

Evaluation of the productivity and plant health of pruned coffee intercropped with annual crops

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Abstract

Alley intercrop with annual crops is a usual practice in coffee cultivation, especially in periods of renewal of the crop by pruning. Its purpose is to make better use of the area, decrease costs of implantation and renovation, mainly in coffee plantations with open lines, through the production of subsistence food with generation of additional and immediate income of the producer. Therefore, the objective of the present study was to evaluate the productivity and plant health of pruned coffee crop in consortium with annual crops in different spacings. The experiment was carried out at the Instituto Federal de Educação, Ciência e Tecnologia do Sul de Minas Gerais – Campus Muzambinho, in the 2016/17 and 2017/2018 crop years, in a coffee plant of Catuaí Vermelho cultivar 144, 12 years old, pruned in 2014. Three intercrops (corn, chia and beans) in two spacings (30.0cm and 60.0cm) plus two additional treatments without intercropping (slashing or applying herbicide) were implanted in the soil. In the crop year 2016/17, a delay in the fruit maturation was observed in the treatment with intercropping spaced at 30.0cm, when compared to the same crops at 60.0cm spacing. The maturation of the fruits in the 2017/18 crop year was delayed in the treatments of consorts spaced at 60.0cm, when compared with the additional treatment. There was an expressive increase of cercosporiosis with cropping culture spacing 60.0cm. It was also observed that the average yield of coffee in the 2016/17 and 2017/18 crop years was affected by the interplant cultures implanted in the spacing of 30.0cm. In general, regardless of the spacings, intercropping negatively influenced the productivity of coffee in both 2016/17 and 2017/2018 crop years.

Keywords: Beans. Chia. Coffee. *Coffea arabica* L. Corn. Yield.

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Introduction

Brazil, as the largest coffee producer and exporter (*Coffea* spp.), occupies the second position in consumption behind the United States of America, becoming increasingly influential in agribusiness at the international level. High costs of agricultural inputs combined with inadequate crop management practices increase the cost of production, making coffee farmers seek new alternatives to reduce these costs and, consequently, increase profitability (NADALETI, 2017).

Intercropping is a usual practice in coffee growing, especially during periods of planting or renewal by pruning (ASTEN, 2011). The initial phase of implantation of the coffee plant has a very high cost, in addition, its economic return begins only at the third year (OUMA, 2009). The renewal of the crop interrupts the production of coffee up to two years, but the situation is complicated by very dense crops, which require periodic pruning from coffee growers (CARVALHO, 2010).

The main purpose of intercropping is to make better use of the area, to decrease the costs of implantation and renovation, especially in crops with open lines, through the production of subsistence food with the generation of additional and immediate income to the producer (SANTOS et al., 2008; CHUNG et al., 2013) through better use of the area, especially in small properties. The coffee consortium can also provide other benefits, such as improvements in soil moisture conservation conditions, reduction of damage caused by winds (DaMATTA; RAMALHO, 2006; PEZZOPANE et al., 2010), possibility of improving soil fertility (VAAST et al., 2005), reduction in the occurrence of spontaneous plants (SILVA et al., 2013), improvement in the use of labor (APARECIDO et al., 2014) and favoring financial return.

Crops intercropped with coffee are intended to favor the main crop. In its adoption, agronomic, economic, and ecological aspects of the production system are considered. However, depending on the species and management, they may bring additional benefits or undesirable losses, directly influencing the potential of the crop (SANTOS et al., 2008).

The adherence to this cultivation system must be based on technical criteria that involve the analysis of several factors, such as the choice of the appropriate species/cultivar, the level of shading, fertility, irrigation, altitude, and climate. Although intercropping has some advantages, both intercropping and coffee cultivation must be well planned for the success of using this practice (CARVALHO et al., 2007). However, the difficulties of mechanization and execution of phytosanitary treatments, the competition of intercalary crops for water, nutrients and light, in addition to the consequent reduction in the growth and production of coffee trees (PAULO et al., 2004), make the recommendation of cultures intercalations in coffee plantations controversial.

Among the intercrop crops most planted in coffee plantations, rice, beans, corn, soybeans, and peanuts stand out. As for the number of rows of intercropping, it basically depends on the species to be introduced and the spacing of the coffee plantation, with a free strip of planting with a width of half a meter, in addition to the projection of the coffee canopy on each side of its lines (SANTOS et al., 2008).

Adopting techniques for growing intercrop crops in coffee plantations based on the most up-to-date recommendations, such as varieties, stands and spatial arrangements, the present study aims to evaluate the intercropping of coffee received with intercrop crops (chia, beans and corn) in different spacing and to evaluate their effect on coffee productivity and plant health in the region of Muzambinho, for two harvests of the coffee crop.

Material and methods

The experiment was developed at the Coffee Industry Sector of the Federal Institute of Education, Science and Technology of the South of Minas Gerais - Campus Muzambinho, in an area with geographical coordinates of 21°20'32.64 "South and 46°32'00.99" West, average altitude of 1,023 meters, humid temperate climate with dry winter and moderately hot summer (Cwb), according to Köppen (SÁ JUNIOR et al., 2012).

The experiment was conducted in the crop years 2016/17 and 2017/2018, in an area cultivated with coffee (*Coffea arabica* L.), of the cultivar Catuaí Vermelho IAC-144 12 years of age, with 3.8m x 1.0m spacing, and received in September 2014.

A randomized block design was adopted, in a factorial scheme 3 x 2 + 2 in plots subdivided in space and with 3 replications, with 3 types of intercropping crops (corn, beans and chia) in two inter-row spacing of the crops (30cm and 60cm), plus two additional treatments (dried with glyphosate or just brushed).

The spacing factor was randomized in the plots and the interim crop factor and the additional ones in the subplots, totaling 8 treatments (combinations of the types of interim crops and the spacing plus the additional ones) and 24 plots. Each plot consisted of 18 plants (3 lines with 6 plants each), the useful plot consisting of 4 plants from the central line, and the others, from borders.

Initially, a soil sampling from the experimental field was carried out in order to characterize its fertility, the fertilizations of the coffee tree and the intercropping of the crop year 2016/17 were made according to the analysis of the soil in depth from 0 to 20cm (TABLE 1) and the fertilizations for the 2017/18 crop year were made according to soil analysis in depth from 0 to 20cm (TABLE 2). Both analyzes were carried out at the Soil and Leaf Laboratory of the Federal Institute of Education, Science and Technology of the South of Minas Gerais - Campus Muzambinho.

Table 1 – Chemical attributes of the soil, at a depth of 0-20 cm, from the experimental area. Muzambinho/MG, august 2015.

Prof.	pH	P	K	Al	Ca	Mg	H+Al	SB	T	P-rem	V	M	M.O.
	H ₂ O	mg dm ⁻³				cmolc dm ⁻³				mg L ⁻¹	%		dag kg ⁻¹
0-20 cm	5.8	47	333	0.0	4.59	0.96	2.60	6.4	9	21.9	71.1	0.0	2.74

Extraction methods: pH: water; M.O.: S. Sulfurosa; P, K, Cu, Fe, Mn, Zn: Mehlich-I; P-rem: CaCl₂; Ca, Mg, Al: KCl; H + Al: SMP buffer; SB: Hot water.

Source: Elaboration of the authors (2017).

Table 2 – Chemical attributes of the soil, at a depth of 0-20 cm, from the experimental area. Muzambinho/MG, august 2016.

Prof.	pH	P	K	Al	Ca	Mg	H+Al	SB	T	P-rem	V	M	M.O.
	H ₂ O	mg dm ⁻³				cmolc dm ⁻³				mg L ⁻¹	%		Dag kg ⁻¹
0-20 cm	6,24	64,4	146	0,0	4,77	0,96	2,63	6,1	8,7	23,2	69,9	0,0	2,61

Extraction methods: pH: water; M.O.: S. Sulfurosa; P, K, Cu, Fe, Mn, Zn: Mehlich-I; P-rem: CaCl₂; Ca, Mg, Al: KCl; H + Al: SMP buffer; SB: Hot water.

Source: Elaboration of the authors (2017).

It was not necessary to apply lime in the experimental area to correct the soil. The soil preparation was carried out in a conventional manner, using a roto-enchanter and leveling harrow, in order to leave the soil in suitable conditions for sowing. For crop year 2016/17, interim crops were established on December 14, 2015 and for crop year 2016/17, they were implanted on December 06, 2016.

The fertilization of corn and chia was carried out according to Raij et al. (1997), and the chia fertilization was based on the culture of mint and spearmint, as they are from the same botanical family. Fertilizers of coffee and beans were made according to Ribeiro et al. (1999), considering level 3 of technology for the fertilization of common bean. The phytosanitary management of coffee followed the pattern carried out by the coffee sector of the Federal Institute of Education, Science and Technology of the South of Minas Gerais - Campus Muzambinho.

The population density of chia and beans, in the spacing of 30.0cm, was 6 plants m^{-1} and in the spacing of 60.0cm, it was 12 plants m^{-1} , whereas the density for corn culture in the spacing of 30.0cm was 1,65 plants m^{-1} and in the spacing of 60.0cm it was 3.3 plants m^{-1} . Regardless of the spacing between the consortiums, they were all implanted at a minimum distance of 50.0cm from the projection of the coffee canopy.

To evaluate the maturation of the fruits, 100.0mL of coffee fruits were harvested from each useful plant of the evaluated plots, totaling 400.0mL of fruits per sample, in the months of June and July 2016 and in the months of May, June and August of 2017. The fruits were quantified and qualified as: Green (fruits with green and greenish exocarp, until the stage of physiological maturity), Ripe (fruits with reddish, red and dark red exocarp) and dried (fruits that had already passed physiological maturity, with brown exocarp and / or dehydrated aspect).

The coffee productivity was evaluated right after the harvest of the experimental plots, carried out in July 2016 and August 2017, quantifying the total fruits harvested in each useful plot in liters, disregarding the sweeping coffee. The values were transformed into productivity, using as a reference the value of 450 liters of “da roça” coffee fruits for each 60kg bag of processed coffee (11% b.u.) (NADALETI, 2017).

The coffee yield was obtained by the ratio between the weight of the processed coffee (11% b.u.) and the volume of “da roça” coffee in liters. For this purpose, 10 liters of “da roça” coffee fruits from each plot were put to dry in suspended terraces until reaching the recommended humidity, later they were benefited and calculations were made to transform the values into yield (NADALETI, 2017).

The physical classification as to the type and intrinsic defects was made according to Brasil (2003). In the presence of more than one defect class in the same grain, the one with the highest equivalence was considered. Defective grains were individually weighed for all defect classes. The granulometric classification of the grains was made in samples of 100 g and was obtained by the percentage of grains retained in the circular sieves (18, 17, 16, 15, 14 and 13) for flat grains and oblong sieves (13,12, 11, 10 and 9) for round grains (mocha) (SILVA et al., 2010).

In order to monitor the dynamics of pests and diseases in coffee plants, evaluations were carried out from January to June, both in the crop year 2016/17 and in the crop year 2017/18, totaling six assessments per year. The sampling was carried out in the middle third of the plant, 3 plagiotropic branches were chosen at random on the north face, plus 3 random branches on the south face, evaluating the 3rd and 4th pair of leaves, which were classified by level of incidence, that is, the presence or absence of pests and diseases in the plant tissue.

The evaluations were made monthly in order to monitor pests and diseases such as: Bicho Mineiro (*Leucoptera coffeella*), Cercosporiosis (*Cercospora coffeicola*), Rust (*Hemileia vastatrix*),

Phoma spot (*Phoma* spp.), Aureolada spot (*Pseudomonas syringae* pv. *Garcae*) and Phoma Tarda (*Ascochyta coffeae*). It was considered present leaves that have the pathogenic agent already installed on them and absent leaves free of infestations or with an onset of attack not yet developed (ROCHA, et al., 2013).

For statistical analysis, analysis of variance was performed for the response variables, with a significance level of 5% (p-value). For the variables that had a significant effect of the intercropping factor or the interaction “spacing and intercropping”, the averages were subjected to the Scott-Knott test at the 5% probability level. For variables that had a significant effect of the spacing factor and/or additional treatments, the means were separated according to the F test, at a significance level of 5% (p-value). All procedures for carrying out statistical analyzes were performed using software R version 3.4.1 (R CORE TEAM, 2017).

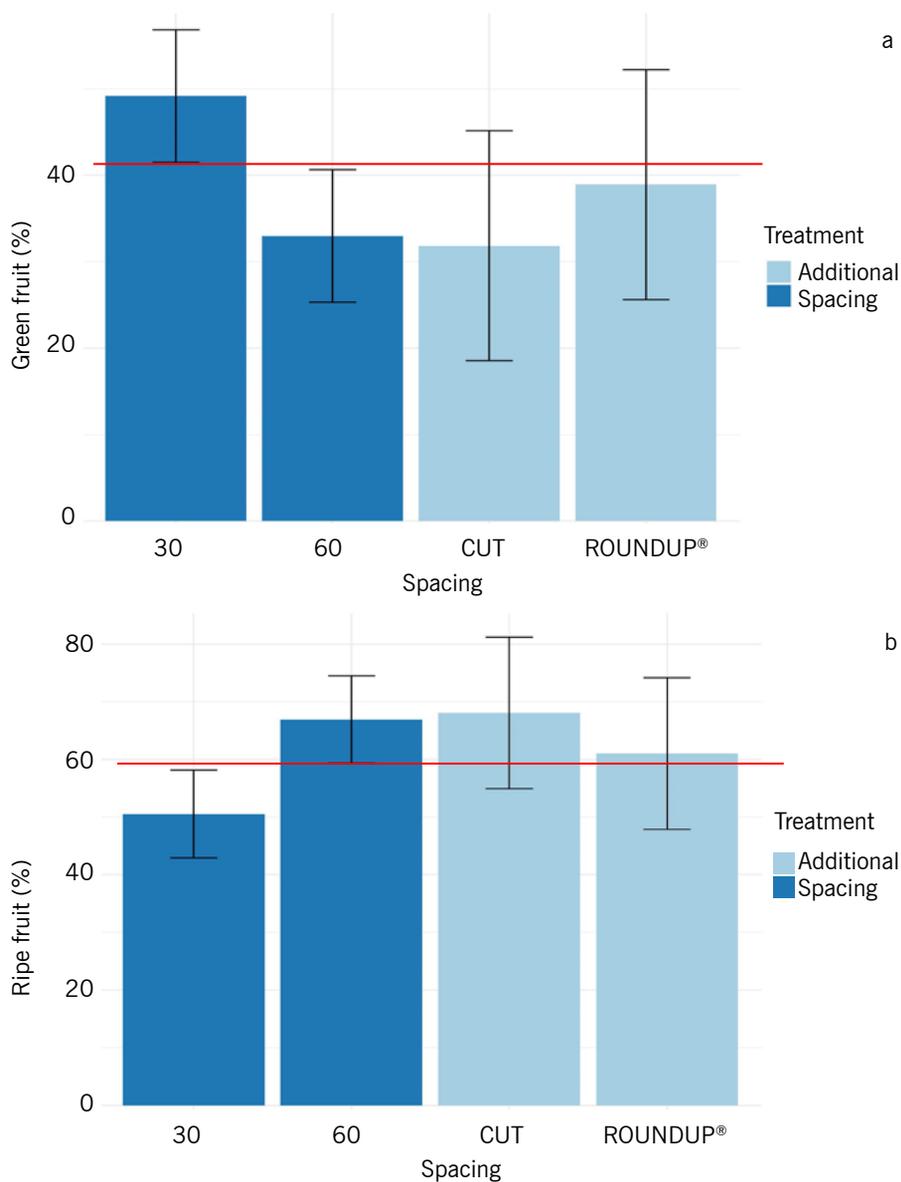
Results and discussion

In crop year 2016/17, based on analysis of variance, significant effects were observed only for the maturation variable and, in crop year 2017/18, there were significant results for the parameters maturation, grain size and incidence of cercosporiosis.

Fruit ripening in crop year 2016/17 was influenced by the spacing factor of the intercrop crop, with a higher percentage of green fruits in treatments in which the consorts were spaced 30cm apart and a higher percentage of ripe fruits in the consorts spaced 60cm (FIGURE 1).

The difference in the results is probably due to the fact that in treatments with consorts spaced at 30cm, that is, with 6 crop lines between those of the coffee tree, there was a greater light interception than in the treatment of consorts spaced at 60cm, with only 3 rows of intercropping. Therefore, this greater shading in the coffee tree may have contributed to the delay in maturation. These results corroborate the studies carried out by Carvalho et al. (2007), at which the authors determined the number of rows and the fertilizer dose of beans intercalated with dense coffee, reporting a shading of the coffee according to the increase in lines of the intercropping, decreasing production and increasing the diameter of the coffee stem.

Figure 1 – Percentage of green (a) and ripe (b) fruits harvested on July 5, 2016 from coffee trees conducted with intercropping in different spacing. Muzambinho/MG, crop year 2016/17.



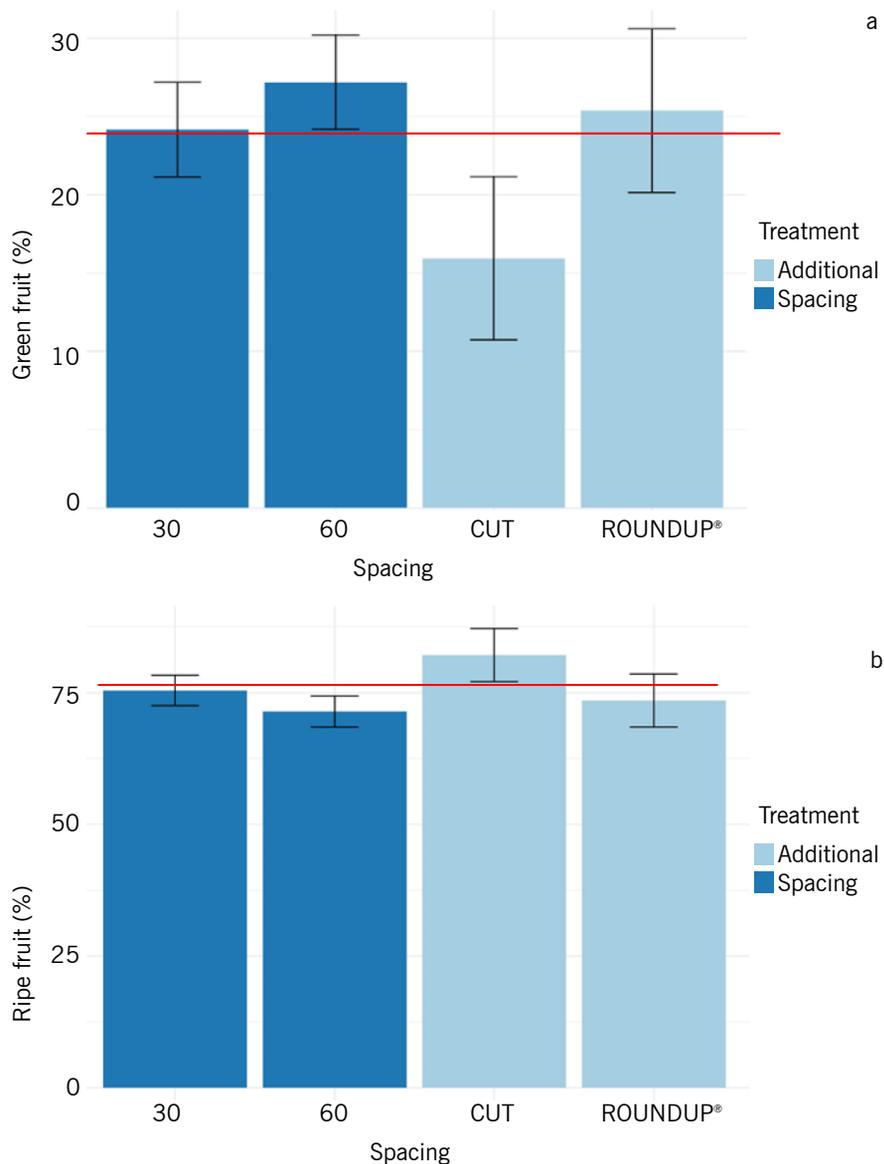
The bars of the treatment averages are within the confidence intervals (95%). Thus, the means in which the confidence interval bars overlap are statistically equal and those that do not overlap are different.

Source: Elaborated by the authors (2017).

In the maturation of the fruits of the 2017/2018 crop year, the percentage of green and ripe fruits showed significance between the additional treatments and the treatments with intercrop crops, with a higher percentage of green fruits in the treatments with consorts spaced 60cm and higher percentage of ripe fruits in the additional grazing treatment (FIGURE 2).

The explanation for this result is that possibly in the cleared plots, there was no interference in the maturation process, since the coffee, being cleared, does not suffer interference from shading, leading to greater maturation, as seen by Pezzopane et al. (2010). In the 60 cm treatment, with three rows of intercropping, a shadier environment was registered, which may have contributed to the delay in maturation.

Figure 2 – Percentage of green (a) and ripe (b) fruits harvested on June 23, 2017 in coffee plants conducted with intercrop crops under different spacing. Muzambinho/MG, crop year 2017/2018.



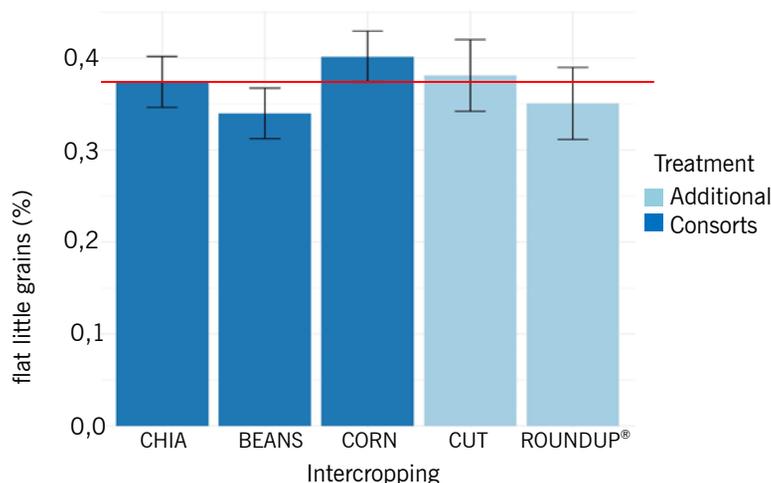
The bars of the treatment averages are within the confidence intervals (95%). Thus, the means in which the confidence interval bars overlap are statistically equal and those that do not overlap are different.

Source: Elaborated by the authors (2017).

The grain size classification for the 2017/2018 crop year showed significant results for the intercrop species grown, with a higher percentage of small flat grains observed in treatments implanted with corn than in those implanted with beans (FIGURE 3), regardless of the spacing of interim crops.

The difference in results is probably due to the fact that the corn crop is more demanding than the bean crop, that is, it has greater demands for water, nutrients and light, so there was a greater interspecific competition with the coffee tree, which directly interfered in the size of the coffee beans (AMARAL FILHO et al., 2005).

Figure 3 – Percentage of small flat beans in the granulometric classification of coffee from coffee plants grown with intercropping in different spacing. Muzambinho/MG, crop year 2017/2018.

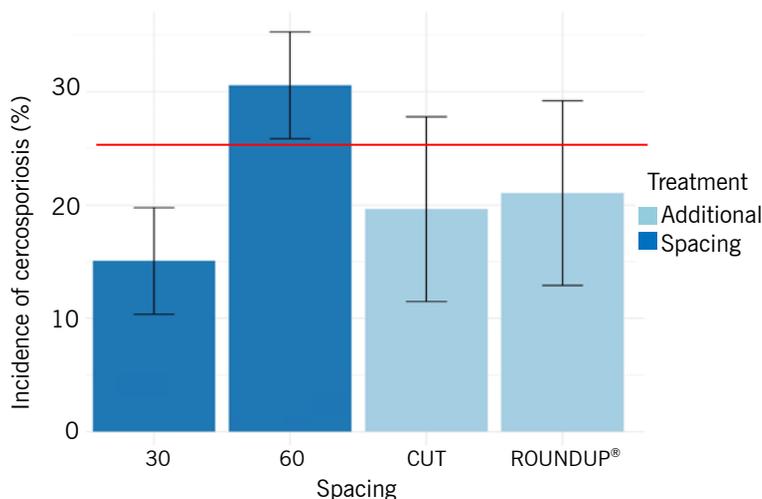


The bars of the treatment averages are within the confidence intervals (95%). Thus, the means in which the confidence interval bars overlap are statistically equal and those that do not overlap are different.

Source: Elaborated by the authors (2017).

Regarding the dynamics of coffee pests and diseases, there was a significant effect of treatments only in the month of May of the 2017/2018 crop year on the incidence of cercosporiosis for the different spacing, a period that coincided with the high crop year. As shown in Figure 4, the incidence was higher in treatments with 60cm than in those with 30cm. This can be explained by the fact that crops at 60cm allowed an environment with greater insolation than in treatments with 30cm, and high insolation promotes ideal conditions for the development of cercosporiosis (SILVA et al., 2013).

Figure 4 – Incidence of cercosporiosis in May 2017 in coffee plants conducted with intercrop crops in different spacing. Muzambinho/MG, crop year 2017/2018.



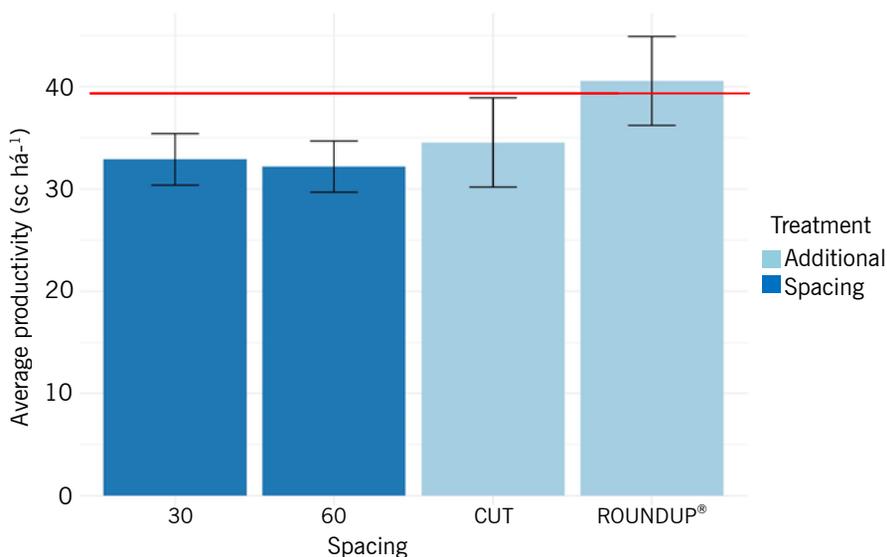
The bars of the treatment averages are within the confidence intervals (95%). Thus, the means in which the confidence interval bars overlap are statistically equal and those that do not overlap are different.

Source: Elaborated by the authors (2017).

Considering the averages of productivity and yields for the sequenced crop years (2016/17 and 2017/18), significant results were observed.

It was observed that the average productivity for this period was influenced by the treatments, with significantly higher averages being reached for glyphosate management compared to intercrop crops (FIGURE 5). Both interim crops implanted in the 60cm spacing and those implanted in the 30 cm spacing negatively influenced the average coffee yield, which can be explained by the greater competition of intercrop cultures for water, nutrients and light (PAULO et al., 2004).

Figura 5 – Average productivity achieved in the two years of evaluation of coffee plants conducted with intercrop crops in different spacing. Muzambinho/MG, crop years 2016/17 and 2017/18.

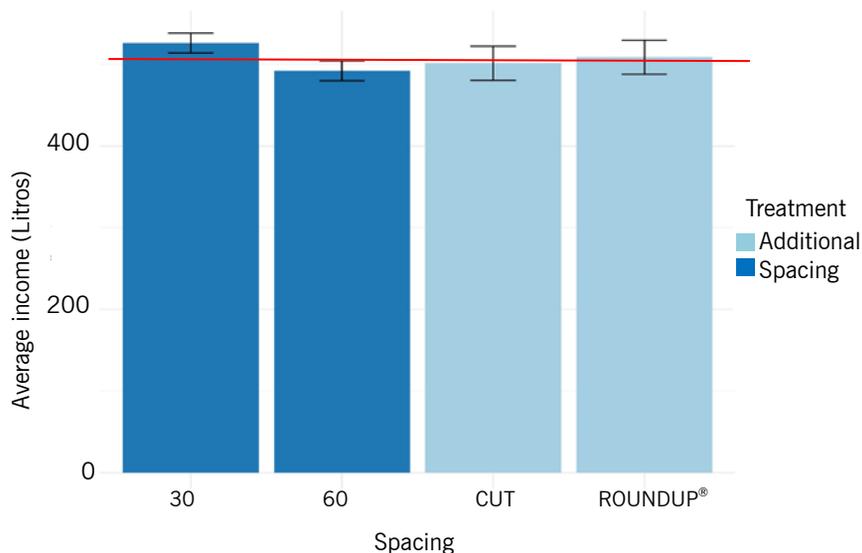


The bars of the treatment averages are within the confidence intervals (95%). Thus, the means in which the confidence interval bars overlap are statistically equal and those that do not overlap are different.

Source: Elaborated by the authors (2017).

It was observed that the average yield for this period was influenced by the spacing, as the yield was lower in treatments with spans spaced at 30cm, than in those of 60cm (FIGURE 6), demonstrating that where there was a greater number of lines of interim crops, greater competition was observed with coffee. For this reason, there was a need for a greater quantity of coffee in natura to produce a 60kg bag of processed coffee (11% b.u.). Similar results were found by Pezzopane (2010), who obtained a lower yield of coffee combined with macadamia.

Figure 6 – Average yield of fruits harvested in the two years of evaluation, in liters, necessary to produce a 60kg bag of processed coffee 11% b.u. in coffee plants conducted with intercrop crops in different spacing. Muzambinho/MG, crop years 2016/17 and 2017/18.



The bars of the treatment averages are within the confidence intervals (95%). Thus, the means in which the confidence interval bars overlap are statistically equal and those that do not overlap are different.

Source: Elaborated by the authors (2017).

Conclusion

In the crop year 2016/17, there was a delay in fruit maturation in treatments with consorts spaced at 30cm, when compared to the same consorts at 60 cm spacing. In the evaluation of the ripening of the fruits of the 2017/18 crop year, there was a delay in the treatments of consorts spaced at 60cm, when compared with the additional treatment.

The corn crop compared to the bean crop in the 2017/18 crop year negatively interfered in the coffee grain size, as it resulted in a higher percentage of small flat beans. The incidence of cercosporiosis in the month of May of crop year 2017/18 was more severe in interim crops with 60cm than in those of 30 cm.

It was also observed that the average coffee yield in crop years 2016/17 and 2017/18 was affected by the interim crops implanted in the spacing of 30cm. Regardless of the spacing, the intercrop crops negatively influenced the average coffee productivity in crop years 2016/17 and 2017/18, requiring further studies on these crops in relation to coffee cultivation.

Avaliação da produtividade e da fitossanidade do cafeeiro recepado submetido a diferentes cultivos intercalares

Resumo

O cultivo intercalar é prática usual na cafeicultura, principalmente em períodos de renovação da lavoura pela realização de podas. Tem por finalidade fazer um melhor aproveitamento da área e diminuir custos de implantação e renovação, principalmente em lavouras cafeeiras com entrelinhas abertas, por meio

da produção de alimentos de subsistência com geração de renda adicional e imediata ao produtor. O objetivo deste trabalho foi fazer uma consorciação do cafeeiro recepado com culturas intercalares em diferentes espaçamentos e avaliar seus efeitos na produtividade e fitossanidade do cafeeiro. O experimento foi realizado no Instituto Federal de Educação, Ciência e Tecnologia do Sul de Minas Gerais – *Campus* Muzambinho, nos anos-safra 2016/2017 e 2017/2018, em lavoura cafeeira da cultivar Catuaí Vermelho 144, com 12 anos de idade, recepada no ano de 2014. Foram implantados três consortes (milho, chia e feijão) em dois espaçamentos (30,0cm e 60,0cm) mais dois tratamentos adicionais (roçado e herbicida). No ano-safra 2016/2017, observou-se um atraso na maturação dos frutos nos tratamentos com culturas intercalares espaçadas em 30,0cm, quando comparado aos mesmos cultivos em espaçamento de 60,0cm. Na avaliação de maturação dos frutos do ano-safra 2017/18, houve um atraso nos tratamentos de consortes espaçados a 60,0cm, quando comparados com o tratamento adicional roçado. Teve aumento expressivo de cercosporiose nos cultivos intercalares com 60,0cm. Observou-se ainda que o rendimento médio do cafeeiro nos anos-safra 2016/2017 e 2017/2018 foi prejudicado pelas culturas intercalares implantadas no espaçamento de 30,0cm. De maneira geral, independente dos espaçamentos, as culturas intercalares influenciaram negativamente a produtividade média do cafeeiro nos anos-safra 2016/2017 e 2017/2018.

Palavras-chave: Café. Chia. *Coffea arabica* L. Feijão. Milho. Rendimento.

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