, potassium, sulfur, boron and copper were satisfactory for the crop and did not differ between the management systems adopted in the field.
Keywords: Coffee growing; Organic fertilization; Sustainable management.

Resumo
A utilização de práticas de manejo que reduzem a aplicação de produtos fitossanitários e garantem sustentabilidade ao processo produtivo tem sido cada vez mais utilizada na cafeicultura. O objetivo deste trabalho foi avaliar os parâmetros vegetativos, produtivos e nutricionais de cafeeiros em função de sistemas de manejo. O experimento foi instalado em 2018 em Monte Carmelo, Minas Gerais. O delineamento experimental foi em blocos casualizados com quatro tratamentos e cinco blocos. Os tratamentos foram compostos por doses de composto orgânico aplicadas em cobertura: (T1): 150 g planta^{-1} (1,7 t ha^{-1}); (T2): 300 g planta^{-1} (3,4 t ha^{-1}); T3: 500 g planta^{-1} (5,7 t ha^{-1}); e T4 (controle: manejo padrão da fazenda). O manejo convencional proporcionou incremento no número de internódios no ramo plagiotrópico do cafeeiro e na produtividade da primeira safra da lavoura. Os sistemas de manejo não influenciaram o formato e tamanho dos grãos de café. O uso da adubação orgânica e ausência de aplicação de produtos fitossanitários proporcionou a obtenção de cafés especiais, além de acelerar o processo de maturação dos frutos. O manejo com adubação orgânica apresentou eficiência por manter em níveis satisfatórios o pH e os teores matéria orgânica, saturação por bases, CTC efetiva, fósforo, enxofre, cálcio, cobre, ferro, manganês e zinco no solo. Os teores foliares de fósforo, potássio, enxofre, boro e cobre foram satisfatórios para a cultura e não diferiram entre os sistemas de manejo adotados na lavoura.
Palavras-chave: Cafeicultura; Adubação orgânica; Gestão sustentável.

Resumen
El uso de prácticas de manejo que reducen la aplicación de productos fitosanitarios y garantizan la sostenibilidad al proceso productivo ha sido cada vez más utilizado en la caficultura. El objetivo de este trabajo fue evaluar los parámetros vegetativos, productivos y nutricionales de las plantas de café en función de los sistemas de manejo. El experimento se instaló en 2018 en Monte Carmelo, Minas Gerais. El diseño experimental fue en bloques al azar con cuatro tratamientos y cinco bloques. Los tratamientos consistieron en dosis de compost orgánico aplicado en topdressing: (T1): 150 g planta^{-1} (1.7 t ha^{-1}); (T2): 300 g planta^{-1} (3,4 t ha^{-1}); T3: 500 g planta^{-1} (5,7 t ha^{-1}); y T4 (control: manejo estándar de granja). El manejo convencional proporcionó un incremento en el número de entrenudos en la rama plagiotrópica del cafeto y en la productividad de la primera cosecha del cultivo. Los sistemas de manejo no influyeron en la forma y tamaño de los granos de café. El uso de fertilización orgánica y la ausencia de aplicación de fitosanitarios permitió obtener cafés especiales, además de acelerar el proceso de maduración de los frutos. El manejo con fertilización orgánica mostró eficiencia al mantener en el suelo niveles satisfactorios de pH y contenido de materia orgánica, saturación de bases, CIC efectiva, fósforo, azufre, calcio, cobre, hierro, manganeso y zinc. Los contenidos foliares de fósforo, potasio, azufre, boro y cobre fueron satisfactorios para el cultivo y no difirieron entre los sistemas de manejo adoptados en el cultivo.
Palabras clave: Cultivo de café; Fertilización orgánica; Gestión sostenible.

1. Introduction

The *Cerrado* in the State of Minas Gerais stands out in the Brazilian and the international scenario in the production of coffee as it is the first region in the country to obtain the denomination of origin. The purpose of the denomination is to demarcate the region because of its unique characteristics of climate, terrain, soil, and altitude, combined with good practices in the management and conduction of crops, to produce a quality product. Through the designation of origin, certification promotes greater visibility and appreciation of the product sold in the competitive market (Federação dos Cafeicultores do Cerrado, 2020).

Because of the extensive areas planted with coffee trees in Brazil and the intense application of phytosanitary products, there is great pressure from pests and diseases on the crop, therefore increasing production costs and causing imbalances in the environment. In this context, organic agriculture stands out as an alternative for more sustainable management of coffee production, being described as a production process free of phytosanitary products, in which the management takes place in a sustainable way, establishing an ecological balance and producing food of higher quality and durability (Associação de Agricultura Orgânica – AAO, 2018).

Organic fertilization can bring benefits to the productivity and sustainability of the production process. In this context, experiments carried out in Muzambinho, state of Minas Gerais, showed that the use of fertilizer containing 5% of Microgeo® and 15% of fresh cattle manure provided a yield of harvested/processed coffee similar to the conventional management of the Catucaí Amarelo 2SL crop, in which significant differences were not found in the productivity of the treatment with biological and conventional fertilization, which produced on average, 43.2 and 45.2 sacs ha^{-1} of processed coffee, respectively (Figueiredo *et al.,* 2017).

Organic management can also benefit soil macrofauna, providing greater diversity of insect taxonomic groups compared to conventional management (Santos *et al.*, 2018). In this context, Lammel *et al.* (2015) found that the use of coffee husks and castor bean cake in coffee crops resulted in an increase in individuals of the subclasses *Oligochaeta* and *Isopoda* in relation to conventional mineral fertilization, intercropped with Brachiaria and with forage peanuts between the rows (Lammel *et al.*, 2015), which demonstrates the sustainability of this management.

Regarding the physical attributes, the organic matter of the soil contributes to the improvement of the structure, aeration and water storage in the soil. Consequently, it contributes to the reduction in temperature variation, especially by preventing the temperature from reaching very high values, which can compromise some biological processes and reduce nutrient uptake (Guimarães *et al*., 2014). Increasing the organic matter content in the soil also contributes to increasing the availability of nutrients and the retention of cations. This increase in the exchange capacity contributes to minimize the effects of salinization and decrease the leaching of nutrients in the soil profile (Partelli *et al*., 2014). Regarding the biological attributes, there is an increase in the biodiversity of microorganisms that solubilize nutrients for the plant (Trani *et al*., 2013), which can provide more favorable conditions for the development of coffee (Aragão *et al.,* 2020).

The objective of this work was to evaluate the vegetative, productive and nutritional parameters of coffee plants as a function of management systems.

2. Methodology

The experiment was set on Araras farm, in the municipality of Monte Carmelo, state of Minas Gerais. The city is located in the Triângulo Mineiro and Alto Paranaíba region at an average altitude of 870 m, south latitude 18°43’29’’ and west longitude 47° 29’ 55’’. The temperature ranges from a minimum of 15.2°C to a maximum of 32.2°C, with an average annual rainfall of 1,600 mm. The soil was classified as Red Latosol. Soil analyses were carried out in January 2018, before the treatment differentiation, at the 0-0.20 m and 0.20-0.40 m depths and the results are the following: pH = 5.8 and 6.3; P (Mehlich) = 102.5 and 124.8 mg dm^{-3}; K^+ = 0.5 and 0.5 $cmol_c$ dm^{-3}; Ca^{+2} = 6.6 and 6.6 $cmol_c$ dm^{-3}; Mg^{+2} = 1.0 and 1.0 $cmol_c$ dm^{-3} and; V (%) = 74.0 and 77.0.

The seedlings were planted in December 2016, using the cultivar Catucaí Amarelo 20/15 cv 479 and the treatment differentiation was carried out in January 2018. The spacing used was 3.80 m between rows x 0.60 m between plants, with a density of 4,385 plants ha^{-1}. At planting, fertilization was carried out in the furrows with the application of 300 g m^{-1} of limestone with PRNT equal to 85%, 400 g m^{-1} of gypsum, 350 g m^{-1} of phosphate (37% of P_2O_5), and 2.0 kg m^{-1} of poultry litter organic compost.

The experimental design used was the randomized blocks, with five blocks and four treatments. The plot consisted of 20 plants; the six central plants were considered useful. Each plot was interspersed with a border line to avoid interference between treatments. The experiment had 20 plots. The total area of each plot was 45.6 m².

Three treatments consisted of the topdressing application of commercial organic compost consisting of materials of plant and animal origin (Table 1) at the following doses: T1: 150 g plant^{-1} (1.7 t ha^{-1}); T2: 300 g plant^{-1} (3.4 t ha^{-1}); and T3: 500 g plant^{-1} (5.7 t ha^{-1}).

Table 1. Characterization of the organic compounds used in the experiment.

Attributes	Results
N	1.20 dag kg^{-1}
P_2O_5	1.60 dag kg^{-1}
K_2O	0.93 dag kg^{-1}
Ca	4.50 dag kg^{-1}
Mg	0.42 dag kg^{-1}
S	0.55 dag kg^{-1}
B	0.0002 dag kg^{-1}
Cu	0.009 dag kg^{-1}
Fe	1.20 dag kg^{-1}
Mn	0.07 dag kg^{-1}
Zn	0.008 dag kg^{-1}
SiO_2	43.10 dag kg^{-1}
Total organic carbon	14.50 dag kg^{-1}
Total humic extract	26.10 dag kg^{-1}
Humic acid	17.00 dag kg^{-1}
Fulvic acid	9.10 dag kg^{-1}
Moisture at 65°C	27.6 dag kg^{-1}
pH	7.40
Electrolytic conductivity	1.4 dS cm^{-1}
CEC	312.0 mmol kg^{-1}
CEC/C ratio	21.5
C/N ratio	88
Organic matter	27.4 dag kg^{-1}

Analysis according to the methodology of the Manual of Official Analytical Methods for Fertilizers and Correctives (MAPA 2017).
Source: Authors.

Following the application of the organic compost in topdressing, liquid organic fertilizer was applied in the foliar spray at a dose of 3 mL L^{-1} of water and via drench, with a spray volume of 600 mL plant^{-1} of liquid organic fertilizer at a dose of 3 mL L $^{-1}$ of water. Each treatment had an application interval for top dressing, drench, and spraying: T1 (Topdressing: 90 days, drench: 30 days; and spraying: 20 days); T2 (Topdressing: 30 days; drench: 90 days; and spraying: 30 days); and T3 (Topdressing: 30 days; drench: 60 days; and spraying: 15 days) The liquid organic fertilizer is composed of organic carbon and K_2O at concentrations of 30 g L^{-1} and 2.0 g L^{-1}, respectively. The control treatment (T4) consisted of the farm standard management with the application of mineral fertilization via fertigation and soil. For fertilization via fertigation, 695.65 kg ha year^{-1} of urea (45% N); 229.77 kg ha year^{-1} of KCl (58% K_2O); 40.74 kg ha year^{-1} of magnesium (8% Mg and 12% S); 10.43 kg ha year^{-1} of boron and 184.79 kg ha^{-1} of formulated 19–04–19 (N-P_2O_5-K_2O). In soil fertilization, 269.69 kg ha^{-1} of KCl

(58% K_2O) and 6.5 t ha^{-1} of organic compost were applied. Liming in the farm standard treatment was carried out in the total area at a rate of 1.6 t ha^{-1} with PRNT limestone equal to 85%. The standard treatment also received foliar applications of fertilizers and phytosanitary products for pest and disease control.

Growth evaluations were carried out bimonthly, starting at differentiation of treatments (January 2018) to June 2019. For the characteristics of height, crown diameter, and stem diameter, the measurement was performed on the six central plants of the plot. As for the number of primary plagiotropic branches and the number of nodes per primary plagiotropic branch, only the three central plants of each plot were evaluated. The measurements were performed as follows: plant height was measured with a ruler from the ground level to the point of insertion of the terminal bud, in centimeters; stem diameter was measured with the aid of a caliper, at 1 centimeter from the ground level, measured in millimeters; the crown diameter was measured with a ruler, taking as a measurement standard the two branches towards between the lines that presented the greatest length, in centimeters. The number of pairs of primary plagiotropic branches, the productive branches originating from the central orthotropic branch, and the number of nodes in the primary plagiotropic branch were counted. The nodes were counted in a selected plagiotropic branch in the middle third of the plant.

To calculate the daily growth rate of the traits height, stem diameter, and crown diameter, the current evaluation was subtracted from the previous month divided by the number of days between the two evaluations. The number of pairs of primary plagiotropic branches and the number of nodes in the primary plagiotropic branch were multiplied by thirty so that the result was expressed as a monthly rate.

In June 2019, the first harvest was carried out in the experimental area by stripping the fruits belonging to the six plants in the plot. Harvest was carried out when the percentage of green fruits was less than 20%.

After determining the volume produced by the plot, a 10-L sample was taken and dried on a suspended terrace. Once the moisture of 11% was reached, the mass and volume of the dried cherry coffee were determined. Next, the samples were processed and submitted to the determination of the mass, volume, and moisture of the grain. The ratio of the initial volume of cloth-harvested coffee fruits, the volume of the 10-L sample, and the mass of the sample already processed provided the yield in kilograms of each plot, which was extrapolated to sacs ha^{-1}.

To analyze the percentage of fruits in the different stages of maturation of the total volume of coffee harvested in each plot, a 0.3-L sample was taken to sort the fruits in the categories flower-bud, green, green-cane, cherry, raisin, and dry.

The evaluation of beverage quality was performed following the protocol of the Specialty Coffee Association of America (SCAA, 2008).

In August 2018, after harvesting, soil sampling was carried out in each plot at a 0-0.20 m depth. After being air-dried, the samples were sieved through a 2-mm opening mesh to determine the following attributes: pH (Water); P, Na, and K (Mehlich-1); S (Monobasic Calcium Phosphate 0.01 mol L^{-1}); Ca, Mg and Al (Potassium Chloride 1.0 mol L^{-1}); H+Al (SMP Buffer Solution); Organic Matter (Sodium Dichromate and Sulfuric Acid); B (heated Barium Chloride 1.25 g L^{-}1); Cu, Fe, Mn and Zn (DTPA solution at pH 7.3) (Silva, 2009).

Leaf sampling was carried out in December 2018, where leaves from the third and fourth pair of productive branches were collected, in the four quadrants of the middle third of the six central plants of the plot, totaling 48 leaves per plot. After collection, the leaves were washed with deionized water and then dried in a forced-air circulation oven at 70°C until reaching constant weight (Jones Junior *et al.*, 1991). Leaf contents of N (Sulphur Digestion); P, K, Ca, Mg, S, Cu, Fe, Mn and Zn (Nitro Perchloric Digestion), and B (Dry Digestion) (Silva, 2009) were all determined in this experiment. Soil and leaf analyses were performed at the Brazilian Laboratory of Environmental and Agricultural Analysis – LABRAS.

Data were subjected to analysis of variance employing SISVAR software (Ferreira, 2019) after meeting the assumptions of normality of residues, homogeneity of variances, and additivity of blocks. When significant differences were detected between treatments, the variables were compared through the LSD Test at the 5% probability level.

3. Results and Discussion

No significant difference was observed among the treatments individually and for the interaction between treatments and evaluation times for all growth variables at the 5% probability level by the F Test. Management systems had a significant effect at the level of 10 % probability only for the number of nodes per primary plagiotropic branch. As for the evaluation times factor, all growth characteristics were significant at the 1% probability level.

The standard treatment (with the application of phytosanitary products and mineral fertilization) provided an increment of 0.66 internodes per plagiotropic branch of coffee in relation to the treatment in which 1.7 t ha^{-1} of organic compost was applied monthly applications of liquid fertilizer via drench and every 20 days using foliar sprays (Table 2).

Table 2. Height (cm), stem diameter (mm), crown diameter (cm), number of pairs of primary plagiotropic branches (NPPPB), and number of nodes in the average primary plagiotropic branch (NNAPPB) of coffee trees according to the management systems

Treatment	Height	Stem diameter	Crown diameter	NPPPB	NNAPPB
T1	103.17 a	32.03 a	118.15 a	11.07 a	5.49 b
T2	101.90 a	33.22 a	124.53 a	11.01 a	5.80 ab
T3	98.83 a	32.15 a	118.31 a	11.44 a	5.78 ab
T4	105.99 a	33.68 a	127.11 a	10.80 a	6.15 a

Means followed by the same letter do not differ significantly from each other by the LSD test at the significance level of 5%.
Source: Authors.

It is likely that the applied dose of nutrients in this treatment was insufficient to meet the coffee demand, especially in the production phase, as the fruits constitute the drain with greater activity in the plant (Laviola *et al.*, 2007), which harmed the emission of node per plant. It is worth mentioning that this trait has a high positive correlation with production, as found in the work of Teixeira *et al.* (2012).

Several factors are related to coffee growth. According to Amaral *et al.* (2007), Amaral *et al.* (2006), Ferreira *et al.* (2013), and Covre *et al.* (2016), the coffee plant grows with seasonal periodicity throughout the cycle, being mainly influenced by climatic variations, rainfall, fruiting, maturation cycle of cultivars, age of branches and nutritional status and fertilization management of plants.

Regarding growth rate, no significant difference was found between treatments in isolation and for the interaction between treatments and times, referring to all growth variables. However, for the different times, there was a significant difference at the level of 10% of probability by the F Test.

The growth rates in height and stem diameter were higher in January to March, with a growth of 2.59 mm day^{-1} and 0.05 mm day^{-1}, respectively (Table 3).

Table 3. Mean growth rate in height (mm day^{-1}), stem diameter (mm day^{-1}), crown diameter (mm day^{-1}), and number of pairs of primary plagiotropic branches – NPPPB (unit month^{-1}) of coffee trees according to the different times of year.

Season	Mean growth rate			
	Height mm day^{-1}	Stem diameter mm day^{-1}	Canopy diameter mm day^{-1}	NPPPB unit month $^{-1}$
Jul/Sept	0.67 c	0.02 b	0.61 c	0.96 b
Sept/Nov	1.39 b	0.03 b	1.81 b	1.29 b
Nov/Jan	1.35 b	0.06 a	3.69 a	1.91 a
Jan/Mar	2.59 a	0.05 a	0.83 c	1.02 b

Means followed by the same letter do not differ significantly from each other by the LSD test at the significance level of 5%.
Source: Authors.

The growth of primary plagiotropic branches from November to January was higher than the other seasons, with the emission of almost two pairs per month. Concerning crown diameter, higher growth occurred at the same time, with a gain of 3.69 mm day^{-1}. The number of nodes in the primary plagiotropic branch was disregarded in the assessment of the growth rate because of the high amount of breakage and die-back in the branches in the last assessment caused by the incidence of diseases in the treatments with organic management.

Contrasting results were observed by Dubberstein *et al.* (2017), who found higher coffee growth rates in mid-September to early April when the highest rainfall occurs in the South Western Amazon. As these regions have different climates and the seasonal variation of coffee growth is mainly affected by precipitation and temperature, the differences observed in the outcome of the experiment are justified.

A significant effect of the treatments on the productivity of processed coffee at the 5% probability level was observed. For beverage scoring according to the methodology of the American Association of Specialty Coffees, no significant effect was found in management systems at 5% probability by the F Test. Also, no difference was found for fruit percentage at the stages flower-bud, green, green-cane, and cherry; however, for the raisin and dry stages, a significant difference was found at the level of 5% and 1% of probability, respectively.

The treatment corresponding to the conventional management, with the application of phytosanitary products and mineral fertilizer, provided an increase of 8.4 sacs ha^{-1} (Table 4) in relation to treatments 2 and 3 (organic fertilization without application of phytosanitary products).

Table 4. Coffee beverage score and mean yield according to the management system.

Treatment	Means	
	Beverage score	Yield (sc ha^{-1})
T1	81.2 a	16.96 ab
T2	80.6 a	13.73 b
T3	81.2 a	11.23 b
T4	79.6 a	20.89 a

Means followed by the same letter do not differ significantly from each other by the LSD test at the significance level of 5%.
Source: Authors.

Likely, the fertilization used in the treatments with organic compost and liquid fertilizer was not adequate for the first year of production of the coffee crop. In addition, the strong pressure of pests (coffee miner bug) and diseases (cercosporiosis) in the experimental area may have caused a reduction in production for treatments T1, T2, and T3 where the application of phytosanitary products was not carried out.

The conversion process from the conventional to the organic system in coffee plantations during the first two years may promote a nutritional imbalance in the plants with a negative effect on productivity (Assis & Romeiro, 2004). In this context, Malta *et al.* (2007) found that the application of organic fertilizer only was not enough to meet the coffee needs, resulting in lower productivity in the second year of crop conversion in relation to conventional management. Sustainability with organic agriculture is achieved only after a few years of adopting the principles of this management system (Darolt, 2000).

Despite the non-significance between the management systems for the sensory analysis of the beverage, it appears that all treatments in which the application of organic compost was carried out, without application of phytosanitary products, reached a special beverage standard (above 80 points according to the Specialty Coffee Association of America), while in conventional management, the average beverage score was 79.6 points, falling below the specialty quality (Table 4).

Similar results were obtained by Malta *et al.* (2008), who verified the superiority of coffee beverages with the use of bovine manure alone or associated with coffee husks and green manure in coffee plantations in the second year of conversion in relation to conventional management, particularly in terms of sweetness, body and after taste.

The treatments did not differ significantly for the percentages of fruits in the flower-bud, green, green-cane, and cherry stages by the F Test at the 5% probability level. However, Treatment 4 displayed the highest percentage of fruits in the raisin stage (37.23%) and the lowest percentage of dried fruits in relation to the other managements by the LSD test at the level of 5% of probability (Table 5).

Table 5. Mean percentage of fruits in the flower-bud, green, green cane, cherry, raisin, and dry stages of coffee trees as a function of management systems.

Treatment	Flower-bud	Green	Green-cane	Cherry	Raisin	Dry
T1	0.26 a	3.02 a	1.32 a	10.22 a	26.28 b	58.90 a
T2	0.0 a	4.76 a	2.62 a	14.40 a	21.74 b	56.48 a
T3	0.52 a	4.76 a	3.07 a	12.58 a	24.82 b	54.25 ab
T4	0.0 a	4.24 a	3.35 a	12.50 a	37.23 a	42.68 b

Means followed by the same letter do not differ significantly from each other by the LSD test at the significance level of 5%.
Source: Authors.

The high percentage of dried fruits in treatments 1 and 2 (organic fertilization without application of phytosanitary products) demonstrates that organic fertilization in coffee plants causes an early fruit maturation in relation to conventional management using phytosanitary products. This fact is likely to be related to the defoliation that occurred in coffee trees in which the application of phytosanitary products was not carried out, which provided a greater input of light into the plant canopy, and consequently, the fruit maturation was accelerated.

Except for potassium, soil analysis did not show any significant differences among treatments for the evaluated chemical attributes, by the F Test at the level of 5% of probability.

No significant difference was found for the average contents of pH, organic matter, base saturation, and effective CEC by the F Test at the 5% probability level (Table 6).

Table 6. Mean chemical characterization of coffee soils as a function of management systems.

Treatment	pH	M.O	V	t	
	(H_2O)	(dag kg^{-1})	(%)	($cmol_c$ dm^{-3})	
T1	5.98 a	3.60 a	72.6 a	8.68 a	
T2	6.06 a	3.66 a	74.4 a	8.73 a	
T3	6.20 a	3.70 a	77.0 a	10.34 a	
T4	6.06 a	3.70 a	70.6 a	8.20 a	
	P meh.	K^+	$S\text{-}SO_4^{2-}$	Ca^{2+}	Mg^{2+}
		(mg dm^{-3})			($cmol_c$ dm^{-3})
T1	130.76 a	198.20 b	141.2 a	7.08 a	1.11 b
T2	115.48 a	188.40 b	150.4 a	7.16 a	1.11 b
T3	271.10 a	271.00 a	126.4 a	8.28 a	1.37 a
T4	93.10 a	190.00 b	82.4 a	6.54 a	1.17 ab
	B	Cu	Fe	Mn	Zn
			(mg dm^{-3})		
T1	0.72 ab	3.26 a	26.6 a	7.00 a	4.66 a
T2	0.59 b	3.24 a	24.0 a	7.38 a	3.88 a
T3	0.67 b	3.68 a	26.6 a	7.48 a	5.28 a
T4	1.19 a	3.86 a	20.6 a	8.86 a	3.72 a

Means followed by the same letter do not differ significantly from each other by the LSD test at the significance level of 5%.
Source: Authors.

The pH values (5.5 to 6.5) in all treatments were satisfactory, falling into the ideal range for coffee cultivation. Organic matter (O.M.) obtained statistically similar responses in all treatments evaluated in the experiment besides being within the ideal levels recommended for coffee (2.1 - 4.5 dag kg^{-1}) (Guimarães *et al.* 1999).

According to Rasmussen & Collins (1991) and Siqueira & Franco (1988), the similarity of the values found in the conventional and organic systems is related to the short period of change between the management systems. The response of the implantation of an organic system occurs in the long term because the carbon in the organic residues is in its labile form, taking up to 10 years to be transformed into more stable organic matter and capable of influencing the attributes of the soil. The management of organic fertilization must be continuous in a given area so that the differences are satisfactory enough to meet the critical levels for cultivation (Theodoro *et al.* 2003).

Base saturation and effective CEC were within the ideal levels for the crop (60 - 80% V and 4.6 - 8.0 $cmol_c$ dm^{-3} of effective CEC) in all treatments (Table 6). This effect was found by Fernandes *et al.* (2013) who evaluated organic fertilization in substitution for mineral fertilization. There was an increase in base saturation followed by a reduction in acidity in treatments with higher doses of organic fertilizers.

A significant difference was observed in the LSD Test at the 5% probability level for potassium and magnesium levels in Treatment 3 (organic management) (Table 6). However, levels were classified as optimal in all treatments (>80 mg dm^{-3} for K and 0.9 - 1.5 $cmol_c$ dm^{-3} for Mg). Levels of calcium in the soil were excellent, with values above the adequate range for the crop (2.4 - 4.0 $cmol_c$ dm^{-3}), in all treatments (Guimarães *et al.* 1999). No significant differences were observed among treatments for phosphorus content.

There was no significant difference among treatments for the micronutrients copper, iron, manganese, and zinc at the 5% probability level by the F Test. Boron was the only micronutrient to show a significant difference, with higher levels in treatment 4 (farm standard) (1.19 mg dm^{-3}) in comparison to treatments 2 and 3, which also presented high levels (>0.6 mg dm^{-3}) of this nutrient (Table 6) (Guimarães *et al.* 1999).

Phosphorus showed excellent levels (> 13.5 mg dm^{-3}) in all treatments, according to the recommendations for this nutrient in the fertilization of coffee trees in production (Guimarães *et al.* 1999).

The levels of micronutrients in the soil of coffee trees grown in organic management have shown satisfactory results. In this context, Fernandes *et al.* (2013) found significant increases in boron, copper, zinc, and manganese in treatments with applications above 10.0 t ha^{-1} of poultry manure.

Crops in a native forest system also provide a rise in the levels of soil micronutrient due to the accumulation of organic matter, with a rise in zinc, iron, manganese, and boron levels in native forest treatment compared to conventional management (Carmo *et al.* 2012).

Foliar contents of magnesium and iron showed a significant difference in the function of the management systems adopted in the coffee crops at the level of 5% of probability by the F Test.

Also, no significant difference was found between treatments with organic management and conventional management for nitrogen, phosphorus, potassium, and sulfur in leaf contents. Except for nitrogen, levels of phosphorus, potassium, and sulfur were within the ideal range in all treatments. These results demonstrate that the spraying intervals and doses applied in treatments with organic and conventional management met the nutritional requirements of the crop (Table 7).

Table 7. Mean chemical characterization of coffee leaves as a function of management systems.

Treatment	Macronutrients (g kg^{-1})					
	N	P	K	Ca	Mg	S
T1	26.20 a	1.54 a	22.00 a	10.66 b	2.32 ab	1.92 a
T2	26.18 a	1.62 a	23.16 a	12.00 a	2.56 a	2.00 a
T3	26.02 a	1.68 a	24.38 a	10.94 ab	2.26 b	2.02 a
T4	26.42 a	1.48 a	23.50 a	11.74 ab	2.08 b	1.96 a

	Micronutrientes (mg kg^{-1})				
	B	Cu	Fe	Mn	Zn
T1	60.2 a	21.4 a	170.0 a	61.0 b	10.4 ab
T2	65.6 a	19.2 a	150.4 a	78.2 ab	8.6 b
T3	65.6 a	19.4 a	153.4 a	69.6 b	14.8 a
T4	62.8 a	18.8 a	119.8 b	99.2 a	10.6 ab

Means followed by the same letter do not differ significantly from each other by the LSD test at the significance level of 5%.
Source: Authors.

Similar results were observed by Fernandes *et al.* (2013), who did not observe any significant difference between the different doses of poultry litter for the foliar contents of nitrogen, phosphorus, potassium, and sulfur, pointing to the efficiency of organic management in the foliar supplementation of the coffee plant.

The foliar calcium contents (12.0 g kg^{-1}) were higher in treatment 2 (organic management) in relation to treatment 1. On the other hand, the content of magnesium (2.56 g kg^{-1}) was higher in treatment 2 than in treatments 3 and 4. However, only calcium met the ideal levels for the crop (10.0 - 13.0 g kg^{-1}), even in the other treatments, while magnesium did not reach adequate levels (3.1 - 4.5 g kg^{-1}) in any treatment (Guimarães *et al.* 1999). The frequency of application of treatment 2, which was 30 days for spraying, was sufficient to provide the ideal foliar calcium levels for the crop.

The micronutrients boron and copper did not differ significantly at the 5% probability level, while the iron was statistically superior in treatments with organic management. Manganese in treatment 4 and zinc in treatment 3 showed differences by the LSD test at the 5% probability level (Table 7).

According to the recommendation by Guimarães *et al.* (1999), the foliar levels of boron, iron, and manganese were satisfactory in all treatments evaluated. The micronutrient means showed that the iron values were higher in all treatments with organic management, differing statistically only from the conventional treatment. Manganese contents were higher in the standard treatment than in treatments 1 and 3 (organic management). Treatment 2 (organic management) (8.6 mg kg^{-1}) did not provide ideal levels of zinc, while the other treatments were within the adequate range (10 – 20 mg kg^{-1}) (Table 7).

In a work conducted by Araújo *et al.* (2007), the increase in the doses of compound fertilizer provided a rise in the levels of N, K, and Mg and a reduction in P, Ca, B, Cu, Fe, and Mn.

Supplementation using compost, drench, and fortnightly spraying had no effect on coffee nutrition, therefore, short intervals of fertilizer applications to supply the macronutrients calcium, potassium, and magnesium are not justified. Despite the lower productivity in the first harvest of the crop, the management with organic fertilization and the absence of phytosanitary products can be an alternative to the conventional one, currently used in coffee plantations, as it met the nutritional requirements of the crop and did not harm the development of the plants. As it is a perennial crop, it is necessary to study the vegetative and productive behavior of coffee for several crops, relating production costs between the two management methods to achieve more conclusive results.

4. Conclusion

Conventional management provided an increase in the number of internodes in the plagiotropic branch of coffee and the yield of the first crop of the crop.

The use of organic fertilization and the absence of application of phytosanitary products resulted in the production of coffees with score above 80 points according to SCAA standard (specialty coffees).

Coffee trees that received organic fertilization showed an acceleration in the fruit maturation process.

The management with organic fertilization showed efficiency by maintaining the levels of pH, organic matter, base saturation, effective CEC, phosphorus, sulfur, calcium, copper, iron, manganese, and zinc in the soil at satisfactory levels.

The foliar contents of phosphorus, potassium, sulfur, boron, and copper were satisfactory for the crop and did not differ between the management systems adopted in the crop.

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