

Original Research Article

Utilization of agricultural residues as alternative substrates in the production of Conilon coffee seedlings

ABSTRACT

Research related to the use of agricultural residues as alternatives to commercial substrates has become fundamental for reducing the production costs of coffee seedlings. The objective of this study was to evaluate the growth variables of Conilon coffee seedlings produced in tubes with substrates composed of coffee straw, increasing levels of drying residue from coffee-bean processing (*moinha*), and decreasing amounts of coconut fiber and pine bark, replacing the use of commercial substrate alone. The experimental design was a completely randomized design with six treatments and six replications, comprising five treatments with increasing proportions of *moinha*, decreasing amounts of coconut fiber and pine bark (0/20/50, 10/15/45; 20/10/40, 30/05/35, and 40/0/30%), and fixed proportions of coffee straw (30%) and one treatment with Bioplant commercial substrate (control). Evaluations of the variables were performed at 118 days after sowing (DAS) and consisted of determining the leaf number, plant height, stem diameter, and values of shoot, root, and total plant dry matter. The use of 40% *moinha* + 30% coffee straw + 30% pine bark is recommended as an alternative to the commercial substrate for the production of Conilon coffee seedlings in tubes.

Keywords: coffee moinha, coffee straw, coconut fiber and pine bark.

1. INTRODUCTION

The use of good quality seedlings is one of the most important steps in the process of planting coffee plantations. At this stage, the substrate used is one of the main factors related to seedling quality. According to [1], the substrate should provide efficiency in germination and emergence of seedlings, an adequate supply of nutrients and oxygen, and elimination of CO₂. In addition, [2] emphasize the need for adequate water retention so that the germination process can take place in the best possible way and is able to supply the water and nutritional needs of the plant during its growth and development.

The most frequently used coffee seedling types are those produced in polyethylene plastic bags with substrate composed of soil and cattle manure and enriched with chemical fertilizers and those produced in polyethylene tubes using commercial substrate. According to [3], the use of commercial substrate has been growing considerably due to the occurrence of phytonematodes in some regions and the great demand for seedlings.

In order to reduce the costs incurred when using commercial substrates, the use of agricultural residues generated in each region becomes an economically interesting alternative for the production of coffee seedlings. In addition, it is a way to minimize the environmental impact caused by the incorrect disposal of these wastes in the environment.

Among the residues generated in large quantities in the Espírito Santo state with potential to be used in the composition of alternative substrates for the production of Conilon coffee seedlings in tubes, coffee *moinha*, coffee straw, coconut fiber, and pine bark stand out. Due to attributes such as the ease of drainage of pine bark [4], high porosity and the presence of micropores, which are responsible for good aeration and retention of water in the coconut fiber environment [5], and the organic matter and natural source of potassium and nitrogen in coffee straw, by the potential fertilizer, especially the nitrogen present in the *moinha* [6,7], such residues become interesting in the composition of alternatives to commercial substrate. Among these residues, coffee *moinha* and straw are generated and discarded in great quantities in Espírito Santo state when compared to coconut fiber and pine bark. In this sense, the higher the amount of *moinha* instead of coconut fiber and pine bark in the composition of the alternative substrate, the lower the costs in this stage of production without any damage to the quality of the seedlings. In this case, it is necessary to know the proportions of *moinha*, coconut fiber, and pine bark in the composition of the alternative substrate that will provide better quality Conilon coffee seedlings for planting. The objective of this study was to evaluate the growth variables of Conilon coffee seedlings grown in tubes with substrates composed of coffee straw and increasing levels of residues from the drying of coffee beans (*moinha*) and decreasing amounts of coconut fiber and pine bark, replacing the use of commercial substrate alone.

2. MATERIAL AND METHODS

The experiment was implemented and conducted from November 2016 to March 2017 at the coffee seedlings nursery of Demuner Farm, located in the municipality of São Roque do Canaã, Espírito Santo state, Brazil, at the geographical coordinates of latitude 19° 49' south, longitude 40° 38' west and altitude of 130 m above sea level.

The climate, according to the Köppen classification, is Cwa type (subtropical with dry winter), with an average annual temperature of 24.6 °C and annual average precipitation ranging from 700 to 1,200 mm. The air temperature and relative humidity during the experimental period varied in the ranges of 19.9–38.2 °C and 47.5–69.5%, respectively.

The residues used in the alternative substrates for the production of coffee seedlings were obtained from the drying process of coffee beans, also known as *moinha*, coffee straw, coconut fiber, and pine bark. The coffee *moinha* and straw were generated on the farm where the experiment was implanted, since coconut fiber and pine bark were commercially acquired.

The chemical and physicochemical characterization of residues used in the composition of the substrates for the production of coffee seedlings was carried out at the Water Quality and Solid Residues Laboratory of IFES, Santa Teresa campus. The physical-chemical analysis consisted of the determination of the electrical conductivity (EC) using a bench conductivity meter. The chemical analysis was based on the determination of the pH by means of a benchmark and the quantification of concentrations of easily oxidizable organic carbon (OC_{eo}), total organic carbon (OC_t), total nitrogen (N_t), phosphorus (P), and potassium (K), following the methodology described by [8].

Table 1 shows the chemical and physicochemical attributes of the *moinha* (MO), the coffee straw (CS), the coconut fiber (CF), and the pine bark (PB) used in the experiment.

87 **Table 1. Chemical and physical-chemical attributes (EC) of the coffee *moinha* (MO),**
 88 **coffee straw (CS), coconut fiber (CF), and pine bark (PB) used in the experiment**
 89

Residues	pH	EC dS m ⁻¹	OC _{eo}	OC _t	N _t	P	K	Ca
-----dag kg ⁻¹ -----								
MO	5.60	6.49	45.3	58.9	3.7	0.14	0.71	–
CS	–	–	–	–	1.79	0.13	1.99	0.44
CF	7.15	0.09	57.1	74.1	0.66	0.05	0.14	–
PB	5.5	0.00113	37.0	48.0	0.40	0.10	0.17	–

90 *pH* – Hydrogen potential in water; *EC* – Electrical conductivity; *OC_{eo}* – easily oxidizable organic carbon;
 91 *OC_t* – total organic carbon; *N_t* – total nitrogen; *P* – phosphorous; *K* – potassium
 92

93 The experimental design was a completely randomized design with six treatments and six
 94 replications. Five treatments contained increasing proportions of *moinha* and decreasing
 95 proportions of coconut fiber and pine bark (0/20/50, 10/15/45; 20/10/40, 30/05/35, and
 96 40/0/30%) and fixed proportions of coffee straw (30%) and one treatment comprised
 97 Bioplant® commercial substrate (control), as described in Table 2. Each experimental unit
 98 contained 18 seedlings, giving a total of 648 seedlings throughout the experiment.
 99

100 **Table 2. Description of applied treatments**
 101

T0	Commercial substrate (Bioplant®)			
Alternative Substrate	<i>Moinha</i>	Coffee straw	Coconut fiber	Pine bark
T1	0	30	20	50
T2	10	30	15	45
T3	20	30	10	40
T4	30	30	5	35
T5	40	30	0	30

102 The seedlings were arranged in trays in vertical rows of 18 tubes. For each replication, there
 103 were 12 border six on each side, with the six central seedlings of the row being evaluated,
 104 so that a total of 216 seedlings were evaluated during the experiment.
 105

106 In all treatments, 2 g of Osmocote® (slow release fertilizer) per tube was used, which was
 107 necessary for the best development of seedlings during the 118 days of development. In
 108 addition, two ratification fertilizations were carried out, the first at 50 days and the second at
 109 100 DAS the plantlets.

110 The genotype used in this research was the LB1 clone from Conilon coffee. LB1 clone was
 111 selected because of its wide acceptance in the region.

The plantlets were obtained from the orthotropic branch of the Conilon coffee tree cuttings and planted in 280-mL plastic tubes. Irrigation was performed daily, maintaining the field capacity of the substrates.

The experimental period in the field lasted 118 days, and the biometric and gravimetric variables were evaluated. The biometric variables evaluated were the number of leaves (NL), the seedling height (SH), and the stem diameter (SD). Among the gravimetric analyses, dry masses of the aerial part, root, and total seedlings were evaluated. To obtain the height of the above-ground part, a millimeter ruler was used and the measurement was taken from the base of the stem to the apical bud from which the last pair of leaves originated. The stem diameter was obtained using a precision digital caliper. To obtain the dry masses of the above-ground part and the root, the cuttings were done close to the substrate, carefully washing the roots in running water on a sieve. Then, the above-ground parts and the roots were packed in paper bags and placed in an oven with forced air circulation at 65 °C for 72 hours. Subsequently, the materials were weighed on an electronic precision scale with an accuracy of 0.01 g.

Due to the qualitative difference between the commercial substrate treatment (T0) and the treatments with alternative substrate (T1, T2, T3, T4, and T5), the comparison was done using the Dunnett test, comparing each of the alternative substrates with the commercial substrate.

An " α " value of 0.05 was used for all procedures and the statistical analysis was performed using Assistat 7.7 software [9].

3. RESULTS AND DISCUSSION

Table 3 presents the estimated mean values of seedling height (SH), number of leaves (NL), stem diameter (SD), shoot dry matter mass (SDMM), root dry matter mass (RDMM), and total dry matter mass (TDMM) in response to treatments containing different proportions of agricultural residues in the alternative substrate and the conventional substrate (control) for Conilon coffee seedlings at 118 DAS.

Table 3. Estimated means of number of leaves (NL), seedling height (SH), stem diameter (SD), shoot dry matter mass (SDMM), root dry matter mass (RDMM), and total dry matter mass (TDMM) in response to different treatments

Variables	TREATMENTS						α Error
	Commercial	T1	T2	T3	T4	T5	
	Substrate (T0)						
NL (un)	9.17	11.48*	10.14	9.80	10.22	10.42	0.0141
SH (cm)	20.10	21.68	21.09	21.73	23.51*	21.89	0.0413
SD (mm)	5.46	5.38	5.61	5.45	5.61	5.59	0.7326
SDMM (g)	3.10	3.30	3.22	3.08	3.41	3.32	0.4673
RDMM (g)	1.35	1.54	1.43	1.42	1.52	1.40	0.1565
TDMM (g)	4.46	4.84	4.65	4.50	4.93	4.73	0.3018

145 * Averages in the rows followed by an asterisk (*) differ from the control at the 5% probability level
146 according to the Dunnett Test

147 T0: Commercial substrate Bioplant® (control); T1: 0% coffee *moinha* + 30% coffee straw + 20%
148 coconut fiber + 50% pine bark; T2: 10% coffee *moinha* + 30% coffee straw + 15% coconut fiber + 45%
149 pine bark; T3: 20% coffee *moinha* + 30% coffee straw + 10% coconut fiber + 40% pine bark; T4: 30%
150 coffee *moinha* + 30% coffee straw + 5% coconut fiber + 35% pine bark; and T5: 40% coffee *moinha* +
151 30% coffee straw + 0% coconut fiber + 30% pine bark.

152
153 The number of leaves is a very important attribute for the good development of a crop, since
154 the photosynthetic process is the result of light interception and its conversion into light
155 chemical energy, which, in turn, depends on the number and size of the leaves as well as
156 their time in the plant [10]. According to Table 3, the value of NL obtained by treatment T1
157 (0% coffee *moinha* + 30% coffee straw + 20% coconut fiber + 50% pine bark) was
158 statistically higher than that obtained by the control (T0) and presented the highest value
159 (11.48 un). The other treatments containing increasing amounts of *moinha* and decreasing
160 amounts of coconut fiber and pine bark did not provide different results from the control with
161 regard to this variable. The NL values obtained when using the alternative substrates
162 (between 9.48 and 11.8 units.) can be considered satisfactory when compared with the
163 results obtained by [11] and [12]. [11], studying the use of dehydrated tanning sludge as a
164 substrate in the production of clonal Conilon coffee seedlings in polyethylene bags, did not
165 obtain a number of leaves greater than 9 units 120 days after planting the plantlets.
166 Equivalent values were obtained by [12], who studied sources and proportions of organic
167 material for the production of coffee seedlings (*Coffea arabica* L.) and obtained a maximum
168 value of 5.66 pairs of leaves (11.32 un) in humus substrate of earthworm at 95 days after
169 sowing (DAS) in the tubes. In the other hand, [3], when studying the production of Arabica
170 coffee seedlings in substrates with increasing proportions of organic material in commercial
171 substrate, presented results superior to those obtained this research, reaching values
172 ranging from 9.66 to 17 units. However, it must be considered that the authors performed the
173 evaluations at 210 DAS, a time well beyond that considered in this study (118 DAS).

174 One of the main characteristics observed by coffee seedlings producers to determine the
175 trade point is the height of the seedlings [11].

176 According to Table 3, only the T4 treatment (30% coffee *moinha* + 30% coffee straw + 5%
177 coconut fiber + 35% pine bark) gave a seedling height statistically superior to the control
178 according to the Dunnett test. The other treatments (T1, T2, T3, and T5) did not differ from
179 the control. Nevertheless, the SH results obtained in treatments with alternative substrates
180 (21.09 to 23.51 cm) were much higher than those obtained by some authors, evidencing the
181 potential of the residues used in the alternative substrates.

182 [13], when studying the growth and quality of Conilon coffee seedlings produced in different
183 containers, obtained mean values of plant height in tubes and bags filled with standard
184 substrate (70% sieved earth + 30% cattle manure + chemical fertilizers) of 8.15 cm and 9.61
185 cm, respectively, at 160 DAS. [14] obtained the highest plant height (9.76 cm) when the
186 cuttings were cultivated in organic compost consisting of grease residues (Organosuper®)
187 and cattle manure with litter (1:1 ratio) in bags of polyethylene at 125 DAS. [15], when
188 evaluating the initial development of Conilon coffee in clayey soils using seedlings produced
189 in Plantmax® + soil (1: 1 v/v ratio); homemade substrate (soil mixed with cattle manure and
190 sand in a ratio of 1: 1: 1 v/v/v); Plantmax® (mixture of organic matter of vegetable origin and
191 expanded vermiculite); and soil + coffee straw (1: 1 v/v ratio), obtained a maximum height of
192 6.4 cm at 140 DAS.

193 In the seedling phase, the stem diameter is a very important parameter to evaluate the
194 rusticity of the species [16], besides being one of the fundamental characteristics when
195 deciding whether the seedling is in the moment of the planting.

196 According to Table 3, it was observed that there was no significant difference in the variable
197 stem diameter (SD) between treatments with alternative and commercial (control)
198 substrates. The SD values obtained in treatments with alternative substrates (5.38 to 5.61

mm) were higher than those found by other authors. [17], when studying types of basal cuttings and substrates in the formation of clonal Conilon coffee plants, did not obtain values of stem diameter greater than 3.6 mm at 100 DAS. [15], when evaluating the initial development of Conilon coffee in clayey soils using seedlings produced in Plantmax® + soil (1: 1 v/v ratio); homemade substrate (soil mixed with cattle manure and sand in a ratio of 1: 1: 1 v/v/v); Plantmax® (mixture of organic matter of vegetal origin and expanded vermiculite); and soil + coffee straw (1: 1 v/v ratio), obtained a maximum stem diameter value of 3.9 mm at 140 DAS. Similarly, [13] obtained a maximum stem diameter of 3 mm in Conilon coffee seedlings grown in tubes at 160 DAS.

The dry biomass of the above-ground part is related to the quality and quantity of leaves [16]. This characteristic is important because the leaves constitute one of the main sources of photoassimilates and nutrients for adaptation of the seedlings.

There was no significant difference between the treatments with alternative substrates and the conventional (control) one for the variables of shoot dry matter mass (SDMM), root dry matter mass (RDMM), and total dry matter mass (TDMM) (Table 3) in Conilon coffee seedlings. In a similar way to the other variables, the results of SDMM, RDMM, and TDMM in the alternative substrates studied in this study were superior when compared to the results obtained by [13] and [11]. [13] did not obtain values for the above-ground, root, and total plant dry masses superior to 2, 1.5, and 4 g, respectively, for Conilon coffee seedlings grown in standard substrate tubes at 160 DAS. [11], when studying the use of dehydrated tanning sludge as a substrate in the production of clonal coffee plants from Conilon, did not obtain higher values than 1.92, 0.47, and 2.38 g, respectively, in seedlings produced in polyethylene bags at 120 DAS the cuttings.

In general, it is noted that any of the substrates containing different ratios of agricultural residues may be used as an alternative to the commercial substrate in the production of Conilon coffee seedlings, since most of the growth variables evaluated did not differ from those obtained with the control (commercial substrate). However, as the availability of *moinha* in the region is higher than the availability of coconut fiber and pine bark, the use of 40% *moinha* + 30% coffee straw and 30% pine bark is recommended as an alternative to the commercial substrate for the production of Conilon coffee seedlings in tubes.

Thus, the results obtained in this work suggest an alternative to the commercial substrate, which may reduce production costs and provide a suitable destination for agricultural residues such as coffee *moinha*, coffee straw, coconut fiber, and pine bark.

4. CONCLUSION

The use of 40% *moinha* + 30% coffee straw + 30% pine bark is recommended as an alternative to the commercial substrate for the production of Conilon coffee seedlings in tubes.

COMPETING INTERESTS

The authors state that there are no competing interests.

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