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INITIAL GROWTH OF COFFEE PLANTS FERTIGATED WITH LIQUID BIODIGESTER EFFLUENT

ABSTRACT: The fertigation with liquid effluents has become an interesting alternative for reducing production costs in the cultivation of coffee. The objective of this study was to evaluate doses of effluent from a biodigester (fermentation) in the initial development of coffee plants. The experiment was conducted in a greenhouse in pots of 13 dm^3. The experimental design was randomized blocks, with six doses of fertigation. The treatments were: T1 = water + mineral fertilization; T2 = three applications week-1; T3 = two applications week-1; T4 = one application week-1; T5 = one application every 2 weeks; T6 = one application every 3 weeks. It was evaluated plant height, stem diameter, fresh and dry biomass of shoot and root system and leaf contents of macro and micronutrients. The fertigation with liquid effluent does not provide significant changes in the initial development of coffee plants in a greenhouse. At the initial stage of the coffee plant development, the treatments including fertigation were similar to mineral fertilization. However, high levels of leaf N, Ca, Mg, Fe, and Mn, above the critical levels determined for plant development, were observed when fertigation was applied. These high levels can improve coffee plant performance and production at late ages.

KEYWORDS: *Coffea* sp., Plant biometrics, Waste fermentation, Leaf analysis, Macro and micronutrients.

CRESCIMENTO INICIAL DO CAFEEIRO FERTIRRIGADO COM EFLUENTE LÍQUIDO DE BIODIGESTOR

RESUMO: O uso de fertirrigação com efluente líquido de biodigestor é uma alternativa interessante para redução dos custos de produção na cultura do café. O objetivo deste estudo foi avaliar o uso de diferentes doses de água residuária provenientes de um biodigestor, no desenvolvimento inicial do cafeeiro. O experimento foi conduzido em casa de vegetação modelo em arco, em vasos de 13 dm^3. O delineamento utilizado foi de blocos ao acaso com seis doses de fertirrigação com efluente líquido de biodigestor. Os tratamentos constituíram em T1 = Água + Adubação mineral; T2 = Três aplicações/semana; T3 = Duas aplicações/semana; T4 = Uma aplicação/semana; T5 = Uma aplicação a cada 2 semanas; T6 = Uma aplicação a cada 3 semanas. Foi avaliada a altura de planta, diâmetro do caule, matéria verde e seca da parte aérea da planta bem como do sistema radicular e, teor foliar de macro e micronutrientes. Evidenciou-se que, a fertirrigação com efluente líquido de biodigestor não proporciona alterações significativas no desenvolvimento inicial de cafeeiros em casa de vegetação. Além disso, o uso do efluente líquido de biodigestor proporcionou níveis elevados de N, Ca, Mg, Fe e Mn, acimas dos níveis críticos determinados para a planta.

PALAVRAS-CHAVE: *Coffea* sp., Biometria de plantas, Fermentação de resíduos, Análise foliar, Macro e micronutrientes.

CRECIMIENTO INICIAL DEL CAFÉ FERTIRRIGADO CON EFLUENTE LÍQUIDO BIODIGESTER

RESUMEN: El uso de fertirrigación con efluentes de biodigestor líquido es una alternativa interesante para reducir los costos de producción en el cultivo del café. El objetivo de este estudio fue evaluar el uso de diferentes dosis de aguas residuales de un biodigestor en el desarrollo inicial del café. El experimento se llevó a cabo en un invernadero arqueado econn macetas de 13 dm^3. El diseño utilizado fue bloques aleatorizados con seis dosis de fertirrigación, o sea, con efluente líquido de biodigestor. Los tratamientos consistieron en T1 - Agua + Fertilización mineral; T2 - Tres aplicaciones/semana; T3 - Dos aplicaciones/semana; T4 - Una aplicación/semana; T5 - Una aplicación cada 2 semanas; T6 - Una aplicación cada 3 semanas. Se evaluó la altura de la planta, el diámetro del tallo, la materia verde y la materia seca de la parte aérea de la planta, así como el sistema radicular y el contenido de las hojas de macro y micronutrientes. La fertirrigación con efluente líquido del biodigester no proporciona cambios significativos en el desarrollo inicial de los cafetales en un invernadero. Además, el uso de efluente líquido biodigester proporcionó altos niveles de N, Ca, Mg, Fe y Mn, por encima de los niveles críticos determinados para la planta.

PALABRAS CLAVES: *Coffea* sp., Biometría vegetal, Fermentación de residuos, Análisis de hojas, Macro y micronutrientes.

INTRODUCTION

O Brazil is the largest producer and exporter of coffee, harvesting 62 million bags in 2020 (CONAB, 2020), which represents 37% of the global coffee market. To achieve such production, the coffee sector incorporates new technologies in many stages of its production process; among them, the use of high-quality seedlings, mechanization and efficient irrigation systems are highlighted (FAVARIN et al., 2003; VIEIRA, 2008; ASSIS et al., 2014).

In this sense, irrigation is one of the most widely used technologies to expand the areas cultivated with coffee. Irrigation is also intended to meet the plant's constant need for water, to minimize the problems with short summers (long drought) and to maximize the efficiency of fertilizers application via fertigation (DOMINGHETTI et al., 2014). The Brazilian regions of great use of coffee irrigation are the Triângulo Mineiro and Alto Paranaíba, Minas Gerais state, the north of Espírito Santo state, south and west of Bahia state (MANTOVANI; VINCENT, 2015).

The use of irrigation and fertigation has minimized the problem of lack of water that occurs in certain regions as those located at the Cerrado biome (Savanah like biome), mitigating the problem of seasonality that occurs in the coffee culture, where great productivity is observed in the first year and a sharp fall in the following year (KONZEN, 2006).

According to Magiero (2013), the use of fertigation in coffee plantation increases the absorption of nutrients present in the fertilizers, providing higher yields when compared to the conventional systems of coffee cultivation. Guimarães et al. (2010) evaluated the use of fertigation distributed in 12 applications annually and observed that it is possible to reduce up to 70% of the dose of fertilizer recommended when compared to cultivation without irrigation. Their results also indicated that a better absorption of nutrients by the coffee plants had occurred, which resulted in a high coffee yield and low fertilization costs. Irrigation management during the dry seasons of the year can also affect the biochemical composition and coffee quality (VINECKY et al., 2017).

Some studies have shown that the application of wastewaters and effluents in soil by the conventional way or by fertigation can improve the efficiency and the quality of the products produced, changing physical and chemical attributes of the soil and in addition, giving destination to environmental liability and reducing environmental pollution (SOUZA et al., 2005; SANDRI et al., 2007; RIBEIRO et al., 2009); however, there are different wastewater sources which need to be better assessed to be used in coffee plants.

The wastewater from the washing and cleaning of the coffee fruits was used as a source of some macronutrients by Ferreira et al. (2006), Medeiros et al. (2008), Ribeiro et al. (2009). Those authors observed improvements of the nutritional status of the coffee plant, which favored vegetative development by increasing plant height and the diameter of the orthotropic branches when compared to the irrigated area with natural water and conventional fertilization.

The industrial liquid effluents can also be used as fertilizers in the crop production process; however, if not correctly treated they can cause negative environmental impacts due to their physicochemical characteristics. Souza et al. (2005) evaluated the fertigation with wastewater from an urban origin in coffee culture. They observed that this effluent did not supply all the nutrients needed for plant development, and the conventional fertilizer management obtained greater productivity.

The wastewater from pig farming is produced in large quantities, which, if not handled and treated properly, can contaminate the environment, especially the water bodies (CARDOSO et al., 2015). One of the ways to treat at low cost these wastewaters is through the anaerobic digestion, which reduces potential contaminants and generates biogas, an alternative energy source, besides allowing the recycling of effluent transforming it into a natural fertilizer (AMARAL et al., 2014).

The application of fertilizer based on pig slurry assists in the reduction of the production costs because it is a nutrient-rich material (SEDIYAMA et al. 2014). The wastewater from pig farming after being treated presents several soluble elements, among them the nitrogen (ammoniac form), phosphorus and micronutrients; however, this wastewater presents high sodium levels and electrical conductivity, which prevents its indiscriminate uses in fertigation (SILVA et al., 2012; FERREIRA et al., 2019). According to Bloom & Smith (2017), soil can inhibit plant growth if the mineral ions reach concentrations that limit the availability of water or exceed the levels for certain nutrients.

There is a growing need to investigate the possible changes that may occur with the use of wastewater in agriculture. Also, there a need to establish the criteria of wastewater managements, the environmental sustainability of this technology, and the effect on the development and crop yield. In this context, the objective of this study was to evaluate the use of liquid effluent from an anaerobic biodigester in the initial development of coffee plants.

MATERIAL AND METHODS

The study was conducted in the experimental area of the Instituto Federal do Triângulo Mineiro (IFTM), camps Uberaba, located at the geographic coordinates 19º39'19" latitude South and 47º57'27" longitude West and 795 m above sea level, in a greenhouse (bow shape), in pots (13 dm^3), between January and May of 2017.

The climate of the region is classified as Aw, according to the classification of Köppen (1948), with hot and rainy summers and cold and dry winters. The average annual rainfall, temperature and relative humidity of the air in the region is 1,600 mm, 22.6 ºC and 68%, respectively (SDET, 2009).

The soil used was classified as a dystrophic Red Latosol (EMBRAPA, 2013), medium texture, which showed the following chemical characteristics in the 0-0.2 m layer: 190 g dm^{-3} of clay; 95 g dm^{-3} of silt; 715 g dm^{-3} of sand, pH ($CaCl_2$) 4.3; organic matter = 10.7 g dm^{-3}; P (resin) = 1 mg dm^{-3}; K = 0.047 cmolc dm^{-3}; Ca = 0.15 cmolc dm^{-3}; Mg = 0.02 cmolc dm^{-3}, H+Al = 2.2 cmolc dm^{-3}; CTC = 2.42 cmolcdm^{-3}; Al = 0.5 cmolc dm^{-3}; base saturation = 9%; S-SO_4 = 9.6 mg dm^{-3}; B = 0.1 mg dm^{-3}; Cu = 0.3 mg dm^{-3}; Fe = 6.4 mg dm^{-3}; Mn = 0.9 mg dm^{-3}, and Zn = 0.1 mg dm^{-3}.

The experimental design consisted of randomized blocks with six doses of fertigation with liquid effluent from an anaerobic biodigester: T1 = water + mineral fertilization; T2 = three applications $week^{-1}$; T3 = two applications $week^{-1}$; T4 = one application $week^{-1}$; T5 = one application every two weeks, and T6 = one application every three weeks. Each experimental plot consisted of 3 pots (13 dm^3) containing each one coffee plant cultivar Catuaí IAC 144. The coffee seedlings used had 6 to 7 pairs of leaves and were approximately 60 days old, Seedlings were acquired from a commercial nursery.

The chemical analysis of the liquid effluent from the biodigester of IFTM was performed at the Laboratory of Organic Matter and Residues from the Federal University of Viçosa and presented the following concentrations: N = 291.06, P = 27.71, K = 125.81, Ca = 7.22 and Mg = 0.33 g kg^{-1}. The elements S, B, Zn, Fe, Cu, Mn, Cd, Pb, and Cr were not detected. The electrical conductivity observed in the sample was 3,110 μS cm^{-1}, equivalent to 3.11 dS m^{-1}.

The cultural management carried out with the coffee seedlings followed the recommendations of CFSEMG (1999). All treatments were watered three times per week, alternating between fertigations or clean water, according to the treatment. Fertigation or clean water was applied at 500 ml volume, totaling 1.5 liters of water in each pot per week. All the seedlings and treatments received the same fertilization with 90 g of P_2O_5 (simple superphosphate), plus 5 g of N as ammonium sulfate ($(NH_4)_2SO_4$) and 5.3 g of K, as potassium chloride (KCl). Only the treatment 1 (T1) received second fertilization (covering fertilization) with 5 g of $(NH_4)_2SO_4$ and 5.3 grams of KCl per pot. In May 2017 insecticide (Abamectin) and fungicide (Metconazole) was applied to control pests and diseases.

The evaluations were carried out four months after the transplant of seedlings when the coffee plants were about 180 days old. The following characteristics were evaluated: plant height, measured from substrate-level to the apical meristem of the orthotropic branch, stem diameter, measured at 1 cm above substrate-level, number of inserts of plagiotropic branches (nodes), fresh and dry biomass of the shoot and root system, leaf contents of macro and micronutrients.

The results were submitted to analysis of variance using the SISVAR® statistical program (FERREIRA, 2011). The averages were compared by the Scott-Knott test ($p<0.05$) when the F test accuse significant differences ($p<0.05$) among treatments (ZIMMERMANN, 2014).

RESULTADOS E DISCUSSÃO

The summary table of the analyzes of variance indicated no significant differences between the fertigation treatments and treatment with mineral fertilization for none of the morphological characteristics evaluated (Table 1).

These results demonstrate that the liquid effluent from anaerobic digestion can be used as a fertilizer for coffee seedlings since it has provided the necessary nutrients to the initial development of coffee seedlings.

Table 1. Summary of analysis of variance of the parameters assessed in 180 days-old coffee plants as function of the fertigation. Uberaba, MG. 2018.

Source of Variation	DF	Pr > Fc						
		PH	SD	NN	SFM	SDM	RFM	RDM
Treatments	5	0.4627^{ns}	0.1516^{ns}	0.7292^{ns}	0.3422^{ns}	0.6922^{ns}	0.8552^{ns}	0.8444^{ns}
Error	16	--	--	--	--	--	--	--
Average	-	38.83	7.60	11.73	61.50	47.35	22.42	13.16
CV (%)	-	7.42	8.05	6.19	17.81	9.51	41.25	41.31

* = significative ($p<0.05$); ^{ns} = non significative ($p>0.05$; plant height (PH), stem diameter (SD), number of nodes (NN), shoot fresh mass (SFM); shoot dry mass (SDM); root fresh mass (RFM); root dry mass (RDM).

According to Faria et al. (2015), the use of effluents in the cultivation of coffee can be considered a viable alternative because it presents low investment compared to the conventional treatment, with costs varying between 30 to 50% of the total cost, low operational and energy consumption and in addition, the effluent promotes improvements in soil physical attributes, increases productivity and reduces environmental pollution risks.

Considering that the ideal substrate for plant development meets the physical needs and contain sufficient essential nutrients, Silva et al. (2010) analyzed the initial development of *C. canephora* seedlings in different combinations of substrate and containers and observed that the sugarcane bagasse and filter cake proved to be suitable for the production of *C. canefhora* seedlings. The authors also pointed out that the use of such residues as a substrate for the seedlings production offers, besides, to reduce production costs, environmental advantages, since the discard procedure could represent a negative impact on the environment.

Even when no significant differences were observed between treatments with liquid effluent, the plant height ranged between 36.44 and 40.49 cm. In contrast, SD ranged between 6.88 and 7.85 mm; these values are high when compared to values reported in the literature for plants of the same age (Table 2). These results indicate that no nutritional deficiency occurred what does not affect the initial development of the coffee seedlings. Even so, for most of the evaluated parameters, the lowest values occurred in the treatment with mineral fertilizer (T1). Dias et al. (2009) observed that the coffee seedlings Catuai IAC 144 reached 22.8 cm in height and stem diameter of 2.8 mm at 105 days of evaluation.

Table 2. Biometric parameters of 180 days-old coffee plants in function of the fertigation. Uberaba, MG. 2018.

Treatments	Biometric Parameters						
	PH	SD	NN	Shoot		Root System	
				FM	DM	FM	DM
	cm	mm	--	..........................g..........................			
T1	36.44	6.88	11.67	53.17	44.92	19.17	11.32
T2	38.45	7.51	11.67	63.15	46.52	19.00	11.00
T3	39.25	7.68	11.35	54.65	46.15	23.82	14.00
T4	39.37	7.56	11.65	65.15	48.15	22.00	12.90
T5	40.79	7.85	12.17	65.00	49.50	25.17	14.90
T6	38.72	8.15	11.85	67.85	48.85	25.35	14.82
F	0.98^{ns}	1.91^{ns}	0.56^{ns}	1.23^{ns}	0.61^{ns}	0.38^{ns}	0.39^{ns}
CV (%)	7.35	10.82	12.02	5.05	8.69	41.25	10.49

^{ns} = non significative. T1 = water + mineral fertilization; T2 = three applications week^{-1}; T3 = two applications week^{-1}; T4 = one application week^{-1}; T5 = one application every 2 weeks; T6 = one application every 3 weeks. Plant height (PH), stem diameter (SD), number of nodes (NN), fresh mass (FM); dry mass (DM).

According to Karasawa et al. (2003) and Figueirêdo et al. (2006), electric conductivity values above 0.9 cm dS^{-1} and 1.5 dS cm^{-1}, respectively, are detrimental to the development of coffee seedlings after the transplant. However, this effect was not observed in this study. The biodigester effluent presented an electrical conductivity of 3.11 dS cm^{-1}; however, no difficulty or nutritional deficiency was found in the initial development of the coffee seedlings.

Analyzing the contents of macronutrients in coffee leaves it was observed that there were no significant differences ($p<0.05$) in the levels of N, P, S, K, Ca and Mg (Table 3). According to Malavolta et al. (1997), the critical economic and physiological level of an element on the leaf is that below which the yield decreases and that above which the fertilization becomes antieconomic.

Table 3. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) in 180 days-old coffee leaves in function of the fertigation. Uberaba, MG. 2018.

Treatments	Macronutrients					
	N	P	K	Ca	Mg	S
	...dag kg^{-1}...					
T1	5.01^{ns}	0.078^{ns}	2.29 a	0.446 c	0.212 b	0.189^{ns}
T2	5.59	0.088	2.08 a	0.853 b	0.325 a	0.187
T3	5.25	0.082	1.79 b	0.897 b	0.325 a	0.194
T4	4.75	0.082	1.80 b	0.892 b	0.325 a	0.177
T5	4.93	0.082	1.75 b	1.047 a	0.325 a	0.185
T6	4.77	0.082	1.49 b	1.132 a	0.325 a	0.184
F	2.26	7.04	4.57	28.96	25.29	1.05
CV (%)	7.35	10.82	12.02	8.69	10.49	5.05

Averages followed by the same letter do not differ among treatments by the test of Scott-Knott (p<0,05). T1 = water + mineral fertilization; T2 = three applications $week^{-1}$; T3 = two applications $week^{-1}$; T4 = one application $week^{-1}$; T5 = one application every 2 weeks; T6 = one application every 3 weeks.

Gonçalves et al. (2009) assessed the critical level of macronutrients in coffee seedlings (*C. arabica*) and found that when coffee plants have four pairs of leaves, it is the ideal stage for sampling, aiming to evaluate the nutritional status of the plant. At this stage of the coffee plants, the critical range for N is between 2.26 to 2.62 dag kg^{-1}, P: 0.22 to 0.25 dag kg^{-1}, K: 2.59 to 2.92 dag kg^{-1}, Ca: 0.69 to 0.76 dag kg^{-1}, Mg: 0.11 to 0.12 dag kg^{-1} and S: 0.15 to 0.24 dag kg^{-1}. In the present study, the contents of N, Ca and Mg were well above these critical limits.

In plants at a more advanced stage, Martinez et al. (2015) noted that the critical levels of nutrients for plants during the fruiting phase and production are located between 2.7 and 3.2 dag kg^{-1} for N, P: 0.15 and 0.2 dag kg^{-1}, K: 1.90 and 2.40 dag kg^{-1}, Ca: 1 and 1.4 dag kg^{-1}, Mg: 0.31 and 0.36 dag kg^{-1} and S: 0.15 and 0.2 dag kg^{-1}. It is important to emphasize that there is not a determination of optimal ranges of leaf contents of macro and micronutrients for plants newly deployed.

The values of N in this study ranged from 4.74 to 5.59 dag kg^{-1} and were well above the values considered critical to the development of coffee seedlings, which was confirmed by the nonoccurrence of any symptom of deficiency of this nutrient in none of the treatments evaluated. The same occurred for K in the control with mineral fertilization (T1) and where fertigation was more frequent (T2).

The P provided through fertigation, however, was not enough to nourish the plant, since the observed values were 50% lower than that determined as critical to the development of coffee plants. According to Pinto et al. (2013), the ideal range for nutrients in coffee leaves was 3.08 to 3.29 dag kg^{-1} for N, P: 0.26 to 0.33 dag kg^{-1} and K: 2.18 to 2.21 dag kg^{-1}, indicating that the plants in this study presented P deficiency.

Phosphorus is one of the nutrients that limit the growth of coffee seedlings by reducing the development of the root system, being normal the critical P level higher for young plants than for plants in production (Carmo et al., 2014). In this study, the P levels were below the critical level (Table 3), which probably affected the growth of the coffee seedlings.

The leaf concentrations of Ca, Mg and S (Table 3) were close to critical levels determined for coffee culture, demonstrating that these elements were not provided at adequate levels for normal coffee plant development.

Regarding the content of micronutrients found in the leaves of the coffee seedlings it was observed (i) no significant differences among treatments for Cu and Zn, and the highest values found were in the treatment with mineral fertilizer (T1), and (ii) that the levels of Fe were high (Table 4).

Table 4. Copper (Cu), iron (Fe), zinc (Zn), manganese (Mn) and boron (B) in 180 days-old coffee leaves in function of the fertigation. Uberaba, MG. 2018.

Treatments	Micronutrients				
	Cu	Fe	Zn	Mn	B
	....................mg kg^{-1}....................				
T1	2.27 a	338.25^{ns}	4.97^{ns}	183.22 a	48.42 a
T2	1.22 b	333.68	4.88	160.05 a	37.37 b
T3	1.15 b	424.37	5.23	156.37 a	36.78 b
T4	1.12 b	333.60	5.23	118.48 b	44.60 b
T5	1.05 b	327.77	5.23	138.93 b	52.87 a
T6	1.00 b	310.02	5.23	124.47 b	61.93 a
F	15.08	0.23	0.14	5.50	7.49
CV (%)	16.45	42.30	42.40	12.23	12.95

Averages followed by the same letter do not differ among treatments by the test of Scott-Knott ($p<0,05$). T1 = water + mineral fertilization; T2 = three applications week^{-1}; T3 = two applications week^{-1}; T4 = one application week^{-1}; T5 = one application every 2 weeks; T6 = one application every 3 weeks.

Critical levels for nutrients in the leaf vary between 8 and 16 mg kg^{-1} for Cu, Fe: 90 and 180 mg kg^{-1}, Zn: 8 and 16 mg kg^{-1}, Mn: 120 and 210 mg kg^{-1} and B: 59 and 80 mg kg^{-1} (Martinez et al., 2015). Based on these levels, it can be argued that the coffee seedlings fertigated were poorly nourished for Cu, Zn and B, and that the contents of Fe and Mn were well above the levels considered critical.

According to Silva et al. (2010) the coffee seedlings when well-nourished in Mn features good performance concerning plant height and stem diameter, as can be seen in this study, where PH and SD were higher than the values found in the literature for coffee plants of the same age.

Studying the use of fertigation with urban wastewater on the yield of coffee, Souza et al. (2005) found that the wastewater used does not supply all the needs for coffee development and supplementary fertilization to maximize the development and productivity of culture was necessary. This supplementation could be done after assessing the nutritional status of the plant and soil so that the intake of nutrients from urban wastewater is improved and may reduce the use of fertilizers. Neiva Jr. et al. (2019), however, indicated the potential of the use of urban wastewater (textile) in proportions between 8 and 16% for the production of coffee seedlings.

The results of leaf macro and micronutrients after the application of different doses of liquid effluent indicated that the values were close to the critical level for most of the nutrients. This also suggests that the product is not enough to meet the complete demand of nutrients from the coffee plants in their initial stages.

The higher occurrence of some nutrients in coffee leaves may not have significantly affected the performance of coffee plants in their initial stage of development. Still, it probably will improve the vegetative and reproductive performance of coffee plantation in the long term. The use of wastewaters can affect many plant variables, as it was observed by Berilli et al. (2018). Those authors indicated that the use of wastewater positively affected the coffee plant development; however, it did not change the content or the fluorescence of the chlorophyll.

CONCLUSIONS

The fertigation with liquid biodigester effluent resulted in no significant changes at the initial coffee plant development.

The biometric results observed in this study for the fertigation treatments were similar to the mineral fertilizer treatment.

High levels of leaf N, Ca, Mg, Fe, and Mn were identified when fertigation was applied.

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