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Population density of Arabica coffee cultivars for bean quality and yield[1]

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ABSTRACT

For the implantation of a coffee tree crop, aiming at a high yield, each cultivar, depending on the plant distribution and density, can express differently its results. This study aimed to evaluate the yield potential and grain quality of Arabica coffee cultivars grown under different spacings between rows and between plants. A randomized block design was used, with three replications, in a split-split-plot scheme, being the plots three coffee cultivars (Obatã IAC-1669-20, Tupi IAC-1669-33 and Catuaí Vermelho IAC-144), four spacings between rows (1.8 m, 2.0 m, 2.5 m and 3.0 m) and four spacings between plants in the row (0.5 m, 0.7 m, 0.8 m and 1.0 m), totaling 48 treatments. The type of coffee bean (flat, peaberry and elephant) and yield per hectare were evaluated. The Obatã cultivar showed the highest potential yield, in relation to Tupi and Catuaí Vermelho, and also the highest percentage of flat grains. The factors, in order of importance, that interfere with the potential yield of processed coffee are the cultivar and the spacing between rows and between plants.

KEYWORDS: *Coffea arabica*; coffee growing; morphological characteristics of coffee trees.

RESUMO

Densidade populacional de cultivares na produtividade e qualidade de grãos de café arábica

Na implantação da lavoura cafeeira, visando a uma alta produtividade, cada cultivar, dependendo da distribuição e da densidade de plantas, pode expressar, de maneiras diferentes, seus resultados. Objetivou-se avaliar o potencial produtivo e a qualidade de grãos de cultivares de café arábica, em função de espaçamentos entre linhas e entre plantas. Utilizou-se o delineamento de blocos ao acaso, com três repetições, em esquema de parcelas subsubdivididas, sendo os fatores três cultivares de café (Obatã IAC-1669-20, Tupi IAC-1669-33 e Catuaí Vermelho IAC-144), quatro espaçamentos entre linhas (1,8 m; 2,0 m; 2,5 m; e 3,0 m) e quatro espaçamentos entre plantas na linha (0,5 m; 0,7 m; 0,8 m; e 1,0 m), totalizando 48 tratamentos. Foram avaliados os tipos de grão (chato, moca e concha) e a produtividade por hectare. A cultivar Obatã apresentou maior potencial produtivo que a Tupi e Catuaí Vermelho, bem como maior porcentagem de grãos chatos. Os fatores, em ordem de importância, que mais interferem no potencial produtivo de café beneficiado são a cultivar e o espaçamento entre linhas e entre plantas.

PALAVRAS-CHAVE: *Coffea arabica*; cafeicultura; características morfológicas de cafeeiro.

INTRODUCTION

In coffee cultivation, spacing determines the number of plants per area and is based on the spacing between rows multiplied by the spacing between plants in the row. Depending on the growing conditions, the plant population density can significantly modify the yield of coffee beans.

Coffee crops are highly influenced by the interaction genotype-environment. The yield reached by a given cultivar is related, in addition to other technical aspects, to the adopted spacing. According to Pereira et al. (2011), reducing the spacing between rows and between plants in the row results in increased coffee yields. The number and distribution of plants are decisive to obtain high coffee yields and should be considered in the adoption of spacings for coffee crops.

Given that coffee crops in Brazil are grown in extensive areas, there can be several coffee

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production systems using different spacings and a different number of plants, when the coffee crops are started. This implies a yield variation in several production regions, frequently resulting in a low expression of the genetic potential of the cultivar selected for planting.

According to Ferraz et al. (2012), coffee growing in Brazil takes place in environments with a great diversity of climate, soil, relief, physiological characteristics (cultivar, age, skirt and crown diameter, fruit color, etc.), phytosanitary infestations and crop managements (cropping systems, irrigation, mechanization, fertilization and spraying). The diversity of these factors may strongly influence coffee yields, and even crop management, when carried out in a homogeneous way, and reduce the rural producers' profitability.

For Siqueira et al. (1985) and Sakai et al. (2013 and 2015), increased coffee yields can be reached by an increase per area unit, followed by an increase in plant population, mainly in the first harvests.

In Colombia, Uribe & Mestre (1988) observed that a population of 10,000 plants ha^{-1}, with the use of one, two or three plants per pit and differentiated spacing, provided the maximum yield. According to Scaranari & Nogueira Neto (1963) in Brazil, and Mitchell (1976) in Kenya, a density of 5,000 plants ha^{-1} provided the highest yield, while Rodriguez et al. (1966), in Puerto Rico, found the best density using 6,000 plants ha^{-1}; however, Hangdong & Bartolomeu (1966) showed a population of 3,333 plants ha^{-1} as the most adequate one.

Considering that smaller spacings are mainly adopted to increase the coffee yield per area, it is important to emphasize that changes in spacings can generate differentiated results in coffee cultivars, interfering in crop practices, as well as stressing the need for programmed pruning. In addition, if the plant yield potential is not exploited, the production costs may increase.

As a result of this search for a greater yield and competitiveness in the coffee agribusiness, Oliveira et al. (2010) observed the use of innovative production systems in the sector, seeking to increase the competitiveness through market differentiation for quality.

According to Silveira et al. (2015), for the coffee bean size of the Obatã cultivar, under dry conditions and first production, 42 % of the grains were larger than 16 mm with conventional fertilization, while, under fertigation, this percentage was more than 75 %.

Thus, the present study aimed to evaluate the yield and grain quality of three small size Arabica coffee cultivars in different planting spacings.

MATERIAL AND METHODS

The experiment was conducted at an experimental area of the Fundação de Pesquisa e Difusão de Tecnologia Agrícola Luciano Ribeiro da Silva, in São José do Rio Pardo, São Paulo state, Brazil (21º37'16"S, 46º53'15"W and 750 m of altitude).

A randomized complete block design, with three replicates, was used in a split-split-plot factorial scheme. Three cultivars of Arabica coffee under dry conditions were evaluated, of which two were resistant to rust (Obatã IAC-1669-20 and Tupi IAC-1669-33) and one susceptible to rust (Catuaí Vermelho IAC-144). The seedlings were planted in 2004, at four spacings between rows (1.80 m, 2.00 m, 2.50 m and 3.00 m) and four spacings between plants in the row (0.50 m, 0.70 m, 0.80 m and 1.00 m), with one plant per plot, totaling 48 treatments.

The fertilizations at implantation, formation and production were performed according to the recommendations proposed by Raij et al. (1997). Yield was evaluated at the first three harvests: 2005/2006, 2006/2007 and 2007/2008.

Yield was evaluated based on the amount of fruits (cherries, green and withered berries) harvested manually in plants from the useful area of each plot. After that, a sample of 2.0 kg of berries was collected and stored in plastic net bags for sun drying. After the drying period, the samples were processed and weighed, thus producing the data used to calculate the coffee yield.

A grain quality evaluation was performed only for the 2008 harvest. Samples of 100 g of each treatment were collected, manually separated and sorted by flat, peaberry and elephant beans, and then weighed separately. According to the ABIC (2013), flat grains have a convex dorsal surface and ventral plane or slightly concave, with a central groove in the longitudinal direction - these are considered normal for coffee. The peaberry type has an ovoid shape and a central groove in the longitudinal direction. Elephant grains have a shell shape resulting from the separation of imbricated grains resulting from fertilization of two ova in a single ovary.

The data were submitted to analysis of variance, applying the F test to verify significant differences among the treatments, and the Tukey test at 5 % of significance to compare means.

RESULTS AND DISCUSSION

The interactions of spacing between either rows, plants or cultivars were not significant for the characteristics evaluated using the F test at 5 % of significance (Table 1). This same result was found in the interactions spacing-between-rows x spacing-between-plants, and spacing-between-plants x spacing-between-cultivars. However, the analysis of spacings between rows and between cultivars showed a significant difference in the percentage of flat grains (of greater commercial interest) and in yield, with a tendency of increased yields as the spacing between rows decreases, regardless of the cultivar. The spacing between rows of 1.80 m showed a superior yield, if compared to those of 2.50 m and 3.00 m, reaching up to 54 % more, in terms of yield.

The spacing between rows, between plants and between cultivars, in isolation, showed a significant difference by the F test at 5 % of significance. A higher percentage, regarding the spacing between plants of 0.50 m, was observed for flat-type grains, when compared to the spacing between plants of 1.0 m; and the Obatã cultivar was superior to Catuaí Vermelho and Tupi, both in terms of flat grains and yield. This finding may be explained by the intrinsic genetic aspect of this cultivar, which is considered a hybrid plant, and it is probably more adapted to the climate of the region under study.

For the 3.00 m spacing between rows, there was a lower percentage of flat grains, in relation to other spacings (Table 1). As for the peaberry-type grains (of lower economic interest), the highest percentage was observed also for the 3.00 m spacing, to the detriment of the others. In relation to spacing between plants, a similar behaviour was observed to spacing between rows, in which the mean values of flat grains were lower in the larger spacings between plants (0.80 m and 1.00 m).

Regarding cultivars, Fazuoli (1986) indicates that the percentages of normal seeds of the flat type should range between 82.3 % and 89.1 %, values that are higher than those found in the present study.

Table 1. Mean values for coffee characteristics of the cultivars Obatã, Catuaí Vermelho and Tupi, grown under different combinations of spacings between either rows (BR) and plants (BP) or cultivars, and yield.

Treatments	Processed coffee beans (%)			Yield (kg ha^{-1})
	Flat	Peaberry	Elephant	
BR (m)				
1.80	64.64 ab	22.90 b	12.47 a	4,180.20 a
2.00	65.95 a	23.38 b	10.67 a	4,086.00 ab
2.50	64.04 ab	23.30 b	12.66 a	2,715.00 c
3.00	62.69 b	25.89 a	11.42 a	3,184.80 bc
BP (m)				
0.50	65.38 a	23.06 b	11.56 a	932.40 a
0.70	65.20 a	23.21 b	11.59 a	3,559.20 ab
0.80	64.31 ab	23.55 ab	12.14 a	3,424.80 ab
1.00	62.41 b	25.66 a	11.92 a	3,249.60 b
Cultivars (VAR)				
Obatã	67.12 a	22.89 b	9.99 b	45.00 a
Catuaí Vermelho	61.18 c	27.33 a	11.50 b	2,444.40 b
Tupi	64.69 b	21.38 b	13.93 a	2,735.40 b
F (BR)	3.44*	4.05**	2.91*	17.95**
F (BP)	3.47*	3.20*	0.26*	2.99*
F (VAR)	22.36**	27.62**	17.57**	129.79**
F (BR * BP)	1.07^{ns}	0.66^{ns}	1.33^{ns}	0.56^{ns}
F (BR * VAR)	2.75*	1.47^{ns}	2.30^{ns}	5.34 **
F (BP * VAR)	0.81^{ns}	1.46^{ns}	0.49^{ns}	1.12^{ns}
F (BR * BP * VAR)	0.66^{ns}	0.63^{ns}	0.88^{ns}	0.82^{ns}
CV (%)	6.80	17.07	27.81	28.41

Means followed by the same letter in the columns do not differ significantly from each other by the Tukey test at 5 % or 1 % of significance. F = F test value for factors and interactions; ^{ns} not significant; * significant at 5 % of probability; ** significant at 1 %.

In relation to the elephant-type grains, no significant changes were observed in the mean values for spacings between rows and between plants; however, between cultivars, a percentage of larger elephant grains was observed for the Tupi cultivar.

The results showed a higher yield in densified spacings and also a higher percentage of flat grains and a lower percentage of peaberry grains. The more the spacings between rows and between plants in the row are reduced, the greater the number of flat beans and the fewer the peaberry grains, without altering the shell defect. Rezende et al. (2010) did not find significant differences in the processed coffee classification, when working with irrigation at different times, in Arabica coffee.

Higher yields were observed for Obatã, including the best grain quality, with 67.12 % of flat grains, and the lowest average value for elephant grains (9.99 %). In addition to such an excellent yield, Obatã showed the highest presence of flat grains and fewer defects in the coffee beans. It is important to emphasize that the evaluation of grain quality was performed in 2008, a year of high yields.

Data for average processed coffee yields, at the first three harvests, and F test values for factors and their interactions are shown in Table 2. Yield was significantly affected by the evaluated production factors (spacings between rows, between plants and between cultivars); however, there was no significant interaction between these factors.

The yield of the three cultivars increased significantly by reducing the spacings between rows and between plants, with a more expressive effect for spacings between rows. This behaviour justifies the need for adjustments in the spacings for the implantation of small coffee crops, especially spacings between rows, in order to maximize the potential of cultivars, in order to obtain higher yields per cultivated area.

According to Matiello et al. (2010), in the last 30 years, there has been a tendency to distribute plants better along the row, at smaller distances, ranging from 0.5 m to 1.0 m, with only one plant per pit. These authors verified an increase of 28 % in the yield per area, as well as a reduction of yield per plant, thus reducing postharvest wear. On the other hand, they warn that it may increase the risk of rust attack and plant verging.

The highest processed coffee yield was observed in the first triennium, which was obtained

Table 2. Yield of processed coffee beans for the cultivars Obatã, Catuaí Vermelho and Tupi, grown in different combinations of spacing between rows (BR) and between plants (BP), in the first three harvests.

Treatments	Processed coffee beans yield (kg ha^{-1})			
	2006	2007	2008	Average
BR (m)				
1.80	4,059.00 a	619.80 ab	4,180.20 a	2,953.20 a
2.00	3,186.00 ab	519.60 b	4,086.00 ab	2,597.40 ab
2.50	2,245.20 b	291.60 b	2,715.00 c	1,750.80 c
3.00	1,873.20 b	933.60 a	3,184.80 bc	1,997.40 bc
BP (m)				
0.50	3,256.20 a	595.80 a	3,932.40 a	2,595.00 a
0.70	3,057.60 a	520.20 a	3,559.20 ab	2,379.60 ab
0.80	2,748.60 a	583.80 a	3,424.80 ab	2,252.40 ab
1.00	2,302.80 a	663.60 a	3,249.60 b	2,071.80 b
Cultivars (VAR)				
Obatã	3,315.00 a	508.20 a	5,445.00 a	3,088.20 a
Catuaí Vermelho	2,631.00 a	600.60 a	2,444.40 b	1,891.80 b
Tupi	2,578.80 a	665.40 a	2,735.40 b	2,011.80 b
F (BR)	12.78**	11.11**	13.68**	13.99**
F (BP)	4.34^{ns}	0.45^{ns}	4.38^{ns}	7.72*
F (VAR)	6.2^{ns}	0.71^{ns}	38.18**	56.29**
F (BR * BP)	2.39^{ns}	0.40^{ns}	0.79^{ns}	0.86^{ns}
F (BR * VAR)	0.68^{ns}	1.19^{ns}	2.58^{ns}	2.25^{ns}
F (BP * VAR)	2.33^{ns}	1.63^{ns}	1.61^{ns}	1.52^{ns}
F (BR * BP * VAR)	0.56^{ns}	1.23^{ns}	1.31^{ns}	0.97^{ns}

Means followed by the same letter in the columns do not differ significantly from each other by the Tukey test at 5 % or 1 % of significance. F = F test value for factors and interactions; ^{ns} not significant; * significant at 5 % of probability; ** significant at 1 %.

using spacings of 1.80-2.0 m between rows and 0.5-0.7 m between plants. However, there was no significant difference for the spacings 0.5 m, 0.7 m and 0.8 m between plants. It was noted that the smallest row spacing (1.8 m) provided a yield 47 % higher than that obtained in the largest row spacing (3.0 m). Such a high yield is equivalent to approximately 960 kg of processed coffee per hectare, a significant value.

Sakai et al. (2015) evaluated the yield of Catuaí Amarelo coffee in different populations, with two-row spacings (1.6 m and 3.2 m) and three spacings in the row (0.50 m, 0.75 m and 1.00 m), and concluded that the spacing of 1.6 m in the row presented the highest yield in first three production cycles.

The results indicated that smaller spacings between rows and between plants resulted in a coffee yield increment at the first harvest, what corroborates the results obtained by Paulo et al. (2005), who verified a linear yield increase for the cultivars Obatã and Catuaí Amarelo, with a planting density increase at the first two harvests.

In the average of three harvests, Obatã showed a yield superior to Tupi and Catuaí Vermelho, what indicates a greater yield potential in the first three years of production. The average yield obtained by Obatã in the first triennium was 3,060 kg ha^{-1}, above the average Brazilian yield. It is noteworthy that this cultivar yielded 63 % and 53 % more than Catuaí Vermelho and Tupi, respectively.

A maximum yield of 5,400 kg and a minimum one of 480 kg ha^{-1} were observed for Obatã in 2008 and 2007, respectively, what can be attributed to a biennial yield oscillation, interspersing a low harvest with a high one. Considering that such behaviour was observed in the three cultivars, it can be inferred that the biennial yield in densified systems had already occurred since the first harvests.

Martins et al. (2015) evaluated a two-year coffee crop under dry conditions, which normally has a yield potential of 1,800 kg ha^{-1}. In comparison to the yield of 2014, this yield decreased to 774 kg ha^{-1}, and when adding losses in the picking process (16 %), the final yield was 648 kg ha^{-1} - values below those found for the evaluated cultivars.

CONCLUSIONS

1. Reducing the spacings between rows and between plants provides an increase in the yield of processed coffee beans, for the cultivars Obatã, Tupi and Catuaí Vermelho, in the first three years of production;
2. Obatã showed a higher yield of processed coffee beans in the first triennium, if compared to Tupi and Catuaí Vermelho;
3. The factors that most affect the yield potential of processed coffee beans are, in order of importance, cultivar, spacing between rows and spacing between plants.

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