

Original Research Article

Pit dimensions in the early development of conilon coffee propagated by seeds and stacking

ABSTRACT

The knowledge about the interactions between pit dimensions and propagation methods can provide important information for the Conilon coffee crop, since these basic steps can influence the entire productive cycle of the tillage. The objective of this work was to infer the initial development (vegetative and radicular) of Conilon coffee propagated by seed and stake, and cultivated in pits with different dimensions. It was used a randomized block design with four replicates of three plants. The treatments were disposed in subdivided plots, where the plots represented two methods of propagation (seed and stacking), and the subplots three dimensions of pit (20x20x20 cm; 30x30x30 cm and 40x40x40 cm). The number of leaves, stem diameter, plant height, main root length, root volume, dry mass of aerial part and root, and relation aerial/root part, were evaluated at 18 months after transplanting. There was a significant interaction between the methods of propagation and the pit dimensions only for the number of leaves and root length, where in the smaller pits, the seedlings propagated by seed were superior to the clonal ones. The other variables analyzed presented significant differences only for the pit dimensions factor. The initial development of the Conilon coffee isn't influenced by the method of propagation. The dimension of the pit directly influences the initial development of the Conilon coffee Incaper 'Vitória 8142' clone number 10, and pits with largest dimensions provide an increase in the initial development of the plants.

Keywords: Coffea canephora, radicular system, aerial part, sexual and assexual porpagation, soil volume

1. INTRODUCTION

Brazil is the largest producer and exposter, and the second largest consumer of coffee in the world with production of about 55 million sacs benefited in 2016 [1]. The state of Espírito Santo presentes the second largest planted area in Brazil, amounting 385,54 thousand hectares cultivated and estimated production between 7,34 million and 8,43 million sacs benefited for the year of 2017. About 61,06% of this area is cultivated with Conilon coffee (*Coffea canephora*), making Espírito Santo the largest producer of the species in Brazil, with estimated production for 2017 from 4,61 to 5,30 million of sacs benefited [2].

Despite being the largest producer, Espírito Santo has had a sharp decline in Conilon coffee production in the last years [2]. This fact may be related to unfavorable climatic conditions and to the increase in the production cost of the activity. Labor is responsible for most of the

cost of production in coffee farming, which in the specie *Coffea arabica* can represent up to 32% of the total cost [3]. Labor costs were intensified in the coffee sector of Espírito Santo, where small properties with a sharp declivity predominate [4], a fact that makes mechanization unfeasible, increases the demand for labor and makes it difficult to manage the crop, especially in planting and harvesting.

The planting of Conilon coffee can be done semi-mechanically or manually, however, the biggest difficulty in this phase is opening the pits. It is common among the producers to practice manual pitting with the aid of hoes. This activity is time-consuming, demands a lot of labor, and has high physical attrition [5]. The time and labor expended to opening the pit are related to the topography, physical structure of this soil and especially to the pit dimension. According to the most common management recommendations for Conilon in Espírito Santo [6], the standard size used in the pitting for planting is 40x40x40 cm. This recommendation can raise the production cost due to excessive labor demand. Besides, few studies were done with the purpose of evaluating the interaction of pit dimensions and the radicular development, mainly due to the great difficulty in studying this part of the plant.

It is believed that the propagation method should be taken into account in the recommending of the pit dimensions. The plants propagated in a sexual way have a pivotal radicular system [7], which may have a greater capacity to break the coexisting walls of the pit and to exploit a larger volume of soil, even in small pits. However, the plants propagated by cuttings don't present a pivotal root, with formation of several lateral adventitious roots [7], which, generally, don't present good ability to break the cohesive walls of the pit.

In most commercial conilon coffee plantations it is used seedlings propagated by cuttings [8], because it is a physiologically viable method that guarantees the maximum homogeneity of the crops [9, 10]. However, [11] observed higher tolerance of seedlings propagated by seeds to water stress, when assessing the water deficit in the initial development of two conilon coffee cultivars. For this reason, in regions with low rainfall, the crops should come from seminiferous seedlings or, if clonal, should be irrigated, a fact that isn't always possible.

Information on the behavior of plants propagated by seeds and clones in different dimensions of pits can help producers choosing the best size to be used in each propagation method. Therefore, the objective of this work was to infer about the initial development (vegetative and radicular) of conilon coffee plants from seeds and cuttings, cultivated in pits with different dimensions.

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

The experiment was held in an experimental area of the Federal Institute of Espírito Santo - Campus Santa Teresa, at 138 meters height and coordinates 19°48'9"S and 40°40'32"W, in the period of april 2013 to October 2014. The area soil is classified as dystrophic red argisol. According to the Köppen classification, the climate of the region where the study area is located is of the Cwa type (subtropical dry winter) with temperature and average annual rainfall of 18°C and 845.2 mm, respectively.

The experimental delineation was a randomized block design with four replications. The experimental unit was represented by three pits containing one plant each. The treatments were arranged in subdivided plots, where the plots referred to the two methods of propagation (seed and cutting), and the subplots with three dimensions of pit (20x20x20 cm, 30x30x30 cm and 40x40x40 cm).

The seedlings used were of the variety Incaper 'Vitoria 8142' clone number 10. These seedlings were grown in polyethylene plastic bags with 260 cm³ of substrate, being it composed of the mixture of 70% of soil of B horizon, 22.5% of manure cattle, 2% of dolomitic limestone, 5% of simple super-phosphate and 0.5% of potassium chloride [12]. The pits were opened with the aid of a hoe, following the dimensions of each treatment, and in each pit was transplanted a seedling with six pairs of leaves.

80 The soil corrections and fertilization of planting and cover were performed according to the
 81 recommendations of [12] in function of the result of the soil chemical analysis, which is
 82 shown in Table 1. The irrigation was the same in all treatments and was performed by
 83 localized micro-sprinkler, with a four day irrigation shift, maintaining soil moisture always
 84 close to field capacity. The management (weeding, scrubbing, pest and disease control and
 85 conduction) was the same in all treatments and held according to the recommendations of
 86 [12], being the most common for conilon coffee in Espirito Santo.
 87

88 **Table 1. Soil chemical composition of the experimental area in two collection depths**

Parameter	0-20 (cm)	21-40 (cm)
pH (in H ₂ O)	6.4	5.4
Al exchangeable (cmolc dm ⁻³)	0.0	0.3
H + Al (cmolc dm ⁻³)	1.7	2.4
Ca (cmolc dm ⁻³)	2.0	0.8
Mg (cmolc dm ⁻³)	0.5	0.4
P Mehlich (cmolc dm ⁻³)	49.0	14.0
P remaining (mg L ⁻¹)	13.0	4.0
K (cmolc dm ⁻³)	97.0	47.0
S (cmolc dm ⁻³)	9.0	4.3
Organic matter (dag kg ⁻¹)	1.8	1.1
Fe (mg dm ⁻³)	85.0	123.1
Zn (mg dm ⁻³)	9.9	8.2
Cu (mg dm ⁻³)	3.2	2.9
Mn (mg dm ⁻³)	218.1	154.2
B (mg dm ⁻³)	4.1	4.2
Na (mg dm ⁻³)	34.1	17.5
Base saturation (V) (%)	61.8	35.5
CTC effective (cmolc dm ⁻³)	4.4	3.7
CTC at pH 7.0 (cmolc dm ⁻³)	6.0	5.2

90 The treatments were evaluated 18 months after transplanting. For the evaluation of the
 91 roots, the horizontal plane excavation method was used, complemented by the monolith
 92 method, in which were used water jets to remove the soil around the roots without damaging
 93 them [12].
 94 The plants were removed from the soil by means of a jet of water directed at the roots,
 95 where the soil particles were drained with water, leaving only the roots. After removal, the
 96 roots were immersed in water for two hours and then washed with tap water to remove
 97 remaining soil adhered.
 98 The following variables were evaluated: number of fully expanded leaves (NL); stem
 99 diameter (SD), measured with pachymeter within five centimeters of the plant collar; plants
 100 height (PH), given by the distance between the apex and the lap of the plant; main root
 101 length (RL), given by the distance between the collar and the root of the largest root; root
 102 volumes (VR), by the method of the test tube, following the methodology used by [13]; dry
 103 mass of aerial part (DMAP) and root (DMR) determined by forced drying of air at $65^{\circ}\text{C} \pm 5^{\circ}\text{C}$
 104 until reaching a constant mass; and the relation between the aerial part and the root (DMAP
 105 / DMR), given by the division between the dry mass of the aerial part by the dry mass of the
 106 root.
 107 The data were submitted to the normality test and analysis of variance. The qualitative
 108 variable was compared by the Tukey test ($P = 0,05$) and the quantitative by the regression
 109 analysis, using SAEG 9.1 software.

111 3. RESULTS AND DISCUSSION

112
 113 There was a significant interaction between the propagation methods and the pit dimensions
 114 only for the number of leaves and root length. The plants propagated by seeds had higher
 115 leaves production in relation to the ones propagated by clone only in the pits of 20x20x20
 116 cm. For the root length, it was shown that the propagation by clone was superior than the
 117 one by seed, in pits of 30x30x30 cm, as Table 2 shows.

118
 119 **Table 2. Interactions between the number of leaves and root lenght of the propagation**
 120 **methods for each pit dimension evaluated**

121

Number of leaves		
Pit dimensions (cm)	Seed	Clone
20x20x20	431 a	164 b
30x30x30	794 a	698 a
40x40x40	829 a	858 a
Root Length		
Pit dimensions (cm)	Seed	Clone
20x20x20	26.55 a	32.67 a
30x30x30	37.67 b	49.13 a

40x40x40

57.67 a

53.00 a

The averages followed by the same letters in the row, don't differ from each other, by the Tukey test at

5% probability

For the number of leaves per plant, there was a quadratic effect of the regression for both propagation methods. The largest number of leaves per estimated plant (866) for clonal seedlings was observed in pits with estimated dimensions of 39.4x39.4x39.4 cm, with small slope of the parabola in pits of 40x40x40 cm, indicating that larger dimensions didn't provide leaves in the plants. In seminiferous plants, the highest number of leaves was estimated in (855) in pits of 35x35x35 cm. These results indicate that seedlings propagated by seeds probably require a smaller volume of soil to express their maximum leaf development for plants at that age, as shown in Figure 1.

In relation to the main root length, it was observed a quadratic behavior of the regression only for the seminiferous plants, in which the largest estimated length (53.2 cm) was observed in pits with estimated dimensions of 38x38x38 cm, with a reduction in length from this point. For clonal plants, there was a linear regression effect, where the length of the main root increased proportionally to the increase in pit size (Figure 1).

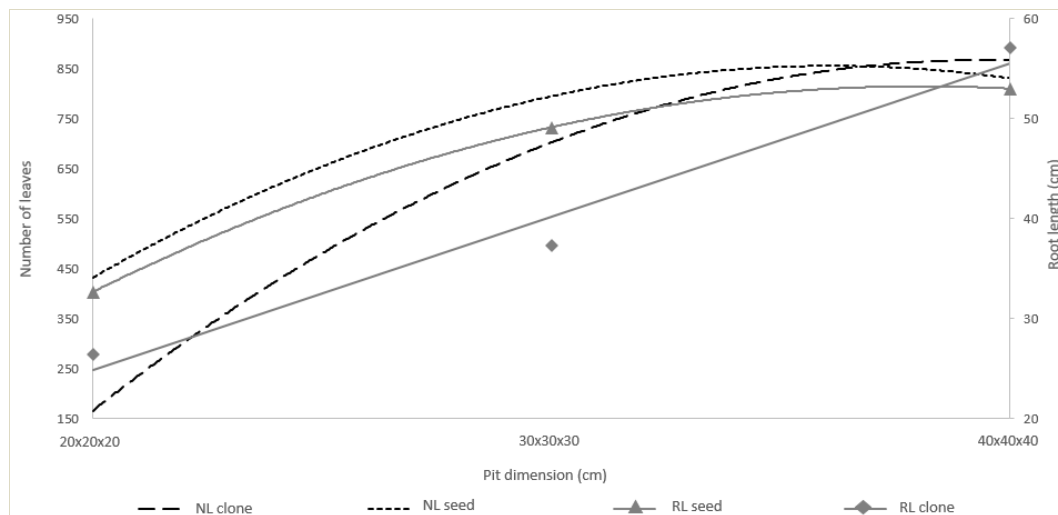


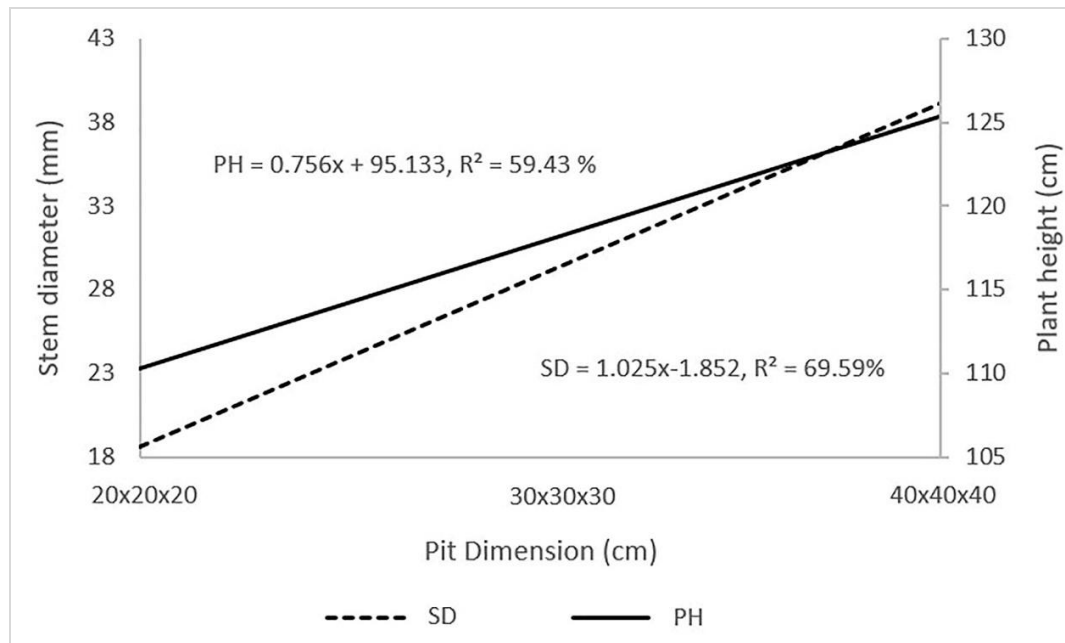
Figure 1. Number of leaves (NL) and root length (RL) in each propagation method in function of the pit dimensions

Equations: NL seed: $-1.633x^2 + 117.9x - 1273$, $R^2 = 78.97\%$; NL clone: $-1.86x^2 + 146.6x - 2022$, $R^2 = 97.35\%$; RL seed: $0.044x^2 - 1.108x + 30.94$, $R^2 = 93.53\%$; RL clone: $-1.532x - 5.7267$, $R^2 = 67.06\%$

According to Figure 1, it's possible to see that in pits of smaller size the seedlings propagated by seed presented greater development when compared with the clonal ones. However, when the size of the pit is increased, it is verified that the clonal plants tend to perform better than the seminiferous ones. Probably, in pits of larger dimensions the clonal plants can better express their potential as a function of the volume of soil explored.

According to [7], plants from seeds have a pivotal root, while clonal roots have several lateral adventitious roots. This fact may explain the better performance of seminiferous seedlings in pits with reduced size, since the pivoting root has a greater capacity to break the walls of the pit and expand the area of water and nutrient absorption, unlike what occurs in clonal

seedlings, where the radicular system is retained only in the volume of soil contained in the pit. Besides, it's possible to observe a similar behavior in regression between the number of leaves and the root growth. This fact may be related to the greater area of soil exploration by the roots in the pits with larger dimensions. In this case, the roots may have absorbed a greater amount of water and nutrients, contributing to the increase of the number of leaves, which consequently increased the photosynthetic rate of the plant and allowed a greater translocation of photoassimilates to the roots by phloem, providing greater root growth. The other analyzed variables (PH, SD, RV, DMAP, DMR) didn't present significant differences in relation to the propagation method, being observed a effect only in the pit dimensions. There was a positive linear effect of the regression for stem diameter and plant height, where the increase of the pit provided higher primary and secondary growth of the plants, as shown in Figure 2.



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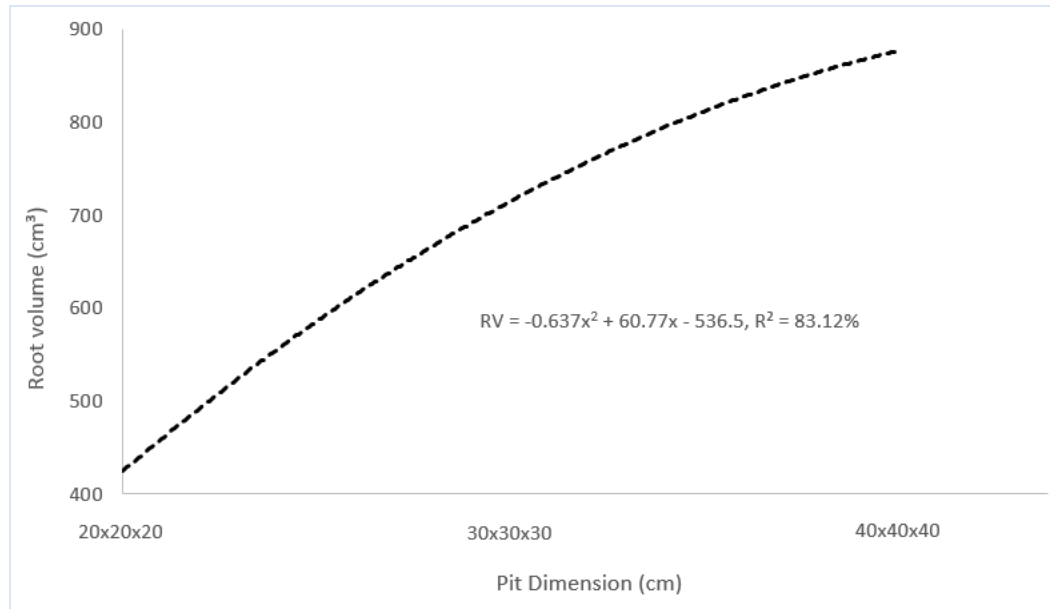
170 **Figure 2. Plant height (PH) and stem diameter (SD) for both propagation methods in**
 171 **function of pit dimensions**

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173 The values obtained for primary and secondary plant growth may be related to the
 174 characteristics of the soil used, which was the dystrophic red argisol, these soil peculiarities
 175 may have provided the mechanical restriction of the roots in the walls of smaller pits, causing
 176 difficulties in the development of the root system. These data corroborate those found by
 177 [14] that reported that directly planting has reduced the radicular development of several
 178 plants due to the high degree of cohesion and adhesion of the particles present in the
 179 dystrophic red argisol.

180 The mechanical restriction can reduce the emission of new roots, increasing the
 181 predominance of old roots, with a high accumulation of suberin. Suberization can become a
 182 physical barrier that hinders the entry of water and nutrients into the roots, since suberin is a
 183 hydrophobic substance [15]. The reduction of water intake impairs the transpiration of the
 184 plant, affecting the production of photoassimilates, cell multiplication and reducing plant
 185 growth.

186 In relation to the root volume, the quadratic behavior of the regression was observed, in
 187 which the highest estimated volume (912.5 cm³) for both propagation methods should occur
 188 in pits of 48x48x48 cm, as shown in Figure 3. However, it was noticed that the volume of the
 189 pits has increased proportionally to the increase of the dimensions of the pits tested, being
 190 possible to observe this behavior visually after washing the roots, as shown in Figure 4.
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Figure3. Root volume for both propagation methods in function of pit dimensions



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Figure 4. Photograph of the radicular system after washing, showing the root volume behavior as a function of pit dimensions

The root volume is very important for the development of the plants, since plants with a more massive radicular system have the capacity to exploit greater volume of soil and consequently to absorb more water and nutrients and increase the tolerance to the water deficit. It was verified that the root volume may have been influenced by soil mechanical restriction in the roots, because the plants grown in larger pits, wich means, with greater availability of low cohesive soil, tended to increase the volume of roots, as shown in Figure 4. [16] when working with radicular confinement effects on biometric measurements and CO₂ assimilation in conilon coffee plants, observed that, 30 weeks after transplanting, the seedlings grown in larger containers presented an increase in root volume, corroborating with the data from the present study.

It was observed a positive linear effect of the regression for dry mass of the aerial part and the root, in which there was increase of masses as a function of the increase of the size of the pit for both propagation methods, in addition it is noticed that the relation dry mass of aerial part/root has behaved in a similar way, although a subtle slope of the line was observed for this variable, as shown in Figure 5.

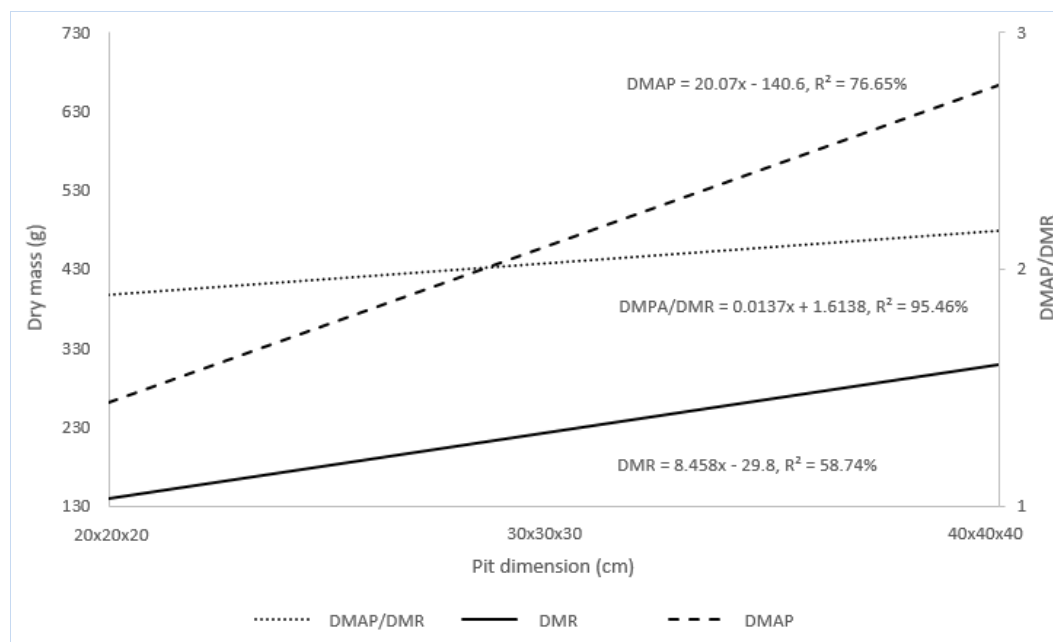


Figure 5. Dry mass of aerial part (DMPA), of the root (DMR) and relation aerial/root part (DMPA/DMR) for both propagation methods in function of pit dimensions

According to [17] the biomass production of the plant is an important and highly consistent feature in the evaluation of the development of plant species, complementing the data of primary and secondary growth. Similar behavior was observed when comparing the biomass of the aerial part with the biomass of the roots, evidencing a relation between aerial part and the radicular system of the plants.

However, it can be seen that the dry mass of the aerial part presents a greater slope when compared to the dry mass of the radicular system. This indicates that, as the size of the pits increases, the aerial part tends to develop more than the radicular system, as indicated by the aerial/root ratio, which, even with a slight inclination of the line, has been increasing with the rise of pit dimensions.

The results of dry mass, both of the aerial part and of the root, are corroborated by those found by [18], who verified the effect of container volumes on the development of *Coffea arabica* plants, and found that the seedlings cultivated in pots with larger volume (3400 ml)

had a higher dry mass of aerial part and root 30 weeks after transplanting. However, the authors verified that the relation aerial part/root was lower for the treatment with a larger volume container, contrary to the one observed in the present study, in which larger pits provided higher relation aerial part/root. Probably this result may have occurred due to the method and time of cultivation, once the plants cultivated in the soil were exposed to the physical barrier (wall of the pits), since they remained in the pits during 18 months, fact that provided mechanical restriction in the radicular system growth at a certain point of growth and prevented the roots from developing at the same rate of growth as the aerial part of the plants.

4. CONCLUSION

The initial development of the Conilon Incaper Vitória 8142 number 10 coffee isn't influenced by the propagation method.

The pit dimension directly influences the initial development of the coffee Conilon Incaper Vitória 8142 clone number 10, with pits with larger dimensions providing an increase in the initial development of the plants.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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