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High Metal Contents in Coffee Plant Organs Developed in Tubets with Different Proportions of Biosolid Composts and Carbonized Rice Hulls

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ABSTRACT

The objective of this study was to analyze the effect of biosolid composts (BC) and carbonized rice hull (RH) on the production of Coffea arabica L. cv Catuaí Vermelho seedlings (IAC H 2077-2-5-99) grown in tubets. A totally randomized experimental design with five treatments and four replications was conducted in a nursery , to evaluate Co, Ni, Cr, Pb, Cu, Mn and Zn contents in roots, stems and leaves. Higher contents of Cr, Co, Ni, Pb, Cu and Zn were found in roots, while leaves carried the highest content of Mn. Zn in leaves went from average to high in plants developed in BC. In plants developed in RH. Mn content was about four times higher than the adequate concentration. Ni, Co, Cr, Pb and Cu contents found in leaves were considered normal, according to international standards. The best treatment for coffee seedling nutrition was 50% RH + 50% BC.

Key words: Coffea arabica L., substrate, sewage sludge, coffee nutrition, coffee seedling

INTRODUCTION

The greatest problem in urban sanitation is the final destination of sewage sludge residues. So far, many stations have kept these residues near their facilities, posing considerable risks to the environment (Lara, 1999; Fernandes et al.).
The Paraná Sanitation Company - SANEPAR - defines sewage sludge as solid residues created by treatment systems of residual water. However, according to WEF (Water Environmental Federation) regulations, these residues should be classified as biosolids, provided they are predominantly organic and beneficial (Andreoli and Pegorini, 1998).
Due to their high nutrient content and performance as a conditioner of physical, chemical and biological properties of the soil, the use of bio-solids as organic fertilizers has been recommended as an alternative for the final destination of these residues.
According to Miyazawa et al. (1998), high contents of N, P, K, Ca, Mg and S can be found in biosolids. They reduce soil density, favor the formation of aggregates (Jorge et al., 1991) and increase overall porosity (Pagliai et al., 1981 and Ortega et al., 1981). Nevertheless, the presence of pathogenic microorganisms (such as *Escherichia coli* and *Salmonella*), toxic organic composts (pesticides, fungicides and others) and heavy metals such as Cd, Hg, Pb, Cr, and Cu are the main restrictions to the use of biosolids in agriculture (Tiller, 1989; Tsadilas et al., 1995).
When composting is controlled, biosolids can be

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more advantageous and consequently have different applications (Soccol et al., 1997). Thermophilic microorganism populations occur throughout the composting process, which keeps the environment temperature high for many days (55-65ºC), killing most pathogenic microorganisms. According to Fernandes et al., (1996), the helminth eggs probability was reduced to 100% during the composting process. In corn cultures, the application of biosolid composts led to an increase in dry matter production in shoot height (Berton et al., 1989; Amaral et al. 1996), as well as in productivity (Biscaia and Miranda, 1996).

According to Wallace and Wallace (1994), compost products based on sewage sludge used in landscape gardening have been commercialized in the Los Angeles area (USA). Plants have shown toxicity symptoms due to the presence of Zn and, in some cases, an increase in Cd, Cu, Pb and Ni contents, in are as which have been using this kind of product for more than 40 years. Carbonized rice hulls are considered good substrates for seedlings production through seeds and stake rooting. They are composed of a light, porous material that allows good airing and draining, keeps a constant volume and is free from weeds, nematodes and pathogens. Due to the carbonizing process (Souza, 1993) there's no need to treat them chemically. Rice hulls can be used pure or mixed with other substrates for the formation of seedlings of different kinds of plants such as forest, fruit, agricultural and ornamental plants. Carbonized rice hulls that are properly fertilized can be used in the production of coffee plant seedlings.

The production of seedlings is among the best alternatives for biosolid use in agriculture. In this type of production, the biosolid can be used alone (not mixed with other materials) and, depending on the concentration of heavy metals there can be a reduction in the growth and development of seedlings as well as in the phytotoxicity symptoms.

This study was developed to evaluate heavy metal contents in the roots, stems and leaves of *Coffea arabica L* 'Catuaí Vermelho IAC-99' seedlings developed in tubets filled with different proportions of bio-solid compost and carbonized rice hulls, using a slow-liberation fertilizer.

MATERIALS AND METHODS

The experiment was conducted in a nursery located in Londrina, PR, 23° 23' south (latitude) and 51° 11' west (longitude) of Greenwich, with the average height of 566 m., in a Cfa type of climate, according to Köppen. The radiant flux density was attenuated by a black polypropylene screen with a 50% retention capacity. In the suspended irrigation system, micro-sprinklers with an outflow of 75 $L.h^{-1}$ were used. During the experiment, seedlings were irrigated three times a day (at 8.30 am., 12.30 pm. and 5.30 pm.) for 15 minutes.

Basic *Coffea arabica* L. cv Catuaí Vermelho IAC-99 seedlings were sown in a seedbed with washed thick sand. After the plantules reached the 'matchstick' stage, on October 26 1999, they were transplanted to black, rigid, 0.14 m high polypropylene tubets measuring 0.035 m (internal diameter) in the upper opening, 0.015 m (diameter) in the lower opening, weighing 120 ml, and with six longitudinal strias inside.

Substrates consisted of carbonized rice hull proportions (RH) and bio-solid composts (BC) provided by the Paraná Sanitation Company - SANEPAR. Tubets were filled manually sixty days before transplantation, and alternately distributed on a screen net (with 0.04 m and a 14 mm wire) fixed on iron tables 1.30 m wide, 4.5 m long and 0.80 m high. The slow liberation fertilizer known as Osmocote® was added to all treatments, in an 8.0 $kg.m^{-3}$ substrate dose. According to the manufacturer, this fertilizer contains 15% N (7% ammoniac and 8% nitric); 9% P_2O_5; 12% K_2O; 3.5% Ca; 1% Mg; 2.3% S; 0.02% B; 0.05% Cu; 0.45% Fe; 0.06% Mn; 0.02% Mo and 0.05% Zn.

For the chemical analysis, the carbonized rice hull samples and biosolid composts were dried in a greenhouse with forced air circulation at 65°C until reaching constant weight. Nitrogen analysis was done through sulfuric digestion (H_2SO_4 + $CuSO_4$ + K_2SO_4). The carbon content was measured by the Walkley-Black method and the pH was determined by calcium chloride 0.1M. For the extraction of P, K, Ca, Mg, S, Na, B, Cu, Zn, Fe, Mn, Co, Ni, Cr, Pb and Cd, a 1N (HNO_3 + $HClO_4$) solution was used. The heavy metals Co, Ni, Cr, Pb, Cd, Cu, Mn and Zn were determined by atomic emission spectrometry with induced plasma, using a Thermo Jarrel-ash ICAP 61E

(ICP-EAS) model spectrometer.

A total randomized experimental design with five treatments and four replications was used. Each plot was composed of six plants in rows and six in columns, with a total of 36 plants. Treatments were obtained from the following mixtures in volume (v/v):

T1 = 100% carbonized rice hull (RH) and 0% bio-solid compost (BC);
T2 = 75% carbonized rice hull (RH) and 25% bio-solid compost (BC);
T3 = 50% carbonized rice hull (RH) and 50% bio-solid compost (BC);
T4 = 25% carbonized rice hull (RH) and 75% bio-solid compost (BC);
T5 = 0% carbonized rice hull (RH) and 100% bio-solid compost (BC).

Four plants were taken from the center of each plot, 180 days after transplantation. Root, stem and leaves were identified and placed in porous paper bags for drying. Dried matter was obtained in a greenhouse with forced air circulation at 75°C where the plant parts remained until they reached constant weight.

The determination of Co, Ni, Cr, Pb, Cd, Mn and Zn contents in each part of the plantules was carried out through atomic emission spectrometry with induced plasma, with a Thermo Jarrel-ash ICAP 61E (ICP-EAS) model spectrometer.

Data were submitted to an analysis of variance and the means were compared by the Genetic and Statistical Analysis System (GSAS), version 5.0 (Euclides, 1983).

RESULTS AND DISCUSSION

Table 1 shows nutrient and heavy metal contents in two substrates used in the experiment. Table 2 shows heavy metal contents in roots, stems and leaves from cultivated coffee plant seedlings, in carbonized rice hulls, in bio-solid composts (alone and mixed).

Table 1 - Macro and micro nutrient contents in carbonized rice hulls and bio-solid compost UEL, Londrina, PR 2001.

Source	N	P	K	Ca	Mg	S-SO_4	C	Na	B	Cu	Zn	Fe	Mn	Co	Ni	Cr	Pb	Cd	pH	Humidity at 65°C
	g.kg^{-1}							mg.kg^{-1}												
Carbonized rice hull	7.4	2.05	7.5	2.05	1.82	1.18	175.8	100	9	53	86	12.779	705	X[1]	X	X	X	X	6.5	5.8
Bio-solid compost	28.7	5.60	1.7	24.8	2.6	4.3	338.7	250	16	517	1.560	22.235	503	13	63	108	198	0	5.5	10.4

[1] not evaluated

Chrome

Chrome was most accumulated in the root (8.40 to 14.31 mg.kg^{-1} dry matter (DM), and the stem showed the lowest content for this element (6.98 to 7.47 mg.kg^{-1} DM). Leaves showed average contents (7.89 to 10.97 mg.kg^{-1} DM). Coffee seedlings grown on pure or mixed with carbonized rice hull biosolid composts (BC) presented significantly higher Cr content in the roots when compared to those grown on pure carbonized hull (RH). However, no difference was found for stems. Cr content was significantly higher in seedlings grown on 25% of RH + 75% of BC than in those grown on 100% of RH and 100% of BC. The use of biosolids from Treatment Stations in Paraná in bean plant plantations resulted in Cr contents similar to those of the witness. (Miyazawa et al., 1998). According to Dias et al. (1996), when the BC dose in the graniferous sorghum crop was increased, there was a linear growth in the Cr availability in the soil. To Bidwell and Dowdy (1987), the Cr concentrations in the culm and corn grains oscillated according to the year of cultivation, with no correlation with the sludge used.

The Cr content found in the biosolid compost analysis was 108 mg.kg^{-1} dry matter, which is much lower than the 750 mg.kg^{-1} accepted by the European Economic Community for the incorporation of the material to the soil (Fernandes et al., 1993). The Cr concentration in biosolid has varied between 8 and 40,600 mg.kg^{-1} dry matter and these considerable variations depend on the economical activities carried out in each sampled region (Bidwell and Dowdy, 1987).

Table 2 - Means of Chrome, Cobalt, Nickel, Lead, Manganese, Copper and Zinc in leaves, stems and roots of coffee seedlings developed in carbonized rice hulls (RH) and in biosolid compost (BC) and its mixtures.

	Treatments	Cr	Co	Ni	Pb	Mn	Cu	Zn
					mg.kg^{-1}			
Roots	RH(100%)	8.40 B	2.40 A	3.77 B	3.38 B	179.01 A	9.57 C	107.82 B
	RH(75%)+ BC(25%)	11.60 A	2.71 A	12.48 A	12.47 A	99.66 B	37.48 B	1398.89 A
	RH(50%)+ BC(50%)	12.79 A	2.94 A	12.69 A	14.40 A	88.65 B	41.48 B	1302.00 A
	RH(25%)+ BC(75%)	13.29 A	2.88 A	11.80 A	17.00 A	76.39 B	46.99 AB	1358.59 A
	BC(100%)	14.31 A	3.44 A	12.65 A	18.85 A	89.72 B	59.19 A	1474.65 A
Stems	RH(100%)	6.98 A	0.23 B	3.87 B	2.95 A	132.75 A	6.07 B	18.77 B
	RH(75%)+ BC(25%)	6.98 A	0.26 B	5.38 A	1.94 A	74.71 B	8.77 AB	99.47 A
	RH(50%)+ BC(50%)	7.32 A	0.41 AB	6.10 A	4.71 A	63.59 B	9.85 A	79.91 A
	RH(25%)+ BC(75%)	7.47 A	0.44 AB	5.43 A	3.60 A	58.13 B	10.70 A	82.32 A
	BC(100%)	7.31 A	0.52 A	5.11 AB	3.04 A	56.35 B	11.07 A	88.00 A
Leaves	RH(100%)	7.89 C	0.81 A	3.65 B	6.19 A	477.76 A	8.60 A	12.83 A
	RH(75%)+ BC(25%)	9.15 ABC	0.93 A	5.33 A	6.89 A	175.86 B	7.73 A	17.81 A
	RH(50%)+ BC(50%)	10.26 AB	1.21 A	6.24 A	9.10 A	152.00 B	6.85 A	15.48 A
	RH(25%)+ BC(75%)	10.97 A	1.23 A	5.19 A	8.94 A	113.07 B	6.79 A	15.46 A
	BC(100%)	8.86 BC	0.76 A	4.85 AB	7.85 A	116.32 B	9.72 A	22.05 A

Means followed by the same letters in the seedling part column do not differ among themselves by the Tukey test at the 5% of probability

Internationally speaking, the Cr content in soils varies from 18.7 to 285 mg.kg^{-1} (Souza et al., 1996). The critical levels of Cr vary from 75 to 100 mg.kg^{-1} (Kabata Pendias and Pendias, 1984). According to these criteria, the Eutrophic Structured Red Soils (Souza et al., 1996) present higher Cr contents than these critical levels and those found in the chemical analysis of the bio-solid compost used as substrate in this experiment.

Cobalt

The highest Co content was found in the roots (2.40 to 3.44 mg.kg^{-1} DM), while the lowest content was found in the stems (0.23 to 0.52 mg.kg^{-1} DM). Leaves presented intermediate levels of Co contents (0.81 to 1.23 mg.kg^{-1} DM). Miyazawa et al. (1998) found lower levels Co contents - from one to 4.56 mg.kg^{-1} dry matter - while working with different kinds of biosolids in bean plant tissues. BC mixed with RH produced an increase in Co content in the stem. Seedlings grown on pure BC presented significantly higher Co content in the stem than those grown under RH treatments. Content differences were not significant for roots and leaves.

Co content found in the biosolid compost sample used in this experiment was 13 mg.kg^{-1} dry matter. This is much lower than the 50 mg.kg^{-1} dry matter, and the 100 mg.kg^{-1} dry matter recommended by Switzerland for the incorporation of the material to the soil (Fernandes et al., 1993).

According to international criteria, the Co content in soils varies from 1.0 to 70 mg.kg^{-1} dry matter (Souza et al., 1996), and Co critical levels are from 25 to 50 mg.kg^{-1} (Kabata-Pendias and Pendias, 1984). Eutrophic Structured Red Soils present higher Co contents than the critical levels established by these criteria (Souza et al., 1996), as well as the contents found in the chemical analysis of the biosolid compost used as substrate in this experiment.

Nickel

Highest Ni content was found in the root (3.77 to 12.69 $mg.kg^{-1}$ DM). Content levels were similar in the stem and leaves, and varied from 3.65 to 6.24 $mg.kg^{-1}$ DM. Arteaga (1996) also found higher Ni contents in the wheat root than in the shoot height. Miyazawa et al. (1998) found Ni contents in bean plant shoot heights, varying from less than two to 4.98 mg.kg, while working with different kinds of biosolids in bean plant shoot heights. Pure or mixed BC produced a significant increase in Ni content in the roots. The stem as well as the roots of the seedlings grown on pure RH presented lower Ni content, which differed significantly from the content found in seedlings grown on the RH with BC mixture. The use of biosolids from Treatment Stations in Paraná in bean plantations resulted in Ni contents similar to those in the witness (Miyazawa et al., 1998). According to Dias et al. (1996), when the bio-solid dose is increased, there is a linear growth in Ni availability in the soil.

The Ni content found in the dry matter resulted from the use of a biosolid compost in this experiment was 63 $mg.kg^{-1}$, which is much lower than the 200 $mg.kg^{-1}$ DM recommended by Switzerland and Germany, and by the 300 $mg.kg^{-1}$ DM recommended by the European Economic Community for its incorporation to the soil. However, the Ni content was higher than the 30 $mg.kg^{-1}$ DM recommended by Denmark (Fernandes et al., 1993).

According to international criteria, the Ni content in soils varies from 0.7 to 269 $mg.kg^{-1}$ (Souza et al., 1996). The Ni critical level is established at 100 $mg.kg^{-1}$ (Kabata-Pendias and Pendias, 1984).

Lead

Higher contents of Pb were observed in the root (3.38 to 18.85 $mg.kg^{-1}$ DM). They were lower in the stem (1.94 to 4.71 $mg.kg^{-1}$ DM) and intermediate in the leaves (6.19 to 9.10 $mg.kg^{-1}$ DM). The lowest level of Pb content was obtained from coffee seedlings grown on pure RH, which differed significantly from the root content grown on the RH and BC mixture or on pure BC. As for the stem and leaves, no significant differences in content were found among the treatments.

There is usually a higher accumulation of Pb in the root than in the shoot height (Chu and Wong, 1987) in *Brassica chinensis* and *Lycopersicum esculentum*, as well as in wheat (Arteaga, 1996). However, Pb may accumulate more in the shoot height than in the root in carrots (Chu and Wong, 1987).

The use of biosolids from Treatment Stations in Paraná in bean plant plantations resulted in Pb contents similar to those of the witness (Miyazawa et al., 1998). On the other hand, there is a linear growth in the Pb availability when the bio-solid dose is increased (Dias et al. 1996).

Pb content in biosolid dry matter in this experiment (198 $mg.kg^{-1}$) is lower than the 400 $mg.kg^{-1}$ DM recommended by Denmark and the 750 $mg.kg^{-1}$ DM recommended by the European Economic Community for the incorporation of the material to the soil (Fernandes et al., 1993).

Pb concentration in biosolids varies from 29 to 3,600 $mg.kg^{-1}$ DM, and these variations depend most probably on the economical activities of the sampled regions (Miyazawa et al., 1998).

According to international criteria, the Pb content in soils varies from 0.5 to 135 $mg.kg^{-1}$ (Souza et al., 1996) and Pb critical levels are between 100 and 400 $mg.kg^{-1}$ (Kabata-Pendias and Pendias, 1984). Taking into consideration this critical level, it can be said that all soils without anthropic actions have Pb contents lower than the critical levels.

Manganese

The highest Mn content levels were observed in coffee plant leaves (113.07 to 477.76 $mg.kg^{-1}$ DM), and the lowest in the stems (56.35 to 132.74 $mg.kg^{-1}$ DM). The roots showed intermediate content levels (76.39 to 179.01 $mg.kg^{-1}$ DM).

Adequate contents for coffee plant leaves vary from 80 to 100 $mg.kg^{-1}$ DM (Malavolta et al., 1997). So, according to this standard, seedlings presented higher leaf contents than the adequate for all substrates.

While working with a standard substrate for coffee, Guimarães (1994) observed that Mn content in leaves and stems decreased according to the age of the coffee plant, varying from 60.1 $mg.kg^{-1}$ DM (in seedlings with one leaf pair) to 22.7 $mg.kg^{-1}$ DM (in seedlings with eight leaf pairs), and from 18.6 $mg.kg^{-1}$ DM to 13.4 $mg.kg^{-1}$ DM in the plant stem, with one and eight leaf pairs respectively.

Mn contents in coffee plant roots are close to 30 $mg.kg^{-1}$ DM in seedlings with one to eight pairs of leaves. Depending on the species, Mn may accumulate more in the leaves, as in carrots, or in the roots, as in *Brassica chinensis* and *Lycopersicum esculentum* (Chu and Wong, 1987), than in the shoot height. In this study, notwithstanding the part of the plant analyzed, Mn content was higher and significantly different every time pure RH was utilized during leaf formation. The use of BC mixed with RH reduced Mn content in the leaves to an adequate level. These results are due to the higher Mn content found in the analysis of carbonized rice hull. While studying bean plant cultures, Miyazawa et al. (1998) observed that higher Mn concentration in the substrate increased the content of this metal in the plant shoot height tissues.

Mn contents found in the biosolid compost and carbonized rice hulls used in this experiment was 503 $mg.kg^{-1}$ DM and 705 $mg.kg^{-1}$ DM, respectively. Switzerland recommends Mn content of 500 $mg.kg^{-1}$ DM at the most for the incorporation of the material to the soil (Fernandes et al., 1993). According to Miyazawa et al. (1998), Mn contents higher than 300 $mg.kg^{-1}$ DM in the biosolid caused toxicity symptoms in the bean plants.

Copper

On average, higher accumulation of Cu (9.57 to 59.19 $mg.kg^{-1}$ DM) was found in coffee plant roots. Leaves and stems presented similar content levels, varying from 6.07 to 11.07 $mg.kg^{-1}$ DM. Adequate content levels for coffee plant leaves vary from 11 to 14 $mg.kg^{-1}$ DM (Malavolta et al., 1997). These are higher than the contents observed in seedlings, in all substrates. Pure or mixed BC produced a significant increase in Cu content in the roots. The highest Cu content was found in the roots of seedlings grown on pure BC and on 75% of BC mixed with 25% of RH and in the stems of seedlings grown on 50% of BC + 50% of RH, 75% of BC + 25% of RH and 100% of BC. These results differ significantly from those found in seedlings grown on pure RH. There were no content differences in the leaves. However, whenever pure BC was used, the Cu content got closer to the minimum adequate level for leaves.

While working with a standard substrate for coffee, Guimarães (1994) determined that Cu content in roots, stems and leaves increases according to the age of the plants. In the root, it changes from 14.9 $mg.kg^{-1}$ DM to 57.1 $mg.kg^{-1}$ DM; in the stem, from 13.1 $mg.kg^{-1}$ DM to 22.2 $mg.kg^{-1}$ DM, and in the leaves from 6.5 $mg.kg^{-1}$ DM to 11.8 $mg.kg^{-1}$ DM, respectively for coffee plant seedlings with one to eight pairs of leaves.

Depending on the species, the Cu accumulates more in the leaves, as in *Brassica chinensis* and *Lycopersicum esculentum* (Chu and Wong, 1987), and in wheat (Arteaga, 1996), than in the shoot height. The use of biosolids from Treatment Stations in Paraná in bean plant plantations resulted in Cu contents similar to those of the witness (Miyazawa et al., 1998).

The Cu contents found in biosolid composts and carbonized rice hulls used in this experiment were 517 $mg.kg^{-1}$ DM and 53 $mg.kg^{-1}$ DM, respectively. Switzerland and the European Economic Community accepts maximum contents of 1,000 $mg.kg^{-1}$ DM. In Sweden, contents up to 3,000 $mg.kg^{-1}$ DM are accepted (Fernandes et al., 1993).

Zinc

Coffee plant roots showed the highest accumulation of Zn (107.82 to 1474.65 $mg.kg^{-1}$ DM). Leaves accumulated the least (12.83 to 22.05 $mg.kg^{-1}$ DM), and the stem showed intermediate content levels (18.77 to 99.47 $mg.kg^{-1}$ DM). Adequate Zn content levels for coffee plant leaves are from 15 to 20 $mg.kg^{-1}$ DM (Malavolta et al., 1997). When carbonized rice hulls were used as substrate, Zn leaf contents were lower than the standard, but this did not happen when the bio-solid compost was used. Leaf contents from seedlings cultivated in substrate mixtures were within the standards. Coffee trees demand a high level of Zn during their nutrition process. BC has become an important nutritious source for coffee trees.

Depending on the species, Zn accumulates more in the leaves, as in carrots, or in the roots, as in *Brassica chinensis* and *Lycopersicum esculentum* (Chu and Wong, 1987), than in the shoot height. Arteaga (1996) did not notice any significant differences between the accumulated contents in the root and in the shoot height in wheat. Coffee seedlings grown on pure BC or mixed with RH presented significantly higher Zn content in the roots and stems than in those grown on pure RH. There was no difference in leaf content among the treatments.

Zn contents found in the biosolid compost and carbonized rice hulls were 1,560 $mg.kg^{-1}$ DM and 86 $mg.kg^{-1}$ DM, respectively (Table 2). The European Economic Community accepts maximum contents of 2,500 mg.kg^{-1} DM. In Sweden, the values can reach up to 10,000 mg.kg^{-1} DM, so that sewage sludge from treatment stations can be incorporated to the soil (Fernandes et al., 1993).

According to international standards, the Zn content in soils varies from 1.5 to 264 mg.kg^{-1} (Souza et al., 1996) The Zn critical levels are between 70 to 400 mg.kg^{-1} (Kabata-Pendias and Pendias, 1984).

In general, the 50% of RH + 50% of BC treatment is the best for the nutrition of coffee trees, reducing the excessive Mn to an adequate level and the Zn from an adequate low to an adequate average level.

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RESUMO

Estudou-se o efeito do biossólido compostado (BC), da casca de arroz carbonizada (CA) e das misturas na produção de mudas de *Coffea arabica L. cv* Catuaí Vermelho, IAC-99, em tubetes. O experimento foi instalado em viveiro para avaliar os teores de Co, Ni, Cr, Pb, Cd, Cu, Mn e Zn na raiz, caule e folha. O delineamento experimental utilizado foi o inteiramente casualizado, com cinco tratamentos e quatro repetições. Os maiores teores de Cr, Co, Ni, Pb, Cu e Zn foram encontrados na raiz e o maior de Mn na folha. O teor de Zn na folha foi de adequado médio a adequado alto em plantas desenvolvidas em BC ou em suas misturas. Em plantas desenvolvidas em CA o teor de Mn foi superior cerca de quatro vezes a concentração considerada adequada. Os teores de Ni, Co, Cr, Pb e Cu verificados nas folhas podem ser considerados normais segundo padrões internacionais. O tratamento melhor para a nutrição do cafeeiro foi 50% de CA + 50% de BC.

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