

CONILON COFFEE YIELD USING THE PROGRAMMED PRUNING CYCLE AND DIFFERENT CULTIVATION DENSITIES

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ABSTRACT: Determining the correct population of plants and number of orthotropic stems to be kept per area, along with optimal pruning management, is very important for crops of *Coffea canephora*. The aim of this work was to improve conilon coffee cropping management, evaluating the influence of the programmed pruning cycle with different combinations of spacing and numbers of orthotropic stems per plant on crop yield. Two experiments were carried out: one with smaller spacing and lower numbers of stems per plant, and another with larger spacing and higher numbers of stems per plant. Both assays followed a triple factorial scheme 2 x 3 x 4 (2 spacing x 3 numbers of stems per plant x 4 harvests) in a random block statistical design, using four replications and 11 plants per plot. The results show that a reduction in spacing associated with an increase in number of stems per plant has a positive effect on the conilon coffee yield.

Index terms: *Coffea canephora*, spacing, management, orthotropic stems.

PRODUTIVIDADE DO CAFEEIRO CONILON CONDUZIDO COM A PODA PROGRAMADA DE CICLO E DIFERENTES DENSIDADES DE CULTIVO

RESUMO: A determinação da população de plantas e hastes por hectare, juntamente com o manejo de podas, é de suma importância para a implantação e condução de lavouras de *Coffea canephora*. Conduziu-se, este trabalho, com o objetivo de aprimorar as indicações de manejo ora existentes para a cultura do cafeeiro conilon, avaliando a influência da utilização da poda programada de ciclo com diferentes combinações de espaçamento e número de hastes por planta sobre a produtividade. Foram realizados dois ensaios: um com menores espaçamentos e números de hastes por planta, e outro com maiores espaçamentos e número de ramos por planta. Ambos seguindo um esquema fatorial triplo, em delineamento estatístico de blocos ao caso, com quatro repetições e parcelas experimentais formadas por onze plantas. Os resultados mostram que a redução do espaçamento associado ao aumento do número de hastes por planta tem efeito positivo sobre a produtividade do café conilon.

Termos para indexação: *Coffea canephora*, espaçamento, manejo, ramos ortotrópicos.

1 INTRODUCTION

Determining the correct population of plants and number of orthotropic stems per area has, along with pruning management, great importance for crops of *Coffea canephora*. Initially, the creation of conilon coffee cropping was made by seminal propagation, which resulted in crops with high heterogeneity due to their high genetic variability (BRAGANÇA et al., 2001; FERRÃO et al., 2007b). This scenario made it difficult to establish a management system that could use optimal numbers of plants per hectare and stems per plant.

The high variability presented by *C. canephora*, associated with the different agro-climatic and topographic conditions where

this species is cultivated, makes this species excellent for studies of growth and improvement (PEZZOPANE et al., 2010). This process can be complex, since optimal plant population and spacing may be influenced by many factors, such as the genotype, climate, soil fertility, mechanization, topography and the level of technology adopted by the producer (CARVALHO et al., 2006; FONSECA et al., 2007).

The prevailing cropping system for conilon coffee uses a total plantation density of 2,222 to 3,333 plants per hectare and a total of 10,000 to 16,000 orthotropic stems per hectare (FONSECA et al., 2007). The increase of the crop density is particularly desirable for small areas and crops not suitable for mechanization.

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Even with the global tendency for cultivation with density increased, there is still need for scientific data regarding the management of coffee with this technology, aiming to set adequate recommendations for dense crops, such as nutrition (BRAGANÇA et al., 2009) and irrigation (SCALCO et al., 2011).

Pruning management has great importance for renewal, reviving and yield stability in coffee plantations, with direct influence on physiological parameters of the plants. Plants of *C. canephora* show continued growth, developing vertical and horizontal stems, called orthotropic and plagiotropic respectively. After a certain age these stems senesce and their ability to produce fruit decreases, resulting in reduced vigor and excessive sprouting. Therefore, for commercial exploitation of this species, it is necessary for humans to interfere with plant growth through pruning management. This allows adequate levels of crop yield to be maintained by eliminating and gradually replacing orthotropic and plagiotropic stems that are losing their productive capacity (FERRÃO et al., 2007b; FONSECA et al., 2007).

The pruning technology for *C. canephora* has been studied and improved over the years through the efforts of the Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural (Incaper). The most recent technology for recommended pruning for this species is the Programmed Pruning Cycle or Poda Programada de Ciclo (VERDIN FILHO et al., 2008). This technology provides several advantages, especially in easy of understanding and implementation, while reducing manual labor and improving overall crop yield.

To improve the actual knowledge of conilon coffee cropping management, this study aimed to evaluate crop yield as influenced by the programmed pruning cycle with different combinations of spacing and numbers of orthotropic stems per plant, to identify the effects of different populations of orthotropic stems per area on fruit production.

2 MATERIALS AND METHODS

The study was conducted at the experimental farm of Marilândia (Fazenda Experimental de Marilândia – INCAPER), located at 19°24'S, 40°32'W, north of Espírito Santo State, southeastern Brazil. The altitude is 202 m with hilly topography and the soil is a dystrophic Oxisol (EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA, 1997).

The climate is typically rainy from November to February; partially dry in March, April and October and dry from May to September (FEITOSA et al., 1979). The average annual temperature is 24.2 °C, ranging from 13.9 °C to 33.5 °C.

The cultivar of *Coffea canephora* Pierre ex A. Froehner used was EMCAPA 8111. This cultivar has an average yield of 58 bags of 60 kg of green coffee per hectare (BRAGANÇA et al., 2001) and is it recommended for Espírito Santo State according to studies on agricultural zoning (PEZZOPANE et al., 2010).

The experiment was conducted without irrigation (only rainfed) and fertilization was performed following current technical recommendations for conilon coffee in Espírito Santo State (PREZOTTI et al., 2007), as well as following the recommended phytosanitary practices (FERRÃO et al., 2007a).

The experiment consisted of two separated assays, each following a 2 x 3 x 4 triple factorial design, studying the combinations of two spacings and three numbers of stems kept per plant over four years of harvest. The combinations used in the assays were established to allow a total population of stems per hectare compatible with the current recommendation (Table 1). For both assays, a randomized block statistical design used four replications and experimental plots composed of eleven plants arranged in lines.

The assays were managed using the programmed pruning cycle beginning in 2006. Plants were cleaned of new shoots and plagiotropic branches that had exceeded 70% of their production capacity were removed.

In this pruning management it is recommended to remove the damaged orthotropic stems, always choosing the less vigorous, less productive and more internally located stems in the canopy of the plant. In the following year, the remaining orthotropic stems are eliminated, restarting the production cycle with reinvigorated stems (VERDIN FILHO et al., 2008).

The crop yield evaluations began after two years of the introduction of the programmed pruning cycle technique and were conducted over four consecutive harvests from 2008 to 2012. To determine the crop yield of each plot, a hulling ratio of 4:1 was used (every 4 kg of harvested coffee generating 1 kg of green coffee), resulting in the estimated yield in commercial bags of 60 kg of green coffee per hectare (bags ha⁻¹).

TABLE 1 - Spacing, number of orthotropic stems per plant and total population of stems per hectare evaluated in each assay.

Assays	Spacing (m)	Number of orthotropic stems per plant	Number of orthotropic stems per hectare
Assay I	2.0 x 1.0	2	10,000
	2.0 x 1.0	3	15,000
	2.0 x 1.0	4	20,000
	2.5 x 1.0	2	8,000
	2.5 x 1.0	3	12,000
	2.5 x 1.0	4	16,000
Assay II	3.0 x 1.0	3	10,000
	3.0 x 1.0	5	16,667
	3.0 x 1.0	6	20,000
	3.0 x 1.5	3	6,667
	3.0 x 1.5	5	11,111
	3.0 x 1.5	6	13,333

The plots were harvested when approximately 80% of fruits were completely mature. Upon harvest, all of the fruits in the plot were weighed and identified.

The data were subjected to analysis of variance by the F test ($p \leq 0.05$) and the means were compared using the Tukey test at 5% of probability, according to the significance of the factors and their interactions. All statistical analyses were performed using the statistical software GENES (CRUZ, 2013).

3 RESULTS AND DISCUSSION

For both assays, the analysis of variance indicated the significance of the interactions between the pairs of factors, with triple interaction not occurring. The overall mean in Assay I was about 40% higher than in Assay II, indicating that the reduction in spacing between conilon coffee plants likely had a positive effect on the final yield. Paulo and Furlani Júnior (2010) obtained similar results studying growing populations of *Coffea Arabica* L. per hectare, and the authors observed significant increases in crop yield.

In general, the adverse weather conditions can limit fruit production in coffee plants, especially due to the occurrence of drought and unfavorable temperatures (DAMATTA; RAMALHO, 2006). As the experiment was conducted under rainfed conditions, this negative influence was observed in both assays for the harvest of 2009, a year marked by a long period of drought that coincided with the flowering period.

Assay I: Spacing of 2.0 x 1.0 m (5,000 plants ha-1) and 2.5 x 1.0 m (4,000 plants ha-1)

Table 2 shows the means of yields obtained using 2, 3 and 4 stems per plant. Note that using a greater number of stems per plant resulted in increased crop yield throughout all the year, with the exception of 2009, when all treatments showed reduced yield due to the influence of the drought and it was not possible to find statistical differences between the treatments. The use of only two stems per plant resulted in lower yields, which were statistically inferior in the 2008, 2010 and 2011 years harvests.

Reducing the distance between lines from 2.5 to 2.0 m did not affect the yield during the first three years. However, in the fourth harvest an increase of approximately 20 bags per hectare were observed, caused by increased cultivation density (Table 3).

Superior yield due to a reduction in spacing, both between lines and between plants, has already been observed in *C. arabica* (PAULO; FURLANI JÚNIOR; FAZUOLI, 2005). It is possible that a similar phenomenon takes place in conilon coffee, although with a difference in magnitude. The interaction between spacing and number of stems per plant is presented in Table 4. The crop yield throughout the year was higher in treatments that combined smaller spacing with higher numbers of stems per plant. With 2.0 x 1.0 m spacing, the crop yield increased with the increase in the number stems per plant, whereas with 2.5 x 1.0 m spacing, the highest yields were obtained with > 3 stems per plant. The 2.0 x 1.0 spacing was more productive than 2.5 x 1.0 with the use of two and four stems per plant and did not differ when three stems were used.

TABLE 2 - Crop yield (in bags of 60 kg per hectare) of conilon coffee comparing the interaction between numbers of stems per plant and the harvest over time (obtained in Assay I) conducted with the programmed pruning cycle at the experimental farm of Marilândia (Fazenda Experimental de Marilândia – INCAPER).

Number of stems	Crop yield (bags ha ⁻¹)				
	2008	2009	2010	2011	Mean
2	42.55 Bc	10.02 Ca	46.40 Bc	74.76 Ab	43.43
3	53.94 Bb	11.60 Ca	63.63 Bb	94.59 Aa	55.94
4	69.12 Ba	13.15 Ca	77.20 Ba	98.29 Aa	64.44
Mean	55.20	11.59	62.41	89.22	54.61

Means followed by the same uppercase letter in the line and lowercase in the column do not differ by the Tukey test at 5% of probability.

TABLE 3 - Crop yield (in bags of 60 kg per hectare) of conilon coffee comparing the interaction between spacing and the harvest over time (obtained in Assay I) conducted with the programmed pruning cycle at the experimental farm of Marilândia (Fazenda Experimental de Marilândia – INCAPER).

Spacing (m)	Crop yield (bags ha ⁻¹)				
	2008	2009	2010	2011	Mean
2.0 x 1.0	58.54 Ba	8.80 Ca	65.77 Ba	99.07 Aa	58.05
2.5 x 1.0	51.87 Ba	14.38 Ca	59.05 Ba	79.36 Ab	51.17
Mean	55.20	11.59	62.41	89.22	54.61

Means followed by the same uppercase letter in the line and lowercase in the column do not differ by the Tukey test at 5% of probability.

TABLE 4 - Crop yield (in bags of 60 kg per hectare) of conilon coffee comparing the interaction between the number of stems per plant and spacing (obtained in the Assay I) conducted with the programmed pruning cycle at the experimental farm of Marilândia (Fazenda Experimental de Marilândia – INCAPER).

Spacing (m)	Crop yield (bags ha ⁻¹)			
	2 stems	3 stems	4 stems	Mean
2.0 x 1.0	47.51 Ca	58.38 Ba	68.25 Aa	58.05
2.5 x 1.0	39.36 Bb	53.50 Aa	60.64 Ab	51.17
Mean	43.43	55.94	64.44	54.61

Means followed by the same uppercase letter in the line and lowercase in the column do not differ by the Tukey test at 5% of probability.

Assay II: Spacing of 3.0 x 1.0 m (3,333 plants ha-1) and 3.0 x 1.5 m (2,222 plants ha-1)

In this assay, which studied wider spacing, the use of a greater number of stems per plant significantly increased the crop yield, except in 2009 (Table 5).

The interaction between spacing and the harvests showed that reducing the distance between plants from 1.5 to 1.0 m had a significant effect only in 2010 (Table 6).

Table 7 presents the interaction between spacing and number of stems per plant. Similar to

what was observed in Assay I, the combination of smaller spacing and a higher number of stems per plant yielded a higher crop yield throughout the year. The yield using 3.0 x 1.0 m spacing increased when with a higher number of stems per plant; and for 3.0 x 1.5 m spacing, the highest yields were obtained when more than five stems were kept per plant. The 3.0 x 1.0 m spacing was superior to 3.0 x 1.5 m when six stems per plant were kept.

Overall, the highest yields are obtained from plantations presenting the highest populations of stems per hectare.

TABLE 5 - Crop yield (in bags of 60 kg per hectare) of conilon coffee comparing the interaction between the numbers of stems per plant and the harvest over time (obtained in Assay II) conducted with the programmed pruning cycle at the experimental farm of Marilândia (Fazenda Experimental de Marilândia – INCAPER).

Number of stems	Crop yield (bags ha ⁻¹)				
	2008	2009	2010	2011	Mean
3	28.80 ABb	19.38 Ba	33.89 Ab	33.48 Ab	28.89
5	38.99 Bb	14.42 Ca	56.82 Aa	51.95 Aa	40.55
6	50.28 Aa	12.88 Ba	56.50 Aa	58.83 Aa	44.62
Mean	39.36	15.56	49.07	48.08	38.02

Means followed by the same uppercase letter in the line and lowercase in the column do not differ by the Tukey test at 5% of probability.

TABLE 6 - Crop yield (in bags of 60 kg per hectare) of conilon coffee comparing the interaction between spacing and the harvest over time (obtained in Assay II) conducted with the programmed pruning cycle at the experimental farm of Marilândia (Fazenda Experimental de Marilândia – INCAPER).

Spacing (m)	Crop yield (bags ha ⁻¹)				
	2008	2009	2010	2011	Mean
3.0 x 1.0	40.86 Ba	12.80 Ca	56.34 Aa	48.60 ABa	39.65
3.0 x 1.5	37.85 Ba	18.32 Ca	41.80 ABb	47.57 Aa	36.39
Mean	39.36	15.56	49.07	48.08	38.02

Means followed by the same uppercase letter in the line and lowercase in the column do not differ by the Tukey test at 5% of probability.

TABLE 7 - Crop yield (in bags of 60 kg per hectare) of conilon coffee comparing the interaction between the number of stems per plant and spacing, obtained in Assay II, conducted with the programmed pruning cycle at the experimental farm of Marilândia (Fazenda Experimental de Marilândia – INCAPER).

Spacing (m)	Crop yield (bags ha ⁻¹)			
	3 stems	5 stems	6 stems	Mean
3.0 x 1.0	30.38 Ca	39.10 Ba	49.45 Aa	39.65
3.0 x 1.5	27.39 Ba	41.98 Aa	39.78 Ab	36.39
Mean	28.89	40.55	44.62	38.02

Means followed by the same uppercase letter in the line and lowercase in the column do not differ by the Tukey test at 5% of probability.

According to Pavan and Chaves (1994), denser cropping systems improve the productive capacity of the soil, providing aggregate stability and moisture retention.

In cropping with higher cultivation density, the main roots may become deeper in the soil, it is turning the plants more efficient in the use of available water and in the translocation and utilization of nutrients (AUGUSTO et al., 2007).

The increased cropping density of *C. canephora* allowed better use of the area.

The higher population per hectare provided increased crop yield, also as observed for many cultivars of *C. arabica* by Paulo and Furlani Júnior (2010) and Paulo, Furlani Júnior and Fazuoli (2005).

4 CONCLUSIONS

Under the limits evaluated, a reduction in spacing associated with an increase in the number of orthotropic stems per plant had a positive effect on the crop yield of conilon coffee.

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