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RESEARCH PAPER

Foliar fertilization in the propagation of conilon coffee in alternative substrates

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Abstract

S.S. Berilli, R.A. Sales, H.R. Ribeiro, A.A.F. Zooca, R. A. Salles, A.P.C.G. Berilli, W.R. Ribeiro, S.J. Freitas, and T.S. Costa. 2020. Foliar fertilization in the propagation of conilon coffee in alternative substrate. Int. J. Agric. Nat. Resour. Tannery sludge has been highlighted for substrate use in the propagation of seedlings, combining the solution of an environmental problem with its potential for agronomic use. However, when a new fertilizer component enters into the composition of a substrate, it remains to be seen whether other characteristics are affected. Thus, the objective of this work was to verify whether supplementary foliar fertilization is necessary when using a substrate with tannery sludge in the propagation of conilon coffee seedlings of the variety "Vitótria Incaper - 8142". A 2×13 factorial arrangement was used, the first factor being the presence or absence of conventional leaf fertilization, and the second factor being the 13 coffee conilon Vitoria-Incaper 8142 genotypes arranged in a randomized complete block design with four replications. The genotypes V7 and V9 presented leaves of reduced size, leading to a smaller leaf area, which coincided with a lower accumulation of aerial and total dry matter mass. Higher flavonoid indexes were found in the genotypes V1, V2, V6, and V13, indicating a higher sensitivity of these materials to the components present in the tannery sludge. In general, fertilization provided better initial development as well as a better seedling quality index.

Keywords: *Coffea canephora*, physiology, propagation, sustainability.

Introduction

The constant production of solid waste generated by industries has become the primary source of pollution worldwide. Silva *et al*. (2019) suggested that if not properly disposed of, solid waste can cause severe damage to the environment. According to the authors, one of the possible solutions would be the reutilization of solid waste, for example, as an alternative substrate,

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generating savings and, above all, improvements for the environment.

The use of organic residues in agriculture has increasingly aroused the attention of researchers and led to increased efforts to demonstrate their effects on several species of interest, with the objective of reducing the environmental impact generated by the disposal of these materials (Restrepo *et al*., 2013; Sales *et al*., 2017). There is a strong potential for the use of industrial residues, which are strongly correlated with the growth and physiology of agricultural plants, as observed by Oberpaur *et al.* (2012), Sales *et al*. (2018a), Berilli *et al*. (2018a) and Quartezani *et al*. (2018).

Among organic residues, it is possible to highlight the tannery sludge generated by the leather processing industries, which presents enormous potential for use in agriculture. This residue contains a high content of organic matter and mineral elements, which are essential for the development of plants (Tavares *et al*., 2013; Berilli *et al*., 2018b). It can be used both in liquid and solid form and incorporated into substrates for use in the propagation of seedlings (Sales *et al*., 2018b; Berilli *et al*., 2018b).

The coffee industry in Brazil is fundamentally important for economic and social development; the productivity of the workforce, job security, the generation of jobs, and tax collection are particularly important (Ferrão *et al*., 2008). According to data compiled by CONAB (2018), Brazil is the world's largest producer and exporter of coffee, with an estimated harvest of 58 million bags in 2018, 24% of which is conilon coffee (*Coffea canephora* Pierre).

The conventional method of conilon coffee seedling production depends on complementary foliar fertilization through leaves. However, there are no studies that show the effect of foliar fertilization when alternative substrates, such as tannery sludge, are used. It is known that tannery sludge is a nutrient-rich component that can be made available to plants over long periods, (Araújo *et al*., 2008), thus serving as a replacement for foliar fertilization. The objective of this work was to verify whether supplementary foliar fertilization is necessary when using a substrate with tannery sludge in the propagation of conilon coffee seedlings of the variety "Vitótria Incaper - 8142".

Material and Methods

The experiment was carried out at the seedling propagation nursery of the Federal Institute of Education, Science and Technology of Espírito Santo, Campus Itapina, located in the municipality of Colatina, ES (19° 32' 22" S, 40° 37' 50" W; 71 meters above sea level). The climate of the region is Tropical Aw, according to the climatic classification of Köppen, with a well-defined rainy season between October and January and an average climatological precipitation of 1029.9 mm (Sales *et al*., 2018c). A 2×13 factorial arrangement was used, considering the presence or absence of conventional foliar topdressing fertilization as the first factor. The second factor was the 13 conilon coffee genotypes. The treatments were arranged in a complete randomized block design with four replicates. Each treatment contained seven seedlings, totaling 182 plants per block, and 728 plants in all the experiments.

The substrate was prepared 30 days in advance in the following composition: 20% dehydrated tannery sludge, 30% humus and 50% red ravine soil. After the homogenization of the components, 600 ml polyethylene bags were filled, and beds were formed.

Seedlings of coffee conilon (*C. canephora*) were obtained from the variety "Vitória Incaper 8142" (13 genotypes) produced at the aforementioned institute. The seedlings were obtained from cuttings of orthotropic branches of adult tissue, removed from crops with adequate phytosanitary and nutritional characteristics. After the removal of the branches of the mother plants, they were moved to the greenhouse, where 30 cm of the ends of the orthotropic branches were removed. Then, the cuttings were standardized between 6 and 8 cm in height, leaves with 1/3 of the leaf area, plagiotropic branches and 1 cm retained above the leaf pair insertion. The cuttings were planted as soon as they were prepared in a previously wetted substrate.

The seedlings underwent foliar fertilization (three applications) with nitrogen and potassium using 0.3 g of urea and 0.3 g of potassium chloride, filled to a 100 mL volume with water. This solution contained 1.35 g L^{-1} of N and 1.80 g L^{-1} of K_2O, which were used in this experiment because they represent the conventional fertilization regime for the production of coffee seedlings in commercial nurseries. The first application occurred shortly after the emergence of the second pair of leaves; the subsequent applications occurred every 30 days.

The tannery sludge used in the experiment was supplied by the company Capixaba Couros LTDA, located in the municipality of Baixo Guandu, state of Espírito Santo. The residue underwent laboratory analysis to determine the values of the chemical parameters shown in Table 1.

Table 1. Result of the solid organic substrate analysis used in the experiment

Parameter	Unit	Content
Total organic matter	(g dm^{-3})	293.60†
Compostable organic matter	(g dm^{-3})	110.20
Organic carbon	%	6.12
C/N ratio	-	3/1
Nitrogen	(g dm^{-3})	17.30
Phosphorus	(g dm^{-3})	5.20
Potassium	(g dm^{-3})	0.60
Calcium	(g dm^{-3})	226.90
Magnesium	(g dm^{-3})	15.30
Sulfur	(g dm^{-3})	13.20
Sodium	(g dm^{-3})	5.50
Chromium	(g dm^{-3})	37.00
Boron	(g dm^{-3})	0.26

†Results based on dry matter (mass/mass)

The experiment lasted 150 days, during which time the plants reached a commercial size. The following characteristics were evaluated: leaf number (LN), plant height (height), stem diameter (SD), and leaf area (LA) measured with the aid of the LI-3100C (LI-COR, Nebraska USA) device. The leaf chlorophyll index was measured by a SPAD-502-PLUS (Konica Minolta, Japan). In addition, the dry matter mass of the aerial part (APDM*m*), root dry matter mass (RDM*m*) and total dry matter mass (TDM*m*) were evaluated. The dry matter mass was obtained by incubating the material in a forced air circulation oven at 72 °C for 72 h and then weighing it on a precision analytical scale. After obtaining these data, the leaf area ratio (LAR), obtained through Eq. 1, was calculated in cm^2 g^{-1}, and the Dickson Quality Index (DQI) of the seedlings was obtained by Eq. 2.

$$LAR = \left(\frac{LA}{TDMm}\right) \quad \text{- Eq. 1}$$

$$IQD = \frac{TDMm}{\left(\left(\frac{Height}{SD}\right) + \left(\frac{APDMm}{RDMm}\right)\right)} \quad \text{- Eq. 2}$$

In addition to the SPAD chlorophyll index and leaf area, the leaf physiology analyses were performed with a multiplex® (Force-A, France) fluorometer with multiple light excitation sources. The indexes of various compounds, such as nitrogen balance (NBI-R), total chlorophyll (SFR-R) and flavonoids (FLAV) were estimated. The analyses were performed in the morning between 9h00 a.m. and 11h00 a.m. and on only one side of the seedlings. The equipment was pointed toward the canopy, from top to bottom, at an angle of approximately 45 degrees.

The data were analyzed with an analysis of variance and F test and, when significant, a Scott-Knott test was used at a 5% significance level. R software was used for the analyses.

Results and Discussion

The V3 genotype of the "Vitória - Incaper 8142" variety was not analyzed in this experiment because of the low survival index of the seedlings (approximately 20%). According to Dardengo *et al*. (2010), this genotype is considered intrinsically difficult to propagate.

The analysis of variance in Table 2 indicates that there was no significant interaction between the factors studied (leaf fertilization x genotypes) for any of the characteristics evaluated in conilon coffee trees of the variety "Vitória - Incaper 8142". Therefore, only the simple effects of the factors (genotypes and foliar fertilization) on the developmental variables of the seedlings were analyzed.

A significant effect of the genotypes was observed (Table 2) for all of the characteristics evaluated, except for the number of leaves, plant height, and LAR index. These results show that the initial development is not uniform among the genotypes of the variety studied. According to Contarato *et al*. (2010), the genotypes of this variety are divided into two groups for initial development, with one group being superior over the other. Regarding the fertilization levels (Table 2), only the SPAD and LAR variables, together with the physiological variables of total chlorophyll, nitrogen balance and flavonoid index, did not have a significant effect; that is, foliar fertilization promoted the development of the conilon coffee seedlings but did not influence the evaluated physiological variables.

Table 3 shows the effect of conventional foliar fertilization on the development of conilon coffee seedlings. Except for the SPAD (Table 3) and leaf area ratio (Table 4) variables, all the other evaluated characteristics showed significant increases in the treatments that received foliar fertilization. This highlights the importance of complementary fertilization even on an alternative substrate with the use of tannery sludge,

Table 2. Summary of the analysis of variance of the characteristics of "Vitória Incaper 8142" conilon coffee seedlings: plant height (Height), stem diameter (SD), leaf number (LN), leaf area (LA), leaf chlorophyll index (SPAD), mass of the dry matter of the aerial part of the plant (APDM*m*), root dry matter mass (RDM*m*), total dry matter mass (TDM*m*), leaf area ratio (LAR), Dickson quality index (DQI), total chlorophyll (SFR-R), nitrogen balance index (NBI-R) and flavonoid index (FLAV).

Source of variation	DF	Mean square (QM)						
		Height (cm)	SD (mm)	LN	LA (cm²)	SPAD	APDM*m* (g)	RDM*m* (g)
Genotypes	11	15.95^{ns}	0.506**	3.73^{ns}	7902**	112.81**	0.97**	0.11**
Foliar fertilization	1	142.67**	1.83**	54.05**	65216**	4.86^{ns}	8.81**	0.42**
Genotype × foliar f.	11	5.79^{ns}	0.19^{ns}	2.12^{ns}	2976^{ns}	19.24^{ns}	0.29^{ns}	0.05^{ns}
Residue	69	8.28	0.17	3.09	2578	15.84	0.36	0.05
Overall mean		13,83	3,50	8,39	211,18	31,77	3,43	0,70
CV%		20.94	11.88	21.41	24.04	12.56	20.69	30.49
Source of variation	DF	TDM*m* (g)	LAR (cm² g^{-1})	DQI	SFR-R	NBI-R	FLAV	
Genotypes	11	1.65*	75.96^{ns}	0.04**	0.49*	3.98*	0.08**	
Foliar fertilization	1	13.04**	79.75^{ns}	0.10**	0.05^{ns}	0.43^{ns}	0.001^{ns}	
Genotype × foliar F.	11	0.94^{ns}	90.03^{ns}	0.02^{ns}	0.19^{ns}	0.48^{ns}	0.01^{ns}	
Residue	69	0.57	173.83	0.01	0.24	0.91	0.001	
Overall mean		3.59	60.14	0,44	2.83	2.53	0.30	
CV%		21.02	21.92	26.95	17.22	37.65	27.17	

*Significant at 5% probability ($p < 0.05$), **Significant at 1% probability ($p < 0.01$), ns: not significant.

which is rich in nutrients and organic matter. It is important to highlight plant height and leaf area, which showed increases of 16% and 26%, respectively, compared to the treatment that did not receive fertilization.

Table 3. Mean values of plant height (Height), stem diameter (SD), leaf number (LN), leaf area (LA), and leaf chlorophyll index (SPAD) of "Vitória Incaper 8142" conilon coffee seedlings, with and without fertilization

Fertilization	Height (cm)	SD (mm)	LN	LA (cm^2)	SPAD
Without	12.52 b	3.38 b	7.45 b	176.70 b	31.92 a
With	14.96 a	3.66 a	8.96 a	239.97 a	31.47 a

The means followed by the same letter are not different from each other at a 5% probability level ($p<0.05$) according to a Scott-Knott test.

The leaf area ratio is a measure related to the increase in the dry matter per leaf area; thus, although leaf fertilization provided higher values of dry matter, it also increased the leaf area, which generated a ratio proportional to that in the treatment without fertilization (Table 4).

Table 4. Mean values of the dry matter of the aerial parts of the plants (MSA*m*), root dry matter mass (MSR*m*), total dry matter mass (MST*m*), Dickson quality index (DQI) of the seedlings and leaf area ratio (LAR) of "Vitória Incaper 8142" conilon coffee seedlings, with and without leaf fertilization

Fertilization	APDM*m* (g)	RDM*m* (g)	MST*m* (g)	DQI	LAR (cm^2 g^{-1})
Without	2.59 b	0.63 b	3.22 b	0.41 b	59.22 a
With	3.20 a	0.76 a	3.96 a	0.48 a	61.05 a

The means followed by the same letter are not different from each other at a 5% probability level ($p<0.05$) according to a Scott-Knott test.

Despite the greater amount of nitrogen in the treatment that received foliar fertilization, no increases were observed in the chlorophyll indexes (Table 3 and Table 5). However, greater average values of leaf number and consequently of leaf area were found, resulting in greater photosynthetic capacity, which in turn provides higher carbon fixation, thus explaining the greater stem diameter and height (Table 3) and higher total dry matter mass (Table 4).

Table 5. Mean values of chlorophyll (SFR-R), nitrogen balance (NBI-R), and flavonoids (FLAV) obtained by using a Multiplex® device with "Vitória Incaper 8142" conilon coffee seedlings, with and without leaf fertilization

Fertilization	SFR-R	NBI-R	FLAV
Without	2.85 a	2.60 a	0.30 a
With	2.80 a	2.47 a	0.31 a

The means followed by the same letter are not different from each other at a 5% probability level ($p<0.05$) according to a Scott-Knott test.

Foliar fertilization contributed to significant gains in dry matter mass (Table 4), both to the aerial part of the plant and to the root system. The dry matter masses of the roots and aerial parts of the plants were greater by 17% and 19%, respectively, than those in the plants without fertilization. Fertilization also led to the seedlings having higher quality indexes, which is a fundamental characteristic for the adequate development of the seedlings when transplanted to the field.

Foliar fertilization did not lead to any differences in the variables obtained by the Multiplex®, as shown in Table 5. This result shows that despite improving the gain in several developmental characteristics, such as plant height, leaf area, and dry matter, fertilization did not change the secondary metabolism or the chlorophyll or nitrogen balance indexes of the seedlings.

It is important to emphasize that foliar fertilization did not influence nitrogen balance, even though the plants that received the applications showed improvements in several characteristics, including the seedling quality index (Table 4). These results can be explained by the nitrogen balance, which is measured by an indirect correlation of the chlorophyll content in the leaves and did not present differences (Table 3 and Table 5). Therefore, this indicates that the nitrogen supplied by the foliar fertilization did not lead to a more significant amount of nitrogen per unit of leaf area but instead led to increases in other components of the plants, such as proteins, enzymes, ATP and NADPH, which promoted the optimal vegetative development and, consequently, seedlings of a better quality.

Among the variables analyzed in Table 6, only the stem diameter and SPAD index differed among the genotypes. For the stem diameter, genotypes V1, V2, V4, V6, V10, and V11 presented the best averages, ranging from 3.56 to 3.82 mm, which is at least 5% higher than all the other genotypes evaluated. These results are similar to those found by Covre *et al.* (2013), in which stem diameter was assessed after the initial development of the 13 genotypes in a conventional substrate composed of soil, cattle manure and chemical fertilizer. The genotypes V1, V2, V3, V4, V8, V9, V10, V11, and V12 had remarkably high stem diameters. The small divergence between these experiments can be attributed to the different responses that genotypes can express when grown in different substrates.

Regarding the SPAD index (Table 6), genotypes V9 and V11 stood out as having the highest average values. Thus, it can be inferred that the V11 genotype presents a more considerable amount of chlorophyll and, consequently, accumulated nitrogen in the leaves, since the chlorophyll molecule is formed by a central magnesium atom bound to four nitrogen atoms (Streit *et al.*, 2005), with a higher average chlorophyll index observed for the genotype (Table 8).

It should be noted that the number of leaves of genotype V9 did not differ from that of the other genotypes; however, genotype V9 presented a smaller leaf area over the same number of leaves, meaning that the leaves of this genotype had a reduced size. This generates the hypothesis that this condition allowed the concentration of the chlorophyll molecules in a smaller area, causing a high SPAD value due to the concentration and dilution effect. The authors Sales *et al.* (2018b), after applying doses of tannery sludge via leaves in conilon coffee plants, observed a linear increase in the number of leaves. However, they noted that there was a reduction in leaf area for the dose that maximized the gain (15.77 mL L^{-1}) and attributed this fact to the reduced leaf size, as observed in this experiment. Hence, it is possible to conclude that the use of tannery sludge in conilon coffee plants tends to increase the number of leaves and reduce the leaf area of the seedlings. In terms of

Table 6. Mean values of plant height (Height), stem diameter (SD), leaf number (LN), leaf area (LA), and leaf chlorophyll index (SPAD) of "Vitória Incaper 8142" conilon coffee seedlings

Genotypes	Height (cm)	SD (mm)	LN	LA (cm^2)	SPAD
V1	14.66 a	3.61 a	9.70 a	250.73 a	27.45 b
V2	14.21 a	3.82 a	8.15 a	208.73 a	29.44 b
V4	13.60 a	3.65 a	7.32 a	192.83 a	29.97 b
V5	10.94 a	3.46 b	8.29 a	217.41 a	28.70 b
V6	13.73 a	3.96 a	8.76 a	236.06 a	29.95 b
V7	14.01 a	3.26 b	7.80 a	161.45 b	31.15 b
V8	14.30 a	3.41 b	7.95 a	223.53 a	31.43 b
V9	11.87 a	3.08 b	8.27 a	143.48 b	40.34 a
V10	14.85 a	3.56 a	7.56 a	192.83 a	31.05 b
V11	15.98 a	3.73 a	9.07 a	233.93 a	38.07 a
V12	12.54 a	3.30 b	8.05 a	212,24 a	30.83 b
V13	14.24 a	3.43 b	7.58 a	220.55 a	31.93 b

The means followed by the same letter are not different from each other at a 5% probability level ($p<0.05$) according to a Scott-Knott test.

the survival of seedlings grown in full sun, this characteristic is favorable, since leaves with high leaf areas tend to experience more evapotranspiration (Damatta & Rena, 2000).

Furthermore, the number of leaves of genotype V11 is not different from that of the other genotypes; nevertheless, V11 is among the genotypes that have relatively high leaf areas (Table 6). Consequently, this results in larger leaves and, combined with the high SPAD index value, provides a greater capacity to absorb radiation, which results in a higher photosynthetic rate. This result can be seen in Table 7; genotype V11 had the highest carbon uptake (i.e., the greatest mass of total dry matter).

Table 7 shows the values of the dry matter mass divided into the aerial parts of the plants, the roots, and the total mass. Concerning the aerial parts of the plants, smaller averages were found for genotypes V4, V7 and V9 than for the other genotypes. These genotypes also presented the lowest average values for the root systems, together with V12 and V13.

The values of the root dry mass obtained in this experiment ranged from 0.50 to 0.95 g, according to the genotypes analyzed. Genotype V8 presented a value of 0.78 g, close to that found by Berilli *et al.* (2018b), in which a mean value of 0.85 g was discovered for the same genotype after cultivating plants in substrate with the addition of 20% tannery sludge, 20% humus and 50% soil for 210 days.

When the total dry matter mass was evaluated (Table 7), it was observed that genotypes V4, V7 and V9 had the lowest values. Genotypes V7 and V9 presented values of 3.06 and 2.60 g of total dry matter mass, which were lower than that of V11 by more than 29% and 39%, respectively. Hence, the smaller leaf area obtained by genotypes V7 and V9 (Table 6) interfered with the mass production of total dry matter, that is, carbon fixation. This is because the leaf area of a plant is mainly responsible for the photochemical stage of the plants, generating energy and consequently participating in the production of photoassimilates, which will be responsible for maintenance and growth (Sales *et al.*, 2017).

The values of the total dry matter mass found in this study were higher than those obtained by

Table 7. Mean values of the dry matter mass of the aerial parts of the plants (APDM*m*), root dry matter mass (RDM*m*), total dry matter mass (TDM*m*), Dickson quality index (DQI) of the seedlings and leaf area ratio (LAR) of "Vitória Incaper 8142" conilon coffee seedlings

Genotypes	APDM*m* (g)	RDM*m* (g)	TDM*m* (g)	DQI	LAR (cm^2 g^{-1})
V1	3.18 a	0.75 a	3.93 a	0.47 a	65.97 a
V2	3.09 a	0.76 a	3.84 a	0.49 a	56.03 a
V4	2.62 b	0.63 b	3.26 b	0.41 b	61.22 a
V5	2.91 a	0.74 a	3.65 a	0.51 a	59.45 a
V6	2.97 a	0.72 a	3.69 a	0.48 a	62.62 a
V7	2.48 b	0.58 b	3.06 b	0.36 b	62.37 a
V8	3.01 a	0.78 a	3.79 a	0.47 a	59.07 a
V9	2.10 b	0.50 b	2.60 b	0.32 b	55.21 a
V10	3.30 a	0.75 a	4.05 a	0.47 a	59.91 a
V11	3.31 a	0.95 a	4.26 a	0.56 a	57.19 a
V12	2.93 a	0.64 b	3.56 a	0.43 b	59.99 a
V13	2.86 a	0.58 b	3.45 a	0.38 b	63.17 a

The means followed by the same letter are not different from each other at a 5% probability level ($p<0.05$) according to a Scott-Knott test.

Berilli *et al*. (2014). These authors cultivated conilon coffee seedlings in a conventional substrate (soil + cattle bovine manure + sand in 1:1:1 ratio); 120 days after planting, a total dry matter mass of 2.38 g was obtained. However, the experiment was kept in the field for 30 days less, which contributed to the lower results.

The best values of the Dickson quality index for the seedlings (Table 7) were obtained for genotypes V1, V2, V5, V6, V8, V10, and V11. It is worth mentioning that this index takes into account the balance in the distribution of biomass throughout the plant. In addition, the higher the index, the better the quality of the seedlings. No statistically significant differences were observed for the leaf area ratio. This shows that, in general, the genotypes used in the study presented the same increase in dry matter per unit of leaf area.

Table 8 shows that for the chlorophyll index, higher values were observed for genotypes V9 and V11. This confirms the values obtained by the SPAD (Table 3), for which the same genotypes had the highest averages. For the flavonoid index, genotypes V1, V2, V6, and V13 stand out as having higher average values than the other genotypes. The higher production of this secondary metabolite by these genotypes may indicate their sensitivity to the chromium and sodium found in the tannery sludge, which can accumulate in the different tissues of the plants and may lead to changes in the chloroplasts (Berilli *et al*., 2016; Berilli *et al.,* 2018c).

According to Kandil *et al*. (2004), stressed plants tend to produce a greater amount of flavonoids as well as other polyphenols. Thus, the amount of chromium and sodium present in the substrate was sufficient to raise the levels of this compound in genotypes V1, V2, V6, and V13, although they did not cause toxicity since these genotypes showed proper growth and good quality. Greater results were found by Quartezani *et al*. (2018) for V2, with values of 0.63 for the flavonoid index, using substrates with 85% soil and 15% tannery sludge (v/v).

Hence, the use of foliar fertilization in seedlings is necessary, since it guaranteed a greater leaf area of the plants as well as a greater accumulated total dry matter, reaching increases of more than 20% compared to those in the plants without fertilization. According to the recommendations of

Table 8. Mean values of chlorophyll (SFR-R), nitrogen balance (NBI-R), and flavonoids (FLAV) obtained by using a Multiplex® device with "Vitória Incaper 8142" conilon coffee seedlings

Genotypes	SFR-R	NBI-R	FLAV
V1	2.62 b	1.82 c	0.45 a
V2	2.65 b	2.01 c	0.42 a
V4	2.54 b	2.74 b	0.20 c
V5	2.80 b	2.37 c	0.22 c
V6	2.88 b	1.40 c	0.46 a
V7	2.88 b	3.45 a	0.19 c
V8	2.93 b	2.90 b	0.21 c
V9	3.46 a	3.95 a	0.22 c
V10	2.77 b	2.15 c	0.30 b
V11	3.15 a	2.87 b	0.26 b
V12	2.70 b	2.25 c	0.31 b
V13	2.68 b	2.51 c	0.39 a

The means followed by the same letter are not different from each other at a 5% probability level ($p<0.05$) according to a Scott-Knott test.

CEPLAC (2018), foliar fertilization is necessary for coffee plants soon after the emergence of the second pair of leaves. In addition, tannery sludge added to the substrate appeared to be an excellent alternative to coffee seedling producers, since no toxicity was observed in the seedlings.

Leaf fertilization provided the most significant improvements for all the evaluated growth characteristics, leading to the best qualities in the plants. Nevertheless, it did not exert a significant effect on the secondary metabolism or chlorophyll indexes. The V7 and V9 genotypes presented smaller leaf areas, which resulted in less carbon fixation and lower total dry matter masses. Despite the greater indexes of flavonoids in genotypes V1, V2, V6, and V13, no deleterious effects were found in the total dry matter mass gain.

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Resumen

S.S. Berilli, R.A. Sales, H.R. Ribeiro, A.A.F. Zooca, R. A. Salles, A.P.C.G. Berilli, W.R. Ribeiro, S.J. Freitas, y T.S. Costa. 2020. Fertilización foliar en la propagación de café conilon en sustrato alternativo. Int. J. Agric. Nat. Resour. El lodo de curtiembre se ha destacado para el uso de sustratos en la propagación de las plántulas, combinando la solución de un problema ambiental con su potencial para el uso agronómico. Sin embargo, cuando un nuevo componente de fertilizante entra en la composición de un sustrato, queda por ver si otros tractos culturales se ven afectados. Por lo tanto, El objetivo de este trabajo fue verificar si la fertilización foliar suplementaria es necesaria cuando se usa sustrato con lodo de curtiduría en la propagación de plántulas de café conilon de la variedad “Vitótria Incaper - 8142”. Se utilizó una disposición factorial de 2×13, siendo el primer factor la presencia o ausencia de fertilización foliar convencional, y el segundo factor fue el de 13 genotipos de conilón de café Vitoria-Incaper 8142 dispuestos en un diseño de bloques completos al azar con cuatro repeticiones. Los genotipos V7 y V9 presentaron hojas de tamaño reducido que dieron un área foliar más pequeña, y eso coincidió con una menor acumulación de masa aérea y de materia seca total. Se encontraron índices de flavonoides más altos en los genotipos V1, V2, V6 y V13, lo que indica una mayor sensibilidad de estos materiales a los componentes presentes en el lodo de curtiembre. En general, la fertilización proporcionó un mejor desarrollo inicial, así como un índice de mejor calidad de las plántulas.

Palabras clave: *Coffe canephora*, fisiología, propagación, sostenibilidad.

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