NEW MANAGEMENT TECHNOLOGY FOR ARABICA COFFEE: THE CYCLIC PRUNING PROGRAM FOR ARABICA COFFEE

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ABSTRACT: This study aimed to better understand the productive behavior of *Coffea arabica* when cultivated using the new management of Cyclic Pruning Program for Arabica Coffee (CPPAC), stablished using the same principles of the Cyclic Pruning Program for Conilon Coffee. The experiment was carried out in Baixo Guandú, Espírito Santo state, in the Southeast region of Brazil, in order to test the conditioning of this new pruning management for Arabica coffee (CPPAC) over the crop yield of a plantation of Catuaí Vermelho IAC 81. It was found increased crop yield with use of the (CPPAC) over the traditional management of Arabica coffee, considering five consecutive years of production. The (CPPAC) technique can be used as a viable alternative for pruning management of Arabica coffee.

Index terms: Number of stems, *Coffea arabica*, harvest, crop yield.

NOVA TECNOLOGIA DE PODA PARA O CAFÉ ARÁBICA: PODA PROGRAMADA DE CICLO PARA O CAFÉ ARABICA

***RESUMO*:** *Este estudo teve como objetivo compreender melhor o comportamento produtivo do café, Coffea arabica quando cultivado usando a nova tecnologia da Poda Programa de Ciclo para o Café Arábica (PPCA), estabelecida usando os mesmos princípios da Poda Programa de Ciclo do Café Conilon. O experimento foi desenvolvido em Baixo Guandu, no Espírito Santo, na região Sudeste do Brasil, a fim de testar o condicionamento dessa nova tecnologia de poda para o Café Arábica (PPCA) sobre o rendimento da colheita de uma plantação de café Catuaí Vermelho IAC 81. Foi encontrado aumento da produtividade com o uso da PPCA sobre a poda tradicional do café arábica, considerando cinco anos consecutivos de produção. A técnica da PPCA pode ser usada como uma alternativa viável para a poda do café arábica.*

Termos para Indexação: *Número de hastes, Coffea arabica, colheita, produtividade.*

1 INTRODUCTION

Coffee has always been among the main crops in Brazilian economy, giving the country a prominent position as the largest producer and exporter of this product. In the season 2015, more than 43.24 million 60-kg bags of processed coffee were produced, with 32.05 million Arabica coffee (*Coffea arabica* L.) and 11.19 million conilon coffee (*Coffea canephora* Pierre ex A.Froehner). In Brazil, the Espírito Santo statest ands out as the second largest producer of coffee while occupying only 0.5% of the national territory (COMPANHIA NACIONAL DE ABASTECIMENTO - CONAB, 2015).

During coffee cultivation, after successive harvests, it is common to observe that the orthotropic and plagiotropic branches diminish their vigor and consequently the plant loses productive capacity. Thus, an intervention becomes necessary to reverse this situation, and in that sense, the pruning emerges as an interesting alternative in the quest for revitalization of coffee crops (FERNANDES et al., 2012).

Pruning is a technique that stimulates the formation of new branches and more photosynthetically active leaves (AGUSTÍ-FONFRIA, 2003), controls the vegetative growth, and enhances brightness and ventilation of canopies (SARTORI et al., 2007). The correct applicability of pruning techniques in commercial crops must take into consideration several factors such as variety, vegetative vigor, spacing, fertilization, irrigation, soil management, among others (SANTAROSA

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et al., 2013). Coffee plants are cultivated with different densities in Brazilian regions, depending on soil and weather conditions. Thus, to increase land use efficiency, adjusting the adequate spacing for planting and subsequent handling is required. For crops in mountainous areas and using short cultivars, the recommendation of several authors include densities above 5,000 plants per hectare (ANDROCIOLI FILHO; CARAMORI; CARNEIRO FILHO, 2002; FERNANDES et al., 2012; FERRÃO et al., 2008; MATIELLO et al., 2010; SANTINATO; FERNANDS; FERNANDES, 2008; THOMAZIELO; PEREIRA, 2008).

Increased density is a practice that changes the microclimate of the plantation, modulating light, temperature and relative humidity in the canopies. This condition, if not properly managed, can promote the occurrence of plant diseases (MEIRA; RODRIGUES; MORAES, 2009; MIRANDA, 2006; PAIVA et al., 2011; SANTOS; SOUZA; POZZA, 2004; TALAMINI, 2003).

Different authors presented papers related to the main pruning managements recommended for Arabica coffee (JAPIASSÚ et al., 2010; PEREIRA et al., 2007, 2013; QUEIROZ-VOLTAN et al., 2006; SILVA et al., 2016), these pruning managements are called "recepa", "esqueletamento" and "decote" (in Portuguese). "Recepa" is the most drastic pruning, removing almost all aerial coffee parts, cutting is made 40 to 60 cm above the ground. "Esqueletamento" can also be regarded as a severe pruning, cutting reproductive branches about 40 cm of the trunk. For both pruning systems, the pruning may result in reduction of root system and plant recovery will be influenced by the new shoot buds. "Decote" is a pruning that eliminates the plant apex, with heights that usually ranges from 1.60 to 2.60 meters from soil level.

However, most of these techniques cause drastic effects on plants which can lead to plant death, in some cases, or reduction of root system and longer recovery time before a new production, among others. Some authors, testing different pruning intensities (GONÇALVES et al., 2014; KUMAR et al., 2010; SOUZA et al., 2014), found that the crop yield decreases with the increasing intensity of drastic pruning.

For *C. canephora*, it was recently developed a new management called Cyclic Pruning Program for Conilon Coffee (CPPCC), which is based on introducing a number of 12,000 and 15,000 orthotropic stems per hectare. Once determined the optimum number of orthotropic stems per plant, they remain on the plant for three or four harvests, at this time, 50 to 75% of the stems are removed, promoting the thinning which case it holds the selection of new shoots that will form the new shoots, always selected at the base of the plant. The remaining stems after this process will produce only one more year and then will be removed, remaining only new shoots under development. It is noticeable that there is no null harvest in CPPCC, with a great advantage for the producer, ensuring it to obtain production every year (VERDIN FILHO, 2011).

An increase in crop yield was obtained in studies working with the (CPPCC) using different plant spacing, number of orthotropic stems per plant, and total number of stems per hectare. It was observed that by reducing the spacing and increasing the number of orthotropic stems, the plantation tends to gain in productivity (VERDIN FILHO et al., 2014).

In this context, there are several strategies for pruning management of coffee plants, but a differential management of Arabica coffee could benefit its cultivation, especially in the mountain regions. Based on these assumptions, this work was carried out to study the implications of the use of the Cyclic Pruning Program for Arabica Coffee (CPPAC) over the crop yield.

2 MATERIALS AND METHODS

The study was carried out in the municipality of Baixo Guandú, at altitude of 634 m over sea level, with latitude 19º21'44.32"S and longitude 40°50'31.95"W, located in the Northwest region of Espírito Santo State, in the Southeast region of Brazil. The climate, following the Koppen classification, is tropical humid with an average temperature of 24.2 ºC and the region presents wavy-topography (FEITOSA et al., 1999).

The experiment followed a randomized block design, with six treatments, evaluated with four replicates and experimental plots consisting of five plants. The results of the cumulative productivity were obtained by summation of productivity over the five harvests. The treatments were established in an eight-year-old plantation, formed by the cultivar Catuaí Vermelho IAC 81, of intermediate maturation cycle, planted in a spacing of 2.5 x 1.0 m. The six pruning management levels consisted descriptions in Table 1.

TABLE 1 - Description of treatments: number of stems per plant and the number of stems per hectare.

Treatment	Description	Number of stems per plant	Number of stems per hectare
T1	Traditional pruning without removal of reproductive branches	2	8.000
T2	CPPAC with removal of 70% of reproductive branches that produced in the season	2	8.000
T3	CPPAC with removal of 50% of reproductive branches that produced in the season	2	8.000
T4	Traditional pruning without removal of reproductive branches	3	12.000
T5	CPPAC with removal of 70% of reproductive branches that produced in the season	3	12.000
T6	CPPAC with removal of 50% of reproductive branches that produced in the season	3	12.000

CPPAC =Cyclic Pruning Program for Arabica Coffee.

The five productive harvest levels consisted of the coffee harvest in the years 2010 to 2014. A second test was used to verify the reproductive behavior of Arabica coffee along the productive crops due to the cycle of pruning. For this, we used a split plot in time 6x5, the plots factor management of pruning on six levels, the subplots the productive crop factor of five levels, with randomized blocks and four blocks. After harvest, the plants were cut at 20-30 cm in height and the six treatments described in Table 1 were applied. After the start of growth of the new shoots, two thinning operations were performed at approximately 90 and 150 days after the cutting. Also in 2013, it was made a descriptive analysis for the following variables: a) classification by maturity: was taken samples of each parcel and quantified the percentage of fruit fully ripe, green, dry and voids; b) Time spent in the harvest: to determine the time to harvest the plots the time spend was measured and converted into d/h (workday hours), and quantified the volume of coffee per share and transformed into bags of 80 L per d/h.

Considering these treatments, the pruning management used in the experiment was adapted from the similar technique pruning recommended for the species *C. canephora* called Cyclic Pruning Program for Conilon Coffee (VERDIN FILHO et al., 2009).

After the first harvest, the respective percentage of reproductive branches in treatments T2, T3, T5 and T6 were removed from the plants and after that, this removal of reproductive branches took place every two years, differently from the CPPCC which carries it out every year. It is noteworthy that two to three shoot thinning were done each year. Thus, the plants were cultivated until the fifth harvest, proceeding the reduction of the orthotropic stem number of treatments T2, T3, T5 and T6, leaving only one rod per plant, in order to prioritize the growth of the new shoots, allowing a vigorous renewal for a final cycle and preventing the total cut of the steams and the consequent null harvest of the next year. Thus, after the fifth harvest, shoots with 40 days of age and a maximum height of 25 cm were selected to be kept, aiming to keep the same number of orthotropic stems per plant, from 2 to 3 stems, according to the treatment. At this time, the plant present shoots growing fast and one orthotropic stem that will secure the sixth harvest. This last stem was removed immediately after this harvest.

With this process, the first cycle of pruning ends and a new cycle can start in the Cyclic Pruning Program for Arabica Coffee (CPPAC) with a fully renovated plant that will be able to express their productive potential.

For the standard pruning in treatments T1 and T4, the only interference was the standard conduction of the stems, without debranching for up to the fifth crops, when the plants were then cut again.

The fertilization and cultural practices were performed according to current recommendations for coffee culture in the region (FERRÃO et al., 2008; PREZOTTI, 2007).

The variables studied were: a) in all treatments: crop yield (bags of 60 kg ha^{-1}) of Arabica coffee on the basis of management stems over five harvests, (from 2010 to 2014). To determine the crop yield of each plot was used the ratio of 6: 1 (every 6 kg of coffee cherries harvested generate 1 kg of green coffee), resulting in the yield in sacks of 60 kg commercial green coffee per hectare (bags of 60 kg ha^{-1}); b) Uniformity of maturation (%): the fruits were separated in fully ripe, green, dried and voids at the time of harvest, samples were taken from each plot and quantified in percentage; (c) Manpower employed in the harvest: the time spent to harvest each plot was measured and converted into d/h (workday hours), and quantified the volume of coffee per share and transformed into bags of 80 L per d/h.

The crop yield data were submitted to analysis of variance, and in presence of significance difference, means were compared by Tukey test at 5% of probability. The statistical analyzes were performed using the statistical program "GENES" (CRUZ, 2013).

3 RESULTS AND DISCUSSION

The interaction between pruning management and consecutive harvests years was observed based on behavior of Arabica coffee plants.

In the mean tests presented in Table 2, it is presented that the second crop (2011), has the highest productivity. In the first harvest (2010), productivities were high and statistically similar for all treatments, Paulo, Furlani Júnior and Fazuoli (2005) and Silva et al. (2004) assessing plant density also had productivity growing in the first harvests.

In the second harvest, the treatments with three stems per plant (T4, T5 and T6) stood out. In the third harvest, the treatments T2, T3, T1 and T5 were the highest productivity. For the fourth harvest, treatments with three stems (T5, T6 and T4) promoted higher crop yield. And the fifth harvest treatments with two rods (T2, T3 and T1) and (T4) with three rods, made the average values were higher for this variable. It is noteworthy that the procedures for pruning and stem thinning were inserted after the first and third harvests, which reflected in significant gains in production of the subsequent season for the treatments conducted with three stems.

Thus, it is observed that for the managements T4, T5 and T6, the crop yields recover during the next year after pruning and thinning procedure. The return of the higher crop yield from 2012 to 2013 was not observed for plants cultivated with T1 and T3, being verified significant reduction in productivity (Table 2). Pereira et al. (2011), reported that there is influence of spacing over the biennially, with an emphasis on plant density. In general, it is observed that there is an alternating productivity between treatments with two and three orthotropic stems per plant after the second harvest. This study corroborates Pereira et al. (2007), to conclude that the production per area is increased with higher plant densities.

However, due to the fact the management with three stems have demonstrated high production rate in the second harvest, as well as good recovery capacity along the sequential harvests, it is suggested that this type of management led to higher crop yield in Arabica coffee plantation, especially when associated with the CPPAC with removal of reproductive branches that have produced 70% of its production load. Surely this was because the plants in this condition could present a greater canopy, better leafiness, with the largest number of reproductive structures and photosynthetic capacity. Valadares et al. (2013) reports that denser crops provide better use of solar radiation and cycling of nutrients, due to higher leaf surface and root density, which provide higher production rates with the use of a larger number of stems per area.

Higher number of stems per plant promotes greater production of photoassimilates (reserves) and hence greater issuance of flowers. Campagnolo and Pio (2012) and Moreira et al. (2004) observed that increased plant density promotes increased productivity, but causes a lock between the lines (canopies superposition), therefore, there is a need for different and adequate pruning management.

Studying the means along the years, the higher crop yields (bags of 60 kg ha^{-1}), were obtained in the second and first harvests (2011 and 2010).

The superiority of these treatments is presented in Figure 1, through the cumulative productivity. It is observed that the best treatment (T5) reached 231.0 bags ha^{-1}, against 179.2 bags ha^{-1} from the standard pruning method (T1). This result represents a total production increase of 51.8 bags ha^{-1} for the producer within five years using only the management of pruning to achieve this gain.

TABLE 2 - Means of crop yield (bags of 60 kg ha^{-1}) along five consecutive harvests of Catuaí Vermelho IAC 81 conducted with six pruning managements; Alto Mutum Claro, Baixo Guandú, Espírito Santo, Brazil.

Treatments	Description	2010	2011	2012	2013	2014
T1	2 stems per plant, Traditional pruning, without removal of reproductive branches	43.67ABa	46.22Ab	33.36Cab	22.55Dc	33.41 BCabc
T2	2 stems per plant, "CPPAC" with removal of reproductive branches which produced 70%	45.61Aa	42.11Ab	38.61ABa	31.64Bbc	41.57ABa
T3	2 stems per plant, "CPPAC" with removal of reproductive branches which produced 50%	49.88Aa	39.83ABb	34.31 Bab	23.74Cc	39.64ABab
T4	3 stems per plant, Traditional pruning without removal of reproductive branches	39.65Ba	75.30Aa	22.51Cc	38.52Bab	36.70Babc
T5	3 stems per plant, "CPPAC" with removal of reproductive branches which produced 70%	46.99Ba	74.58Aa	30.94Cabc	48.75Ba	29.74Cbc
T6	3 stems per plant, "CPPAC" with removal of reproductive branches which produced 50%	45.21Ba	65.87Aa	26.87Cbc	48.19Ba	26.98Cc

CPPAC = Cyclic Pruning Program for Arabica Coffee

Means followed by the same lower case letter in the column or capital on the line do not differ statistically by Tukey test at 5% probability.

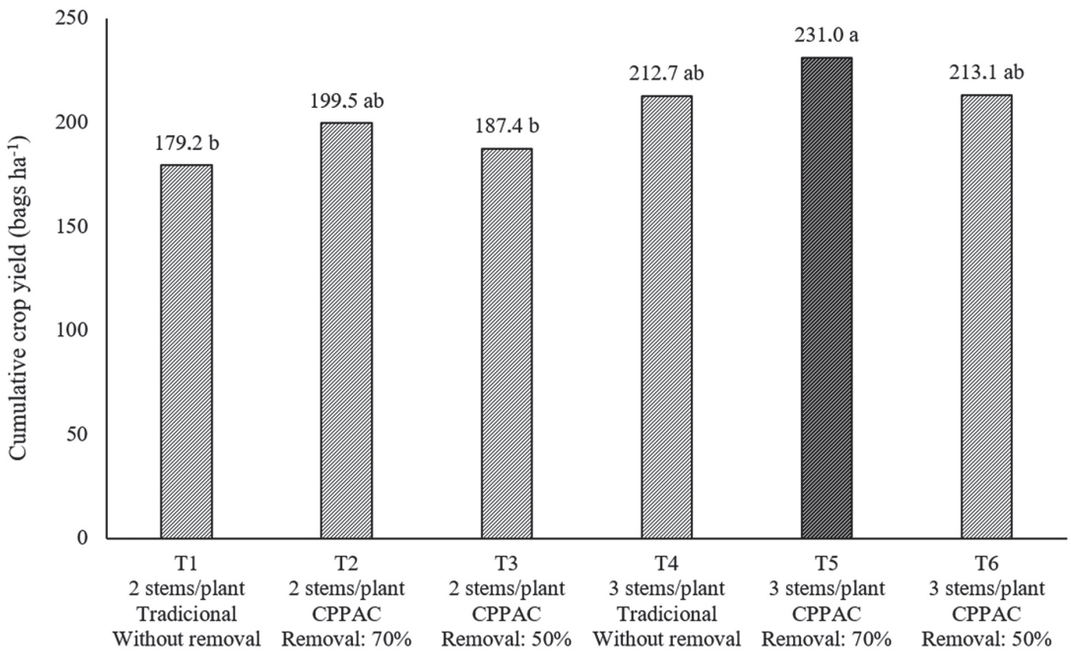

FIGURE 1 - Accumulated productivity in five years (bags of 60 kg ha^{-1}) the variety of Arabica coffee Catuaí Vermelho IAC 81, conducted with the scheduled pruning cycle; Alto Mutum claro, Baixo Guandu, Espírito Santo, Brazil.

It is worth noting that research results also show increased productivity in denser systems during the first harvests (PAULO; FURLANI JÚNIOR; FAZUOLI, 2005), which corroborates the need for recommendation of a pruning system to exploit the better conduction of the plants.

The pruning management in this study, as the spacing of cultivation, phytosanitary treatment, the fertilization, atmospheric conditions, in short, all the plants were subjected to the same growing conditions, just by changing the way the plant architecture was managed, that is, by modifying the pruning technique and insert the CPPAC, it was possible to obtain a considerable increase in the crop yield of Arabica coffee.

The present study corroborates Andrade et al. (2014), Carvalho et al. (2013) and Ronchi et al. (2015), that studying plant density and pruning management, the authors found increased productivity in farming.

With the development of the work, it was observed higher uniformity of maturation and faster harvest in treatments with the sequential removal of reproductive branches after production. The rate of harvest of the crop, has almost doubled in the treatments of removing branches (PPCCA) compared with the control (T1 and T4), the same treatments and also showed a lower percentage cherry fruit. These data demonstrate that there can be a reduction of labor at harvest due to improved crop management. However, it noted that, for the adoption of this technology is necessary to use manpower to carry out pruning and thinning, which can be balanced with increased crop yields and faster harvest.

The main advantages observed with the new pruning management of Arabica coffee proposed in this study were: a) average 50% reduction in manpower required to harvest the T2 and T5 treatments when compared to treatment T1. b) greater uniformity in maturation; c) increase in crop yield of up to 28.9%; d) elimination of the more severe types of pruning (like low cutting of stems) and consequently the evasion of years with null harvests, increasing the crop stability along the years; e) standardization of pruning and ease of understanding of the new plant management system.

In general, it is observed that the productivity of Arabica coffee was favored by the management of plants with three stems and removal of reproductive branches that have produced more than 70% of its production capacity. It is possible that this result has been obtained on the basis of physiological and morphological improvement in Arabica coffee plants, which certainly was the formation of stronger systems in these plants, as well as improvements in gas exchange indexes, with a possible increase in liquid carbon assimilation rates, which can be grounded at higher production rate.

It is possible that this pruning management has favored the source/sink relations in coffee plants, which is due to favorable changes in the photosynthetic apparatus (PEREIRA et al., 2013; THOMAZIELLO; PEREIRA, 2008.). In addition, pruning helps considerably in nutrient cycling, soil conservation, maintenance of soil organic matter in the soil, among others, it provides the vegetative parts taken from plants grown in the culture medium (THOMAZIELLO; PEREIRA, 2008).

Greater investment in area and volume of the canopy favors the soil exploration capacity in search for water and nutrients, due to the joint development of the root system in relation to shoots, in accordance with Alves et al. (2011), Mota et al. (2006), Pereira et al. (2011) and Ronchi et al. (2015). It is possible that plants with more stems and more vigorous canopies (due to removal of weak branches) present better development of the root system, contributing to their growth and production. In addition, several studies indicate that the formation of microclimates inside the canopy of vigorous coffee plants is capable of mitigating climate variables such as radiation and temperature (PARTELLI et al., 2014; PEZZOPANE et al., 2010, 2011), which can promote lower pressure of environmental conditions over physiological processes. Thus, it is possible that the gains in crop yield over five consecutive harvests are justified by the improvement of physiological characteristics of Arabica coffee conducted with this management pruning.

TABLE 3 - Proportion of ripe, green, dry and void fruits, and harvest speed (bags/d/h) of Catuaí Vermelho IAC 81 conducted with traditional pruning and under new Cyclic Pruning Program for Arabica Coffee (CPPAC); Alto Mutum Claro, Baixo Guandú, Espírito Santo, Brazil.

Treatments*	Proportion of fruits (%)				Harvest speed
	Ripe	Green	Dry	Void	bags (80 L) workday hours
T1	63.0	26.4	5.7	4.9	5 a 7
T2	71.7	25.7	1.6	1.0	10 a 14
T3	71.5	25.2	1.9	1.4	10 a 14
T4	62.8	26.7	5.9	4.6	5 a 7
T5	71.4	24.8	1.7	2.1	10 a 12
T6	71.8	25.2	1.7	1.3	10 a 12

* T1 = 2 orthotropic stems / plant, traditional pruning without withdrawal Plagiotropic; T2 = 2 orthotropic / plant stems, with (CPPCA) with Plagiotropic withdrawal that produced 70%; T3 = 2 orthotropic / plant stems, with (CPPCA) with Plagiotropic withdrawal that produced 50%; * T4 = 2 orthotropic stems / plant, traditional pruning without withdrawal Plagiotropic, T5 = 3 orthotropic stems / plant, with the (CPPCA) with withdrawal Plagiotropic that produced 70%, T6 = 3 orthotropic / plant stems, with (CPPCA) with withdrawal plagiotropic that produced 50%.

4 CONCLUSION

For the studied conditions, the crop yield of Arabica coffee is favored considerably by the cultivation with three orthotropic stems per plant and use of cyclic pruning program for Arabica coffee, with removal of reproductive branches that produced 70% of their production capacity.

The use of this pruning management may be recommended as a technique that increases area use and productivity rates.

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