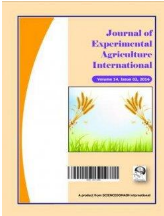

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Pit Dimensions in the Early Development of Conilon Coffee Propagated by Seeds and Cuttings

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Authors' contributions

This work was carried out in collaboration between all authors. Authors DCB and DFB designed the study, conducted the experiment in the field and managed the writing of the manuscript. Authors KMV and CMM performed the evaluations of the parameters analyzed in the study. Author IRH performed the statistical analysis. Authors SJF and SSB managed the writing of the manuscript. Author ACVF managed the bibliographic searches. All authors read and approved the final manuscript.

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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 production cycle of the tillage. The objective of this study was to access the initial development (vegetative and radicular) of Conilon coffee propagated by seed and stake and cultivated in pits with different dimensions. The experiment was a randomized block design with four replicates of three plants. The treatments were arranged in a 2x3 factorial scheme, with two

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propagation methods (seed and cutting), and three pit dimensions (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 18 months after transplanting. There was a significant interaction between the propagation methods and the pit dimensions, only for the number of leaves and root length, wherein 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 propagation method. The pit dimensions directly affects the initial development of the Conilon coffee Incaper 'Vitória 8142' clone number 10, and pits with the largest dimensions provide an increase in the initial development of the plants.

Keywords: Coffea canephora; radicular system; aerial part; sexual and asexual propagation; soil volume.

1. INTRODUCTION

Brazil is the largest producer and exporter, and the second largest consumer of coffee in the world with production of about 55 million sacs benefited in 2016 [1]. The state of *Espirito Santo* presents the second largest planted area in Brazil, with 385,54 thousand hectares cultivated and an estimated production of 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 *Espirito Santo* the largest producer of this species in Brazil, with an estimated production for 2017 from 4.61 to 5.30 million of sacs benefited [2].

Despite being the largest producer, *Espirito Santo* had a decrease in the Conilon coffee production in the last years [2]. This may be related to unfavourable climatic conditions and to the increase in the production cost. Labor is responsible for most of the production cost in the coffee crop, in which *Coffea arabica* species can represent up to 32% of the total cost [3]. Labor costs were intensified in the coffee crop of *Espirito 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 for 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 spent 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 *Espirito Santo* [6], the standard size used in the pits 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 difficulty in studying this part of the plant.

It is believed that the propagation method should be taken into account in recommending the pit dimensions. The plants that were sexually propagated 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 do not present a pivotal root, with formation of several lateral adventitious roots [7], which, generally, do not have the ability to break the cohesive walls of the pit.

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

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

2. MATERIALS AND METHODS

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

The experiment 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 a 2x3 factorial scheme, with two propagation methods (seed and cutting), and three pit dimensions (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, composed with a mixture of 70% of the 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.

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

The treatments were evaluated 18 months after transplanting. For the evaluation of the roots, the horizontal plane excavation method was used, complemented by the monolith method, in which water jets were used to remove the soil around the roots without damaging them [12].

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

Parameter	0-20 (cm)	21-40 (cm)
pH (in H_2O)	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

The plants were removed from the soil by a water jet directed at the roots, where the soil particles were drained with water, leaving only the roots. After being removed, the roots were immersed in water for two hours and then washed with tap water to remove the remaining soil adhered.

The following variables were evaluated: number of fully expanded leaves (NL); stem diameter (SD), measured with a pachymeter within five centimeters of the plant stem; plant height (PH), given by the distance between the plant apex and stemand the; main root length (RL), given by the distance between the stem and the root of the largest root; root volumes (VR), by the test tube method, following the methodology used by [13]; dry mass of aerial part (DMAP) and root (DMR) determined by a drying oven at 65°C ± 5°C until reaching a constant mass; and the relation between the aerial part and the root (DMAP / DMR), given by the division between the dry mass of the aerial part by the dry mass of the root.

The data were submitted to the normality test and analysis of variance (ANOVA). The qualitative variable was compared by the Tukey test (P = 0.05) and the quantitative by the regression analysis, using SAEG 9.1 software (2007).

3. RESULTS AND DISCUSSION

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

Table 2. Interactions between the number of leaves and root length of the propagation methods for each pit dimension evaluated

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 a small slope of the parabola in pits of 40x40x40 cm, indicating that larger dimensions did not provide leaves in the plants. In seminiferous plants, the highest number of leaves were estimated in (855) the 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 Fig. 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 the 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 (Fig. 1).

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 soil volume contained in the pit.

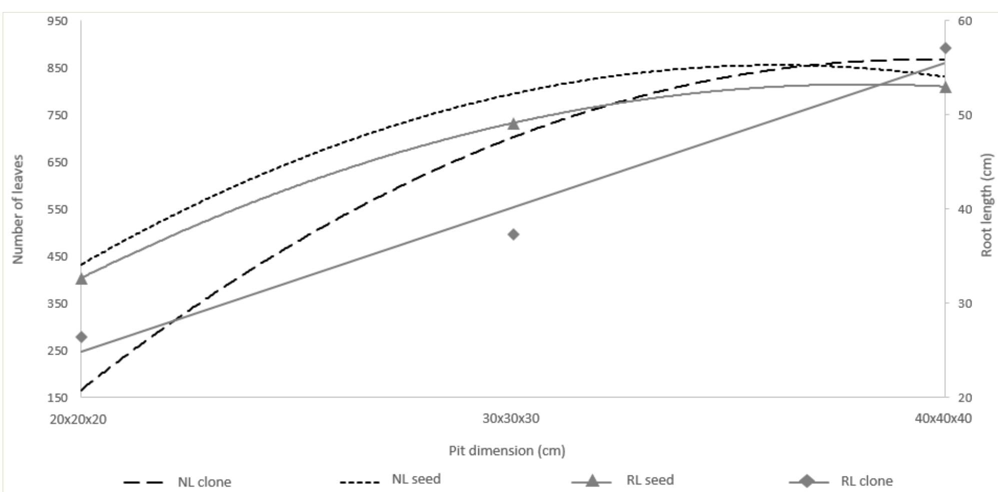

Fig. 1. Number of leaves (NL) and root length (RL) in each propagation method in function of the pit dimensions

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: $-1.532x – 5.7267$, $R^2 = 67.06\%$

Moreover, it is possible to observe a similar behavior in regression between the number of leaves and the root growth. This may be due to the greater soil area 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) did not present significant differences in relation to the propagation method, being observed an 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 plant growth, as shown in Fig. 2.

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

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

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

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 soil volume and consequently to absorb more water and nutrients and increase the tolerance to water deficit. It was verified that the root volume may have been influenced by

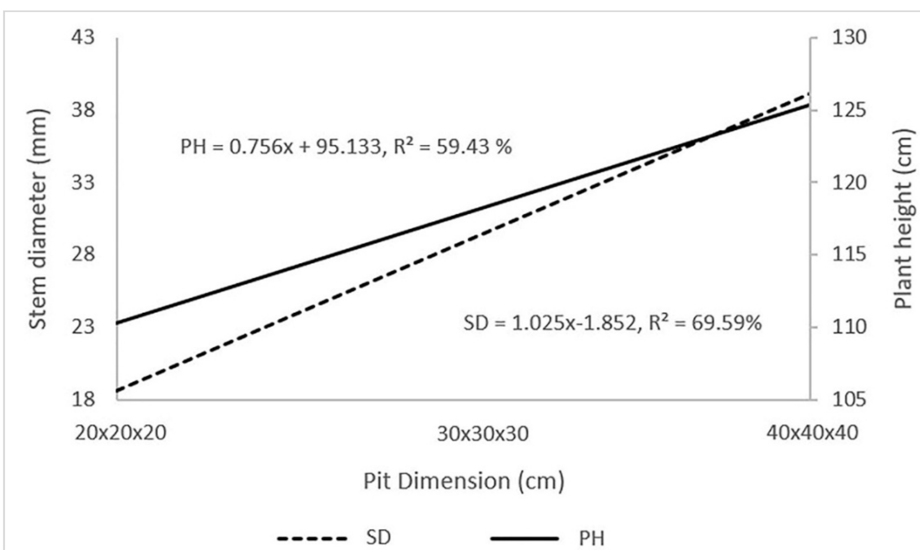

Fig. 2. Plant high (PH) and stem diameter (SD) for both propagation methods in function of pit dimensions

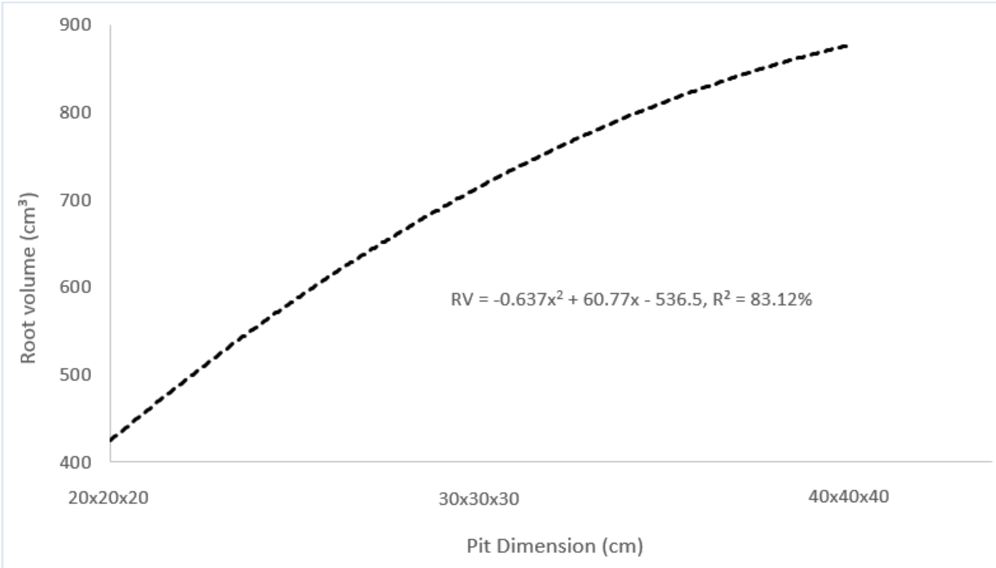

Fig. 3. Root volume for both propagation methods in function of pit dimensions

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

soil mechanical restriction in the roots, because the plants grown in larger pits, with greater availability of low cohesive soil, tended to increase the roots volume, as shown in Fig. 4. [16] when working with radicular confinement effects on biometric measurements and CO_2 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 an 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 Fig. 5.

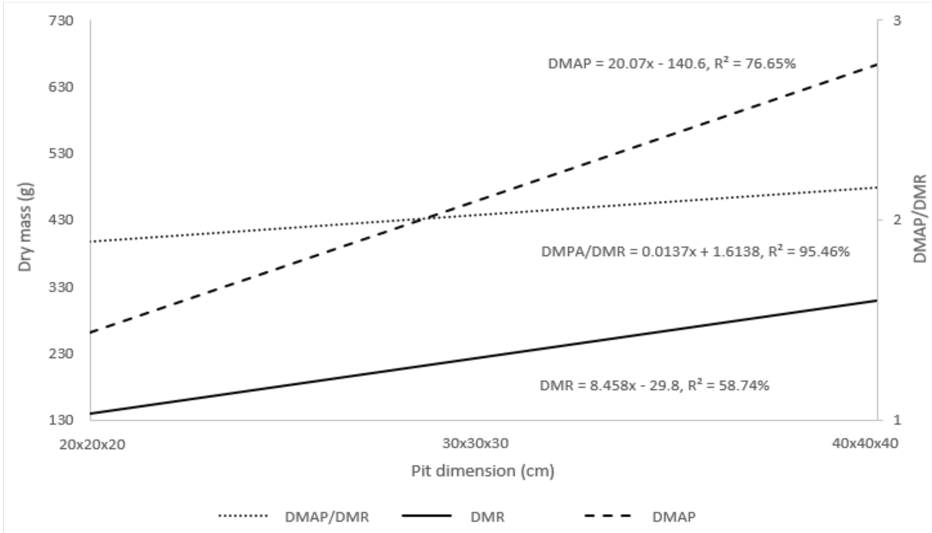

Fig. 5. Dry mass of aerial part (DMAP), of the root (DMR) and relation aerial/root part (DMAP/DMR) for both propagation methods in function of pit dimensions

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, 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 part, which, even with a slight inclination of the line, it grew due to the increase of the pit dimensions.

The results of dry mass, both aerial part and of the root, are corroborated by those found by [16], who verified the effect of container volumes on the development of *Coffea arabica* plants, and found that the seedlings cultivated in pots with a 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 those observed in the present study, in which larger pits provided higher relation aerial part/root.

This may be 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, which provided mechanical restriction in the radicular system growth at a certain point of growth and prevented the roots from developing at the same growth rates as the aerial part of the plants.

4. CONCLUSION

The initial development of the Conilon Incaper Vitória 8142 number 10 coffee is not influenced by the propagation method.

The pit dimension directly influences the initial development of the coffee Conilon Incaper Vitória 8142 clone number 10, with larger pits 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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