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THE INTENSITY OF THE DRYING PROCESS INFLUENCING THE GERMINATIVE POTENTIAL OF SEEDS OF *Coffea canephora* HARVESTED FROM GENOTYPES OF EARLY MATURATION

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ABSTRACT

Several physical, chemical, and biological attributes of coffee seeds can be influenced by the drying and storage conditions. To propagate the recommended cultivars using seeds, it is often necessary to grow seedlings from genotypes of different maturation cycles, for which the mature seeds are only available in different moments throughout the year. This study aimed to test the germination of seeds of *Coffea canephora* Pierre ex A. Froehner from genotypes of early maturation, after being subjected to different periods of natural or artificial drying. For this end, two trials were developed, following split-plot (in time) scheme and completely randomized design, to study the moisture content of seed dried by two different drying process along 27 periods (between 0 and 320 hours), and the germinative potential, based on the germination speed index and proportion of germinated seeds after 30 days, of seeds dried by two drying process and 12 levels of seed moisture (between 50% and 8%). The results show that artificial drying at 35 ˚C removes seed moisture faster than the natural

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drying at 25 ˚C. Both drying methods can be used for decreasing seed moisture. However, the faster water loss negatively affects the germinative potential of seeds of genotypes of *C. canephora* of early maturation. The natural drying at 25 ˚C seems to have lesser impacts over the germination process, which may represent a good alternative if the seeds are stored at low levels of moisture.

Keywords: Conservation; Propagation; Robusta coffee; Storage; Water content.

A INTENSIDADE DO PROCESSO DE SECAGEM INFLUENCIANDO O POTENCIAL GERMINATIVO DE SEMENTES DE *Coffea canephora* COLHIDAS DE GENÓTIPOS DE MATURAÇÃO PRECOCE

RESUMO

Vários atributos físicos, químicos e biológicos das sementes de café podem ser influenciados pelas condições de secagem e armazenamento. Para propagar as cultivares recomendadas usando sementes, muitas vezes é necessário cultivar mudas de genótipos de diferentes ciclos de maturação, para as quais as sementes maduras só estão disponíveis em diferentes momentos ao longo do ano. Este trabalho teve como objetivo testar a germinação de sementes de *Coffea canephora* Pierre ex A. Froehner a partir de genótipos de maturação precoce, após serem submetidas a diferentes períodos de secagem natural ou artificial. Para tanto, foram desenvolvidos dois ensaios, em esquema de parcelas subdivididas (no tempo) e delineamento inteiramente casualizado, para estudar o teor de umidade de sementes secas por dois diferentes processos de secagem ao longo de 27 períodos (entre 0 e 320 horas), e a germinação potencial, baseado no índice de velocidade de germinação e proporção de sementes germinadas após 30 dias, de sementes secas por dois processos de secagem e 12 níveis de umidade das sementes (entre 50% e 8%). Os resultados mostram que a secagem artificial a 35˚C remove as sementes mais rapidamente do que a umidade de secagem natural a 25˚C. Ambos os métodos de secagem podem ser usados para diminuir a umidade das sementes. No entanto, a perda de água mais rápida afeta negativamente o potencial germinativo de sementes de genótipos de *C. canephora* de maturação precoce. A secagem natural a 25˚C parece ter menor impacto sobre o processo de germinação, o que pode representar uma boa alternativa se as sementes forem armazenadas em baixos níveis de umidade.

Palavras-chave: Armazenamento; Café Conilon; Conservação; Propagação; Teor de água.

1 INTRODUCTION

Brazil is one of the largest producers of coffee worldwide, and the species *Coffea canephora* Pierre ex Froehner is one of the most important Brazilian agricultural commodities. This country stands out as one of the largest worldwide exporters of this product (ICO, 2019). The coffee quality is built along the entire cultivation, from planting to harvest, under the influence of both genotypic and environmental effects; however, post-harvest management is often related as the leading cause of losses in the final quality of the product (AMEYU, 2017; BORÉM *et al.*, 2008; BYTOF *et al.*, 2000; CHENG *et al.*, 2016; FLAMBEAU; YOON, 2018; HAMEED *et al.*, 2018; SIQUEIRA *et al.*, 2016).

Several physicals, chemicals, and biologicals attributes of coffee seeds can be influenced by the drying and storage conditions (ENYAN *et al.*, 2013; LOWOR; AMOAH, 2008; PEREIRA *et al.*, 2018; STEEN *et al.*, 2017; TSEGAYE *et al.*, 2014). Variations in the entire seed structure can occur during the drying process, especially related to temperature, moisture, and mechanical integrity of the seeds (BORÉM *et al.*, 2008; CORADI *et al.*, 2007).

During the harvest, it is common that coffee fruits with uneven levels of maturity and sizes are put together, forming a heterogeneous mass with high moisture (often near 60% w. b.), which is highly susceptible to development of microorganisms, processes of unwanted fermentation and other chemical changes (BYTOF *et al.*, 2000; 2007; DÍAZ-DE-CERIO *et al.*, 2019; RESENDE *et al.*, 2010; SIQUEIRA *et al.*, 2016). The post-harvest practices should be promptly adopted to separate, increase the homogeneity, transport, dry, and store before detrimental effects caused by these unwanted processes develop.

Because of the intricate relationship between the post-harvest treatments and the overall quality of the product, the drying process has been targeted by research for several years (BORÉM *et al.*, 2008; CORADI *et al.*, 2007; SIQUEIRA *et al.*; 2016). However, most research has been focused on the determination of adequate techniques and temperatures for drying grains to improve the final beverage quality. Meanwhile, there is still a lack of research aimed to improve the drying processes for seed storage, which comprise an entirely different field, since it is not possible to subject seeds to the same drying process commonly used for grains, without causing damage to their germinative potential because of thermal stress and mechanical damage (MARQUES *et al.*, 2008; SIQUEIRA *et al.*, 2016).

Moreover, *C. canephora* is a species which presents high genetic variability for several agronomic traits, because of its high natural rate of crossbreeding, caused by its gametophytic self-incompatibility (LASHERMES *et al.*, 1996). The most important trait used for classification and clustering of genotypes used in the cultivars is the duration of their maturation cycles (the period from flowering to harvest), which may vary from early (34 weeks) to late (45 weeks) (FERRÃO *et al.*, 2019). To propagate the recommended cultivars using seeds, it is often necessary to grow seedlings from genotypes of different maturation cycles, for which the mature seeds are only available in different moments throughout the year. This scenario creates the necessity to store and conserve the seeds until all the genotypes are available.

This study aimed to test the germination of seeds of *Coffea canephora* Pierre ex A. Froehner from genotypes of early maturation, after being subjected to different periods of natural or artificial drying.

2 MATERIALS AND METHODS

The seeds used in this experiment were acquired from an isolated field for multiplication of genotypes, in the Marilândia Experimental Farm (FEM) at the Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural (Incaper), in the municipality of Marilândia, in the northwestern region of the State of Espirito Santo, in the Southeast Region of Brazil, at the coordinates 19°23'54.5"S and 40°32'05.0"W (WGS 84). The altitude of the place is 229 m, and the topography of the region is wavy-rugged. According to the Köppen classification, the climate is Aw (GRIESER *et al.*, 2006), with a hot and rainy season from November to February, and a cold and dry season from March to September.

The multiplication field was composed of the genotypes of early maturation which take part in the composition of the seminal cultivar "Emcaper 8151 - Robusta Tropical" (National Cultivar Registry #06382). The field was isolated by forest vegetation from all sides, allowing cross-pollination among the group of genotypes of early maturation.

The plants were cultivated in rainfed conditions, presenting seven years of age during the harvest sampled in this experiment, and are managed according to the recommendations for *C. canephora* in the studied region (FERRÃO *et al.*, 2019).

Mature fruits from the matrix-plants (standardized in age, growth, nutritional, and phytosanitary status) were harvested manually in May 2017, when the plants presented above 80% of their fruits fully matured (FERRÃO *et al.*, 2019). The fruits were immediately semi-pulped and transported to the laboratory, where they were manually processed to get fully pulped seeds. The seeds were immersed in a sodium hypochlorite solution (5%) for 30 minutes and then washed with distilled water. The processed and treated seeds were separated in samples, which were adequately identified to compose the experimental plots and sent to be dried.

The experiment was composed of two trials that followed completely randomized designs. The first trial was designed to assess the effect of two different drying processes and several periods of exposure to drying over the seed moisture content. The second trial aimed to study the effect of the two drying processes and final seed moisture content over the germination, using the results of the previous trial to establish adequate drying periods for each level of seed moisture content.

The first trial followed a split-plot scheme with two drying processes in the parcels (natural and artificial drying), and 27 drying periods in the sub-parcels (periods between 0 and 320 hours). Three repetitions were used, and each experimental plot was composed of a sample of 10 g of seeds.

The second trial followed a split-plot scheme with two drying processes in the parcels (natural and artificial drying), and 12 levels of seed moisture content from 12 different drying periods in the sub-parcels (between 50% and 8% of moisture content). Four repetitions were used, and each experimental plot was composed of a sample of 50 seeds.

The seed samples were spread over trays to form a thin and homogeneous layer and submitted to natural or artificial drying, according to the treatments. The natural drying was done in a room with the air temperature being monitored at 25˚C (±1˚C). The artificial drying was done in a laboratory oven (forced air circulation), at the temperature of 35˚C (±1˚C).

The samples (10 g) were left to dry in each process for periods between 0 and 320 hours. After each corresponding period, the seed moisture content of the sample was determined using the direct method of oven-drying the samples (at 105˚C ±0.5˚C) until constant weight (achieved after 24 hours of drying), which was monitored using a precision scale (±0.001 g) (BRASIL, 2009).

After establishing the period required to achieve each level of moisture content, seed samples (200 seeds separated in four repetitions of 50 seeds) were dried in each drying process to test the effects over their germination and emergence.

The parchments of the seeds were manually removed, and the seeds were subjected to chemical treatment with preventive fungicide (immersion for 15 minutes). The prepared seeds were placed on rolls of germitest paper, moistened with distilled water (2.5 times the weight of the paper) and kept in germination chambers (biochemical oxygen demand), under conditions of cycles of alternating temperature (20-30˚C) and fluorescent cold-white lights with photoperiod cycles of 12 hours of light and dark (BRASIL, 2009).

The germination was tested daily, counting the number of seeds which presented the beginning protrusion of the radicle and relating it to the elapsed time to calculate the germination speed index (GSI) through 30 days (MAGUIRE, 1962). At the final of this period, the total number of healthy seedlings, according to the criteria established by Brasil (2009), was counted to calculate the germination percentage (G).

The collected data from each trial were subjected to analysis of variance ($p \leq 0.05$). The existence of an interaction between the drying processes (parcel) and periods (sub-parcel) was tested. The effect of the drying processes was studied using the Tukey's test (TUKEY, 1949), and the effect of the drying time was tested by regression analyses, testing the fit to different equational models and choosing the model based on the adjustment, probability, significance and determination coefficients. The analyses were performed using statistical software GENES (CRUZ, 2013).

3 RESULTS

The decrease of the moisture content showed the existence of a significant interaction between the effects of the drying process and the period in which the seeds are submitted to the process. Therefore, the interaction between these factors was unfolded.

The seed water content observed after each period was similar, regardless of being dried by natural or artificial conditions, up to 4 hours. After this period, the differences between the two drying processes became apparent, and the moisture content from the seeds dried artificially at 35˚C was significantly lower than those dried naturally (Table 1).

Table 1 – The moisture content of seeds from genotypes of *Coffea canephora* Pierre ex A. Froehner of early maturation after periods between 0 and 320 hours being submitted to natural or artificial drying (Marilândia, Espírito Santo, Brazil, 2017).

Drying time (h)	Seed moisture content (%)	
	Natural drying (25˚C)	Artificial drying (35˚C)
0	50.88 A	50.88 A
½	50.98 A	50.57 A
1	49.80 A	49.08 A
2	48.92 A	48.79 A
3	48.78 A	48.50 A
4	49.14 A	48.56 A
5	50.25 A	48.63 B
6	48.63 A	46.29 B

9	45.90 A	42.59 B
12	45.98 A	41.86 B
18	43.44 A	40.73 B
24	42.46 A	34.16 B
30	43.97 A	30.69 B
36	39.30 A	24.86 B
42	38.08 A	20.83 B
48	36.88 A	17.18 B
54	34.82 A	15.76 B
60	33.56 A	13.28 B
66	33.47 A	11.79 B
72	28.88 A	9.89 B
96	26.45 A	8.57 B
120	21.85 A	7.88 B
150	17.98	-
192	15.01	-
216	12.96	-
240	12.83	-
320	13.11	-

Means followed by the same letter in each line do not differ from each other according to Tukey's test, at 5% of probability.

After 120 hours, the moisture content from the seed samples dried artificially started to stabilize, not showing considerable further losses and, therefore, making longer periods unjustified for this drying process.

The seed moisture content was directly influenced by the extension of the drying time, being adjusted to an exponential model of regression for both drying processes. Even if similar in the regression model, the coefficients of the regressions for these processes were very different, showing the faster water loss from the artificial drying, which achieved lower values of SMC several hours before the natural process (Figure 1).

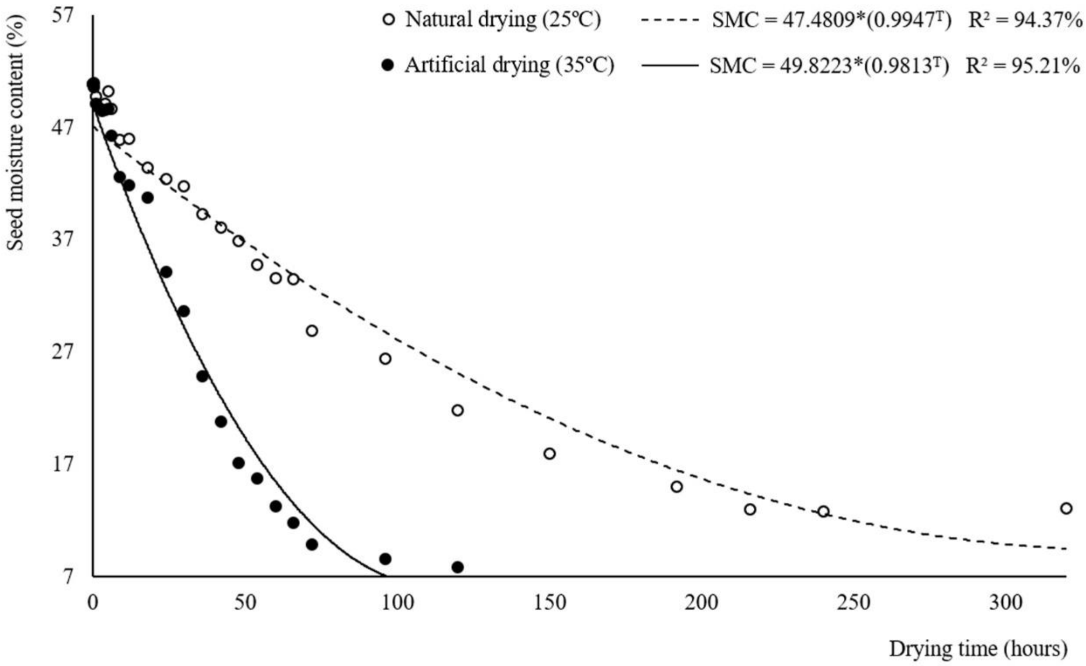

Figure 1 – The moisture content of seeds from genotypes of *Coffea canephora* Pierre ex A. Froehner of early maturation as a function of the time being submitted to natural (empty marker) or artificial (full marker) drying (Marilândia, Espírito Santo, Brazil, 2017).

According to the previous results, the 12 levels of moisture content were established between 48% (recently harvested seeds) and 8% (dried seeds). Both parameters of germination were significantly affected by the drying process and the level of moisture content. The occurrence of interaction between these factors was observed, and the unfolding of this interaction was performed.

The drying from 48% to 20% of SMC, regardless of using natural or artificial drying, returned similar results for the germination speed index. At the level of 18% of SMC and below, significant differences between the two the drying process were observed, and the germination became slower for the seeds dried by the artificial process at 35˚C (Table 2).

The germination percentage was also similar for both natural and artificial drying from 48% to 25% of SMC. Under 20% of SMC, the two drying processes started to present significant differences as the artificial drying returned a lower proportion of seeds with normal germination (Table 2).

Table 2. Germination speed index (GSI) and germination percentage (G) of seeds from genotypes of *Coffea canephora* Pierre ex A. Froehner of early maturation after being submitted to natural or artificial drying until different levels of seed moisture (Marilândia, Espírito Santo, Brazil, 2017).

Seed moisture content (%)	GSI		G (%)	
	Natural drying (25˚C)	Artificial drying (35˚C)	Natural drying (25˚C)	Artificial drying (35˚C)
48	4.82 A	4.82 A	97.50 A	97.50 A
45	4.66 A	4.83 A	97.50 A	96.00 A
40	4.16 A	4.26 A	98.00 A	95.50 A
35	4.46 A	4.28 A	97.50 A	97.00 A
32	3.93 A	4.05 A	96.00 A	95.50 A
28	3.96 A	4.16 A	94.00 A	98.00 A
25	3.98 A	3.95 A	96.50 A	96.00 A
20	3.82 A	3.69 A	98.00 A	92.00 B
18	3.94 A	3.12 B	99.50 A	80.00 B
16	3.95 A	2.54 B	93.00 A	68.00 B
13	4.07 A	2.73 B	94.00 A	73.50 B
8	3.67 A	2.39 B	93.50 A	64.00 B

Means followed by the same letter in each line do not differ from each other according to Tukey’s test, at 5% of probability.

The germination speed index as a function of the moisture content presented fit to polynomial regression models of 2nd degree for seeds subjected to natural drying and a linear regression model of 1st degree for seeds dried artificially. Therefore, it is observed a small decrease in the GSI, for naturally dried seeds, until the minimum point at 13.50% of SMC, when the germination speed slightly rises again. For artificially dried seeds, however, the germination index presents a linear decrease, becoming slower as the drying process furthers (Figure 2A).

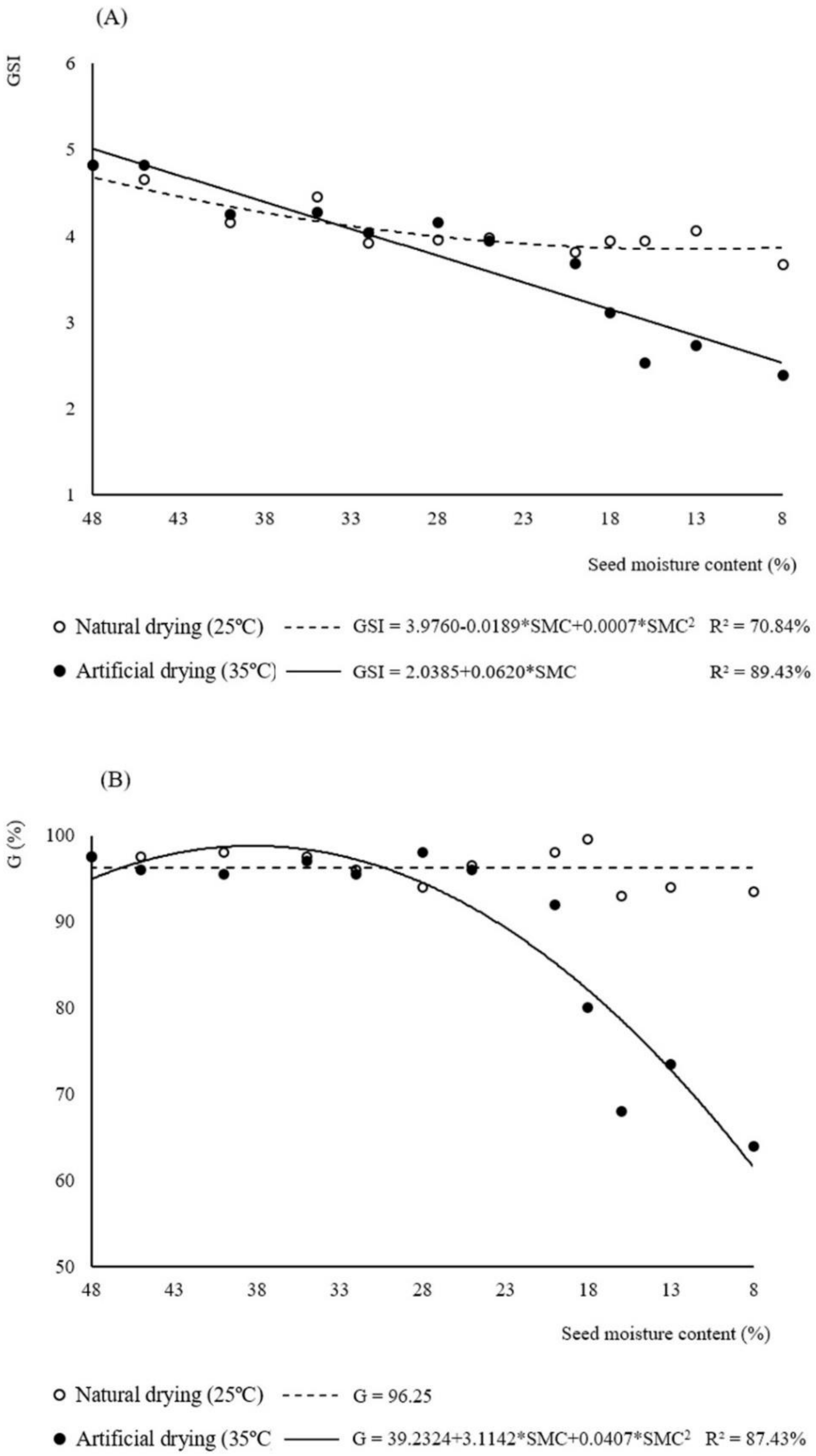

Figure 2. Germination speed index (GSI) and germination percentage (G) of seeds from genotypes of *Coffea canephora* Pierre ex A. Froehner of early maturation as a function of the seed moisture content, after being submitted to different periods of natural (empty marker) or artificial (full marker) drying (Marilândia, Espírito Santo, Brazil, 2017).

The water loss did not influence the proportion of seeds with normal germination after 30 days obtained by natural drying, with values of G staying around 96.25%. However, the artificial drying at 35˚C had an intense effect over this proportion, resulting in a change to a polynomial regression model of 2nd degree, with maximum G at the level of 38.26% of SMC and a sharp decrease in the germination proportion under this level moisture content (Figure 2B).

4 DISCUSSION

It was possible to dry the seeds through natural or artificial processes to achieve low levels of seed moisture. However, the period required to dry the seeds to lower levels of moisture using the natural process was far longer, taking over three times longer to achieve the same level of seed moisture sometimes.

The first four hours of drying returned similar results, regardless of the drying method. The water loss in this initial period is related to the initial removal of surface humidity, which seems not to require a higher temperature to enable the movement of water in this initial stage. This behavior of sharp water loss from freshly harvested to 10-20% of moisture along the drying process corroborates the results of other studies (CORADI *et al.*, 2007; CORRÊA *et al.*, 2006; SIQUEIRA *et al.*, 2016). However, even if the drying pattern has similarities, these studies also show the use of higher temperatures being able to promote the drying rate, changing the magnitude of the regression coefficients, and speeding up the process.

After the initial drying, the methods differentiate themselves for the speed of the drying process. The higher temperature, which was available using the artificial method, promoted the removal of moisture faster than the natural method. This behavior was expected, as the use of the higher temperature causes a larger difference between the water vapor pressure of air and seeds, which facilitates the transference of water molecules and makes the drying process quicker (SIQUEIRA *et al.*, 2016). Higher temperatures decrease water viscosity, which also facilitates the diffusion of the molecules through the seeds (ALVES *et al.*, 2017; CORRÊA *et al.*, 2010).

Both drying processes decreased the germination speed index through time, decelerating the germination of the seeds. However, the germination percentage was only limited by artificial drying. This fact shows that slow natural drying, at 25 ˚C, may cause the deceleration of the germinative process, but it does not make it infeasible.

The detrimental effects over the germinative potential which was observed for the artificial drying were expected, as the use of higher temperatures impacts the physiological quality of coffee (ALVES *et al.*, 2017; ENYAN *et al.*, 2013). The exposure of the seeds to higher temperatures, especially for longer drying periods, promotes the occurrence of thermal damage to the endosperm and embryo, causing losses of membranes integrity and damaging the cells (SAATH *et al.*, 2012; TAVEIRA *et al.*, 2012).

Initially, the drying methods presented similar results for the germinative potential of the seeds, with similar results for germination speed index and percentage until the level of 25% of seed moisture. However, the water loss caused by the artificial method already started presenting lower germination percentages at 20% of seed moisture. Further drying caused a noticeable differentiation among the methods, as the natural drying presented a higher germinative potential for all levels under 20% of seed moisture.

Other researches have also reported alterations in the coffee biochemical characteristics because of the use of drying with higher temperatures, which may contribute to the decrease in the germinative potential of the seeds subjected to artificial drying (ALVES *et al.*, 2017; CORADI *et al.*, 2007; ENYAN *et al.*, 2013; PEREIRA *et al.*, 2018; STEEN *et al.*, 2017).

The response in water loss for drying the seeds naturally or artificially seems similar, but with very different magnitudes. The water loss is fast with the use of artificial drying, making it possible to reach low moisture levels with a few hours of drying. However, the germination was less affected by the slower drying, achieved by using the natural process. This drying method makes it possible to subject the seeds to drying for a longer period with lesser losses to the germinative process since the only verified loss was the slight slower germination speed.

5 CONCLUSIONS

The artificial drying at 35 ˚C removes seed moisture faster than the natural drying at 25 ˚C. Both drying methods can be used for decreasing seed moisture. However, the faster water loss negatively affects the germinative potential of seeds of genotypes of *Coffea canephora* Pierre ex A. Froehner of early maturation.

The natural drying at 25 ˚C seems to have lesser impacts over the germinative process, which may represent a good alternative if the seeds are stored at low levels of moisture.

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