RESPONSE OF IAPAR-59 COFFEE (*Coffea arabica* L.) TO SURFACE APPLICATION OF ORGANIC RESIDUES IN A TYPIC HAPLORTHOX

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ABSTRACT: The objective of this work was to assess the soil fertility, nutritional status and yield of Iapar-59 coffee subjected to 4 exogenous applications on the il surface: 20 t ha^{-1} of dry matter (grey mucuna, leucaena, pigeon pea, perennial peanut, brizantha grass, forage sorghum, sugarcane bagasse, sugarcane filter cake, orange pulp, raw sewage sludge, sewage sludge with virgin lime, coffee straw, bovine manure, chicken litter, chicken manure, sugarcane bagasse with chicken manure and swine manure); 200 m^3 ha^{-1} of swine slurry; 95 kg ha^{-1} of N (ammonium sulphate source). A field experiment was set up in 2002 in a Typic Haplorthox, in Paranavaí, northwestern region of Paraná state, Brazil. From 2003 to 2005 soil (0-5, 5-10, 10-20 and 20-40 cm) and leaf samples were collected and coffee growth and yield were assessed. Grey mucuna increased leaf N contents, leucaena increased soil K (5-40 cm) contents and sugarcane filter cake increased soil Ca (10-40 cm) concentrations. These alterations enhanced growth and yield.

Key words: Organic manure, agroindustry residues, organic carbon, soil fertility, plant nutrition, soil management.

RESPOSTAS DO CAFEEIRO (*Coffea arabica* L.) IAPAR-59 À APLICAÇÃO SUPERFICIAL DE RESÍDUOS ORGÂNICOS EM UM LATOSSOLO VERMELHO DISTRÓFICO TÍPICO

RESUMO: *Objetivou-se avaliar a fertilidade do solo, a nutrição e a produção do cafeeiro Iapar-59 submetido a quatro aplicações superficiais: 20 t ha^{-1} de matéria seca (mucuna cinza, leucena, guandu, amendoim forrageiro, braquiária, sorgo forrageiro, bagaço de cana-de-açúcar, torta de filtro de cana-de-açúcar, bagaço de laranja, lodo de esgoto bruto, lodo de esgoto bruto com cal virgem, palha de café, esterco de curral (bovino), cama de frango, esterco de galinha, bagaço de cana-de-açúcar com esterco de galinha e esterco de suínos); 200 m^3 ha^{-1} de chorume de suínos; 95 kg ha^{-1} de N, tendo o sulfato de amônio como fonte. O experimento de campo foi implantado em junho de 2002 em um Latossolo Vermelho distrófico típico, em Paranavaí, noroeste do Paraná. No período de 2003 a 2005, foram feitas amostragens de solo a 0-5, 5-10, 10-20 e 20-40 cm, amostragens de folhas do cafeeiro, avaliando-se também o desenvolvimento das plantas e a produção. A mucuna cinza aumentou os teores de N nas folhas do cafeeiro; a leucena, os teores de K no solo de 5-40 cm, e a torta de filtro de cana-de-açúcar, os teores de Ca no solo de 10-40 cm. Essas alterações contribuíram para um maior desenvolvimento do cafeeiro e para a sua produção.*

Palavras-chave: Adubação orgânica, resíduos agroindustriais, carbono orgânico, fertilidade do solo, nutrição de plantas, manejo do solo.

1 INTRODUCTION

Occupation of the soils that developed from the Caiuá Formation sandstone, in the northwest of Paraná state, began in the 1960's with deforestation and planting of coffee fields, a process of expansion of the cultivation lands that lasted until the 1980's (KRONEN, 1990). The decline of coffee production in the region is associated to reduced soil fertility, which presents low organic matter levels and demands constant replacement of organic material to maintain fertility levels and covering as a preventive measure against hydric erosion (CARDOSO et al., 1992; FIDALSKI, 1997a, b). Maintaining organic matter concentrations is fundamental to improving the physical properties and water retention of these soils (CARDOSO et al., 1992; MACHADO et al., 2008).

The low organic matter contents of these soils planted with coffee (FIDALSKI, 1997a) have prompted studies on green fertilization and mulching between the rows, associated to mineral fertilization along the plant rows (PAVAN & ANDROCIOLI FILHO, 1995), to enhance the fertility of *Typic Haplorthox* (SANTOS et al., 2006) and crop yield. In this soil class, corn yield was enhanced with green fertilization (MARUN, 1995), and brizantha grass (*Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf.) with surface applications of chicken litter (LIMA et al., 2007).

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Densely planted coffee crops have been improving the fertility of clayey soils in Paraná state since the 1990's (PAVAN et al., 1996). Incorporated and surface applications of manure in coffee fields have provided different responses in different soil classes (CERVELLINI et al., 1995); green fertilizers applied with pigeon pea (*Cajanus cajan* (L.) Millsp.) and Sunn Hemp (*Crotalaria juncea* L.) between the rows reduced yield (PAULO et al., 2001). Chemical, organic or green fertilization of coffee trees has affected soil fertility, as well as the plants' nutritional state and production in different ways (BERGO et al., 2006; CERVELLINI et al., 1995; MORAES et al., 1985; PAULO et al., 2001). Sewage sludge applied in coffee fields did not influence the quality of the beverage (MARTINS et al., 2005). Sugarcane bagasse (*Saccharum officinarum* L.), distributed on the soil surface, altered the chemical characteristics of the soil in Pupunha (*Bactris gasipaes* Kunth) crops in the northwest of Paraná state (TRINTINALIO et al., 2005).

In the soils developed from the Caiuá Formation sandstone, which have a sandy texture on the surface layer, covering between the rows is recommended in perennial crops (FIDALSKI et al., 2006). In this context, after planting of the coffee trees, Chaves (2002) suggests applications of organic fertilizers, without incorporation, with the surface cover fertilizer.

The aim of this work was to assess the soil fertility, nutrition and yield of Iapar-59 coffee after four surface applications of 18 vegetable, animal, agroindustrial and raw sewage sludge organic treatments in a *Typic Haplorthox* with a sandy loam texture.

2 MATERIAL AND METHODS

The experiment was set up in June 2002 at the Agricultural Institute of Paraná (IAPAR), in Paranavaí, northwest of Paraná state (23°5'S, 52°26'W, 470 m). The climate in the area is subtropical (Cfa) and does not present a defined dry season (IAPAR, 2000). The soil is a *Typic Haplorthox with* sandy texture (horizon A with 120 g clay kg^{-1} at 0-18 cm)/sandy loam (horizon Bw with 190 g clay kg^{-1} at 19-200 cm) (SANTOS et al., 2006), that developed from the Caiuá Formation sandstone, in a soft undulated relief.

The chemical characteristics of the soil (0-20 cm) at the time the experiment was set up were: organic C (4.2 g dm^{-3}), pH in $CaCl_2$ (5.8); Al^{3+} (0 $cmol_c$ dm^{-3}); H+Al (2.03 $cmol_c$ dm^{-3}); P (19.0 mg dm^{-3}); Ca^{2+} (0.16 $cmol_c$ dm^{-3}); Mg^{2+} (0.96 $cmol_c$ dm^{-3}); K (0.15 $cmol_c$ dm^{-3}) and base saturation (57.2%).

In the experimental area, dolomitic limestone was previously used to cultivate mango trees. The fruit trees were eradicated and the soil was prepared in a conventional way, with plowing and harrowing, for planting with forrage sorghum (*Sorghum bicolor* (L.) Moench), followed by the coffee experiment, when disk plowing was done followed by a leveling harrow.

The experimental design was in randomized blocks with 4 replications. The experimental plots consisted rows of 12 coffee trees in a 3.0 x 0.70 m spacing.

The following treatments were assessed: 20 t ha^{-1} of dry matter grey mucuna (*Stizolobium cinereum* Piper and Tracy), leucaena (*Leucaena leucocephala* (Lam.) de Wit), pigeon pea (*C. cajan)*, perennial peanut *(Arachis pintoi Krapov.* & W.C. Gregory), brizantha grass (*B. brizantha),* forrage sorghum *(S. bicolor)*, sugarcane bagasse *(CB) (S. officinarum)*, sugarcane filter cake, orange pulp *(Citrus sinensis* (L.) Osbeck), raw sewage sludge (RS), RS with virgin lime (70:30) mixed at the moment of application, coffee straw (*Coffea arabic* L.), bovine manure, chicken litter, chicken manure (CM), CB with CM (50:50), swine manure; 200 m^3 ha^{-1} of swine slurry in a 1% dry matter base; N (95 kg ha^{-1} in an ammonium sulfate base) in 3 applications of 100 g per tree during the rainy season, between October and March; control treatment (without input). The treatments were applied to the soil surface, in 50 cm wide bands on each side of the trees, 25 cm from the stem, in June 2002, February 2003, October 2003 and September 2004.

The vegetation in the planting rows was controlled using a hoe to avoid incorporation of the treatments into the soil. The spontaneous vegetation between the rows was managed through mechanical weeding, whenever necessary. During the experiment, plant health treatments, leaf fertilization, liming and mineral fertilization were not applied to the coffee trees.

In July 2003, after two applications of the treatments, leaf tissue samples were taken from the 3rd leaf pair from the extremity of the branches; the soil was sampled at 0-5, 5-10, 10-20 and 20-40 cm. The samples were taken from the four central trees of each experimental plot. In October 2004, plant height, transverse width of the canopy and the number of branches were assessed; in April 2005 the yield of 10 plants in each experimental plot was assessed.

The treatment and leaf nutrient contents were determined through sulfuric digestion (N and P) and an HCl 1 mol L^{-1} (Ca, Mg and K) solution. In the soil, the following were assessed: P and K (Mehlich-1), organic C (Walkley & Black), pH-$CaCl_2$ (0.01 mol L^{-1}), Ca^{2+}, Mg^{2+} and Al^{3+} (KCl 1 mol L^{-1}), H+Al (SMP buffer solution). The coffee produced in each experimental plot was dried and processed.

Coffee development was assessed through measurements, with a ruler, of tree height and the longitudinal and transverse diameter of the canopy in relation to the direction of the plant rows. The volume of the canopy was determined by the equation $V={}^{2}/_{3}\pi r^2 h$ (MENDEL, 1956), where V is the volume (m^3); r is the canopy radius (m^2); and h is plant height (m).

The leaf and soil nutrient concentrations were previously subjected to homoscedasticity variation by the Levene test (VIEIRA, 1999). Yield, P (0-5 and 5-10 cm) and Ca^{2+} (0-5 cm) data were transformed into the natural logarithm, after which 10 units were added to the original data to meet the assumed homoscedasticity variation. These and the original variables were subjected to variation analysis and comparison of the means by the Dunnett test (BANZATTO & KRONKA, 1989).

3 RESULTS AND DISCUSSION

The N, P, K, Ca and Mg composition varied widely between the treatments (Table 1). The legumes, animal origin, sugarcane filter cake and raw sewage sludge treatments presented higher N, Ca and Mg levels; the animal origin treatments presented higher P levels; and the raw sewage sludge and sugarcane (sugarcane bagasse and sugarcane filter cake) treatments had lower K levels.

The soil organic C concentration increased, at 0-5 cm, with application of the sugarcane bagasse, coffee straw and swine manure treatments; the treatments with rude sewage sludge and swine manure affected soil profile (Table 2). Coffee leaf N concentration was higher with the grey mucuna and ammonium sulfate treatments (Table 2), which did not depend on the soil organic C levels.

The P levels in the soil increased at a 0-40 cm after application of chicken manure, chicken manure with sugarcane bagasse and swine manure, while leaf P concentrations were not influenced by the treatments applied on the soil surface (Table 3). Lima et al. (2007) also verified, in a Typic Haplorthox developed from the Caiuá Formation sandstone planted with *B. brizantha*, an increase in P levels at 0-20 cm after surface application of 10, 15 and 20 t ha^{-1} of chicken litter.

The soil Ca^{2+} levels increased at 0-40 cm with applications of raw sewage sludge, virgin lime and swine manure, at 0-10 cm with chicken manure and at 0-5 cm with perennial peanut, orange pulp, bovine manure, chicken litter and sugarcane bagasse with chicken manure applications. On the other hand, its concentration decreased, at 0-20 cm, in the treatment with ammonium sulfate. These treatments did not influence leaf Ca concentrations (Table 4). The low Ca^{2+} mobility in these soils was verified after surface liming (FIDALSKI & TORMENA, 2005).

The raw sewage sludge with virgin lime treatment increased soil Mg^{2+} levels at 0-40 cm due to the higher concentration of the nutrient in the lime, which was reflected in the higher leaf Mg contents (Tables 1 and 5). Fidalski et al. (2007) proved the efficiency of surface liming by applying dolomitic limestone to a similar soil.

Soil K levels increased at 5-40 cm with applications of leucaena, perennial peanut, forrage sorghum, coffee straw and bovine manure, and at 10-40 cm when treated with pigeon pea, orange pulp, chicken litter, chicken manure, chicken manure with sugarcane bagasse and swine manure (Table 6). K distribution in these soil profiles was also assessed by Fidalski et al. (2007). The high K availability in the soil was not reflected in the leaf tissues, where its concentration decreased with applications of the raw sewage sludge and raw sewage sludge with virgin lime treatments, which was attributed to treatments' lower K contents (Tables 1 and 6). The utilization of raw sewage sludge would demand K replacement to meet the crop's demands (OLIVEIRA et al., 1995).

Table 1 – Mean N, P, K, Ca and Mg contents in the dry matter of the organic treatments

Treatment	N	P	K	Ca	Mg
			($g\ kg^{-1}$)		
Grey mucuna	26.10	2.78	17.00	8.35	2.80
Leucaena	25.30	1.86	14.80	5.90	2.37
Pigeon pea	30.00	3.35	17.00	8.99	2.15
Perennial peanut	21.30	2.70	30.10	17.72	3.12
Brizantha grass	5.20	1.92	7.50	4.37	3.06
Forage sorghum	9.20	1.82	14.80	3.69	3.22
Sugarcane bagasse (CB)	2.20	0.29	1.10	0.68	0.37
Sugarcane filter cake	23.80	2.90	1.90	1.48	1.00
Orange pulp	12.90	1.35	10.50	9.72	1.51
Raw sewage sludge (RS)	35.10	7.97	0.42	9.86	1.01
RS with virgin lime (70:30)	24.40	5.56	0.35	106.50	51.00
Coffee straw	12.80	1.72	22.10	5.47	1.35
Bovine manure	13.20	7.32	18.10	17.83	9.17
Chicken litter	25.10	12.97	20.90	22.09	4.69
Chicken manure (CM)	39.40	21.70	24.50	107.20	5.20
CB with CM (50:50)	22.80	14.63	13.10	48.06	2.79
Swine manure	27.20	20.55	6.50	42.89	3.59
Swine slurry	20.20	13.96	4.60	28.04	2.48

Soil acidification ($p < 0.10$), verified through pH-$CaCl_2$ values, occurred in the raw sewage sludge treatment, in relation to the control, at 0-5 cm (4.45 and 5.18) and 5-10 cm (4.25 and 5.20). The same process was observed for the ammonium sulfate treatment, in relation to the control, at 0-5 cm (4.20 and 5.18), 5-10 cm (3.83 and 5.20), 10-20 cm (3.85 and 5.28) and 20-40 cm (4.08 and 4.68). On the other hand, the raw sewage sludge with virgin lime treatment promoted soil alkalization at 0-5, 5-10, 10-20 and 20-40 cm, verified by the pH-$CaCl_2$ values (7.43 to 8.30) and base saturation (76 to 85%). The treatments with raw sewage sludge and ammonium sulfate raised ($p < 0.10$) Al^{3+} levels to 0.09 and 0.50 $cmol_c\ dm^{-3}$, respectively, raising Al^{3+} saturation to 6% and 43% and reducing base saturation values to 26% and 36%.

The treatments with pigeon pea, brizantha grass, forrage sorghum, sugarcane bagasse, raw sewage sludge, raw sewage sludge with virgin lime, swine manure and swine slurry altered soil fertility, but did not alter coffee development and (Tables 1, 2, 3, 4, 5, 6 and 7). From the results it can be inferred that, in a Typic Haplorthox, organic treatments would have to be supplemented with chemical fertilizers to make their use in coffee production (Iapar-59) viable.

Plant height, diameter and volume of the canopy and/or number of branches were higher after applications of perennial peanut, orange pulp, coffee straw, bovine manure, chicken litter, chicken manure and chicken manure with sugarcane bagasse and ammonium sulfate. The treatments, however, did not increase the yield of processed coffee (Table 7).

Processed coffee yield was low (Table 7), in view of the coffee fields in full production means in Brazil and Paraná state, respectively 1065 and 1294 kg ha^{-1} in the 2004/2005 harvest (ABIC, 2009). These differences are attributed to the first agricultural harvest, low soil fertility and lack of chemical fertilizers (soil and leaf) in the organic treatments, whose production was similar to that of coffee managed with green fertilizers on the soil surface (BERGO et al., 2006).

Table 2 – Mean organic C levels in the soil at four different depths and leaf N concentration (Iapar-59 coffee) in 2003, after two surface applications of the treatments.

Treatment	Depth (cm)				Leaf N
	0-5	5-10	10-20	20-40	
	Organic C (g kg^{-1})				(g kg^{-1})
Control	5.22	4.87	4.39	4.26	20.11
Grey mucuna	6.34	5.97	5.12	462	24.54*
Leucaena	6.51	6.55	5.81*	4.92	21.68
Pigeon pea	5.28	4.70	5.60	6.05	22.77
Perennial peanut	6.19	5.52	5.69	6.92*	20.86
Brizantha grass	5.53	5.44	5.02	5.35	19.80
Forage sorghum	6.35	5.82	5.51	5.18	21.77
Sugarcane bagasse (CB)	9.08*	6.45	5.58	5.34	19.64
Sugarcane filter cake	6.57	5.79	4.80	5.06	21.95
Orange pulp	6.77	5.80	5.69	6.42*	22.29
Raw sewage sludge (RS)	8.62*	6.99*	5.03	5.25	21.52
RS with virgin lime (70:30)	6.91	6.90*	6.08*	5.40	22.20
Coffee straw	8.44*	5.93	4.99	5.24	21.47
Bovine manure	8.83*	6.66	5.36	6.73*	21.71
Chicken litter	6.65	5.74	5.02	4.63	20.48
Chicken manure (CM)	6.84	5.50	4.99	4.66	22.88
CB with CM (50:50)	6.33	5.30	5.07	5.23	19.38
Swine manure	8.56*	6.69	5.88*	6.05*	20.97
Swine slurry	6.85	5.54	5.36	4.66	19.85
Ammonium sulfate	4.96	4.99	4.71	4.29	25.90*
Variation Coefficient (%)	19.92	16.87	13.74	17.55	9.24

(*)Means differ from the control treatment in the Dunnett test ($p<0.10$).

Table 3 – Mean P levels in the soil at four different depths and leaf P concentration (Iapar-59 coffee) in 2003, after two surface applications of the treatments.

Treatment	Depth (cm)				Leaf P
	0-5	5-10	10-20	20-40	
	P (mg kg^{-1})				(g kg^{-1})
Control	21.03	16.48	15.85	14.20	2.54
Grey mucuna	27.00	24.45	17.33	13.18	1.93
Leucaena	26.13	24.93	16.60	14.43	2.08
Pigeon pea	15.48	17.88	23.90	23.08	2.41
Perennial peanut	23.18	22.43	23.33	19.45	2.30
Brizantha grass	19.80	19.68	23.53	26.38	2.26
Forage sorghum	24.93	23.23	15.35	12.53	2.78
Sugarcane bagasse (CB)	14.75	13.78	13.45	9.50	2.29
Sugarcane filter cake	17.15	17.93	12.43	8.85	2.02
Orange pulp	31.83	24.95	29.55	29.80	2.76
Raw sewage sludge (RS)	42.80*	30.15	19.95	11.80	1.77
RS with virgin lime (70:30)	38.43	39.00*	26.63	13.80	1.75
Coffee straw	18.63	18.95	11.78	6.88	2.60
Bovine manure	42.18	32.53	26.35	17.03	2.62
Chicken litter	139.50*	76.73*	31.45	39.40	2.25
Chicken manure (CM)	196.38*	134.28*	52.58*	46.93*	2.59
CB with CM (50:50)	82.65*	65.63*	45.65*	32.58	2.28
Swine manure	254.68*	123.53*	56.58*	59.68*	2.14
Swine slurry	72.28*	46.58*	27.35	15.20	2.33
Ammonium sulfate	17.30	19.18	16.85	12.48	1.70
Variation Coefficient (%)	6.48	7.74	55.32	69.03	22.65

(*)Means differ from the control treatment in the Dunnett test ($p<0.10$).

Table 4 – Mean soil Ca^{2+} levels at four different depths and leaf Ca concentration (Iapar-59 coffee) in 2003, after two surface applications of the treatments.

Treatment	Depth (cm)				Leaf Ca
	0-5	5-10	10-20	20-40	
	Ca^{2+} ($cmol_c$ dm^{-3})				(g kg^{-1})
Control	0.96	1.01	1.01	0.79	10.36
Grey mucuna	1.05	0.93	1.17	1.16	9.40
Leucaena	1.09	0.99	1.18	1.14	9.82
Pigeon pea	1.02	1.06	1.05	1.01	9.72
Perennial peanut	1.46*	1.32	1.26	1.50*	9.84
Brizantha grass	1.14	1.10	1.18	1.37*	11.09
Forage sorghum	0.85	0.86	0.94	0.94	9.25
Sugarcane bagasse (CB)	1.18	1.28	1.35	1.22	12.22
Sugarcane filter cake	1.10	1.15	1.53*	1.34*	10.49
Orange pulp	1.43*	1.28	1.41	1.38*	10.09
Raw sewage sludge (RS)	1.09	0.86	1.18	1.12	11.25
RS with virgin lime (70:30)	1.81*	2.05*	1.76*	2.29*	11.11
Coffee straw	1.20	1.14	1.26	1.15	9.43
Bovine manure	1.64*	1.36	1.40	1.56*	7.85
Chicken litter	1.60*	1.32	1.26	1.38*	9.58
Chicken manure (CM)	2.18*	1.77*	1.36	1.37*	9.30
CB with CM (50:50)	1.58*	1.41	1.12	1.20	10.41
Swine manure	2.12*	1.62*	1.53*	1.61*	11.42
Swine slurry	1.38	1.32	1.51*	1.40*	10.27
Ammonium sulfate	0.43*	0.32*	0.44*	0.67	8.99
Variation Coefficient (%)	10.12	21.57	18.73	21.77	15.97

(*)Means differ from the control treatment in the Dunnett test ($p<0.10$).

Table 5 – Mean soil Mg^{2+} levels at four different depths and leaf Mg concentration (Iapar-59 coffee) in 2003, after two surface applications of the treatments.

Treatment	Depth				Leaf Mg
	0-5	5-10	10-20	20-40	
	(Mg^{2+}, $cmol_c$ dm^{-3})				(g kg^{-1})
Control	0.69	0.64	0.73	0.70	4.02
Grey mucuna	0.71	0.65	0.77	0.81	3.83
Leucaena	0.84	0.71	0.78	0.79	3.54
Pigeon pea	0.69	0.63	0.59	0.60	3.29
Perennial peanut	0.86	0.72	0.81	1.04	3.32
Brizantha grass	0.92	0.77	0.68	0.78	4.44
Forage sorghum	1.08	0.93	0.69	0.69	4.27
Sugarcane bagasse (CB)	0.83	0.80	0.83	0.80	4.72
Sugarcane filter cake	0.89	0.78	1.01	0.97	4.77
Orange pulp	0.71	0.61	0.66	0.72	3.69
Raw sewage sludge (RS)	0.47	0.31	0.45	0.60	4.92
RS with virgin lime (70:30)	3.34*	3.27*	2.15*	2.19*	7.32*
Coffee straw	1.02	0.82	0.87	0.87	3.23
Bovine manure	1.62*	1.19*	0.92	1.07	3.70
Chicken litter	1.09	0.85	0.81	0.93	3.76
Chicken manure (CM)	0.78	0.66	0.68	0.64	2.75
CB with CM (50:50)	0.67	0.60	0.59	0.72	2.88
Swine manure	0.71	0.59	0.61	0.77	3.12
Swine slurry	0.59	0.50	0.68	0.85	4.10
Ammonium sulfate	0.39	0.23	0.20*	0.36	4.62
Variation Coefficient (%)	24.11	27.44	27.29	27.93	1.92

(*)Means differ from the control treatment in the Dunnett test ($p<0.10$).

Table 6 – Mean soil K levels at four different depths and leaf K concentration (Iapar-59 coffee) in 2003, after two surface applications of the treatments.

Treatment	Depth (cm)				Leaf K
	0-5	5-10	10-20	20-40	
	(K, $cmol_c$ dm^{-3})				($g\ kg^{-1}$)
Control	0.15	0.10	0.06	0.07	21.78
Grey mucuna	0.17	0.15	0.13	0.14*	20.43
Leucaena	0.20	0.19*	0.17*	0.15*	22.70
Pigeon pea	0.17	0.16	0.15*	0.14*	22.73
Perennial peanut	0.21	0.22*	0.18*	0.16*	22.75
Brizantha grass	0.14	0.15	0.12	0.11	22.15
Forage sorghum	0.21	0.20*	0.18*	0.17*	22.53
Sugarcane bagasse (CB)	0.15	0.11	0.08	0.07	18.95
Sugarcane filter cake	0.18	0.16	0.13	0.12	17.00
Orange pulp	0.15	0.16	0.14*	0.15*	23.60
Raw sewage sludge (RS)	0.12	0.09	0.05	0.05	14.28*
RS with virgin lime (70:30)	0.09	0.09	0.07	0.06	12.40*
Coffee straw	0.21	0.23*	0.27*	0.25*	26.93
Bovine manure	0.20	0.21*	0,26*	0.23*	23.10
Chicken litter	0.15	0.18	0.18*	0.19*	23.90
Chicken manure (CM)	0.14	0.15	0.20*	0.22*	26.05
CB with CM (50:50)	0.13	0.13	0.16*	0.18*	25.10
Swine manure	0.16	0.16	0.15*	0.12	23.33
Swine slurry	0.13	0.12	0.08	0.07	19.28
Ammonium sulfate	0.11	0.08	0.05	0.05	9.50*
Variation Coefficient (%)	14.38	14.65	13.41	13.58	3.19

(*)Means differ from the control treatment in the Dunnett test ($p<0.10$).

Table 7 – Vegetative growth of Iapar-59 (2004) coffee and production of processed coffee (2005) after four surface applications of the treatments.

Treatment	Height	Canopy	Volume	Branches	Processed Coffee
	(cm)		(m^3)	(n°)	(kg ha^{-1})
Control	51	38	0,02	21	23
Grey mucuna	76*	73*	0,09*	39*	208*
Leucaena	80*	79*	0,10*	40*	269*
Pigeon pea	65	54	0,06	30	158
Perennial peanut	76*	81*	0,10*	41*	24
Brizantha grass	56	43	0,04	23	71
Forage sorghum	63	57	0,06	31	50
Sugarcane bagasse (CB)	51	39	0,03	22	48
Sugarcane filter cake	80*	78*	0,10*	38*	574*
Orange pulp	66	65*	0,07	35*	90
Raw sewage sludge (RS)	62	59	0,06	31	123
RS with virgin lime (70:30)	66	59	0,07	31	213
Coffee straw	67	61	0,07	33*	46
Bovine manure	74*	76*	0,09*	39*	102
Chicken litter	68	63	0,07	35*	39
Chicken manure (CM)	73*	75*	0,09*	40*	98
CB with CM (50:50)	69	68*	0,08	36*	192
Swine manure	68	60	0,07	32	53
Swine slurry	59	45	0,04	27	21
Ammonium sulfate	66	67*	0,07	34*	148
Variation Coefficient (%)	16	23	36,87	18	19

(*)Means differ from the control treatment in the Dunnett test ($p<0.10$).

4 CONCLUSIONS

The pigeon pea, brizantha grass, forrage sorghum, sugarcane bagasse, raw sewage sludge, raw sewage sludge with virgin lime, swine manure and swine slurry treatments altered soil fertility.

The treatments with perennial peanut, orange pulp, coffee straw, bovine manure, chicken litter, chicken manure and sugarcane bagasse with chicken manure improved soil fertility, resulting in a positive development of the coffee trees.

Grey mucuna increased leaf N concentrations, leucaena increased soil K levels (5-40 cm) and sugarcane filter cake increased soil Ca levels (10-40 cm). These alterations enhanced coffee development and yield.

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