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COMPETITIVE PRESSURES ON THE ARTISAN COFFEE ROASTER SEGMENT IN THE STATE OF MINAS GERAIS, BRAZIL: A MULTI-CASE STUDY

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ABSTRACT: The specialty coffee market is still little known and underexplored in Brazil, motivating an analysis of the competitive pressures and structure of the artisan coffee roaster segment in the state of Minas Gerais, in order to better understand it and encourage the adoption of specific policies for its expansion, besides comparing it to the commodity coffee roasting segment. A multi-case study was performed with three companies in this segment through in-depth interviews with their owners. There were significant changes in the competitive forces that shape the coffee industry, when comparing the specialty and commodity coffee segments, both in intensity and in motivations. Among the suggested policies to support the specialty coffee segment are its promotion and dissemination through "consumer education" and awareness raising on the differentiated properties of these products, besides providing subsidized courses and specializations for those who wish to be involved in this marketplace.

Index terms: Specialty coffees, strategy, coffee waves.

PRESSÕES COMPETITIVAS NO SEGMENTO MINEIRO DE TORREFADORAS ARTESANAIS: UM ESTUDO MULTI-CASOS

RESUMO: O mercado de cafés especiais ainda é pouco conhecido e explorado no país, motivando a realização de uma análise das pressões competitivas e estrutura do segmento mineiro de torrefadoras artesanais, de forma a compreende-lo melhor e estimular a adoção de políticas específicas para sua expansão, bem como compará-lo ao segmento de torrefadoras de café commodity. Realizou-se um estudo multi-casos com três empresas deste segmento, por meio de entrevistas em profundidade com seus proprietários. Observaram-se importantes mudanças nas forças competitivas que moldam a indústria de café, quando comparados os segmentos de cafés especiais e commodity, tanto em sua intensidade quanto em suas motivações. Como políticas para apoio deste segmento, sugere-se a promoção e divulgação dos cafés especiais, "educando" o consumidor e conscientizando-o dos atributos de diferenciação destes produtos, bem como a disponibilização subsidiada de cursos e especializações para aqueles que desejem se inserir neste mercado.

Termos para indexação: Cafés especiais, estratégia, ondas do café.

1 INTRODUCTION

In order to explain the constant changes in the global coffee market, the concept of "waves" was created following three distinct movements that influence this market, each one with its own set of priorities, philosophies and contributions to the consumption experience (GUIMARÃES, 2016; GUIMARÃES; CASTRO JÚNIOR; ANDRADE, 2016). Such a concept is constantly evolving, but to the First Wave is attributed the significant increase of coffee consumption and important revolutions in the product's processing and commercialization. The Second Wave would have arisen as a reaction to the low quality attributed to the coffees from the previous movement, being responsible for introducing the concepts of specialty coffees and producing origin, as well as for the popularization of espresso and the beverage consumption in coffee shops. In turn, the Third Wave, the most current movement, is understood as a revolution in the specialty coffee market, marked especially by the radical change of product's perception (now considered as complex as wine) and by the adoption of several new differentiation factors (ANDRADE et al., 2015; BORRELLA; MATAIX; CARRASCO-GALLEGO, 2015; GUIMARÃES; CASTRO JÚNIOR; ANDRADE, 2016).

Regarding the Brazilian roasting and industrialization segment, it can be stated that, in the First Wave, only commodity beans were used, with a high percentage of robusta coffee (*Coffea canephora* Pierre) in the blends and preference for roasted and ground (R&G) or instant coffees.

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In the Second Wave, producing origin concepts were introduced, still at a country level, besides roasting concepts, especially dark roasts. The preference for arabica coffee (*Coffea arabica* L.) beans in the blend composition increased and the discussion about specialty coffees and certifications began. Moreover, coffee capsules received a lot of attention. Finally, the Third Wave used only specialty arabica coffee beans, preferably from single origin (at the region or property level) and with lighter roasting, in order to emphasize the unique characteristics of the beans. The roasting takes place in an artisan way and the focus changed to the commercialization in smaller volumes of roasted coffee to be ground only at the consumption time (MANZO, 2014; GUIMARÃES, 2016; CASTRO JÚNIOR; ANDRADE, 2016)

This "wave" concept aids the understanding of the coffee market, as well as the appearance and enlargement of the niche of specialty coffees, whose number of consumers, professionals and companies related to its production, roasting and preparation (extraction) has grown significantly, although it is still little known and underexplored in the country, which motivated this study. The aim was to analyze the structure of the artisan coffee roasting segment in the state of Minas Gerais, Brazil, in order to understand it and encourage the adoption of policies for its expansion, besides comparing it to the roasting segment of commodity coffee.

Competitive pressures

The search for understanding the organizational performance determinants has resulted in two important aspects of strategic thinking: the resource-based view (RBV) and the structural characteristics of the industry (GALBREATH; GALVIN, 2008). In the first one, a firm's performance is related to its specific resources, understood as "those (tangible and intangible) assets which are semipermanently linked to the firm" (WERNERFELT, 1984, p. 172). The second one, directly related to the structure-conduct-performance (SCP) model (GALBREATH; GALVIN, 2008), assigns this result to the industry structure, in which the conduct of companies is of little importance to their performance (KUPFER; HASENCLEVER, 2002). It is noticed, respectively, excessive focus on internal or external factors to the firm.

Within this latter aspect, the studies of Michael Porter (1979), who revolutionized the field of strategy, created a methodology for the structural analysis of industries ("five forces framework"), recognized for its wide applicability, understanding simplicity and viewing easiness. According to Porter (2008), such methodology would also allow understanding the factors that influence the profitability of an industry (in this case, artisan coffee roasters) and adjusting the company's positioning in a more profitable way. In this respect, Grundy (2006, p. 214) points out that the main contribution of this model "resided in distilling the complex micro-economic literature into five explanatory or causal variables to explain superior and inferior performance" from one industry in relation to the others.

These forces would be the threat of new entrants; rivalry among existing companies; bargaining power of suppliers; bargaining power of buyers; and threat of substitutes. Porter (1979, 2008) describes them as follows: a) threat of new entrants: entry of new competitors into a market, pressuring costs, prices and the investment needed for competition; b) rivalry among existing companies: occurring from different ways, such as the launching of new products or price discounts, being determined by intensity and bases of competition among the players; c) bargaining power of suppliers: powerful suppliers can retain a large part of the value they generate for themselves by charging high prices, limiting services or quality, besides transferring their own costs to industry; d) bargaining power of buyers: powerful buyers can limit the profitability of an industry, by forcing price reductions; e) threat of substitutes: those that can perform the same or similar function as the referred industry.

Each industry would be high or low affected by each of these forces (VARGAS et al., 2013). Furthermore, each one determines "prices, costs and investment requirements, which generate long-term profitability and therefore industry attractiveness" (GALBREATH; GALVIN, 2008, p. 109), thus affecting its performance. In Porter's view (1980:29), "an effective competitive strategy then takes offensive or defensive action in order to determine a defendable position against the five competitive forces." Therefore, it is understood that such forces are "profit extortionists," and that such model does not consider the firm's possible collaborative relationships with the industry's structure determinants, potentially transforming them into "partnership forces" (DULCIC; GNJIDIC; ALFIREVIC, 2012).

Despite its important contribution to the field of strategy, the five forces model has been widely criticized for being static (AFUAH; UTTERBACK, 1997; GRUNDY, 2006; DULCIC; GNJIDIC; ALFIREVIC, 2012), whereas the barriers to entry, substitutes and the number and nature of competitors are not changing together with the industry evolution (AFUAH; UTTERBACK, 1997; VARGAS et al., 2013). Other criticisms involve a) excessive focus on macro analysis at the industry level, in contrast to analyzing more specific segments at the micro level; b) the explanation of value chains without considering that buyers may need to be differentiated between channels, intermediate buyers and final consumers; c) the encouragement of the perception of an industry as a specific and limited entity, less appropriate currently, when its limits seem more fluid; d) the only implicit consideration that the forces are not autonomous and significantly interdependent with one another and with other environmental subsystems (GRUNDY, 2006); e) analytical power limited by the difficulty of measuring the global competitive condition and the degree of each force (LEE; KIM; PARK, 2012); f) and the model perception primarily as "a tool to assess the attractiveness levels of industries rather than gain strategic insight as to how a firm can compete more effectively within its industry" (DOBBS, 2014, p. 34).

In order to overcome some of these limitations, Grundy (2006) proposes some improvements to the five forces model, which will be incorporated in the present study: a) prioritize the five forces within the competitive force field; b) examine the sub-forces in action; c) examine the dynamics and impact of the industry mentality; d) segment markets to examine variations within the competitive landscape. In this way, it is also possible to analyze the evolution of the Brazilian coffee roasting segment in order to overcome the static characteristic of the model (AFUAH; UTTERBACK, 1997; GRUNDY, 2006; DULCIC; GNJIDIC; ALFIREVIC, 2012)

2 MATERIAL AND METHODS

This qualitative and descriptive research (GIL, 2002) based on the methodology proposed by Porter (1979, 2008) and adapted by Grundy (2006) aimed to analyze the competitive pressures and structural transformations of the artisan coffee roasting segment in the state of Minas Gerais, Brazil ("third wave"), besides comparing it to the segment of conventional roasters, typical from the "first wave", as portrayed by Faria *et al.* (2004), among other authors. The better understanding of these segments, especially the artisan coffee roasting one, stimulates and provides the adoption of specific policies for its expansion and consolidation.

Despite the traditional use of the five forces model as a way of measuring or explaining the performance of an industry, its application was chosen in order to demonstrate a new organization/structure of the coffee roasting industry/segment, which can affect both the conduct of companies as their performance in this market.

A multi-case study was performed, as characterized by Yin (2015), with three artisan coffee roasters in the state of Minas Gerais, Brazil, selected by judgmental and non-probability sampling due to the restricted number of these companies and the difficulty in their identification. In order to obtain the necessary information, semi-structured in-depth interviews were performed by electronic means (Skype) and during the months of June and July 2016 with the owners of these companies that, for confidentiality reasons, are denominated Artisan coffee roaster 1 (ACR1), Artisan coffee roaster 2 (ACR2) and Artisan coffee roaster 3 (ACR3). The information was later interpreted through the qualitative content analysis (BARDIN, 2011).

3 RESULTS AND DISCUSSION

The three artisan coffee roasters studied in the present study are located in important coffee producing regions, being one in the "Cerrado Mineiro" and the others in the "Matas de Minas", both located in the state of Minas Gerais, Brazil. All of them are family businesses, with a maximum of four years of operation and seven employees (Table 1).

The ACR1 actuated in the rental and technical assistance of espresso machines, marketing and distributing specialty coffee brands, providing inputs for coffee shops and conducting training and consulting in the segment. In 2012, it was acquired by the new owners, maintaining its original activities, including later a monthly coffee subscription and holding of events, beginning the roasting activity only in 2014. Its action was diversified from the demand for coffees by its school of baristas, since the used specialty coffees are above 85 points in the scale of the Specialty

Coffee Association of America (SCAA), still scarce in the Brazilian market at that time. Another objective was to increase the average ticket price, since the roasting activity would not be sufficient to maintain the company.

The ACR2 operates in the roasting activity (own or outsourced for producers) since 2013. It also operates in the commercialization of "white label", rental and representation of espresso or vending machines (and supply of inputs) and holding events for companies and individual customers. The diversification and offer of complementary services are highlighted as important for gaining the preference of clients.

Besides the roasting (of superior and specialty coffee as well as "white label"), ACR3 operates in the segments of coffee brokerage, consulting, qualification and training, holding events (special coffee shop), rental and commodate of espresso machines. The roasting activity would not be sufficient to maintain the company, being the diversification and its complementary services essential for its survival. Investments, processed volume, age of equipment and installed and idle capacity are presented in Table 2.

The acquired equipment are considered as highly technological and its investment classified as high, especially by the small size of such companies, which corroborates the studies of Guimarães (2016) and Guimarães, Castro Júnior and Andrade (2016) about the characteristics of the Third Coffee Wave representatives.

A low percentage of installed capacity use is observed in these companies, being the highest utilization observed in ACR1. There were varied justifications for such fact. The ACR1 considers that there is a small consumer market, and there is difficulty in disposing of the product. The ACR2 emphasizes that the specialty coffee must be fresh, being not possible and/or recommended the roast of great volumes at a time. The ACR3 experiences a bottleneck in packaging, needing to hire staff and acquire one or two new sealing machines to utilize its full capacity.

Bargaining power of suppliers:

The ACR1 exclusively uses specialty coffees above 85 points, from micro lots of several regions, but predominantly from "Cerrado Mineiro" due to its location. It has 13 suppliers from different areas, such as coffee growers and suppliers of packaging machinery for rental to third parties.

TABLE 1 - Characterization of the studied artisan coffee roasters

Company	Age	Category	Employees[1]	Region
ACR1	4 years[2]	Family business	07	Cerrado Mineiro
ACR2	3 years	Family business	05	Matas de Minas
ACR3	2 years	Family business	04	Matas de Minas

[1] Including the owners

[2]Founded in 2005, but acquired by the current owners, interviewed herein, only in 2012.

Source: Own elaboration.

TABLE 2 - Information on the equipment used by the studied artisan coffee roasters.

Company	Age of equipment	Investment	Installed capacity[1]	Processed volume[1]	Idle capacity
ACR1	Some bought new (four years), others used	R$ 100 thousand	160 kg	80 kg	50%
ACR2	Majority with two years, all acquired new	R$ 70 thousand	8,000 kg	800 kg	90%
ACR3	Majority with two years, most acquired new	R$ 80 thousand	4,000 kg	1,000 kg[2]	75%

[1]Monthly basis

[2]Considering the volume of specialty and superior coffees

Source: Own elaboration.

There are a number of other possible suppliers, mostly small businesses and with low bargaining power. The negotiation among them is based on a price table (quotation), and there is no significant cost of exchange among suppliers.

The ACR2 also works exclusively with specialty coffees, counting on four categories of suppliers: general inputs, cups, packaging and coffee. There are other possible suppliers, but all with high prices, characteristic of the specialty coffee market, according to the interviewee. Currently, several suppliers determine a minimum volume of purchases, precluding the access of small companies, which cannot store such items. The solution would be preferably for imported products, which can still be bought in wide variety and low amount. The cost of exchange, in the case of general suppliers, would be high due to its small number.

The ACR3 works both with specialty coffees and superior ones - hard bean standard for exports. In the case of specialty coffees, the company works with an average of eight producers, but these are not “fixed”: whether they do not provide coffee in the necessary time, the owner searches for others, registering them and collecting information that will be provided in the packaging. For the supply of superior coffee, the company works with 10 producers in its region. Each coffee category demands a trading tactic: while each process of buying specialty coffee is unique due to quality variations, commodity coffee transactions are always based on market value. The criteria for acquiring this raw material are quality, price and ease of trading (standard maintenance and longer payment terms), respectively.

In this case, it is necessary to differentiate coffee suppliers from those packaging ones: there are several potential coffee suppliers in Brazil, but only two good national packaging companies. Nevertheless, there is a low exchange cost between the latter, being only necessary to be attentive in the maintenance of a standard. However, there is little bargaining power of the roaster in this purchase, being the price previously defined. In the coffee acquisition, the interviewee highlights the possibility that new suppliers could not reach a standard. This can also occur with award-winning coffees, being necessary to establish some rules with the producer in advance. Once they are high-quality specialty coffees, a higher price is paid, but negotiated.

Grundy (2006) recommends unraveling the bargaining power of suppliers in four respects: 1) exclusive knowledge; 2) size and number; 3) scarcity of resources; and 4) direct integration (ability to integrate the chain, increasing its competitive power). In the case of the artisan coffee roasteing segment, it can be said that the supply of specialty coffees is still scarce, while the knowledge necessary to produce them is significant. There are still few suppliers of this product, but their integration capacity is great, especially in relation to large producing properties. These aspects are not observed when dealing with packaging suppliers, in which the bargaining power is represented by the low number of suppliers.

Rivalry among existing companies

In the case of ACR1, the interviewee believes that it is “*difficult to talk about competition*”, since there are no other players in her service area with such a diversified action and/or geared towards “*joining forces with other players in this sector*”. The relationship among them is mostly friendly, many of them working together in some aspect, which can be observed in the interviewee’s speech:

“I have a commercial relationship with everyone, but we know many of them personally, preserving a good relationship. Most of them are inside my company, where I sell some product or render some service for them” (ACR1 interviewee).

However, she highlights difficulties related to the offer of compensation, financial or other, so that the customer use the coffees of a company. For her, the basis for competition in this market depends on the customer profile. For instance, she cites the case of coffee machines, whose clients range from restaurants to specialized coffee shops. Thus, she emphasizes that she must work with a differentiated price or give some equipment, but believes that the provision of services is the main factor for customer loyalty.

The ACR2 interviewee believes that the market comprises well all the players, because she does not believe that the client of specialty coffees will be loyal to a brand or company. This is because “*no one will buy from you (company/roaster) every day, he or she wants to taste, call friends, exchange experiences*.” Thus, she believes in the maintenance of partnerships for “customer exchanges”, one partner company indicating the coffees of the other. However, she points out that there are also those who “*think they should run over, put the lowest price...*”.

At local level (acting city), the ACR2 has five competitors, but whether considering the non-special micro roasters, this number can reach 100. At regional and national level, she has not such information. Her main clients are in the states of São Paulo, Rio de Janeiro and the southern region of the country. This is because, in Minas Gerais, she perceives a "burnt and cheap" coffee culture. In this respect, she states that:

"[Consumers] do not drink bad wine, but specialty coffee is seen as expensive. Those who buy from me are relatives, because coffee has a surname and they want it by 'luxury', to give as a gift, or those who know coffee and want to gift it, but it represents 5% of sales, 95% I sell through the site or Facebook" (ACR2 interviewee).

For her, the relationship is good and respectful among some competitors, with information exchange, meetings at fairs and quality recognition with each other's products. However, some players behave in a contrary way:

"There are others ... who say that only their [coffee] is good and those others are not as good. There are those who put their [coffee] in front of yours on the shelf. Those who do this are cheating, saying that their coffee is good and is 100% Arabica. It is not" (ACR2 interviewee).

For her, the main basis for competition in this market is the friendship with some merchant who makes her coffee available in the establishment. Otherwise, it only occurs whether requested by customers. Therefore, the strategy of displaying the product and requesting its availability on the shelf is used. Whether sold, the merchant pays for the product, otherwise, the roasting is obligated to collect such items from the shelves.

The ACR3 interviewee believes that competition in the specialty coffee market is lower than in the conventional one, although present and strong, creating barriers to entry into new coffee shops and stores. He points out that there is also competition with suppliers of traditional coffees, since in the case of specialty ones, there is no way to negotiate for price. He believes there are five local competitors for specialty and superior coffees, with good relationship among them, and up to 100 specialty brands at the regional level. At the national level, the interviewee stated that he could not measure such competition, but he highlighted the market growth and its intensification. He emphasizes that:

"Whether an end customer fails to consume traditional [coffee] to consume specialty one, even if it is not mine, it is already good because the customer is coming to know the specialty ones. In the future, he will consume mine [specialty coffees], it is a 'leap'" (ACR3 interviewee).

The ACR3 interviewee believes that the main basis for competition in the market is still the price. He also highlights quality in service and persistence to win new customers.

Grundy (2006) also proposes to evaluate the rivalry among existing companies as a function of their commitment to the market, their strategy and disposition and their similarities or differences. In the case of artisan coffee roasters, their typically friendly stance and mutual collaboration strategy reduces competition. However, their commitment to the market tends to be high. The small number of companies studied here precludes reliable statements on their similarities and differences, and the analysis of such aspects is a suggestion for future studies.

Threat of new entrants

The ACR1 demonstrates low concern about the threat of new entrants:

"We are very specialized, we follow the market evolution. It is possible to entry someone with more knowledge, I do not know. Because we always seek for training, we try to be updated. So I guess there is no danger, no. In fact, it is good, because it further develops the specialty coffee market" (ACR1 interviewee).

Regarding the main difficulties to start the business, she highlighted the low knowledge of consumers about specialty coffees and the restricted willingness to pay a higher price for these products. Therefore, she adopted actions aimed at consumer education, besides reducing the requirement of bean size in order to achieve a more competitive price.

Another barrier would be the lack of knowledge of this market by its professionals, overcame by their knowledge and previous experiences on specialty coffees. With the exception of non-formal regulations (care to obtain and maintain quality and hygiene), no further instructions for starting the enterprise were followed.

The interviewee does not report any retaliation from her competitors and is unaware of such actions. For her, the current market supply is not only sufficient to meet the demand, but that there is also "*a little overplus*", since the consumer base willing to meet and acquire specialty coffees is still restricted. Once the initial investment has been paid, she considers that exit barriers are small due to the easiness of reselling the equipment.

The ACR2 interviewee is not worried about the threat of new entrants, considering her advantageous entry into the market by "*educating accommodated customers, accustomed to commodity coffee*." The main barriers to entry would be marketing planning and coffee commercialization:

"It is not the first [sale], the first you can sell. But sell the second time to a customer... because he will find that the coffee is weak, spoiled. You have to sell a whole story, do tasting, give a good [coffee] and a bad one, it is a tough job. So I guess, the more people doing, the easier. Even though he [client] does not exclusively buy mine [coffee], but if he buys from the other, someday he will buy from me" (ACR2 interviewee).

Regarding the factors that encouraged and facilitated their entry into this market, the passion for coffee, the satisfaction in creating a quality product and the willingness to share this experience are highlighted. In relation to the regulations for starting the business, she was supported by SEBRAE.

Despite considering that there are no barriers to the entry of competitors, she emphasized the retaliation of companies to new entrants by the unfair competition and defamation:

"There is always the unfair competition; the one that, instead of adding, wants to 'pull your rug'. Sometimes you put your product in a bakery, then comes a friend from the owner, and says that the coffee is bad. As the owner does not understand [about coffee quality], it remains one word against the other" (ACR2 interviewee).

For her, the current offer is enough to meet the demand in the market, but highlights the need for its expansion, which shows significant potential. Regarding the exit barriers, she cites financial and emotional costs:

"When I hear that someone is selling a roaster, I am sad unless it is to buy a bigger one. This is why I talk to producers in the region to be careful about investing, not because they are going to compete with me, but because it is a risk. I have done many courses, but I have to do many more. It is also hard to sell a roaster, a mill. They are expensive equipment" (ACR2 interviewee).

The ACR3 interviewee sees few companies willing to enter the specialty coffee market, both locally and regionally, being more frequent the entry into the conventional coffee market as indirect competitors. In the case of specialty coffee, there is a greater need for capital investment and improvement.

For him, the main barriers to entry are planning, market knowledge, ensuring that customers know and recognize the quality, as well as high initial investment for market opening and acquiring knowledge about specialty coffee roasting. He also highlights the importance of persistence in the conquest of consumer and his training about specialty coffees, "*breaking the stigma of low-quality coffees*."

The main incentives for the business opening were his prior knowledge, since he already acted as classifier and taster (Q-Grader) and his previous role in SEBRAE, where he developed projects with specialty coffee roasters. Regarding the regulations for starting the activities, he checked the regulations of the Ministry of Agriculture, Livestock and Food Supply (MAPA), attended events of the Brazilian Coffee Industry Association (ABIC) and contacted the local city hall, health surveillance and fire brigade.

Regarding the threat of new entrants, the competition for prices stimulated by conventional coffee roasters and its availability of capsule coffee machines are highlighted. However, in the specialty coffees, the investment in market opening and tasting is high, which shows all the work committed for obtaining the final product quality. The ability to meet the current demand would depend on the promotion of specialty coffees, since there would be significant room for growth in this market. However, an obstacle generated by the economic crisis is emphasized:

"Among all the products that consumers can think to improve when their income increase, coffee is the last. The customer improves the meat, dairy products, but coffee is the last one that it is thought to improve" (ACR3 interviewee).

He also believes that there are relevant exit costs due to high investment in machinery, not fully recovered after their sale. For him, only 50% of this amount would be recoverable, while investment in market opening and working capital would be wasted.

Grundy (2006) suggests the classification of the threat of new entrants into physical, informational, economic or psychological barriers to entry. In the case of artisan coffee roasters, economic barriers seem to be more relevant due to the high cost of equipment, whereas physical barriers seem to be medium, since access to consumers is not difficult, but to suppliers (low number of packaging suppliers and the specificity of the used coffee, with the intention to use differentiated coffees also in relation to competitors). Informational barriers are considerably low due to the cooperative stance among competitors, as well as psychological barriers, since it is still an underexplored and considerably expanding market in the country.

Bargaining power of buyers

The ACR1 has approximately 100 to 150 customers, among individuals and legal entities, being this latter predominant. The possibility of consumers pushing their prices are small, being possible to negotiate with coffee shops that buy in the ticket and in larger quantities.

In ACR2, legal entities (coffee shops, restaurants, among others) are also more significant. Few individual consumers buy through the website. Regarding the bargaining power of its customers, she emphasizes that she prefers to "*give as a gift than lower the price*", since this would lead him to earn the respect of consumers. Furthermore, she emphasizes:

"I cannot want to exploit them, the aid must be mutual. There is no use in wanting to make a big sale and he [buyer] gets old coffee because I will be back to square one. Specialty coffee, if it is not fresh, then it is not good. When someone says they want to make a big purchase, I evaluate if it is for an event or something like this. If it is just to put on the shelf, I say that it is better not, that he or she should take less, that I'll deliver more in the following week" (ACR2 interviewee).

The ACR3 has a portfolio of approximately 50 customers, including buyers of corporate and specialty coffees. For supermarkets, considered as the most powerful customers, both product categories are supplied. In this case, the entrepreneur opts for local supermarkets, since the larger ones charge key money and entry fee, precluding the negotiation. The entrepreneur often considers the attempt of price negotiation by customers, which often demand for cups, plates at the point of sale and machinery in commodate at no charge. This is then negotiated, but it is not uncommon to lose customers for companies that offer such benefits at reduced cost or for free.

The bargaining power of buyers is evaluated by Grundy (2006) according to the importance of the product/service in terms of added value; the discretion or emotion associated with them; and the urgency of consumption time. In the case of specialty coffees marketed by artisan coffee roasters, high added value and great emotion associated with the product could be observed, as also observed by Guimarães (2016) and Guimarães, Castro Júnior and Andrade (2016). The urgency related to the consumption time is also high, since the maintenance term of the optimum state of the coffee after the roasting process is short.

Threat of substitutes

For ACR1, the substitutes to those products commercialized in her signature club are wines or craft beers. Regarding the espresso machines, they are usually only exchanged in case of substitution, for preparation of the same beverage or for another of instant coffee. It would be easy to find alternatives to these products, being the prices of their specialty coffees similar to wine and beers. However, such situation would not be applicable to espresso machines, with price well above these alternatives.

In the case of ACR2, other alternatives to coffee are provided to facilitate the purchase by its customers of several items from a single supplier. The interviewee points out that her main competitor is the "coffee from the countryside":

"If it is said that it [coffee] is from the countryside of the Minas Gerais, then people think it is good, that beverage has quality. They have conviction and are offended if I say it is not.This coffee is priceless. It comes from your land, or from your friend's land. It is there taking rain and sun, fermenting... but even so if it is the countryside coffee, it is good. Roasted until charred. So how do you compete with that? It is educating [the consumer]"(ACR2 interviewee).

Such alternatives are easily found by her competitors, with significantly price differences between specialty coffees and commodity ones, harming her business. However, she shows good expectations after the FIFA Soccer World Cup, which served to create awareness among national players for the low quality of coffee in the domestic market and the great national and international demand for high quality and sustainable coffees. Thus, she says to her micro roasting partners: "*do not give up, do not 'prostitute' by starting to make a traditional coffee, because that is regressing*."

For ACR3, the main substitutes for its products are tea, soda, juices, coffee-based beverages and chocolate, easily found in the market, since the points of sale usually "*have these products at the customer's hand*". Regarding the price difference, he considers as very large, especially in the case of espresso coffee, due to the low production cost of its substitutes and low consumption habits by young people.

Regarding the analysis of the threat of substitutes, Grundy (2006) proposes four criteria: the possibility of "do it yourself" by the consumers; the use of other technologies to achieve the same result; emotional issues related to product acquisition; and grouping or disaggregation, understood as "the customer's ability to do something either as part of something else, or to take a packaged offering and to capture value by breaking up the value-added activity into its smaller components" (p. 222). In the case of artisan coffee roasters, there is the possibility of "do it yourself" by the consumers, whether they buy domestic and portable roasters, although the knowledge necessary to achieve a similar result is high. Thus, such possibility is greater in the case of forward integration by coffee growers or backward integration by specialized coffee shops. The use of other technologies is still restricted, while the very characteristic of the artisan coffee roaster business and the consumption philosophies of specialty coffees discourage grouping or disintegration activities. Finally, emotional issues are significant among specialty coffee consumers, minimizing the threat of substitutes.

In Table 3 the results are summarized and discussed.

General discussions

It could be suggested that this is a segment of medium/high attractiveness, since it has low threat of new entrants and low bargaining power of buyers, as well as low/medium rivalry among existing companies. The main adversities that may restrict its profitability are the high threat of substitutes, since they are widely available and significantly cheaper, and in the medium/high bargaining power of suppliers, especially of packaging, since, according to the interviewees, there are only two good players in this market. In the case of the raw material, the bargaining power of coffee growers can be considered as medium, since they are still more vulnerable in this commercial relationship, but once they work with differentiated products (specialty coffees), they get some room for negotiations. In order to prioritize the five forces and facilitate their visualization, Grundy (2006) proposes to substitute Porter's methodology by its classification into favorable, neutral or unfavorable by the alternative approach in vector model, considering the relative importance and weight of each one, represented by the length of lines. Its application to this study can be shown in Figure 1.

There are also important differences between the structure of the commodity and specialty coffee markets. In the first, the bargaining power of suppliers was low due to their high number and negotiation based on international market prices. These products were also highly standardized, which together with the ease of obtaining (high supply), reduced the cost of exchange among suppliers (FARIA *et al*., 2004). In the specialty coffee market, product differentiation and the reduced number of suppliers, even if still higher than artisan coffee roasters, and the exchange cost related to quality assurance of beans, have increased the bargaining power of coffee growers. However, the strongest players in this relationship became the packaging suppliers due to their limited numbers at the national level, which gives them the power to set minimum purchase volumes and determine prices. However, the cost of exchange among them is low due to the unique need to ensure the maintenance of a standard in these products.

Regarding the rivalry among existing companies, a reduced intensity was observed because such market is still small and its players consider that its growth will be beneficial for all, especially for not believing in "loyalty" of customers in the specialty coffee market, which is consistent with the studies of Guimarães, Castro Júnior and Andrade (2016). However, it is worth mentioning that the competition is more friendly among specialty coffee roasters, although there is intense and sometimes disloyal competition by the commodity coffee roasters, which compete with artisan ones, even if indirectly. In their study, Faria *et al.* (2004) also highlighted the predatory competition and low concern with quality and environmental issues by commodity coffee roasters, which was also confirmed by Guimarães (2016) when referring to "First Wave" companies. Thereby, the bases for competition in the market have had few changes, with the maintenance of the price factor and increase of the services rendered (quality and diversity), persistence to conquest customers and sponsorship. The issue of the absence of brand and coffee plantations was also mentioned by Faria *et al*. (2004), which demonstrates the continuity of such discomfort in the market, possibly caused by low investments in marketing and in the image change of the national coffee, especially in the quality of beans.

TABLE 3 - Comparison between the interviewees' perceptions in the present study

Category	Specification	ACR1	ACR2	ACR3
Bargaining power of suppliers	No. of possible suppliers	High	Medium	High (coffee), low (others)
	Bargaining power	Low	Low (coffee), high (others)	Medium (coffee), high (others)
	Exchange cost	Low	Low (coffee), high (others)	Low (others), medium (coffee)
Rivalry among existing companies	Competition level	Low	Medium	High
	No. of competitors	Low	Medium	High
	Bases for competition	Provision of service, price	Sponsorship	Price, quality of attendance, persistence
Threat of new entrants	Threat level	Low	Low	Low
	Entry barriers	Culture, lack of knowledge	Mkt planning and commercialization	Planning, knowledge, investment and quality assurance
	Initial investment	R$ 30,000	R$ 80,000	R$ 120,000
	Retaliation	No	Yes (high)	Yes (high)
	Exit barriers	Low (equipment sales)	High (financial and emotional)	High (equipment sales and sunk costs)
	Market size	Between fair and insufficient	Fair	Fair
Bargaining power of buyers	No. of potential customers	High	High	High
	Bargaining power	Low	Low	Medium
Threat of substitutes	Substitutes	Beers and fine wines	Traditional coffee	Tea, soda, juices, soft drinks (coffee) and chocolate
	Ease of access to subs.	High	High	High
	Price differentials	Low	High	High

Source: own elaboration

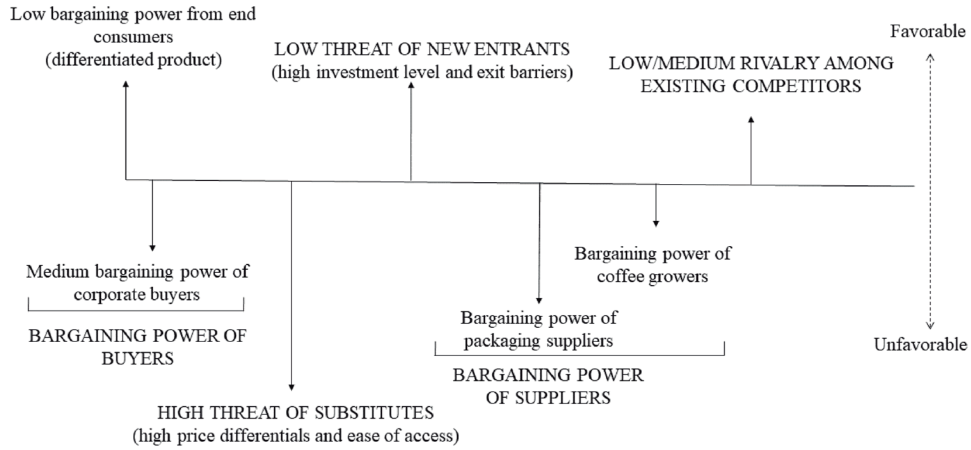

FIGURE 1 - Vector representation of the five forces.

Source: own elaboration based on research data and the proposal of Grundy (2006).

The threat of new entrants remained low, but for different reasons. While Faria *et al.* (2004) attributed such fact to the great loyalty to brands, in the specialty coffee market this is considered as low due to the still limited size and great potential for expansion of this market, which would benefit everyone. In the case of specialty coffees, the main barriers would be the ingrained commodity coffee consumption culture, consumer resistance to paying more for specialty beans (especially for lack of knowledge about the product and not appreciation of new differentiation properties), the need for planning effective marketing and high investments in opening up the market and obtaining knowledge to start operations. The retaliation would be essentially linked to indirect competitors, represented by large commodity coffee roasters, while the main barriers to exit would be the emotional cost and unrecoverable costs related to the actions to open the market and sale of equipment.

A drastic change in the bargaining power of buyers was observed: while the low differentiation of the commodity coffees led to the intense price competition (FARIA *et al*., 2004; GUIMARÃES, 2016), in the specialty market this situation was reversed exactly by differentiation and value added to the product. In this case, individual buyers do not have any bargaining power, while business customers only achieve this by acquiring large volumes, which is uncommon in this market due to quality maintenance purposes. The specialty coffees of artisan coffee roasters are sometimes still sold in supermarkets with high bargaining power, but there are other important marketing routes, such as coffee shops, hotels, bakeries and signature clubs for end consumers. In any case, unfair competition also occurs in the specialty market with regard to defamation of competing products or granting of benefits for the choice of coffee from a particular brand.

It is observed the maintenance of the significant threat of substitutes, due to their wide availability/ease of access. In the case of commodity coffees, the price difference between these products was low, being the threat represented by the low investment in coffee marketing, market stagnation and misconceptions related to the influence of beverage consumption on human health (FARIA *et al*., 2004). In the specialty coffee market, this situation is worsened by the large price differential between its specialty and conventional version, which is also significant in relation to other beverages, such as juices, coffee drinks, teas, soft drinks and chocolate. It is also observed the perception of fine wines and craft beers as direct competitors, especially by perception changes of the product (KLEIDAS; JOLLIFFE, 2010; GUIMARÃES, 2016; GUIMARÃES; ANDRADE, CASTRO JÚNIOR, 2016). The comparison between the results of Faria *et al*. (2004) and the present study can be observed in Table 4.

TABLE 4 - Comparison between the results achieved by Faria *et al.* (2004) and the present study

Category	*Commodity* Roasters	Artisan roasters	Motivations
Bargaining power of suppliers	Low	Medium/High	Differentiated raw material and reduced number of suppliers
Rivalry among existing companies	High	Low/Average	Considerably expanding market
Threat of new entrants	Low	Low	Differentiated product and expanding market
Bargaining power of buyers	High	Low	Significant product differentiation
Threat of substitutes	Medium/High	High	Product differentiation and consequent increase in the price differential

[1] Faria et al. (2004)
[2] Data obtained in the present study
Source: Own elaboration.

Grundy (2006, p. 224) is favorable to the segmentation (prior to analysis of the five forces) of the industry under study, i.e. commodity versus artisan coffee roasters, since for him, "industry structures are like a landscape and highly variable in their attractiveness, meaning that the Porter's model must be used in a more discriminating and localized way to describe them." According to the author, this would become the five forces model more contextual and applicable at the company level. In order to avoid the static characteristic of the model, Grundy (2006) also proposes the comparison among these segments, listing the motivations for their transformations, information herein organized in Table 4. Evidently, it is not assumed that the segment of commodity roasters will evolve to the predominance of artisan coffee roasters, but only to illustrate how the changes of perception and philosophy of product/consumption are presented in this market.

4 CONCLUSIONS

It is concluded that the segment of artisan coffee roasters has medium/high attractiveness by the low threat of new entrants and reduced bargaining power of buyers, besides low/medium rivalry among existing companies. Thus, the limitations on its profitability are the high threat of substitutes and medium/high bargaining power of suppliers.

Wide and significant changes between the segments of commodity and specialty coffee roasting were observed both in the intensity of the studied forces and in their motivations. It is also worth mentioning the relevance attributed by the interviewees to consumer education actions, corroborating the studies of Guimarães (2016) and Guimarães, Castro Júnior and Andrade (2016) on the specialty coffee market, belonging to the Third Coffee Wave movement.

Policies to support and foster the growth of specialty coffee are suggested in order to promote and disseminate this market, "educating" consumers and making them aware on the differentiated properties of these products, besides providing subsidized courses and specializations for those who wish to be involved in this marketplace. This may contribute to improve the national and international image of Brazilian coffee.

The limitations of the present study refer to the low number of studied roasters, essentially in the State of Minas Gerais, Brazil, and to the exclusivity of primary data, obtained through the perception of the interviewed owners. Therefore, it is suggested to increase the number of analyzed actors and their region of action, besides including secondary data that aid the analysis and corroborate the obtained information. Furthermore, it is suggested the study of differences of performance and profitability between the roasters of commodity and specialty coffees.

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NUTRIENT RELEASE FROM GREEN MANURE UNDER DIFFERENT SUN-EXPOSED FACES

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ABSTRACT: The evaluation of the decomposition of plant residues added to the soil for green manures allows better understanding of the nutrient supply for coffee. The aim of this study was to determine the decomposition constant (κ), the half-lifetime ($t_{1/2}$) and the nutrient release from legumes and spontaneous plant under two environmental conditions of sun-exposure in the Zona da Mata of Minas Gerais state. The experimental unit located in Araponga has northwest sun-exposure face and the experimental unit located in Pedra Dourada has the south sun-exposure face. The experimental design was a randomized block in a 2 x 8 x 6 factorial (two environments facing sun-exposure, 8 green manures and 6 residue decomposition assessment times), with four replicates. The results showed that κ and $t_{1/2}$ of the evaluated green manures did not differ between the northwestern face (highest altitude, temperature and incident light) and the south face (lower altitude, temperature and incident light). The κ difference obtained between all green manures was due to its chemical and biochemical composition. At the end of the evaluation period of 240 days an average of 62,3 and 63,1% N; 99,4 and 99,5% P and 92,8 and 93,3% K were released from the green manures of the northwest and south faces respectively. The most promising legume in the total nutrients release on the northwest face was *D. lablab* with 74,6; 10,9 and 69,0 kg ha^{-1} of N, P and K, respectively. To the south face the most promising legume was *C. spectabilis* with 69,1; 10,4 and 47,9 kg ha^{-1} of N, P and K, respectively.

Index Term: Nutrient cycling, plant residues, polyphenols, ratio C/N, plant coffee.

LIBERAÇÃO DE NUTRIENTES DE ADUBOS VERDES SOBRE DIFERENTES FACES DE EXPOSIÇÃO SOLAR

RESUMO: A avaliação da decomposição dos resíduos vegetais adicionados ao solo por adubos verdes permite melhor compreensão do fornecimento de nutrientes para o cafeeiro. O objetivo foi determinar a constante de decomposição (κ), o tempo de meia vida ($t_{1/2}$) e a liberação de nutrientes de leguminosas sob duas condições ambientais de face de exposição solar na Zona da Mata de Minas Gerais. A unidade experimental localizada em Araponga possui face de exposição solar noroeste, já a unidade experimental localizada em Pedra Dourada possui face de exposição solar sul. O delineamento experimental foi em blocos casualizados, em fatorial 2 x 8 x 6 (dois ambientes sob face de exposição solar, 8 adubos verdes e 6 tempos de avaliações da decomposição dos resíduos), com 4 repetições. Os resultados mostraram que a κ e $t_{1/2}$ dos adubos verdes não diferiram entre a face noroeste (maior altitude, temperatura e incidência de luz) e a face sul (menor altitude, temperatura e incidência de luz). A diferença obtida na κ entre os adubos verdes deve-se a sua composição química e bioquímica.Ao final de 240 dias de decomposição foi liberado em média para o cafeeiro 62,3 e 63,1% do N; 99,4 e 99,5 % do P e 92,8 e 93,3% do K no ambiente sob face noroeste e sob face sul, respectivamente. A leguminosa mais promissora na liberação total de nutrientes sob face noroeste foi a *D. lablab* com 74,6; 10,9 e 69,0 kg ha^{-1} de N, P e K, respectivamente. Sob face sul, a leguminosa mais promissora na liberação total de nutrientes foi a *C. spectabilis* com 69,1; 10,4 e 47,9 kg ha^{-1} de N, P e K, respectivamente.

Termos para indexação: Ciclagem de nutrientes, resíduo de plantas, polifenois, relação C/N, cafeeiro.

1 INTRODUCTION

The soils in the Zona da Mata region of Minas Gerais are characterized by being highly weathered and acid, with low fertility and low concentration of nutrients available to plants (Matos et al., 2008; Coelho et al., 2013; Guimarães et al., 2016). For family coffee growers in the region, the use of chemical fertilizer to replenish the nutrients is not feasible due to the low level of available funds, making integrated management of nutrients and water necessary in these areas. Such management focuses on organic matter and crop species able to use local resources in the most efficient manner (Matos et al., 2011; Coelho et al., 2013).

The majority of the coffee plantations in the region are installed on relief ranging from wavy to strongly wavy (Guimarães et al., 2016). This relief situation and coffee cultivation without soil cover are conditions favorable for erosion and with it, high soil, water, organic matter and nutrient losses, making coffee an agricultural activity with low environmental sustainability (Matos et al., 2008).

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One way to achieve agricultural sustainability is focused on the protection of the soil by legumes. In addition to erosion control, legumes improve the soil chemical, physical and biological attributes (Mafongoya and Jiri, 2016; Mendonça et al., 2016). Other advantages of legumes are: having an aggressive root system exploiting deeper soil layers, a symbiotic association with N_2-fixing bacteria contributing to the N nutrition of cash crops, a low C/N ratio which favors their decomposition and mineralization by soil microorganisms, among others (Coelho et al., 2013; Mendonça et al., 2016).

The decomposition and mineralization of crop residues depends on their chemical and biochemical quality and soil characteristics, such as temperature, moisture, clay fraction mineralogy, acidity, biological activity and nutrient availability (Matos et al., 2008). Thus, the sun exposure face on which the plot is located and its environmental characteristics may interfere with the decomposition and mineralization of plant residues on the soil (Matos et al., 2008; Matos et al., 2011; Coelho et al., 2013).

In the South Hemisphere, the path of the sun undergoes declination to the north, resulting in less radiation in the fields facing toward the south, which causes a temperature decrease and an increase in the soil moisture of that face (Ferreira et al., 2005). In the South Hemisphere, Coelho et al. (2013) concluded that the southern facing environment has humic substances that are structurally more resistant to degradation. In the North Hemisphere, where the opposite occurs, Egli et al. (2009) verified higher soil organic matter content in the face with north exposure, indicating that locations that have lower temperature and higher humidity stock more carbon, as well as verifying differences in microbial activity and the cycling dynamics of the contributed material.

When there is no limitation in the environmental conditions and they are influenced by sun-exposed face, the factor that may limit the decomposition kinetics and nutrient release from green manure and therefore, the microbial community activity is the green manure chemical and biochemical quality (Mendonça and Stott, 2003). Over the short term, the decomposition and N mineralization can be influenced by the C/N ratio, polyphenols content and polifenol/N ratio (Fan et al., 2017). Over the long term, the mineralization of C and N can be affected by recalcitrant components, such as cellulose, lignin and the lignin/N ratio (Matos et al., 2008).

Matos et al. (2011) reported the importance of the legumes *Arachis pintoi* Krapov. & W.C.Greg., *Calopogonium mucunoides* Desv., *Stylozanthes guyanensis* (Aubl.) Sw. and *Stizolobium aterrimum* Piper & Tracy as a source of nutrients in coffee present in the mountainous region due to low amounts of lignin/N, lignin/polyphenol and (lignin+ polyphenol)/N ratios, however, differences in the decomposition constant were found on different sun-exposed faces. Thus, for the choice of legumes to be used by the farmer, in addition to considering the amount of mass and nutritional accumulations, the amount of nutrients released over a specific period of time should also be observed (Matos et al., 2011). Some annual (crotalaria, lablab, mucuna and pigeon pea) and perennial legumes (forage peanut, calopo and stylo) have been used by farmers in the region, however, without diagnosing the amount of nutrients released over a given time.

Studies of decomposition and nutrient release of cover crops in no-tillage system of annual crops are present in many studies such as in Teixeira et al. (2009) and Leite et al. (2010). However, there are few reports emphasizing the role of legumes as to decomposition and release of nutrients in the soil for coffee. The aim of this study was to determine the decomposition constant, the half-life and total release of nutrients from legumes and spontaneous plants under two sun exposure environmental conditions in the Zona da Mata of Minas Gerais.

2 MATERIAL AND METHODS

Characterization of study areas

The experiment was carried out on two experimental units (agricultural land) installed in family farm areas. The experimental unit in Araponga is located at 20° 41'S and 42° 33'W and has an altitude of 950 m, average annual maximum monthly temperature of 34,2ºC and an average annual minimum monthly temperature of 12,1ºC, with an average annual temperature of 18,0°C and an average of 1320 mm of rainfall. The land receives sun exposure on the northwest and there is an average daily sun exposure time of 9,1 h (measured in field). The experimental unit in Pedra Dourada is located at 20° 50'S and 42° 08'W, has altitude of 690 m, annual maximum monthly temperature of 32,0°C and an average annual minimum monthly temperature of 10,4°C, with an average annual temperature of 14,0°C and rainfall of 1277 mm. This land receives sun exposure on the south face and has an average daily sun exposure time of 6,8 h (measured in field). Thus, the environment facing the south (Pedra Dourada) has a lower altitude, lower temperature and lower light incidence compared to the northwest facing environment (Coelho et al., 2013).

The landscape of the experimental units is rugged with a nearly 40% slope; the soils are well drained, porous and deep; however, acidic and low nutrients availability. The soils of the two study areas were an Oxisols (Soil Survey Staff, 2014), corresponding to a *Latossolo Vermelho-Amarelo* by the Brazilian classification system (EMBRAPA, 2013). The chemical and physical characterization, in the 0-0,2 m depth at the time of experiment set-up is shown in Table 1.

The coffee plantations were conducted in an organic system since the formation of the seedlings. Before coffee planting, soil amelioration was conducted with limestone and thermophosphate and potassium sulfate were applied according to soil analyses and recommendations of Soil Fertility Commission for the State of Minas Gerais (V. Alvarez et al., 1999). In Araponga 260 kg ha^{-1} of limestone, 64 kg ha^{-1} of gypsum, 125 kg ha^{-1} of potassium sulfate and 800 kg ha^{-1} thermophosphate were applied; in Pedra Dourada, 1200 kg ha^{-1} limestone, 300 kg ha^{-1} of gypsum, 125 kg ha^{-1} of potassium sulfate and 800 kg ha^{-1} thermophosphate were used. In each location the *Coffea arabica* L. coffee plants were grown at a spacing of 2,8 x 0,5 m.

Study design

The experimental design was a randomized complete block design with four replicates in a factorial 2 x 8 x 6 with: two environments with sun-exposed faces (one with northwestern face exposure and one with southern face exposure), 8 green manure that were evaluated in the coffee plant interrows: forage peanut (*A. pintoi*), calopo (*C. mucunoides*), crotalaria (*Crotalaria spectabilis* Röth), (*Stylozanthes guyanensis* (Aubl.) Sw.), pigeon pea (*Cajanus cajan* (L.) Huth), (*Dolichus purpureus* (L.) Sweet), mucuna (*Stizolobium deeringianum* Bort.) and the control consisting of spontaneous plants being predominant *Amaranthus viridis* L., *Bidens pilosa* L., *Emilia fosbergii* Nicolson, and *Eleusine indica (L.) Gaertn.*, and evaluation times (0, 15, 30, 60, 120 and 240 days).

Characterization of legumes

Legumes were implemented during the years 2004-2007, always at the beginning of the rainy season and harvest every 150 days after planting and the residue spread under the canopy of the trees. Sowing occurred in the coffee interrow at a spacing of 0,4 m, totaling 5 planting lines of legumes for each coffee inter row. After germination, 5 plants were allowed per linear meter, corresponding 89.286 plants per hectare.

For the characterization of the green manure, the C and N contents were obtained by dry combustion in a Perkin Elmer CHNS/O 2400 analyzer. The elementary P was determined after nitropercloric digestion. In the same digestion K content was determined by flame photometry; and Ca and Mg by atomic absorption spectrophotometry. The soluble polyphenols were extracted with methanol (50%) and determined by colorimetric method, using the Folin-Denis reagent (Anderson and Ingram, 1996). The cell wall components were obtained via serial method (van Soest et al., 1991), using 2 mL of a 1% amylase solution per sample, in the determination of neutral detergent fiber (NDF) and acid detergent fiber (ADF). The values of hemicellulose in the analyzed material, as a percentage of dry matter, were determined by difference by subtracting the ADF from the NDF. Cellulose contents were also obtained by difference, by subtracting the lignin from the ADF. The average of the chemical and biochemical composition characterization of the evaluated materials is exhibited in Table 2.

Decomposition plant residues and nutrient release rate

To evaluate of the decomposition plant residues and nutrient release rate, conducted only for legumes and spontaneous plants in 2007, 100 grams of fresh plant material were placed in nylon decomposition bags (20x20 cm). The decomposition bags (litterbags) were placed on the soil surface under the coffee canopy. At 0, 15, 30, 60, 120 and 240 days the materials were collected and dried in a forced air circulation oven at 70°C for 72 hours and then ground to pass through a 2 mm sieve. The total N, P and K contents were determined (same method described in the characterization of green manure). From these data, we determined the dry mass (DM), N, P and K percentages remaining in relation to the quantities added initially; and then calculated the amounts of nutrients released to the coffee plants after 240 days.

TABLE 1 - Chemical and physical characteristics of the soil at a depth of 0-0,2 m.

Chemical analysis	Araponga (northwest exposed face)	Pedra Dourada (south exposed face)
Water pH (1:2,5)*	5,24	5,04
[1]Phosphorus (mg/ dm^3)	1,00	2,92
[1]Potassium (mg/ dm^3)	59,80	53,50
[2]Aluminum (cmolc / dm^3)	0,47	0,59
[2]Calcium (cmolc / dm^3)	1,74	0,99
[2]Magnesium (cmolc / dm^3)	0,74	0,47
[3]Organic Carbon (g / kg)	29,04	36,80
[1]Zinc (mg / dm^3)	1,17	1,56
[1]Iron (mg / dm^3)	40,7	14,70
[1]Manganese (mg / dm^3)	10,4	20,20
[1]Copper (mg dm^{-3})	0,50	0,38
Granulometric analysis		
Sand (g / kg)	39	36
Chay (g / kg)	52	45
Textural class	Chayey	Chayey

*In table: pH (hydrogen potential); 1-extractor Mehlich^{-1}; 2-extractor KCl 1mol L^{-1}; 3-method Walkley Black.

Models were used to estimate the decomposition and release of nutrients from the legumes and spontaneous plants. The model that provided the best fit for all species was first order exponential $y = a\ exp^{(-kt)}$ (Olson, 1963), where y is dry weight or nutrient remaining at a given time (days) at a constant decomposition (k). The parameter (a) corresponds to the maximum point, i.e. the initial amount of dry weight or nutrient added by the green manure. Reorganizing the terms of this equation (linearization) it is possible to calculate the decomposition constant, or κ value, by the equation: $\kappa = \ln(a/y)/t$. With the κ value, we calculated the half-life ($t_{1/2}$), i.e., the time required for half of the plant material to decompose, as follows: $t_{1/2} = \ln(2)/\kappa$.

Statistical analysis

The equation coefficients were tested (t-test) at 1, 5 and 15% significance. Pearson correlations between the $t_{1/2}$ and the chemical and biochemical composition of green manure were carried out. Data on dry mass and the amounts of total nutrients released from green manure after 240 days were subjected to analysis of variance and Scott-Knott averages tests. To run the analysis, we used the Sisvar statistical program (Ferreira, 2007).

3 RESULT AND DISCUSSION

There are differences in κ values between legumes and spontaneous plants for each environmental condition exposure (Table 3). Spontaneous plants and *S. deeringianum* obtained the lowest dry matter (DM) κ. The lowest N release κ was observed for *S. guyanensis* and spontaneous plants. Similarly, the *C. mucunoides* and spontaneous plants presented the lowest κ for P and K.

No difference was observed in the κ values for each green manure between the two sun-exposed environments. Comparing the average κ values between the environments with sun-exposed faces (Table 3), P was the most quickly released nutrient in the decomposition process, with an average value of 0.0267 d^{-1} in Araponga and 0.0264d^{-1} in Pedra Dourada. The rapid release of P in the residues is related to the low C/P ratio. C/P ratio lower than 200 in plant residues contributes to the rapid P release (Chacón et al., 2011) that is dependent on the decomposition process by soil microorganisms. Residues with C/P ratio greater than 300 will prevail P immobilization (Dossa et al., 2009).The P released from legumes may be temporarily fixed, primarily in fungal structures and made available to the coffee plant in a gradual way instead of undergoing rapid mineralization and becoming strongly adsorbed on Fe and Al oxyhydroxides which, together with kaolinite, dominates the clay fraction of Oxisols (Silva and Mendonça, 2007).

TABLE 2- Average of the chemical and biochemical characterization of green manure and spontaneous plants of the year 2007on two experimental units in Araponga and Pedra Dourada.

Green Manure	C	N	P	K	HM	CL	LG	PP	C/P	C/N	LG/N	LG/PP	PP/N	(LG+PP)/N
		..........................dag Kg^{-1}..........................												
						Araponga (northwest exposed face)								
A. pintoi	41,5	2,9	0,30	2,5	12,6	30,2	7,3	1,8	138,3	14,3	2,5	4,0	0,62	3,1
C. mucunoides	44,0	3,5	0,32	2,4	14,9	26,7	8,9	1,4	137,5	12,5	2,5	6,3	0,40	2,9
C. spectabilis	51,4	3,3	0,28	1,9	12,6	33,5	7,6	1,2	183,5	15,5	2,3	6,3	0,36	2,6
C. cajan	42,4	3,5	0,27	1,6	17,9	28,1	9,7	1,5	157,0	12,1	2,7	6,4	0,42	3,2
D. lablab	43,7	3,4	0,38	2,1	18,1	27,5	7,6	1,5	115,0	12,8	2,2	5,0	0,44	2,8
S. guyanensis	42,5	3,2	0,29	1,7	14,7	28,6	5,8	1,7	146,5	13,2	1,8	3,4	0,53	2,3
S. deeringianum	48,5	3,3	0,25	1,8	16,7	31,3	7,8	1,9	194,0	14,6	2,3	4,1	0,57	2,9
Spontaneous	64,1	2,2	0,27	3,2	21,4	30,5	9,7	1,2	237,4	29,1	4,4	8,0	0,54	4,9
						Pedra Dourada (south exposed face)								
A. pintoi	43,4	2,9	0,28	2,2	13,0	30,7	7,9	1,7	155,0	14,9	2,7	4,6	0,58	3,3
C. mucunoides	45,2	3,4	0,27	2,1	15,6	24,9	8,6	1,3	167,4	13,3	2,5	6,6	0,38	2,9
C. spectabilis	48,7	3,0	0,31	1,9	12,3	33,0	7,7	1,1	157,0	16,2	2,5	7,0	0,36	2,9
C. cajan	41,8	3,2	0,28	1,5	17,9	27,7	9,0	1,4	149,2	13,0	2,8	6,4	0,43	3,2
D. lablab	47,9	3,3	0,36	2,3	18,4	26,7	7,5	1,5	133,0	14,5	2,2	5,0	0,45	2,7
S. guyanensis	45,6	3,2	0,29	1,8	13,6	29,8	5,9	1,7	157,2	14,2	1,8	3,4	0,53	2,3
S. deeringianum	44,7	3,5	0,26	1,8	15,3	30,7	8,0	1,9	171,9	12,7	2,2	4,2	0,54	2,8
Spontaneous	66,5	2,1	0,26	3,1	19,9	28,8	9,8	1,1	255,7	31,6	4,6	8,9	0,52	5,1

C = carbon; N = nitrogen; P = phosphorus; K = potassium; HM = hemicellulose; CL = cellulose; LG = lignin; PP = total soluble polyphenols; LG/N= rationlignin/ nitrogen; LG/PP= ratio lignin/polyphenols; PP/N= ratio polyphenols/nitrogen; (LG+PP)/N= ratio (lignin+polyphenols) nitrogen.

TABLE 3 - Decomposition constant (κ) and DM (dry matter), N (nitrogen), P (phosphorus) and K (potassium) release estimated by the equation y = a $exp^{(-kt)}$ and the half-life ($t_{1/2}$) of green manure and spontaneous plants under two sun-exposure conditions.

Green manure	DM	N	P	K	DM	N	P	K
	κ(d^{-1})							
	Araponga (northwest exposed face)				Pedra Dourada (southexposed face)			
A. pintoi	0,0022A	0,0045A	0,0286B	0,0143A	0,0022A	0,0047A	0,0283B	0,0141A
C. mucunoides	0,0026A	0,0044A	0,0161C	0,0088C	0,0025A	0,0045A	0,0159C	0,0083C
C. spectabilis	0,0024A	0,0043A	0,0294B	0,0126B	0,0023A	0,0044A	0,0287B	0,0124B
C. cajan	0,0025A	0,0041A	0,0278B	0,0135A	0,0021A	0,0042A	0,0275B	0,0133A
D. lablab	0,0023A	0,0046A	0,0271B	0,0140A	0,0022A	0,0048A	0,0268B	0,0138A
S. guyanensis	0,0021A	0,0034B	0,0354A	0,0137A	0,0021A	0,0035B	0,0351A	0,0136A
S. deeringianum	0,0018B	0,0040A	0,0342A	0,0116B	0,0017B	0,0041A	0,0338A	0,0119B
Spontaneous	0,0019B	0,0031B	0,0152C	0,0072C	0,0019B	0,0033B	0,0149C	0,0077C
Mean	**0,0022**	**0,0041**	**0,0267**	**0,0120**	**0,0021**	**0,0042**	**0,0264**	**0,0119**
	$t_{1/2}$ (d)							
	Araponga (northwest exposed face)				Pedra Dourada (south exposed face)			
A. pintoi	313	154	25	49	314	146	24	49
C. mucunoides	268	157	43	78	276	154	44	82
C. spectabilis	290	162	25	56	302	157	25	57
C. cajan	278	168	26	52	329	166	26	53
D. lablab	300	151	26	48	314	144	26	51
S. guyanensis	329	203	20	52	331	197	20	52
S. deeringianum	384	173	21	59	405	169	21	57
Spontaneous	345	223	46	95	364	211	48	89
Mean	**313**	**174**	**29**	**61**	**329**	**168**	**29**	**61**

Means followed by same letter between green manure on each condition exposed face belong to the same cluster at 5% probability by means of Scott-Knott test.

The second most quickly released nutrient was K (0.0120 and 0.0119 d^{-1} for Araponga and Pedra Dourada, respectively). Unlike P, K is found in nonstructural components and in ionic form in the vacuole of plant cells (Leite et al., 2010), having low dependence on microbial processes for its release (Crusciol et al., 2008). According to the authors, after the management of the phytomass, with the dry material on the soil, there is the initial wetting process of the rainfall, with significant diffusion of K, mainly, of the cells of the surface of the residue.After the saturation of the material by rain, there is a reduction of diffusion K, which happens to be from dead cells of the plant residue. As legumes are less lignified than grasses, hydration of the material is facilitated. In legumes the release of K is considered fast.In a field experiment, Leite et al (2010) also reported fast release of K compared to N and P.

The N κ presented average values of 0.0041 and 0.0042d^{-1} for Araponga and Pedra Dourada, respectively. The lower N decomposition is due to the high soluble polyphenol content, since they have the capacity to complex proteins and thereby reduce the N availability to the soil microorganisms (Matos et al., 2008, Chacón et al., 2011).

The average DM κ values were 0.0021 d^{-1} for Araponga and 0.0022 d^{-1} for Pedra Dourada. Low DM κ values may be related to high concentration of recalcitrant components, such as lignin, cellulose and hemicellulose that prolong the DM decomposition (Stott and Mendonca, 2003). Another factor related to low DM κ values is related to the low P availability for microorganisms, since the P contents of the Oxisols studied were classified as very low (Alvarez V. et al., 1999).

The similarity between the DM decomposition and N, P and K release κ values show no differences between the two sun-exposed environmental conditions for the decomposition period of 240 days. However, working with four legumes, Matos et al. (2011) found average DM κ values of 0.0052d^{-1} for a crop facing south and 0.0026 d^{-1} for a crop facing west in an evaluation period of 360 days. The authors verified a 50.7% reduction in the residue decomposition rate on the western face compared to the southern, i.e., in the environment with less sunlight (south facing) the residue was decomposed more rapidly.

Due to differences in κ values, there was variation among legumes regarding the half-life ($t_{1/2}$) for the DM decomposition rate, and N, P and K release in each location. On average, the time taken for half of the green manure constituents to decompose and be released was 313, 174, 61 and 29 days for DM, N, K and P, respectively, in the location with a northwest-exposed face. In the location with a southern-exposed face, the $t_{1/2}$ of DM, N, K and P was 329, 168, 61 and 29 days, respectively. Matos et al. (2011) also observed that the $t_{1/2}$ for MD> N> K> P, however, the $t_{1/2}$ was 57% shorter for *A. pintoi*, *S. guyanensis* and *S. aterrimum* on southern-exposed face compared to the western exposure.

Due to lower decomposition constant values in spontaneous plants, they presented a $t_{1/2}$ of 345 and 364 days for DM in Araponga and Pedra Dourada, respectively. In these same locations, the shortest DM $t_{1/2}$ was for *C. mucunoides*, being 268 and 276 days, respectively. Longer DM $t_{1/2}$ in mountain environments is positive because one of the functions of green manure is soil protection against hidric erosion (Mendonça and Stott, 2003). Thus, the quick release of P, K and N and the longer DM permanence on the soil benefit coffee nutrition and soil conservation.

According to Mendonca and Scott (2003) the concentration of compounds such as lignin, cellulose and hemicelluloses, as well as the C/P, C/N, lignin/polyphenol, lignin/N and polyphenols/N ratios interfere with the decomposition of residue. Correlations of $t_{1/2}$ with the C/N, C/P, lignin/N, polyphenols/N and (lignin+polyphenol)/N in the present study explain the differences in the decomposition of green manure studied (Table 4).

Unlike the present study, Matos et al. (2011) and Matos et al. (2008) found no correlation between the $t_{1/2}$ and the chemical and biochemical composition of green manure. The authors pointed out that differences in κ and $t_{1/2}$ of the green manure studied occurred because of edaphoclimatic factors of the locations assessed.

After 240 days of decomposition an average of 41.6 and 39.9% DM was decomposed and 62.3 and 63.1% N; 99.4 and 99.5% P and 92.8 and 93.3% K was released for Araponga and Pedra Dourada, respectively (Figure 1).

TABLE 4 - Pearson correlation between the chemical and biochemical constituents and the half-life ($t_{1/2}$) for DM, N, P and K of the green manure.

Half-Life	C	N	P	K	HM	CL	LG	PP	C/P	C/N	LG/N	LG / PP	PP / N	(LG+PP)/ N
							Araponga (northwest exposed face)							
MS ($t_{1/2}$)	0,31	0,23	-0,33	0,37	0,38	0,20	0,37	0,68#	-0,18	0,24	0,18	-0,49	0,73*	0,28
N ($t_{1/2}$)	0,66*	-0,47	-0,50	0,43	0,31	-0,33	0,28	0,36	-0,60#	0,68#	0,50	-0,08	0,56#	0,54#
P ($t_{1/2}$)	0,59#	-0,38	-0,23	0,67#	0,52	-0,03	0,50	-0,49	-0,79*	0,60#	0,76*	0,62#	0,13	0,71*
K ($t_{1/2}$)	0,76*	-0,35	-0,27	0,70*	0,50	-0,12	0,58#	-0,35	-0,78*	0,70*	0,80*	0,50	0,31	0,78*
							Pedra Dourada (south exposed face)							
MS ($t_{1/2}$)	0,27	0,22	-0,38	0,21	0,35	0,18	0,13	0,61#	-0,18	0,22	0,23	-0,25	0,57#	0,31
N ($t_{1/2}$)	0,61#	-0,44	-0,55#	0,39	0,31	-0,32	0,23	0,39	-0,54#	0,62#	0,45	-0,09	0,49	0,48
P ($t_{1/2}$)	0,61#	-0,37	-0,24	0,67#	0,54	-0,31	0,50	-0,49	-0,80*	0,61#	0,76*	0,61#	0,14	0,71*
K ($t_{1/2}$)	0,68#	-0,26	-0,18	0,65#	0,49	-0,18	0,57#	-0,41	-0,74*	0,61#	0,73*	0,54	0,19	0,70*

*; # Significantat 5 and 15%, respectively.

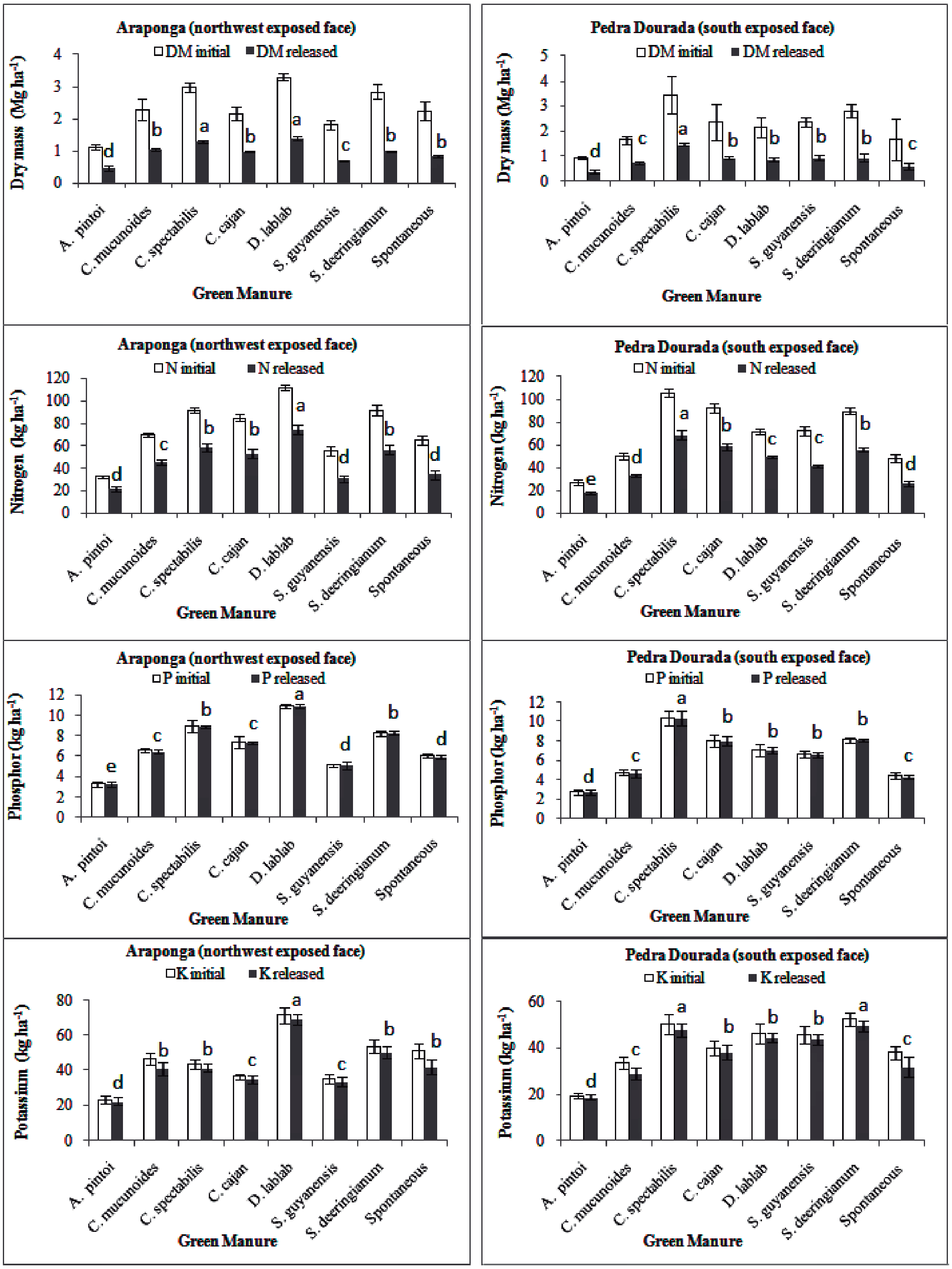

FIGURE 1 - DM decomposition and of N, P and K released from green fertilizers and spontaneous plants after 240 days. Means followed by same letter in the amount of nutrient released do not differ at 5% probability by means of Scott-Knott test. Bars indicate the standard deviation.

There was no difference in the average amount of N, P and K released between the two locations. The N release trend similar to that of the present study was verified by Matos et al. (2011), who obtained 83.5% N released after 360 days.

Differences in nutrient release between the legumes and spontaneous plants were verified at each location. Besides the difference in the decomposition constant and half-life, there are differences in DM, N, P and K initial accumulation for each green manure (Figure 1), which reflected in the amount of the nutrient released. *A. pintoi* was the legume which released the least amount of nutrients, as follows: 21,6; 3,3 and 22,5 kg ha^{-1} N, P and K in Araponga, respectively and 18,4; 2,7 and 18,4 kg ha^{-1} of N, P and K in Pedra Dourada, respectively. The most promising legumes for nutrient release in Araponga was *D. lablab* with 74,6; 10,9 and 69,0 kg ha^{-1} of N, P and K, respectively; and in Pedra Dourada it was *C. spectabilis* with 69,1; 10,4 and 47,9 kg ha^{-1} of N, P and K, respectively.

In Matos et al. (2011), after 360 days *S. guianensis* released, 86,2; 7,1 and 50,4 kg ha^{-1} of N, P and K, respectively; *S. aterrimum* released 93,0; 7,8 and 63,6 kg ha^{-1} of N, P and K, respectively. This study considered only the aerial part decomposition of legumes and spontaneous plants. Thus, legume roots also have a great contribution in the supply of nutrients to coffee plants.

4 CONCLUSIONS

The decomposition constant and nutrient release of legumes and spontaneous plants increased in the order DM<N<K<P.

There was no influence between the northwestern-exposed face and southern-exposed face on the decomposition and nutrient release of the residue.

Under field conditions, the difference in decomposition constant and nutrient release from the green manure residue were dependent on the residue chemical and biochemical composition, since the half-life of the plant residues correlated with the C/N, C/P lignin/N, polyphenols/N and (lignin+polyphenol)/N ratios.

After 240 days of decomposition 62,3 and 63,1% N; 99,4 and 99,5% P and 92,8 and 93,3% K was released to the coffee plants in Araponga and Pedra Dourada, respectively.

The ground cover was prolonged by the low dry matter decomposition (41,6 and 39,9% for Araponga and Pedra Dourada, respectively).

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QUALITY OF NATURAL COFFEE DRIED UNDER DIFFERENT TEMPERATURES AND DRYING RATES

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ABSTRACT: The final quality of coffees depends on the preservation of the cell membranes of the coffee beans, which can be damaged during the drying. Thus, the aim of this study was to assess the immediate and latent effects of the air temperature and drying rate on the sensorial quality of natural coffees, as well as its relationship with the chemical e physiological characteristics of the coffee beans. Mature fruits of arabica coffee were harvested and sundried to moisture content of approximately 35% (wb) and then moved into a mechanical drier under different conditions of drying. This process involved the combination of three dry bulb temperatures – DBT (35°C, 40°C, and 45°C) and two dew point temperatures – DPT (2.6°C and 16.2°C). Thus, the relative humidity of the air used for drying was a dependent variable of DTB and DPT, and as consequences, different drying rates were achieved for each DBT. The increase in the drying rate for the temperatures 35°C and 40°C has a negative effect on the final quality of natural coffee beans. However, for the temperature of 45°C, the effects of the drying rate on the coffee beans are overlaid by the thermal damages that are caused at this level of heating. Higher sensory scores for coffee are linked to lower values of electrical conductivity and potassium leaching of the exudate of the coffee beans, as well as lower values of fatty acids. It is emphasized that while the temperature of 35º C is recommended for the production of specialty coffees the temperature of 45º C is not.

Index terms: Sensory analysis, specialty coffees, relative humidity, dew point temperature.

QUALIDADE DO CAFÉ NATURAL SUBMETIDO A DIFERENTES TEMPERATURAS E TAXAS DE SECAGEM

RESUMO: A qualidade do café depende da preservação das membranas celulares dos grãos, que podem ser afetadas durante a secagem. Assim, este estudo foi realizado com o objetivo de avaliar os efeitos imediatos e latentes da temperatura do ar e da taxa de secagem na qualidade sensorial do café natural e sua relação com as características químicas e fisiológicas dos grãos. Frutos maduros de café arábica foram colhidos e secos ao sol até atingirem a umidade de aproximadamente 35% (b.u.) e então transferidos para um secador mecânico, onde foram submetidos a diferentes condições de secagem, obtidas pela combinação entre três temperaturas de bulbo seco (TBS), 35°C, 40°C e 45°C e duas temperaturas de ponto de orvalho (TPO), 2,6°Ce16,2°C. Assim, a umidade relativa do ar de secagem constituiu-se como uma variável dependente da TBS e da TPO e como consequência da umidade relativa obtiveram-se diferentes taxas de secagem para cada TBS. A análise dos dados indicou que, o aumento na taxa de secagem para as temperaturas de 35°C e 40°C tem efeito negativo na qualidade do café natural. Já para a temperatura de 45ºC, os efeitos da taxa de secagem na qualidade do café natural são sobrepostos pelos danos térmicos que predominam nessa temperatura. Notas sensoriais mais elevadas para o café estão associadas com valores mais baixos de condutividade elétrica, lixiviação de potássio e ácidos graxos. Ressalta-se que enquanto a temperatura de 35ºC é recomendada para a produção de cafés naturais especiais, a temperatura de 45ºC não o é.

Termos para indexação: Análise sensorial, cafés especiais, umidade relativa, temperatura de ponto de orvalho.

1 INTRODUCTION

The quality of the coffee beverage is a fundamental factor to reach the markets that pay the best price for the product, and there is ever increasing demand of the international market for specialty coffees that stand out from common coffees, especially through better beverage quality and complexity (GIOMO; BORÉM, 2011).

Coffee quality is mainly determined by flavor and aroma formed during roasting, based on the chemical compounds present in the green coffee beans. The chemical composition of the beans, for its part, depends on genetic, environmental, and technological factors, such as processing and drying methods (FARAH et al., 2006).

Dry processing of coffee, due to its low water consumption and lower production of polluting

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residues, is a more sustainable processing method in comparison to wet processing (BORÉM; ISQUIERDO; TAVEIRA,2014). However, the literature historically associates dry processed coffees with inferior beverages, compared to wet processed coffees (BORÉM, MARQUES; ALVES, 2008; SANTOS; CHLFOUN; PIMENTA, 2009). Nevertheless, when due care is taken during harvest and processing and drying of the fruit, natural coffees give rise to beverages of excellent quality, more full bodied, and with lower acidity in comparison to wet processed coffees, and they are an essential ingredient for blends of espresso coffee(BORÉM, ISQUIERDO; TAVEIRA, 2014;ILLY; VIANI, 2005).

Without a doubt, drying is the key in production of natural specialty coffees since the presence of the hull and the mucilage with high sugar content reduces the drying rate and increases the risks of undesirable fermentations, compromising their quality (BORÉM; ISQUIERDO; TAVEIRA, 2014).

Due to the greater time necessary for drying of natural coffee, normally temperatures of up to 45°C are used in the coffee mass. However, temperatures higher than 40°C bring about serious damage to coffee quality, and they are not recommended for drying of natural specialty coffees (BORÉM et al., 2012; OLIVEIRA et al., 2013).

An alternative for reducing the drying time of natural coffee without the need for use of temperatures higher than 40°C is reduction in the relative humidity of the drying air. That way, thermal damage resulting from the use of high temperatures is avoided (ONDIER; SIEBENMORGEN; MAUROMOUSTAKOS, 2010). Nevertheless, the isolated effect of the drying rate for the same temperature on the chemical, physiological, and sensory aspects of the coffee is still unknown.

Coffee quality is traditionally evaluated by means of sensory analysis. Yet other analyses, such as determination of electrical conductivity, potassium leaching, reducing and non-reducing sugars, and free fatty acids, among other aspects, can be carried out to assist understanding of physiological changes and changes in chemical composition that occur in coffee during the drying process(CORADI et al., 2007; GUIMARÃES et al., 2002; ISQUIERDO et al., 2012; KLEINWÄCHTER; SELMAR, 2010; MARQUES et al., 2008; SIQUEIRA et al; 2016; SPEER; KÖLING-SPEER, 2006; TAVEIRA et al., 2015).

The effects of the drying on the final quality of coffee beans may be observed immediately or long-term after the drying, mainly when assessed after the storage. After the sixth month of storing of coffee beans, a significant quality decrease takes place, characterized by the lowering of the sensorial scores and by the increasing of the values of electrical conductivity and potassium leaching, if compared to the initial values (RIBEIRO et al., 2011).

The aim of this study was to evaluate the immediate and latent effects of the temperature of the air and drying rate on the sensory scores of natural coffee beans and its relationship with the chemical and physiological characteristics.

2 MATERIALS AND METHODS

Coffee (*Coffea arabica* L.) fruits were harvested in the southern region of the state of Minas Gerais, Brazil (Latitude: 21° 27' 45" S, Longitude: 45° 19' 17.8" W), in fields of the cultivar Mundo Novo, located at an altitude of 1100 m.

The coffee was harvested manually, selecting only mature fruit. After that, fruits with lower specific weight (dried out, attacked by insects, malformed, etc.) were removed through separation in water, and then one more manual selection was made for removal of under ripe and overripe fruits. The mean initial moisture content of the fruits was 65% (wb) determined in a forced air circulation oven at 105 ± 3°C until achieving constant weight (INSTITUTO ADOLFO LUTZ, 2008).

Immediately after selection, the ripe fruits were dried on a suspended drying bed in fine layers of approximately 3 cm thickness until reaching moisture content of 35% (wb). After that, the fruits underwent intermittent mechanical drying, alternating 14 hours of drying with 10-hour rest intervals.

Mechanical drying occurred in the drying system described by Isquierdo et al., (2013) (Figure 1). During mechanical drying, the characteristics of the air were controlled by three air conditioning units in series, coupled to a laboratory air conditioning system (LACS).The speed of the drying air was kept constant at 0.33 ms^{-1}, corresponding to a flow of $20m^3min^{-1}m^{-2}$of perforated sheet metal. The dew point temperature was measured at the output of the air conditioning system by type K thermocouples connected to universal controllers, Novus Automation N1100.

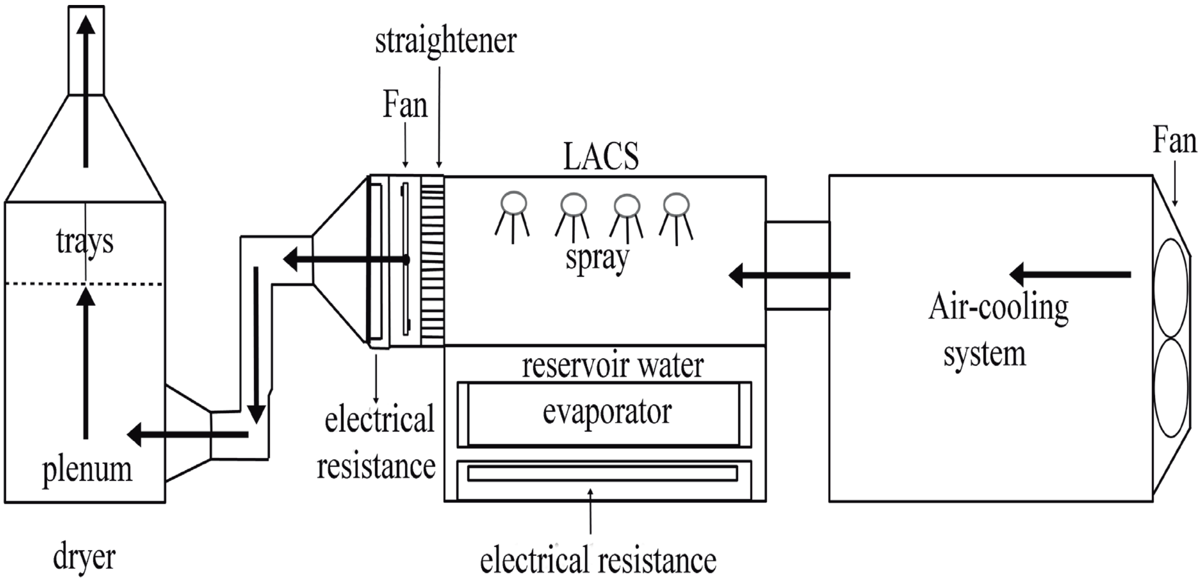

FIGURE 1 - Schematic diagram of the convective dryer used in this study.

Relative humidity was measured by a digital hygrometer inserted in the plenum. Coffee fruit temperature was measured by mercury thermometers inserted in the middle of the coffee mass.

The moisture level of coffee fruits during drying was controlled by the gravimetric method. Trays containing the samples were removed from the drier and weighed every two hours on an analytic balance with 0.01 g resolution until the processed coffee beans reached 11±0.5% (wb)moisture. The final moisture content of the processed beans was determined in a laboratory oven at 105°C for 16 hours according to the ISO 6673 standard method (International Organization for Standardization - ISO, 2003). From the results obtained, the drying rates were calculated by equation 1.

$$\frac{dX}{dt} = \frac{U_i - U_{i-1}}{\Delta t} \tag{1}$$

in which:

$\frac{dX}{dt}$ = drying rate (g. kg $^{-1}$.h^{-1}); U_i= current moisture content (db); U_{i-1}=moisture content in the previous period (db); Δt = time interval between weighings (hours).

The immediate and latent effects of drying were studied, considering the heating of air in the environment as of different states, representing dry environments (dry bulb temperature – Dbt – equal to 20°C and dew point temperature – Dpt – equal to 2.6°C) and moist environments (Dbt equal to 20°C and Dpt equal to 16.2°C). Under these conditions, relative humidity of the air in the environment would be equal to 30% and 80%, respectively, during the period of coffee harvest.

The drying treatments studied were obtained from the combination between three Dbt (35, 40, and 45 °C) and two Dpt (2.6 and 16.2°C). A completely randomized design was considered in a 3×2 factorial arrangement, with four replications. Thus, the relative humidity of the drying air constituted a dependent variable of the Dpt and the Dbt, and as consequences, different drying rates were achieved for each Dbt.

After drying, the coffee was packed in single-sheet brown Kraft paper bags and polyethylene bags and stored in a controlled climate at 10°C and relative humidity of 50%.

After the sixth month of storage there is a significant drop in coffee quality (RIBEIRO et al., 2011). Thus, to evaluate the immediate effects, coffee samples were analyzed after 1 month of storage and latent effects were evaluated after 7 months of storage.

Coffee quality was evaluated through sensory analysis of the beverage. The following analyses were also performed on the coffee beans for the purpose of understanding the immediate and latent effects on the quality of the coffee beans: electrical conductivity, potassium leaching, total, reducing, and non-reducing sugars, and free fatty acids, at two different times: at one month and seven months after drying.

Sensory analysis was made by a panel composed of three cupping judges certified by the Specialty Coffee Association of America (SCAA) according to the methodology proposed by Lingle (2011).

Electrical conductivity of the green coffee beans was determined by the methodology proposed by Loeffler, Tekrony and Egli (1988). Four replicates of 50 beans from each plot were used, which were weighed to a precision of 0.001 g, immersed in 75 mL of distilled water in 180 mL plastic cups, and kept in BOD at 25°C for five hours. Electrical conductivity was read on a benchtop conductivity meter BEL W12D,and the results were expressed in $\mu Scm^{-1}g^{-1}$. After the reading of electrical conductivity, potassium leaching was determined in the solutions. The reading was made on a flame photometer Digimed NK-2002 and the results were expressed in ppm (PRETE; ABRAHÃO, 1995).

Sugars were extracted by the Lane-Enyon method, cited by the Association of Official Analytical Chemists - AOAC (2011) and determined by the Somogy technique, adapted by Nelson (1944).

Free fatty acids were extracted in microcentrifuge tubes containing approximately 65 mg of ground coffee, to which were added 400 µl of a 0.5 N aqueous solution of sodium hydroxide, followed by an ultrasound bath for 10 minutes at 40ºC. After centrifuging at 6200rpm for 30 seconds, a 200 µl aliquot of supernatant was transferred to another microcentrifuge tube. Then, 400 µl of 20% hydrochloric acid, a spatula tip of NaCl, and 600 µl of ethyl acetate were added. After shaking in a vortex for 10 seconds and 5 minutes of rest, a 300 µl aliquot of the organic layer was removed, placed in microcentrifuge tubes, and dried by evaporation, thus obtaining the free fatty acids.

The free fatty acids were methylated with 100 µl BF_3 methanol (14%) containing 1.0 $mgml^{-1}$of methyl laurate (C12:0) used as an internal standard (Christie, 1989). The tube was then heated for 10 minutes in a water bath at 80ºC and then analyzed by Gas Chromatography.

Analyses were made in a gas chromatographHP5890 equipped with a flame ionization detector. An HP-INNoWax (HP) column of 15 m x 0.25 mm was used, with a 120ºC to 220ºC temperature gradient with a heating rate of $10ºCmin^{-1}$,an injector (1/50 split) at 230ºC, and detector at 230ºC. Hydrogen was used as a carrier gas (2 $mlmin^{-1}$) and an injection volume of 1 µl. Peaks were identified by comparison with standardsof SUPELCO 37 fatty acid methyl esters.

The set of data obtained from the sensory, chemical and physiological analyses was examined by principal component analysis (PCA). The PCA routines were carried out using the Chemoface 1.4 software (NUNES et al., 2012). Furthermore, to study the effect of the treatments on the sensory quality of coffee, the data obtained in sensory analysis were subjected to analysis of variance, and when significant differences were observed, the mean values were compared by the Scott-Knott test at 5% significance.

3 RESULTS AND DISCUSSION

Mean and maximum drying times and drying rates as a function of Dbt and Dpt of the drying air are shown in Table 1.

The response of drying rates as a function of Dbt and Dpt of the drying air throughout the drying process is shown in Figure 2.

An increase in the mean and maximum drying rates and reduction in drying time as a result of reduction in Dpt for the same Dbt and as a result of an increase in Dbt can be observed in Table 1 and in Figure 2.

The maximum drying rate occurs at the beginning of the process when the moisture content of the fruits is higher. In this period, the effect of Dpton the drying rate is more evident. At the end of drying, when the coffees have lower moisture contents, differences among the drying rates as a function of Dpt are not seen, indicated by the overlapping of the curves (Figure 2). In regard to Dbt, although the differences are smaller, it can still be observed that higher temperatures lead to higher drying rates. The peaks of the drying rate observed during the process occur at the resumption of drying soon after the 10-hour rest period. This occurs because with the evolution of the drying process, moisture gradients are formed within the fruits, and the moisture deeper within is higher than the surface moisture. These gradients will be increasingly greater the drier the fruits are in continuous processes of dehydration (Isquierdo et al., 2011). During rest, the migration of water from the inside of the fruits to the surface occurs, increasing the drying rates upon resuming the process.

TABLE 1 - Mean and maximum drying time and drying rate of natural coffee as a function of Dbt and Dpt of the drying air.

Dbt (°C)	Dpt (°C)	RH (%)	Drying time (hours)	Drying rate ($g\ kg^{-1}\ h^{-1}$)	
				Mean	Maximum
35	16.2	32.7	76	4.68	11.34
35	2.6	13.1	56	6.41	14.59
40	16.2	25.0	50	6.57	15.89
40	2.6	10.0	38	8.51	23.14
45	16.2	19.2	30	10.60	23.19
45	2.6	7.7	26	13.27	53.12

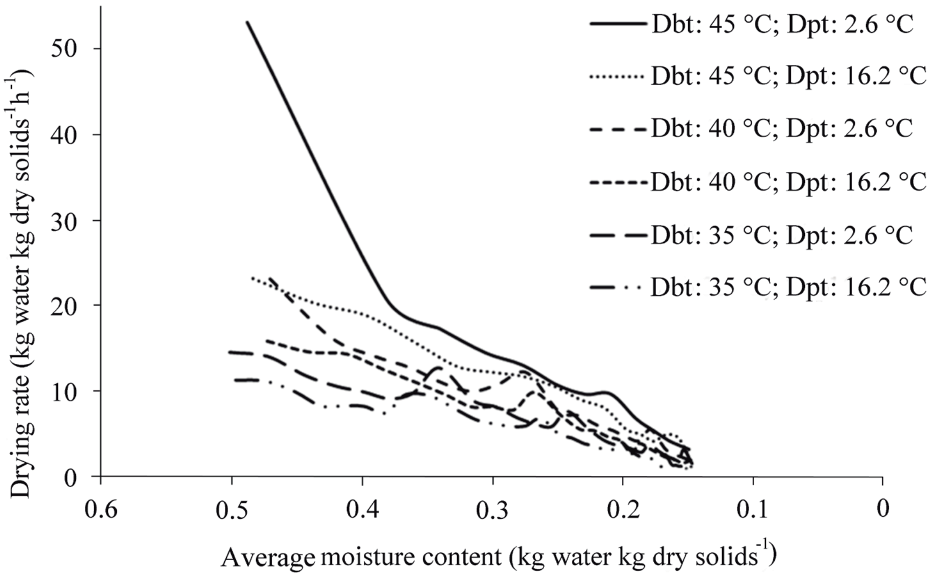

FIGURE 2 - Drying rate of coffee fruits as a function of the Dbt and Dpt of the drying air.

Table 2 shows the mean results of sensory analyses (Score), electrical conductivity (EC), potassium leaching (PL), total sugars (TS), reducing sugars (RS), non-reducing sugars (NRS), and total free fatty acids (FFA) of coffee carried out as a function of Dbt and Dpt considering two different times: one month and seven months after drying.

For the purpose of interpreting the effects of temperature and relative humidity on sensory quality and on the chemical and physiological aspects of coffee, principal component analysis (PCA) was used, generating a biplot (Figure 3) as a result of the values obtained in these analyses. In this analysis, it can be observed that the two principal components are responsible for 82% of the total variance due to the treatments, with 65.10% of the variability explained by the first principal component and 16.9% by the second.

Analyzing the PCA, the formation of two distinct groups can be seen according to the second PC2 axis. Group I is composed of the coffees analyzed after one month of storage and group 2 by coffees analyzed after seven months of storage. The main characteristic that contributed to the separation of these groups was the sugar content (total, reducing, and non-reducing). The coffees of group I show higher sugar contents in relation to the coffees of group II (Table 2). This result is in agreement with Ribeiro et al. (2011) and Selmar et al. (2008), who affirm that reduction in the sugar contents is directly related to the respiratory activity of the beans during storage.

Within group I, the formation of two distinct groups is observed. GroupI.1, with the points lying to the left of the biplot (I.35.16, I.35.2, I.40.16,and I.40.2)is composed of the coffees dried at 35 and 40 °C, regardless of the Dpt,which exhibited the highest scores in sensory analyses.

TABLE 2 - Mean values of the analyses of Score, CE, PL, TS, RS, NRS, and FFAof coffee as a function of Dbt and Dpt.

Treatments			Score	EC	PL	TS	RS	NRS	FFA
Storage (month)	Dbt (°C)	Dpt (°C)		($\mu Scm^{-1}g^{-1}$)	(ppm)	(%)	(%)	(%)	(%)
1	35	16.2	83.94	53.37	16.88	7.78	0.548	7.05	1.634
1	35	2.6	80.83	61.77	19.11	7.85	0.428	7.19	1.286
1	40	16.2	82.69	56.74	17.96	8.17	0.443	7.49	1.379
1	40	2.6	82.06	60.62	18.11	7.58	0.657	6.79	1.738
1	45	16.2	79.25	78.61	20.71	7.34	0.535	6.64	1.618
1	45	2.6	79.06	76.4	23.16	7.54	0.475	6.87	1.819
7	35	16.2	81.79	62.12	18.63	6.45	0.384	5.76	1.699
7	35	2.6	78.79	77.75	24.53	6.37	0.381	5.69	1.656
7	40	16.2	81.75	62.92	19.07	6.24	0.385	5.56	1.203
7	40	2.6	78.83	81.36	24.68	6.28	0.359	5.62	2.474
7	45	16.2	78.67	85.71	26.27	6.21	0.435	5.52	1.990
7	45	2.6	77.5	85.22	25.74	6.25	0.469	5.39	1.606
Overall mean			80.43	70.21	21.24	7.00	0.458	6.30	1.675
CV			1.96	7.84	10.64	15.62	19.09	16.20	28.04
F			6.5628**	18.0489**	9.0961**	2.172*	3.927**	2.244*	1.5255^{ns}

**Significantat 1% by the F test; *Significant at 5% by the F test; ^{ns}Not significant.

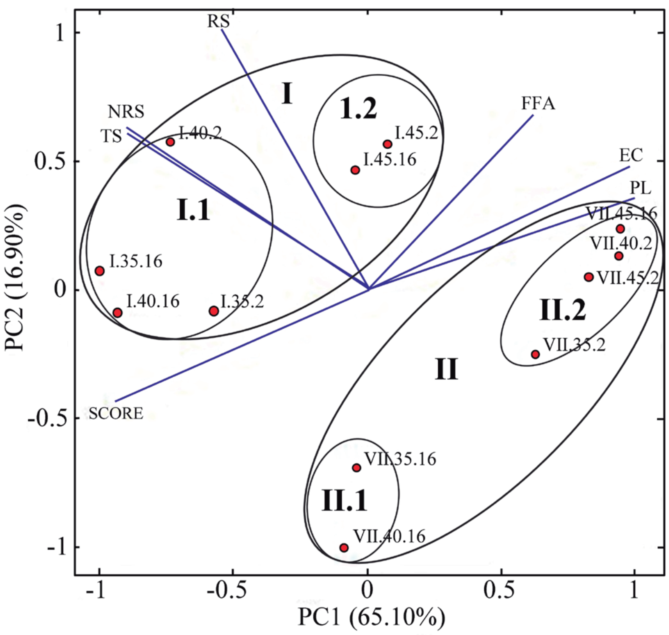

FIGURE 3 - Biplot of the two first axes of principal component analysis for data from three Dbt (35, 40, and 45), two Dpt (2, 16) and two times of analysis (I –one month after drying and VII – seven months after drying) according to the values of sensory analyses (Score), electrical conductivity (EC), potassium leaching (PL), total sugars (TS), reducing sugars (RS), non-reducing sugars (NRS), and total free fatty acids (FFA).

Group I.2, for its part, with points lying in the center of the biplot (I.45.16 and I.45.2),is composed of coffees subjected to a drying temperature of 45°C,and they exhibited the highest values of electrical conductivity and potassium leaching and higher contents of free fatty acids.

Within group II, composed by the coffees analyzed after seven months of storage, the formation of two distinct groups is observed. Group II.1, with points lying in the center of the biplot (VII.35.16 and VII.40.16), exhibiting higher scores in sensory analysis and group II.2, with points lying at the right of the biplot (VII.35.2, VII.40.2, VII.45.16,and VII.45.2), exhibiting higher values of electrical conductivity, potassium leaching, and free fatty acid content.

The results shown in Figure 3 confirm the inverse relation existing between the sensory quality of coffee and the values of electrical conductivity, potassium leaching, and free fatty acid contents, which is in agreement with various studies that showed similar results (CORADI et al., 2007; ISQUIERDO et al., 2011; MARQUES et al., 2008).

The analyses of electrical conductivity and potassium leaching indicate the integrity of the cell membrane system of the coffee beans. Beans that were damaged due to high drying temperatures or by deteriorations that occurred during storage show higher values when undergoing these analyses (BORÉMet al., 2014). Deterioration by drying or during storage can also be indicated by an increase in the free fatty acid content, which is one of the first modifications associated with coffee bean deterioration (SPEER; KÖLING-SPEER, 2006).

Furthermore, it can be observed in Figure 3 that the coffees that obtained the highest scores in sensory analysis and the lowest values of electrical conductivity, potassium leaching, and fatty acid contents were the coffees dried at temperatures of 35 and 40 °C, regardless of the Dpt,and analyzed one month after drying.

The effects of Dbt and Dpt on the sensory analysis of natural coffee carried out one month and seven months after drying are shown in Tables 3 and 4, respectively.

When sensory analysis was carried out one month after drying (Table 3), it can be observed that, regardless of the Dpt, the coffees dried at 45°C show lower scores compared to coffees dried at 35 and 40 °C. In regard to Dpt, it can be observed that only within the Dbt of 35°C does it have a significant effect on coffee quality, such that the higher the Dpt, and consequently higher relative humidity and lower drying rate, the higher the score obtained by natural coffee.

When sensory analysis was carried out after seven months of storage, the effect of Dbt within the Dpt of 16.2°C (greater relative humidity)is the same observed after one month of storage, that is, the coffees dried at 45°C have significantly lower scores compared to coffees dried at 35 and 40 °C. Nevertheless, within the Dpt of 2.6°C, an abrupt decline in the scores was observed after storage for all the Dbt, and the coffees did not show significant differences among themselves. The effect of Dpt is observed for the Dbt of 35 and 40 °C, such that the greater the Dpt, and consequently greater relative humidity and lower drying rate, the greater the score obtained by natural coffee.

The results of this study confirm the negative effects of high temperatures on the quality of natural coffee, which are in agreement with Oliveira et al. (2013), who affirmed that drying temperatures higher than 40°C are not appropriate for the production of natural specialty coffees. All the coffees dried at 45°C obtained scores lower than 80 points by the SCAA methodology, and are not considered specialty coffees.

In regard to the effects of Dpt and relative humidity, it was observed that when they are reduced, there is an increase in the drying rate, and this increase is more evident for the lower Dbt and in the first hours of drying, when the water content of the coffee is higher. In regard to the effect of drying rate on coffee quality, results indicate that an increase in the drying rate negatively affects the quality of natural coffee, and its effect depends on the temperature. For the temperature of 35°C, the negative effects of the drying rate on coffee quality are evident, both for one month and for seven months after drying. For the temperature of 40°C, it is not possible to observe the immediate effect of the drying rate; however, after seven months of storage, it can be seen that the higher drying rates are associated with lower scores in sensory analysis, showing its latent negative effect on the quality of natural coffee. As for the temperature of 45°C,the effects of thermal damage caused by this temperature predominate, making the effect of the drying rate not very evident.

In general, it was observed that high drying rates are harmful to coffee quality, especially when low temperatures are used. Rapid dehydration of coffee causes damage to the cell structure of the endosperm, triggering a series of chemical and biochemical reactions that negatively affect the sensory quality of the beverage.

TABLE 3 - Mean scores obtained in sensory analysis of natural coffee carried out one month after drying as a function of Dbt and Dpt.

Dbt	Dpt	
	16.2 °C	2.6 °C
35 °C	83.94 aA	80.83 aB
40 °C	82.69 aA	82.06 aA
45 °C	79.25 bA	79.06 bA
CV (%)	1.79	

Means followed by the same lowercase letters in the column and by the same uppercase letters in the line belongs to the same cluster (P>0.05) by the Scott-Knott test.

TABLE 4 - Mean scores obtained in sensory analysis of natural coffee carried out seven months after drying as a function of Dbt and Dpt.

Dbt	Dpt	
	16.2 °C	2.6 °C
35 °C	81.79 aA	78.79 aB
40 °C	81.75 aA	78.83 aB
45 °C	78.67 bA	77.50 aA
CV (%)	1.98	

Means followed by the same lowercase letters in the column and by the same uppercase letters in the line belongs to the same cluster (P>0.05) by the Scott-Knott test.

4 CONCLUSIONS

Dry bulb temperatures higher than 40°C are not recommended for drying of natural specialty coffees.

For the drying temperature set at 35°C, the increasing of the drying rate causes a decreasing in the sensory quality of natural coffee.

For the drying temperature of 45°C, the lowering of the quality of natural coffee is explained by thermal damage and the effect of the drying rate is not evident.

Higher scores in sensory analysis of coffee are associated with lower values of electrical conductivity, potassium leaching, and free fatty acid contents.

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SOIL ATTRIBUTES IN CONVENTIONAL TILLAGE OF *Coffea arabica* L.: A CASE STUDY

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ABSTRACT: Coffee production presents great economic and social importance. To increases coffee production and decreases the environmental impacts of its activity, it is necessary to know the soil attributes and their impacts on plant development. Therefore, due to the importance of the soil physical and chemical attributes, as well as the significance of coffee to Brazil, the objective of this study was to evaluate the physical and chemical attributes of an Oxisol planted with coffee conducted under conventional tillage system. For the purposes of analysis and interpretation of the data, the experiment was performed and interpreted in a completely randomized design, with the factorial 3 x 2, referring to three locations in the area of the coffee plantation (planting line, canopy projection, between planting lines) and two soil layers (0 - 0.2 m and 0.2 - 0.4 m), with four replications. It is concluded that no distinctions for soil porosity and total porosity was observed among soil locations, and that 'planting line' position showed superior concentrations of total organic carbon and mean geometric diameter of the soil aggregates.

Index terms: Coffee, soil aggregates, soil organic carbon, macroporosity, microporosity.

ATRIBUTOS DO SOLO COM PLANTIO CONVENCIONAL DE *Coffea arabica L.*: UM ESTUDO DE CASO

RESUMO: A produção de café (*Coffea arabica*) apresenta grande importância socioeconômica no Brasil. Para melhor desenvolvimento da cultura e redução de impactos ambientais, faz-se necessário conhecer os atributos do solo. Dada a importância dos atributos físicos e químicos do solo, bem como a posição de destaque do Estado de Minas Gerais como maior produtor de café do Brasil, o objetivo do estudo foi avaliar os atributos físicos e químicos de um Latossolo Vermelho textura argilosa em uso com café manejado em sistema de plantio convencional, na Região do Triângulo Mineiro. Para efeito de análise e interpretação da exploração dos dados, o experimento foi realizado e interpretado em esquema de delineamento inteiramente casualizado - DIC, com o fatorial 3 x 2, referente a três localizações na área do cafezal (tronco, saia e rua) e duas camadas (0,0 - 0,2 e 0,2 – 0,4 m), com quatro repetições. Conclui-se que a posição do tronco do cafeeiro apresentou maiores concentrações de carbono orgânico total e diâmetro médio geométrico, enquanto que para macroporosidade e porosidade total não houve distinções entre os tratamentos.

Termos para indexação: Café, agregados do solo, carbono orgânico do solo, macroporosidade, microporosidade.

1 INTRODUCTION

Coffee production is of great economical importance to Brazil, both for job creation and for income profits to coffee farmers, helping to prevent the exodus from rural areas. The Brazilian states of Minas Gerais, São Paulo, Espírito Santo, Paraná, Bahia and Rondônia have the largest coffee production, prevailing the *Coffea arabica* specie (ORMOND; FAVERET FILHO, 2002). In addition to the socioeconomic importance, also should be give attention to soil attributes in coffee areas, which area part of the ecosystem and can significantly count for better coffee development and production.

Soil is a natural resource essential for human survival, and responsible for a high quality environment, as well as for the fauna and flora sanity (SHARMA et al., 2005). However, the inappropriate use, especially the adoption of conventional tillage systems of soil management (plowing and harrowing), has caused soil degradation such as the rupture of soil aggregates, soil compaction, fertility decline, fast organic matter oxidation and reduction of the quantity and diversity of soil microorganisms (MOURA, 2004; MILK et al., 2010).

The conventional tillage system contributes to soil and nature degradation because of the high levels of fertilizers and pesticides applied to the crop together with high superficial soil losses specially during rain (CASTELLINI et al., 2006; GÜNDOĞMUŞ, 2006).

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Also, the tillage farming contributes to greenhouse effect through the increase of the carbon dioxide emissions into atmosphere (KALTSAS et al., 2007). The cultivation of *Coffea* spp.., using this system, occurs in most coffee areas of Brazil (PARTELLI et al., 2011),being necessary continuous observation of the soil physical and chemical attributes to reduce the impacts generated by this system.

The physical and chemical soil directly influence the development of crops (BURNS et al., 2006), and the analysis of these attributes are essential to the management strategies that confer an increase in agricultural productivity, especially in perennial crops, as in the case of coffee. Given the importance of the soil physical and chemical attributes to coffee and the damaging effects of soil conventional farming, that the objective of this study was to evaluate the physical and chemical attributes of an Oxisol planted with productive coffee in a soil tillage system.

2 MATERIAL AND METHODS

2.1 Experimental area characterization

The area chosen for this study is located at the coordinates 18º52'00"S and 47º57'40"W, in the municipality of Indianópolis, Minas Gerais state, Brazil. The region has an average altitude of 804 m and climate of the type Aw characterized as tropical rainy season (JONES, 1986).

For the purposes of analysis and interpretation of data exploration, the experiment was performed and interpreted in a completely randomized design, with the factorial 3 x 2, referring to three locations in the area of coffee plantation (planting line, canopy projection, between planting lines) and two soil layers (0-0.2 and 0.2-0.4 m), with four replicates. Posteriorly, soil was classified as a dystrophic red clay texture with predominance of clay fraction ranging between 16 to 29% (EMBRAPA, 1997). The chemical characterization (Soil water pH; potassium-K^+; magnesium-Mg^+; calcium-Ca^{+2}; aluminum-Al^{+3}; and potential acidity-H+Al) was determined according to Tedesco et al. (1995). While, the phosphorus-P was determined using the Mehlich1 methodology following the Tedesco et al. (1995), and textural characterization according the methodologies recommended by Embrapa (1997).

2.2 Coffee management

The coffee (*C. arabica* cv. Mundo Novo) planting was done in 2003 through conventional tillage with the use of plow and grid for the soil preparation (0.2 m). In this same year it was applied cattle manure at the planting time (1 kg $plant^{-1}$). Coffee plants were spaced 4 x 0.7 m between planting lines and coffee plants, respectively. The irrigation system of the coffee area is based on the localized dripping system, which aims to save water, automation, efficiency and labor reducing.

The mineral fertilization was performed in the period from October to March every year, with the application of 350 kg ha^{-1} of NPK 18-01-20 (spreader), fertilization through irrigation and foliar fertilization for micronutrients supplementation. In order to control weeds it was performed manual weeding and the application of 3 L ha^{-1} of glyphosate. Unproductive coffee branches were also removed to give great support structure of production, as described by Thomaziello (2013).

The coffee harvest was mechanized and done manually only for coffee plants where the machine could not reap the coffee beans. Straws, leaves and other crop residues were left over the soil. In the year 2013, there was an average productivity of 40 bags ha^{-1}.

2.3 Soil collection and analyzed variables

The soil samples were collected in 2014 at the layers 0-0.2 m and 0.2-0.4 m. To sample the soil it was used a hoe and a ruler to measure soil depth. Initially, it was removed the excess of organic matter on soil surface and subsequently the samples were dig out. The samples were sent to the soil laboratory properly packaged and labeled in plastic bags.

In the lab the soil samples were air dried and sieved (<2 mm) to obtaining the FSAD (fine soil air dried). The total nitrogen (TN) was determined according to the Kjeldahl method (BLACK, 1965), while the total organic carbon (TOC) was determined by the method of potassium dichromate oxidation in acidic medium. The carbon soluble in water (CSA) was extracted with deionized water (YEOMANS; BREMNER, 1988).The availability of macronutrients (N, P, K, Ca, Mg, S) and micronutrients (B, Cl, Cu, Fe, Mn, Zn) were determined according to Tedesco et al. (1995), as well as the potential acidity (H + Al), aluminum (Al^{+3}) and the water pH (pH-H_2O).

The determination of water dispersible clay (WDC) was done by the method of volumetric pipette according to the methodology described by Gee and Sao (1986) with the use of chemical dispersant (EMBRAPA,1997).

TABLE1 - Physical and chemical characterization of two soil layers 0-0.2 and 0.2-0.4 m in area with coffee cultivation. Indianópolis-MG.

Soil	Chemical and physicalsoil attributes									
	Sand	Silt	Clay	pH	P	K^+	Mg^{2+}	Ca^{2+}	Al^{3+}	H+Al
(m)	------gKg^{-1} (x100)------			(H_2O)	---$mgdm^{-3}$---		------------$cmol_c dm^{-3}$------------			
0-0.2	1.2	1.0	7.4	5.23	13.06	0.53	0.7	1.50	0.2	3.33
0.2-0.4	1.7	2.4	5.9	5.1	28.07	0.65	0.9	1.83	0.2	4.60

The collection of the undisturbed soil samples was performed on the same day of the collection of the deformed soil samples (for chemical and texture analysis). For collection of the undisturbed samples it was used an Uhland sampler and metal rings of Kopeck with sharpen edges. After the ring collection from ground and clean the excess of soil adhered, the non-sharpen ring size was covered with a silk paper and hold tight with a rubber band.

For determination of the geometric mean diameter (GMD) undisturbed soil samples were sieved with a sieve (4 mm) with the quantification of classes of aggregates through wet separation using aYoder equipment (Kemper and Rosenau, 1986). The soil aggregates were separated in class by sieves with 4, 2, 1, 0.5 and 0.25 mm meshes.

Also, it was determined with the soil sample in the volumetric rings (internal volume known): the soil density (SD), total porosity (TP), macropores (Ma) and micropores (Mi). The total porosity was calculated as described by Danielson and Sutherland (1986). The microporosity was determined by the content of water retained in the soil at the potential of -0,006 MPa. The macroporosity was obtained by the difference between the total porosity and microporosity. The density of the soil expressed the relationship between the mass of dry soil and the volume of the sample, and is calculated with the mass of soil dried in an oven at 105ºC for 24 h (BLAKE;HARTGE, 1986).

2.4 Data processing and statistical analysis

The variability of the studied properties was previously evaluated by means of descriptive statistics by calculating the mean values, standard deviations, minimum and maximum values observed. For the variables an analysis of variance (ANOVA) was performed, when the H0 was rejected was compared the measurements of treatments with test of Tukey test ($p< 0.05$). Subsequently, the variables were submitted to analysis multivariate exploratory of grouping by hierarchical methods and main components. Previously to the statistical analyzes, the basic assumptions of ANOVA, normality of errors and homogeneity of variances were tested for all evaluated variables (data not shown).

For the principal components analysis (PCA), the variables: total organic carbon (TOC); pH-H_2O; calcium (Ca^{+2}); magnesium (Mg^{+2}); potassium (K^+); sulfur ($S-SO_4^-$); aluminum (Al^{+3}); zinc (Zn), manganese (Mn); iron (Fe); boron (B); geometric mean diameter (GMD); microporosity (Mi) and macroporosity (Ma). Next, the set of variables were grouped according to their characteristics for better visualization of the relationship between the variables on the axes of coordinates. The new axis and the auto-vectors (new variables) called principal components (CP), are generated by linear combinations of the original variables constructed with the auto-values of the covariance matrix (HAIR et al., 2005; PIOVESAN, 2008). With the goal of obtaining a model more simple and parsimonious, we used the Kaiser criterion (1958), with auto-vectors above the unit. The analysis were conducted in STATISTICA 7.0 software (StatSoft. Inc., Tulsa, OK, USA).

3 RESULTS AND DISCUSSION

3.1 Univariate analysis

The levels of total organic carbon (TOC) presented a variation between 16.75 and 18.82 g kg^{-1}, while the soluble carbon fraction obtained lower concentrations, ranging from0.04 to 0.06 g kg^{-1} (Figure 1).The highest concentrations of TOC occurred in the ‘planting line’ location, considered significantly equal to that found at the ‘canopy projection’ position, and 16.53% higher than ‘between line’ position in the coffee plantation (Figure 1).

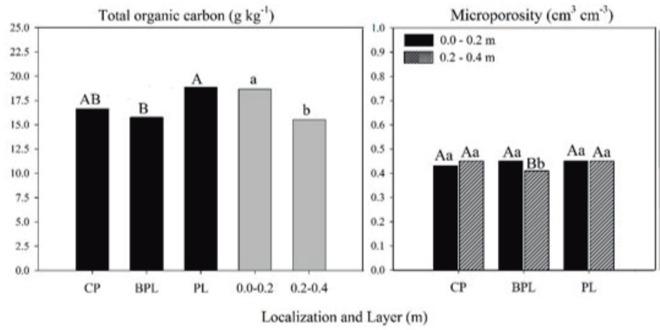

FIGURE 1 - Total organic carbon (g kg^{-1}) and microporosity (cm^3 cm^{-3}) located in the planting line (PL), canopy projection (CP), between planting lines (BPL) position of a coffee plantation in layers of 0 - 0.2 and 0.2 - 0.4 m.

The 'between planting line' position showed lower levels of TOC due to soil compaction by traffic of machines during the cultural treatments, such as fungicides and insecticides spraying, as well as the application of nutrients and weed control with the use of herbicides, which ends up as a result eliminating other green fertilizers that could cover ground, thus contributing to soil compaction and erosion over time. According to Araujo-Junior et al. (2011), this soil compaction is probably due to soil tillage systems, mechanization and the weed control that elevate the soil density, especially at 0-3 cm and 10-13 cm soil layers.

The volume of plant cover accumulated on soil can influence the levels of soil organic matter, favors the action of microorganisms and the humification process of the crop residues produced (MARTINS-NETO; MATSUMOTO, 2010). Among the effects of soil organic matter, what stands out is the stimulation of microorganisms diversity in the soil, due to nutrient cycling and energy for microorganisms activity (MOREIRA; CARNEIRO, 2004; COSTA et al., 2013). ROLDÁN et al. (2003) found that in soils with coverage ≤ at 33%, the microbial biomass was reduced (322 mg kg^{-1}) in relation to soils with 66% (426 mg kg^{-1}) and 100% (654 mg $kg^{-1)}$ surface coverage.

TP and Ma showed no differences between the locations in the coffee plantation, with variations of 0.54 to 0.53 and 0.08 to 0.1 cm^3 cm^{-3}, respectively (Table 2). The amount of Mi showed distinction between the positions (planting line, canopy projection, between planting lines), varying between 0.43 and 0.46 cm^3 cm^{-3} (Figure 1).

High concentration of Mi is generally due to the compression caused by pressure exerted on the ground (SEIXAS; OLIVEIRA JÚNIOR, 2001), and therefore, a decrease in the amount of Ma is also observed (NETO, 2001; STRECK et al., 2004; SILVA et al., 2006; MENTGES et al., 2010). This condition affects soil water infiltration, root growth and the movement of solutes in the soil pore spaces (STONE et al., 2002). However, in our study we did not notice difference between the positions (Table 2).

The 'planting line' position presented high values of GMD, being 38.27% higher than 'between planting line' position (Figure 2). This result is due to a higher concentration of TOC in this position (Figure 1). In 'between planting line' position, the total porosity and aggregation are smaller and consequently the soil density is greater, because these physical attributes are inversely proportional. The passage of machinery in 'between planting line' position favors compression and contributes to reduce TOC. Richart et al. (2005) also identify that the increased use of machines induces soil compaction. The reduction of macro and microporosity after intense traffic of machines is also related to a significant increase in soil density (BALL et al., 1997).

The stability of soil aggregates, as assessed by the GMD, was greater in the soil less compacted ('planting line' position) in relation to 'between planting line' position, and was similar between soil depths (BEUTLER et al., 2005).

3.2 Multivariate analysis

At PCA, there was the formation of a two-dimensional plane generated with first three main components: CP1 (44.95%), CP2 (22.79%) and CP3 (9.12%) that account for 76.86% of the original information (Figure 3 and 4). This result is consistent with the criterion established by Sneath and Sokal (1973), in which the number of CP used in interpretation should be such that explain at least 70% of the total variance of the data, which is the case of this study.

TABLE 2 - Descriptive statistical of the physical variables in an Oxisol cultivated with coffee positioned on (planting line, canopy projection, between planting lines),0 - 0.4 m layer.

	WDC	Ma	TP
Planting line	0.01(±0.01)	0.08(±0.04)	0.54(±0.03)
Canopy projection	0.00 (±0.00)	0.08 (±0.02)	0.53 (±0.02)
Between planting lines	0.00 (±0.00)	0.10 (±0.05)	0.53 (±0.03)

Water dispersible clay (WDC, gKg^{-1}); macropores-Ma(cm^3cm^{-3});total porosity(TP,cm^3cm^{-3}). The variables, Ma, WDC and TP were not significant by Tukey test at (P<0.05).

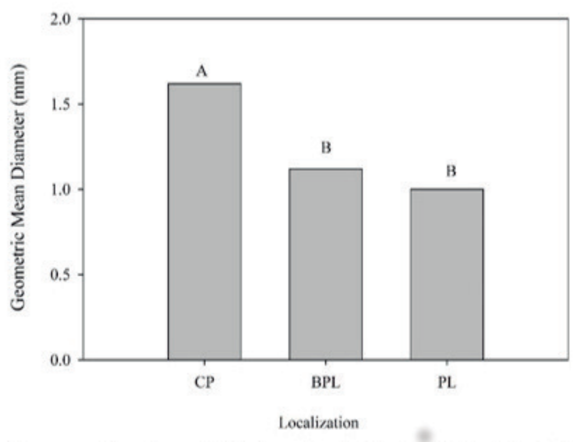

FIGURE 2 - Geometric mean diameter - DMG (mm) located in the planting line (PL), canopy projection (CP), between planting lines (BPL) position of a coffee plantation in layers of 0 - 0.2 and 0.2 - 0.4 m. At the figure, capital letters distinguish DMG for each position by Tukey test (p<0.05). CV: 29.81%.

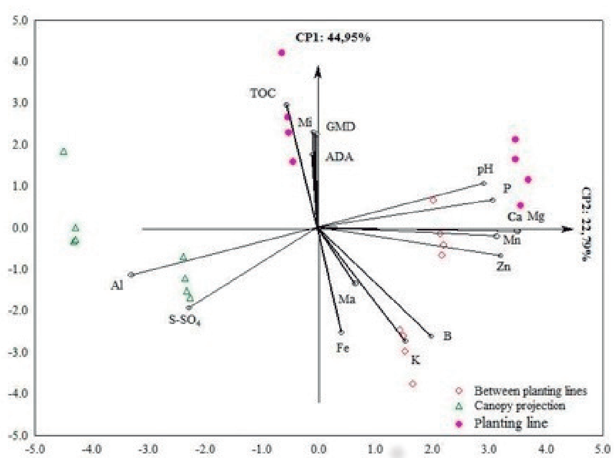

FIGURE 3 - Principal component analysis (PCA) of the CP1 and CP2 with the variables: total organic carbon (TOC); pH-H_2O; calcium (Ca^{+2}); magnesium (Mg^{+2}); potassium (K^+); sulfur ($S\text{-}SO_4$); aluminum (Al^{+3}); zinc (Zn), manganese (Mn); iron (Fe); boron (B); geometric mean diameter (GMD); microporosity (Mi), and macroporosity (Ma).

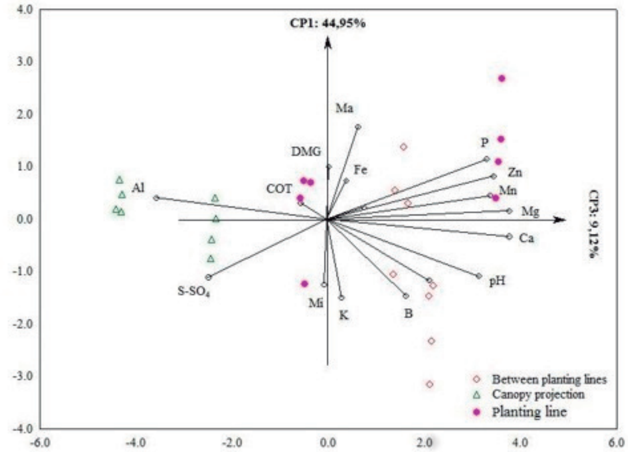

FIGURE 4 - Principal component analysis (PCA) of the CP1 and CP3 with the variables: total organic carbon (TOC); pH-H_2O; calcium (Ca^{+2}); magnesium (Mg^{+2}); potassium (K^+); sulfur (S-SO_4); aluminum (Al^{+3}); zinc (Zn), manganese (Mn); iron (Fe); boron (B); geometric mean diameter (GMD); microporosity (Mi), and macroporosity (Ma).

In CP1 were grouped the chemical attributes related to the availability of nutrients in order of importance from positive: Ca^{+2} (0.99), Mg^{+2} (0.99), Zn (0.91), Mn (0.88), P (0.87), pH-H_2O (0.82), B (0.56),to negative:Al^{+3} (-0.92) and S-SO_4^- (-0.63). In CP2 were grouped the physical and chemicals soil attributes in order of importance from positive: TOC (0.80), DMG (0.61), Mi (0.62), to negative K^+(-0.74); B (-0.71); Fe (-0.68); S-SO_4^- (-0.52). In CP3 were also grouped physical attributes in order of importance Ma (-0.75) and Mi (0.70) (Table 3).

The soil concentration of Ca^{+2} and Mg^{+2} demonstrated in CP2, ranged 1.90 to 2.05 and 0.45 to 1.0 cmolc dm^{-3}, respectively, and with high positive correlation demonstrated in CP1 with overlapping vectors and associated with the 'planting line' position in coffee plantation (Figure 3). This characteristic is due to the fact that these elements are related to their chemical properties that are very similar, such as the ion charge and mobility in soil solution, favoring a competition between these elements by sites of adsorption in soil and the uptake by the root system (SALVADOR et al., 2011).

As a result, the presence in excess of one nutrient (Ca^{+2} or Mg^{+2}) can negatively affect the processes of adsorption and absorption of other (ORLANDO FILHO et al., 1996). El Salvador et al. (2011), observed that the relationship between levels of exchangeable Ca^{+2} and Mg^{+2} in the soil and quantities of Ca^{+2} and Mg^{+2}in leaf responds positively when the leaf content of these elements is 10 g kg^{-1}, and exchangeable Ca^{+2} and Mg^{+2}in soil is of 1 cmolc kg^{-1}. The same was also observed by Hernandez and Silveira (1998).

The inverse relationship of Al^{+3} with the remaining nutrients with positive charges and the pH-H_2O is related with the availability of charges in the soil, which showed a variation between 0.45 to 0.05 cmolc dm^{-3}.The Cerrado soils have as characteristics high levels of Al^{+3}. In addition, these soils are naturally low in exchangeable bases to plants (LUZ et al., 2002; OLIVEIRA et al., 2005). However, lime and fertilizer applications reduce the amount of Al^{+3} retained in soil and replace it by cations (Ca^{+2}, Mg^{+2}, K^+). Thus, when the soils from the Cerrado are included in the production process, is carried out the practice of liming as a form of correction (OLIVEIRA et al., 2005).

The soil pH presented a variation between 4.75 and 5.4 and with high correlation with the P availability in soil, which ranged from 5.9 to 34.75 mg $dm^{-3}$with the highest contents observed at the 'planting line' position. This is probable due to the low solubility of natural phosphates applied close to the "planting line' position. The natural phosphates are an effective source of Pespecially in soils with pH lower than 5.5 (OLIVEIRA et al., 2005).

The relationship of the soil physical attributes grouped in CP2 shows the positive relationship of the TOC and Fe in the formation of soil aggregates (DMG) (Table 3). As with the K, a monovalent cation (+), this correlation has been reversed. The TOC is directly related with DMG, because when occurs the rupture of soil aggregates it causes a destabilisation of organic matter making it susceptible to decomposition by microorganisms (SOLLINS et al., 1996; CORAZZA et al., 1999).

TABLE 3 - Correlation coefficient of main components for the variables: water dispersible clay (WDC); total organic carbon (TOC); geometric mean diameter (GMD); macroporosity (Ma); microporosity (Mi); pH-H_2O; phosphorus (P), potassium (K^+); calcium (Ca^{+2}); magnesium (Mg^{+2}); boron (B); iron (Fe); manganese (Mn); zinc (Zn); sulfur (S-SO_4^-), and aluminum (Al^{+3}).

	CP1 (44.95%)	CP2 (22.79%)	CP3 (9.12%)
WDC	-0.02	0.47	-0.16
TOC	-0.15	**0.80**	-0.32
DMG	0.00	**0.61**	-0.46
Ma	0.19	-0.37	**-0.75**
Mi	-0.02	**0.62**	**0.70**
pH-H_2O	**0.82**	0.29	0.20
P	**0.87**	0.18	-0.04
K^+	0.44	**-0.74**	0.12
Ca^{+2}	**0.99**	-0.02	0.10
Mg^{+2}	**0.99**	-0.02	-0.05
B	**0.56**	**-0.71**	0.12
Fe	0.12	**-0.68**	0.12
Mn	**0.88**	-0.06	-0.30
Zn	**0.91**	-0.18	-0.08
S-SO_4^-	**-0.63**	**-0.52**	-0.12
Al^{+3}	**-0.92**	-0.31	-0.03

*Value refers to the percentage of the variability of the original set of data retained by the respective main components. Correlations in bold (P>0.5 in absolute value) were considered in the interpretation of the main component highly significant (COELHO, 2003).

Thus, the decrease in soil organic matter, especially in soils with low activity clays, cause further declines in the aggregate stability, which demonstrates that both parameters are related (CARTER et al., 1994; FELLER; TOME, 1997; FIELDS et al., 1997).

The soil aggregates are formed by physical forces that act in the process of wetting and drying, freezing and thawing, by compression caused by the root system and by the interactions of minerals and organic compounds from soil. However, for these processes occur is crucial the presence of flocculants and cementing agents, such as iron and aluminum oxides, plant roots and organic matter (BAYER; MIELNICZUK, 2008). Soil organic matter is essential for the stabilization of soil structure because it provides a large amount of radicals that can interact with the surface of the soil minerals and start the formation of soil aggregates (BAYER; MIELNICZUK, 2008).

It was observed that the action of the soil oxides in the process of aggregation is dependent upon both of their concentration and type, as well as the levels of organic carbon present in the soil (FERREIRA et al., 2007). For the same authors occurred only correlation between the levels of organic carbon in the soil and the distribution of aggregates, and between the levels of organic carbon in the soil and the contents of organic carbon in aggregates.

In relation to K, the correlation was reversed, because this chemical element promotes the dispersion of soil particles, causing the rupture of aggregates. This dispersion happens when flocculating cations (Al^{3+}, Ca^{2+}, Mg^{2+}) that often saturates clays, are replace by monovalent cations of higher hydrate ionic radius (MAURI et al., 2011). The inverse relationship of porosity (Ma and Mi) has been put together in CP3. The reductions in Ma in a compacted soil are usually followed by additions in Mi (GENROJUNIOR, 2002; SECCO et al., 2004).

4 CONCLUSIONS

The highest concentrations of total organic carbon occur in the ‘planting line’ of the coffee plantation. The ‘planting line’ location presents higher mean geometric diameter, with additions of 38.27%, compared with ‘between planting lines’ location.

The porosity and total porosity show no distinctions among the three locations evaluated (planting line, canopy projection, between planting lines) in the coffee plantation. The microporosity is low at the ‘between planting line’ position probably due to machinery traffic to coffee cropping activities.

In accordance with the principal components analysis there is the formation of three groups that account for 76.86% of the variability of the original information found here.

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ROOT-KNOT AND LESION NEMATODES IN COFFEE SEEDLINGS PRODUCED IN THE STATE OF MINAS GERAIS, BRAZIL

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ABSTRACT: Understanding the mechanisms of plant-parasitic nematodes (PPN) dispersion is vital to improve control strategies aiming to restrict dissemination of these plant parasites. In the present work, we evaluated the presence of PPN in Arabic coffee (*Coffea arabica*) seedlings produced in commercial nurseries in Minas Gerais, state, Brazil. A total of 2830 samples obtained from 318 coffee nurseries, in 84 counties within the South and Zona da Mata regions in Minas Gerais, Brazil and representing more than 62 million coffee seedlings, were analyzed. *Meloidogyne* spp. was identified in 11 samples from four counties. *Pratylenchus* spp. and *Rotylenchulus reniformis* were detected in 281 and 47 samples, respectively. According to the Regulatory Instruction N° 35 from the Ministry of Agriculture, Livestock and Food Supply (MAPA), in Brazil, coffee seedlings infected by *Meloidogyne* spp. are prohibited for commercialization and/or planting. However, such restrictions do not apply to other PPN. Therefore, seedlings sold in Minas Gerais may constitute sources of dissemination for root-lesion nematodes *(Pratylenchus* spp.*)* and the reniform nematode *(R. reniformis)*.

Index terms: *Coffea arabica, Meloidogyne* spp.*, Pratylenchus* spp.*,* Seedlings.

NEMATOIDE DE GALHAS E DAS LESÕES RADICULARES EM MUDAS DE CAFÉ PRODUZIDAS NO ESTADO DE MINAS GERAIS

RESUMO: O entendimento dos mecanismos de dispersão dos fitonematoides é fundamental para o desenvolvimento de estratégias visando restringir a sua disseminação. No presente trabalho foi avaliada a presença de fitonematoides em mudas de café arábica (*Coffea arabica*) produzidas em viveiros comerciais no estado de Minas Gerais. Foram analisadas 2830 amostras, enviadas de 318 viveiros, localizados em 84 municípios, das regiões Sul e Zona da Mata, representando um total de mais 62 milhões de mudas. *Meloidogyne* spp. foi identificado em 11 amostras, enviadas de quatro municípios. A presença *Pratylenchus* spp. e *Rotylenchulus reniformes* foi constatada em, 281 e 47 amostras, respectivamente. Segundo a instrução normativa N° 35 do Ministério de Agricultura, Pecuária e Abastecimento (MAPA), mudas de café infectadas com *Meloidogyne* spp. são impedidas de comercialização e plantio. No entanto, tais restrições não se aplicam a outros fitonematoides. Portanto, as mudas comercializadas em Minas Gerais podem atuar como em agentes disseminadores dos nematoides das lesões (*Pratylenchus* spp.) e do nematoide reniforme (*R. reniformes*).

Termos para indexação: *Coffea arabica, Meloidogyne* spp.*, Pratylenchus* spp.*,* mudas.

1 INTRODUCTION

In 2016, the gross revenue of Brazilian coffee production was estimated in US$ 7.62 billion (CONSÓRCIO PESQUISA CAFÉ 2016). In the state of Minas Gerais, accountable for more than 70% of the nations´ production of Arabic coffee (CONAB, 2016), coffee plantations generates jobs and preserves workforce in rural areas (SANTOS et al., 2009).

Plant-parasitic nematodes (PPN) are considered a limiting factor for coffee production (CAMPOS; VILLAIN, 2005; CARNEIRO et al., 2008). In Brazil, coffee producers have coexisted with these parasites since the end of the 19th century (GOELDI, 1887). Since then, the devastating effects of diseases caused by them have been reported in all production areas of the country (CASTRO et al., 2008; REZENDE et al., 2013; SALGADO et al., 2015).

Root-knot nematodes (*Meloidogyne* spp.), particularly *Meloidogyne exigua, Meloidogyne paranaensis* and *Meloidogyne incognita,* are the most important species for coffee crops in Brazil due to their destructive potential. Coffee plants infested by *M. exigua* are usually able to sustain a reasonable production; however, up to 45% yield losses may occur (BARBOSA et al., 2004a 2004b; BARBOSA; SOUZA; VIEIRA, 2010; MUNIZ et al., 2OO8). Parasitism by *M. incognita* and *M. paranaensis* produces more drastic symptoms, causing death of severe infested plantation and making planting of susceptible crops on infested areas an anti-economic activity (BOISSEAU et al., 2009; SHIGUEOKA et al., 2016).

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Another group of nematodes frequently found in coffee areas are the root-lesion nematodes (CASTRO et al., 2008; KUBO; EULALIO; OLIVEIRA, 2015) from the genus *Pratylenchus* spp. In India and Indonesia, *Pratylenchus coffeae* is the most destructive PPN in coffee crops (WIRYADIPUTRA; TRAN, 2008). In Central America this species is also harmful (VILLAIN; HERNÁNDEZ; ANZUETO, 2008), while in Brazil reports of coffee crops being anti-economic due to the incidence of this species are unusual (MOURA, PEDROSA, PRADO, 2002). The reniform nematode, *Rotylenchulus reniformis*, is also a frequently reported species in Brazilian coffee crops (BARROS et al., 2014; CASTRO et al., 2008), however, without any references about its effect.

In the southern region of Minas Gerais state, accountable for more than 54% of the coffee production in the state (CONAB, 2016), the presence of *M. paranaensis* and *M. incognita* in coffee crops was not verified after a broad survey performed in 2008 (CASTRO et al., 2008). However, during the last nine years, *M. paranaensis* was identified in plantations in five counties within this region (Alpinópolis, Coqueiral, Três Pontas) (SALGADO et al., 2015), Carmo do Rio Claro and Carmo de Cachoeira. In such plantations, the presence of this nematode caused severe damages. Thus, it urges to know and understand the factors that have contributed to disseminate this nematode in coffee crops within the main producing region in the country.

Use of coffee seedlings infected with nematodes is the main and more efficient form of dissemination for these microorganisms. During the 70´s the employment of coffee seedlings infected with *M. incognita* produced in the state of Parana, was responsible for the introduction of this nematode in several non-infested areas in the state of Sao Paulo (Ferraz, 2008). In 1976/1977, approximately 3.3 million infected coffee seedlings were discarded only in the state of Sao Paulo (FERRAZ, 2008).

Planting seedlings free from pathogens is imperative to stablish perennial crops, thus, the definition of phytosanitary standards for nematodes in coffee seedlings is primordial. Policies and standards for production and commercialization of coffee (*Coffea arabica* L. and *Coffea canephora* Pierre ex A. Froehner) propagation's material were established by the Ministry of Agriculture, Livestock and Supply (MAPA), through the Regulatory Instruction (IN 35) in November 29th 2012.

Despite the improvements occurred in the last decades concerning the awareness of growers and extension workers about the importance of PPN; dissemination of extremely harmful species for coffee crops such as *M. paranaensis* is still increasing in Brazil. Besides that, until now, there is no broad survey of nematodes in coffee seedlings traded in the state of Minas Gerais. Thus, the present work had the objective to verify the phytosanitary status of coffee seedlings regarding the most harmful phytonematodes in coffee crops.

2 MATERIALS AND METHODS

2.1 Analysis of samples

According to the Regulatory Instruction IN 35 from MAPA, in order to perform nematological analyses the laboratory must be registered in the National Network of Agricultural Laboratories of the Unified System of Agricultural Health Service, affiliated to the National Registry of Seeds and Seedlings (RENASEM).

Samples were received at the Laboratory of Nematology from the Federal University of Lavras and were initially evaluated regarding to the number of seedlings sampled per plot. Samples in divergence with IN 35 standards were not analyzed. Correctly sampled trials were visually checked for root-knots. Once root-knots were identified they were detached to be dissected under stereo microscope where females of *Meloidogyne* spp. were evaluated. The remaining roots were placed in a blender with 200 ml water and milled for 20 seconds. Then, the resulting material was sieved with a 425 µm sieve attached over a 38 µm sieve. The material retained in the 38 µm sieve was then collected and centrifuged. Then, the supernatant was observed under light microscope in order to evaluate the presence of juveniles of *Meloidogyne* spp., adults of *Pratylenchus* spp. and females of *R. reniformis*.

During a four months period (October 2016 to January 2017) 2830 samples were analyzed. All samples were tested for presence of *Meloidogyne* spp., however, the presence of *R. reniformes* and *Pratylenchus* spp. was evaluated in 2414 samples. Samples were received form 84 counties, being 83 counties from the state of Minas Gerais (59 - regions South and Central West, 23 - Zona da Mata and Vale do Rio Doce and one from the Triângulo Mineiro) and one from the state of São Paulo. In relation to nurseries, 318 sent samples (251 - South and Central West, 65 - Zona da Mata and Vale do Rio Doce, one from the Triângulo Mineiro and one from the state of São Paulo) (Figure 1). Samples received represented a total of 62.781.899 seedlings from 31 cultivars of *C. arabica*.

FIGURE 1 - Map of the Minas Gerais state. Highlighted counties that sent samples

3 RESULTS AND DISCUSSION

The presence of *Meloidogyne* spp. was observed in 11 samples obtained from four nurseries in the county of Rosário da Limeira, Muriaé, Carangola and Cabo Verde (Table 1). In these nurseries plants from the cultivars Catuaí Vermelho IAC 44 and Paraíso MG 2 were infected. Unfortunately, due to the great number of samples analyzed and the availability of a short period of time to release the technical report, it was not possible to identify *Meloidogyne* and *Pratylenchus* to the species level. Presence of root-knot nematodes (*Meloidogyne* spp.) in coffee plantations results in low productivity, ineffectiveness of soil fertilization, predisposition to parasitism by soil fungi, higher sensitivity to water stress and reduction of prices of agricultural lands (CAMPOS; VILLAIN, 2005; PEREIRA et al., 2012; SALGADO; REZENDE; CAMPOS 2005). Nevertheless, production of coffee seedlings infected by root-knot nematodes has being going on for decades in Brazil (FERRAZ, 2008). In this study, the presence of *Meloidogyne* spp., in 11 samples, proves the risk of dissemination of these PPN through seedlings is still imminent. Thus, surveillance of state agencies over coffee seedlings' trade avoid dissemination of root-knot nematodes.

The presence of *Pratylenchus* spp. was verified in 281 samples, representing 11.6% of the total evaluated samples. The root-lesion nematode was found in samples sent from 39 counties in ten coffee cultivars (Table 1 and Figure 2), however, with a low population density in the samples, mostly lower than 10 specimens per sample. The higher value found was of 38 specimens in a sample.

In India and Indonesia, *P. coffeae* is the most destructive PPN in coffee crops (WIRYADIPUTRA; TRAN, 2008). In Central America lesion nematodes are widely distributed and cause severe losses (VILLAIN; HERNANDEZ; ANZUETO, 2008). In Brazil, despite being a common group of PPN, their influence on coffee plantations has yet to be determined, even though there are reports of the damaging potential of this group of nematodes in coffee seedlings (KUBO et al., 2003; TOMAZINI et al., 2005). Inomoto et al. (2007), suggested that some populations of *Pratylenchus* spp. are highly pathogenic to coffee plants in Brazil, causing damages even when in low population densities. Nevertheless, there are few records of unproductive coffee plantations due to the incidence of these nematodes (MOURA, PEDROSA, PRADO, 2002).

TABLE 1 - Counties, number of samples and nurseries investigated as incidence of *Meloidogyne* spp., *Pratylenchus* spp. e *Rotylenchulus reniformes* .

Counties	*N of samples*	*N of nurseries*	*Meloidogyne* spp	*Pratylenchus* spp	*R. reniformis*
Alfenas	8	1			
Alpinópolis	8	2		X	
Alterosa	26	4		x	X
Andradas	20	1		X	
Areado	32	1			
Baependi	12	1		X	
Boa Esperança	84	12		x	X
Bom Jesus da Penha	4	1			
Bom Sucesso	32	2		X	
Botelhos	60	7		X	
Cabo Verde	44	6	x	X	
Cachoeira de Minas	12	1			
Caiana	8	1		X	
Camacho	8	1			
Cambuquira	24	2		X	
Campanha	8	1			
Campestre	32	7		x	X
Campo Belo	28	2			X
Campos Gerais	64	10			
Candeias	56	7		x	X
Caparaó	8	1			
Capela Nova	4	1			
Carangola	20	2	x		
Carantiga	16	2			
Carmo da Cachoeira	20	2		x	X
Carmo do Rio Claro	16	4		x	
Carvalhópolis	24	4			X
Conceição da Aparecida	20	3		x	X
Coqueiral	56	5		x	
Cordislândia	12	1		X	
Cristais	32	4		x	X
Divino	140	15		x	X
Elói Mendes	12	2			
Ervalia	12	2			
Espera Feliz	72	7			
Espírito Santo do Pinhal (SP)	20	1			
Fervedouro	64	10		X	
Guaranésia	4	1			
Guaxupé	128	11		X	X
Heliodora	12	3		X	
Ibiraci	72	6		X	
Ilicínea	28	3		x	X
Imbé de Minas	4	1			
Inhapim	4	1			

Itamogi	52	6		x	
Jacuí	24	3		x	
Jacutinga	100	8		X	
Jesuânia	32	5			
Juruaia	16	2		x	
Lavras	12	2			
Machado	164	17		x	X
Miradouro	4	1			
Monte Belo	12	2		x	
Monte Santo de Minas	36	4			
Muriaé	4	1			
Muzambinho	84	9			
Nepomuceno	88	13			
Nova Resende	72	8			
Oliveira	60	5			
Orizania	8	1			
Paraguaçu	16	2			
Passos	16	2			
Pedra Bonita	24	2		x	
Perdões	16	1			
Piumhi	96	5			
Poço Fundo	28	4			
Ponte Nova	4	1			
Rosário da Limeira	20	4	x	x	
Santa Margarida	8	2			
Santa Rita do Sapucaí	20	2			
Santo Antônio do Amparo	28	2			
São Domingos das Dores	8	2			
São Francisco do Glória	8	1			
São Gonçalo do Sapucaí	12	1			
São Gotardo	4	1		X	
São Pedro da União	12	1			
São Sebastião da Anta	12	1			
São Sebastião do Paraíso	32	3		x	X
São Tomás de Aquino	16	1			
Tombos	4	1			
Três Pontas	260	22		x	
Ubaporanga	16	4			
Varginha	16	2			
Vieiras	16	2			

FIGURE 2 - Map of the Minas Gerais state. **A** counties with *Pratylenchus* spp. incidence. **B** counties with *Rotylenchulus reniformis* spp. incidence. **C** counties with *Meloidogyne* spp. incidence.

In the present study, the low population of *Pratylenchus* spp. observed in the samples may suggest the presence of some resistance factor in the cultivars evaluated.

Females of *R. reniformes* were observed in 47 samples, received from 15 counties in six coffee cultivars (Table 2), representing 1.94% of the evaluated samples. Only one sample had a population density higher than 20 females of *R. reniformes.*

However, the presence of *R. reniformes* juveniles above 20 specimens per sample was observed in some cases. The reniform nematode (*R. reniformes*) is frequently associated to coffee roots (CASTRO et al., 2008; BARROS et al., 2014). However, Kubo et al., (2009) demonstrated that eight coffee cultivars inoculated with a population of *R. reniformes* did not perform as suitable hosts for this nematode. However, in the present study a sample from cultivar Oeiras was observed with a high number of *R. reniformes* females. Studies concerning resistance of this cultivar against reniform nematodes are scarce.

The infested nurseries by *Pratylenchus* spp. and *R. reniformis* observed in this study were allowed to sell seedling to the coffee farmers. Dispersion of PPN in coffee areas occurs via propagation materials, agricultural tools and floods. However, the most efficient way for dissemination occurs via plant roots, especially seedlings of coffee or arboreal species used in the plantation. Therefore, is important that nurseries and public control agencies constantly inspect the phytosanitary quality of seedlings produced, especially concerning to the presence of PPN (CAMPOS; VILLAIN, 2005)

Regulatory Instruction IN 35 from MAPA determines the technical manager of the nursery as responsible for collecting seedlings samples. However, the number of incorrectly obtained samples received in the laboratories is substantial; in the majority of cases were samples with insufficient number of seedlings. This fact illustrates that care should be taken by the people responsible for sampling to fulfill the standards established by MAPA.

Samples analyzed represent more than 62 million coffee seedlings, 84% of them are traditional *C.* cultivars Catuaí and Mundo Novo (Table 3), which are susceptible to root-knot nematodes. Thus, proper care during sampling in the nurseries and commitment of surveillance institutions to avoid planting of infested seedlings are guaranties to avoid dissemination of PPN. Nevertheless, other PPN may be disseminated, once they are not included in the system of inspection by the surveillance institutions.

TABLE 2 - Coffee cultivars associated with nematodes *Meloidogyne* spp., *Pratylenchus* spp. e *Rotylenchulus reniformes.*

Meloidogyne spp	*Pratylenchus* spp	*R. reniformis*
Catuai vermelho IAC 44	Catuai vermelho IAC 144	Catuai vermelho IAC 144
Paraíso MGS 2	Catuai vermelho IAC 44	Catuai amarelo IAC 62
	Catuai vermelho IAC 99	Mundo novo IAC 379-19
	Catuai amarelo IAC 62	Mundo novo IAC 376-4
	Catuai amarelo IAC 2SL	Paraiso MG H 491-1
	Mundo novo IAC 379-19	Acauã
	Mundo novo IAC 376-4	
	Catucai 785-15	
	Topázio	
	Bourbon IAC J10	

TABLE 3 - Total number of seedlings analyzed by cultivar

Cultivars	Total seedlings
Catuaí Vermelho IAC 144	17,757,302
Catuaí Vermelho IAC 44	3,111,582
Catuaí Vermelho IAC 99	7,309,370
Catuaí amarelo IAC 62	9,666,624
Catuaí amarelo IAC 39	95,200
Catuaí amarelo 24/137	283,500
Catuaí amarelo MULTILINEA F5	280,000
Catuaí amarelo 2015	90,000
Mundo Novo IAC 376-4	5,974,127
Mundo Novo IAC 379-19	8,341,502
Mundo Novo ACAIA	25,000
Catucai 785-15	2,237,966
Catucai amarelo 2SL	2,430,951
Catucai 24-137	142,179
Catucai vermelho MFS	120,000
Oeiras MG6851	628,884
Bourbon amarelo IAC J9	167,791
Bourbon amarelo IAC J10	415,993
Acaia IAC 474/19	1,216,070
Acaia do cerrado 1479	52,200
Topazio MG 1190	1,499,000
Arara	136,000
Icatu amarelo	20,000
Acaua	114,000
Acaua Novo	40,000
MGS Paraiso 2	50,000
Paraiso MG H 419-1	19,457
Obatã IAC 1669-20	355,962
Catigua MG2	63,282
MGS ARANAS	17,957
Catucaiam 24137	120,000
Total seedlings analyzed	62,781,899

4 CONCLUSION

Coffee seedlings produced in Minas Gerais may disseminate PPN such as *Pratylenchus* spp. and *Rotylenchulus reniformes*, which are not targeted by the seedlings' surveillance system.

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PROFILE OF ORGANIC ACIDS AND BIOACTIVE COMPOUNDS IN THE SENSORY QUALITY DISCRIMINATION OF ARABICA COFFEE

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ABSTRACT: This study was conducted to investigate the potential of organic acids and bioactive compounds present in rawbeans to differentiate the sensory quality of coffee from different genotypes and processing methods. During the 2010, 2011 and 2012 crop seasons, beverage quality was analyzed, as well as the profile of organic acids and bioactive compounds caffeine, trigonelline and chlorogenic acids (3,4 and 5-CQA) in raw coffee beans from genotypes Bourbon Amarelo and Acaiá. The samples were collected in commercial fields with altitudes ranging from 932 to 1391 m, in the municipality of Carmo de Minas, MG, Brazil. Two processing methods were adopted: dry process (natural) and wet process (mechanically pulped and demucilaged coffee). All harvest and post-harvest procedures were carried out according to the main technologies for the production of specialty coffees. The sensory analysis was performed using the methodology proposed by the Specialty Coffee Association of America (SCAA). Chemical analyses were performed by High performance liquid chromatography. Data were investigated using Principal Component Analysis (PCA). The variations in the contents of organic acids and bioactive compounds were due to the coffee processing method. For genotypes Bourbon Amarelo and Acaiá, the differences in the organic acid profile, associated with caffeine, trigonelline and chlorogenic acids (3,4 and 5-CQA), were essential to differentiate the quality of mechanically pulped and demucilaged coffee. No significant differences were observed in the sensory quality of natural coffee due to the analysis of organic acids and bioactive compounds.

Index terms: *Coffea arabica* L., sensory analysis, mechanical demucilaging, natural coffees, chromatographyc analyses.

PERFIL DE ÁCIDOS ORGÂNICOS E BIOATIVOS NA DISCRIMINAÇÃO DA QUALIDADE SENSORIAL DE CAFÉ ARABICA

RESUMO: Este estudo foi desenvolvido para investigar o potencial dos ácidos orgânicos e bioativos presentes no grão cru para discriminar a qualidade sensorial do café proveniente de diferentes genótipos e métodos de processamento. Durante as safras 2010, 2011 e 2012, foram analisadas a qualidade da bebida do café e o perfil de ácidos orgânicos e dos bioativos, cafeína, trigonelina e ácidos clorogênicos (3,4 e 5-CQA) do grão cru de amostras dos genótipos Bourbon Amarelo e Acaiá. As amostras foram coletadas em lavouras comerciais com altitudes variando entre 932 a 1391 m, no município de Carmo de Minas, MG, Brasil. Os métodos de processamento adotados foram: via seca (café natural) e via úmida com descascamento e desmucilamento mecânico do fruto. Todos os procedimentos de colheita e pós-colheita foram realizados conforme as principais tecnologias para produção de cafés especiais. A análise sensorial foi realizada utilizando-se a metodologia da Associação Americana de Cafés Especiais (SCAA). As análises químicas foram realizadas por Cromatografia líquida de alta eficiência. Os dados foram investigados aplicando-se a Análise de Componentes Principais (ACP). Os métodos de processamento se diferenciaram devido às variações nos teores de ácidos orgânicos e bioativos analisados. Para os genótipos Bourbon Amarelo e Acaiá, as diferenças no perfil de ácidos orgânicos associado com cafeína, trigonelina e ácidos clorogênicos (3,4 e 5-CQA) foram determinantes para discriminar a qualidade do café descascado e desmucilado mecanicamente. Não foram observadas diferenças na qualidade sensorial do café natural através dos teores de ácidos orgânicos e compostos bioativos presentes em grãos de café.

Termos para indexação: *Coffea arabica* L., análise sensorial, desmucilamento mecânico, cafés naturais, análises cromatográficas.

1 INTRODUCTION

Although the common coffee market represents the majority of all coffee transacted worldwide, the specialty coffee segment has stood out in the international market (Associação Brasileira de Cafés Especiais - BSCA, 2017). Their exotic and rare flavor makes specialty coffees an increasingly valued product, which justifies incentives for research and technological innovations in the pursuit of quality production. Coffee producing countries increasingly show an interest in understanding the factors that influence beverage quality (AVELINO et al., 2005). Brazil is

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traditionally known as a supplier of large amounts of common and low-priced coffees. However, its participation in the specialty coffee market has great increasing potential due to environmental variations, besides the technological level adopted in its coffee cultivation (GIOMO; BORÉM, 2011).

Beverage quality is the main characteristic that differentiates specialty from common coffees. Its complexity is mainly determined by the flavor acquired during roasting of chemical compounds present in raw coffee beans, recognized as quality precursors (ALPIZAR et al., 2004; FARAH et al., 2005; RIBEIRO et al., 2016). Although the chemical matrix of raw beans has high complexity due to the great number of substances, organic acids and bioactive compounds have been recognized in the literature as potential sensory quality descriptors of coffee (BORÉM et al., 2016; FARAH et al., 2005).

Organic acids have important organoleptic properties that interfere with some sensory characteristics of coffee. Since most organic acids consist of volatile compounds, the most influenced beverage attributes are flavor and fragrance. It has been demonstrated that higher concentrations of acids significantly affect the perception of basic flavors, particularly sweet (GALLI; BARBAS, 2004). Furthermore, another important characteristic of the beverage affected by organic acids is acidity (LINGLE, 2011). In general, acids present in coffee account for about 11% of the weight of raw beans and about 6% of the weight of roasted beans. The main acids present in raw coffee beans are citric, malic and quinic, besides chlorogenic acids (GINZ et al., 2000).

Another group of compounds of great importance in the definition of coffee sensory quality are those bioactive, trigonelline, caffeine and chlorogenic acids. Trigonelline and chlorogenic acids are recognized as precursors of other volatile compounds that directly contribute to the taste and aroma of roasted coffee (RIBEIRO et al., 2016). On the other hand, caffeine is associated with undesirable bitterness, which may depreciate the beverage, depending on its concentration (BORÉM et al., 2016).

In Brazil and in the world, several studies were conducted with the objective to understand the relationship between the contents of some chemical compounds and the differentiation of species and cultivation environment, the evaluation of roasting degree, functional properties and also coffee quality (AVELINO et al., 2005; BERTRAND et al., 2008; BICCHI et al., 1995; MAZZAFERA; CARVALHO, 1992). However, there are still uncertainties about the differentiation of coffee sensory quality with the concept related to the pleasure that the beverage can offer from the profile of chemical precursors present in raw coffee beans.

Thus, this study aimed to characterize the profile of organic acids, together with the bioactive compounds present in raw beans and to investigate the potential of these compounds in the differentiation of sensory quality of coffees from different genotypes and processing methods.

2 MATERIALS AND METHODS

2.1 Sample characterization

Throughout the three crop seasons (2010, 2011, and 2012), representative samples of Coffea arabica L. genotypes (Bourbon Amarelo and Acaiá) were collected in the municipality of Carmo de Minas (-22°6’, -45°8’), Minas Gerais, Brazil. The environment was characterized by altitudes ranging between 932 and 1391 m, avarege annual temperature of 19.1 ºC, and average rainfall of 1568 mm (IBGE, 2009).

The Bourbon Amarelo genotype was chosen, since it has exhibited a large potential for high quality, and Acaiá was chosen once it is a widely commercial genotype cropped (BORÉM, 2012). Dry and Wet processing methods were evaluated, as they are the most traditional ways of processing coffee wordwide (BORÉM et al., 2014).

The research was separately conducted in four independent sample groups, which are wet processed Bourbon Amarelo, dry processed Bourbon Amarelo, wet processed Acaiá, and dry processed Acaiá. For each studied group, 27 samples were collected in three crop seasons. The relationship of the final sensory score and the chemical compounds was investigated. Thus, two patterns of sensory quality were undertaken following the results found in previous studies based on the correspondence analysis of coffee quality and processing (BORÉM, 2012).

Therefore, the analyses of the goup of wet processed Bourbon Amarelo samples obeyed the two ranges of sensory scores (bellow 85 points and equal or above 85 points). For the other three groups of samples, the two ranges of sensory scores was studied (bellow 86 points and equal or above 86 points). Due to the differences in the final sensory scores of the samples, each tested group had unbalanceed number of samples (Table 1).

TABLE 1 - Samples obtained during crop seasons and their respective sensory score range for each studied group, wet processed Bourbon Amarelo, dry processed Bourbon Amarelo, wet processed Acaiá, and dry processed Acaiá.

Test	Sensory score range*	Genotype	Processing method	Total of samples
1	<85	Bourbon Amarelo	Wet process	10
	≥85	Bourbon Amarelo	Wet process	17
2	<86	Bourbon Amarelo	Dry process	8
	≥86	Bourbon Amarelo	Dry process	19
3	<86	Acaiá	Wet process	22
	≥86	Acaiá	Wet process	5
4	<86	Acaiá	Dry process	20
	≥86	Acaiá	Dry process	7

*(BORÉM, 2012)

2.2 Harvest and post-harvest technologies adopted in sample obtention and preparation

In order to evaluate the maximum sensory quality potential, each sample was harvested manually and selectively, and only ripe fruits were collected. Subsequently, the fruits were immersed in water and separated by density difference; only ripe and dense fruits were used. After hydraulic separation, a part of the selected fruits was directly led to drying in full sun, representing the "dry process method", resulting in the natural coffee. The other part represented the "wet process method", in which the fruits were subjected to mechanical pulping and demucilaging, by completely removing the mesocarp adhered to the endocarp, resulting in parchment coffee. All procedures related to processing and drying were carried out following the recommendations of good post-harvest coffee practices (BORÉM et al., 2014).

After drying, the samples were stored in a temperature controlled chamber at 10 °C and 60% relative humidity for a period of 30 days. Subsequently, the samples were processed by separating the beans into shape and size. Only flat beans of 16 to 18/64-inch sieves were selected. All defective beans were then removed from the sample. This procedure aimed at standardization and, above all, the minimization of interferences that were not related to the varieties analyzed and processing methods. Finally, each sample was submitted to sensory and chemical analyses.

2.3 Sensory analysis

Sample roasting and sensory analysis were performed according to the methodology proposed by the Specialty Coffee Association of America – SCAA (LINGLE, 2011). The samples were evaluated by four panelists, trained and certified for the analysis of specialty coffees. At each evaluation, five cups of coffee were sampled and scored in the range of 0 to 10 points for each of the following attributes: fragrance/aroma, uniformity, absence of defects, sweetness, taste, acidity, body, balance and overall impression. The final score represented the sum of the attributes, summarized in a single value from the arithmetic mean among the panelists. Each processing method was evaluated separately.

2.4 Chemical analyses

For the chemical analyses, raw coffee beans were ground for about 1 minute in an 11A basic mill (IKA, Brazil), adding liquid nitrogen to facilitate grinding and avoid sample oxidation. After grinding, the samples were conditioned in Falcon tubes and stored in deep freeze at -80 ºC until the analyses were performed.

2.4.1 Organic acids

For the extraction of organic acids, 250 mg of ground raw coffee were weighed and placed in 1.5 mL Eppendorf tubes, with 1 mL of deionized water (resistivity: 18.2 MΩ). The solution was stirred for 10 minutes. Subsequently, it was diluted to 10 mL and a 20 µL filtered aliquot was analyzed by high performance liquid chromatography.

Based on the methodology described by Jhan et al. (2002), 10mM of perchloric acid at a constant flow rate of 0,6 mL/min were used as the mobile phase. The chromatography column used was SCR 1014 (7.9 mm 30 cm) at 50 °C, monitored by UV spectrophotometry at 210 nm.

Standard solutions of the acids of interest were used to identify chromatographic peaks, by comparing retention times and calculating their concentrations in the samples. The final contents of organic acids were given as a percentage of dry matter (% m.s). The following organic acids were quantified: citric, tartaric, malic, quinic, succinic, lactic and acetic.

2.4.2 Bioactive compounds

The analyzed bioactive compounds were caffeine, trigonelline and chlorogenic acids (3-CQA, 4-CQA and 5-CQA). For extraction, 100 mg of ground raw coffee were placed in a 2x12 cm test tube, with a screw cap, and mixed with 5 mL of 70% methanol (HPLC grade), prepared in 18.2 MΩ ultrapure water. The tubes were capped half-way, placed in a water bath at 60 °C for 1 hour and stirred every 10 minutes.

After centrifugation for 10 minutes at 12,000 rpm in 1.5 mL Eppendorf tubes, the supernatant solution was diluted to 1:10 with ultrapure water. After the filtration of a 0.20-μm membrane, 20 μL of the samples were injected into the Shimadzu chromatograph.

The concentrations of the compounds were determined simultaneously, using HPLC. The system consisted of two LC-20AT pumps and a UV-Vis SPD-20A detector (Shimadzu, Kyoto, Japan). Samples and standard solutions were analyzed on a 100-5C18 Nucleodur column, 250 mm x 3.0 mm, 5-μL (Macharey-Nagel). Analyses were performed by isocratic elution of methanol to HPLC/10 mM citric acid, pH 2.5 (25:75), at room temperature and a flow rate of 0.7 mL.min-1.

The Labsolutions software (Shimadzu) was used to process the data. The results were defined by the relationship between the peak areas of caffeine, trigonelline and 5-CQA and the respective known concentration patterns. The other isomers, 3-CQA and 4-CQA, were quantified using the area of standard 5-CQA, combined with molar extinction coefficients, according to the methodology adapted from Farah et al. (2005). The final contents of caffeine, trigonelline, 3-CQA, 4-CQA and 5-CQA were given as a percentage of dry matter (% m.s).

2.5 Statistical analysis

In total, this study comprised four experimental designs, formed by four independente groups, wet processed Bourbon Amarelo, dry processed Bourbon Amarelo, wet processed Acaiá, and dry processed Acaiá (Table 1).

Once the dataset presented groups of unbalanced number of samples and multiple variables, each group was independently submitted to the multivariate analysis. Then, the relationship of the organic acid profile with bioactive compounds determined in raw beans with beverage quality was investigated through Principal Component Analysis (PCA), using the Chemoface statistical software (NUNES et al., 2012). The considered chemical variables were the final contents of the determined compounds. All data were centered on the mean.

3 RESULTS AND DISCUSSION

Table 2 shows the mean contents of organic acids and bioactive compounds for samples of genotypes Bourbon Amarelo and Acaiá, dry and wet process.

The organic acid found at the highest concentration in raw coffee beans was citric. Malic, quinic and succinic acids were found in amounts below 0.6%. Lactic and acetic acids were found in amounts below 0.1%. Although found with very low average contents (0.01%), tartaric acid was only identified in samples processed using the dry method.

In relation to bioactive compounds, the isomer 5-CQA was found at higher amounts, compared to the other chlorogenic acids identified. Trigonelline and caffeine had mean contents above 1% (Table 2).

The composition of organic acids and trigonelline, caffeine and chlorogenic acids (3,4 and 5-CQA) found in this study are in agreement with the values reported in previous studies, which quantified these compounds (KY et al., 2001; ROGERS et al., 1999).

The results for the investigation of organic acids and bioactive compounds with coffee sensory quality for each sample group are shown below.

3.1 Wet processed Bourbon Amarelo samples

Figure 1 shows the scores of organic acids and bioactive compounds for Bourbon Amarelo samples processed using the wet method. For this group, ten samples with a final score below 85, and seventeen with scores equal or above 85, were classified.

Although the first component accounts for almost all data variability, sample differentiation did not occur solely due to this component. In some cases, multivariate phenomena require a third component to explain the differences between the data.

TABLE 2 - Mean contents (% m.s) of organic acids and bioactive compounds for each sample group.

Compound		Bourbon Amarelo		Acaiá	
		Wet	Dry	Wet	Dry
Organic acids	Citric	1.15	1.16	1.27	1.21
	Tartaric	0.00	0.01	0.00	0.01
	Malic	0.52	0.52	0.58	0.56
	Quinic	0.27	0.25	0.31	0.30
	Succinic	0.17	0.17	0.18	0.19
	Lactic	0.04	0.06	0.06	0.05
	Acetic	0.05	0.06	0.05	0.06
Bioactive compounds	3-CQA	0.67	0.55	0.65	0.57
	4-CQA	0.86	0.80	0.88	0.74
	5-CQA	7.39	6.34	6.99	6.10
	Caffeine	1.47	1.31	1.47	1.41
	Trigonelline	1.14	1.08	1.08	1.02

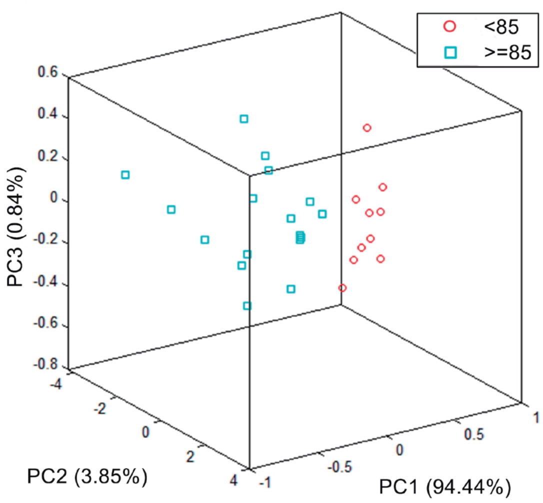

FIGURE 1 - Scores of the three principal components for organic acids and bioactive compounds of wet process Bourbon Amarelo samples. Note: Final scores: samples classified with scores below 85 (<85); Samples classified with a score equal to or greater than 85 (>=85).

Thus, in this study, investigations were performed considering the first three principal components which, together, accounted for 99.13% of the variability among the samples of this group (Figure 1).

It is possible to observe the formation of two distinct groups, according to the considered scores. These results show that samples classified with scores equal to or greater than 85 show differences in organic acids and bioactive compounds in relation to those classified with scores below 85 (Figure 1).

Table 3 shows the weights of organic acids and bioactive compounds for the first three principal components of Bourbon Amarelo samples processed using the wet method.

Among the analyzed compounds, the contents of citric acid and trigonelline were those with the highest weights, showing values greater than 0.60 for the three principal components.

The other organic acids, malic, quinic, succinic and acetic, made more relevant contributions to the third principal component.

TABLE 3 - Weights of organic acids and bioactive compounds for the first three principal components of wet processed Bourbon Amarelo samples.

Parameter		PC1 (94.44%)	PC2 (3.85%)	PC3 (0.84%)
Organic acids	Citric	-0.801	0.639	0.699
	Malic	-0.022	-0.105	0.241
	Quinic	-0.006	-0.150	0.263
	Succinic	-0.002	0.083	0.162
	Lactic	0.001	-0.023	0.014
	Acetic	0.014	0.139	0.220
Bioactive compounds	3-CQA	-0.160	-0.184	-0.112
	4-CQA	0.045	-0.054	-0.019
	5-CQA	0.594	0.485	-0.207
	Caffeine	-0.051	-0.752	-0.528
	Trigonelline	-0.626	-0.605	0.760

However, lactic acid made less relevant contributions for the three components analyzed (Table 3). These results allow to infer that the explanation of the phenomenon does not occur only from citric acid. Although they had lower weights, malic, quinic, succinic and acetic acids contributed to the improvement of data spatialization, allowing sample differentiation.

In relation to the other bioactive compounds, all made important contributions between the principal components, especially 5-CQA and caffeine. However, despite the greater participation of one or another compound, the origin of the scores was explained by the variability in the profile of the analyzed compounds.

3.2 Dry processed Bourbon Amarelo samples

Figure 2 presents the scores of organic acids and bioactive compounds of Bourbon Amarelo samples processed using the dry method. In this sample group, eight received final scores below 86 and nineteen were classified with scores equal to or greater than 86.

The first three principal components accounted for 91.92% of the variability between samples. Even considering the third principal component, it was not possible to observe a spatial distribution capable of forming distinct groups.

Samples classified with scores below 86 and samples with scores equal to or greater than 86 were not differentiated. These results show that the samples of the two final scores do not show variability in the profile of organic acids and bioactive compounds present in raw beans (Figure 2). Therefore, these chemical compounds found in dry processed Bourbon Amarelo coffee samples could not be related to their final sensory score, which means that those compounds do not interfere in the final quality of this coffee.

3.3 Wet processed Acaiá samples

The scores for the profile of organic acids and bioactive compounds of wet processed Acaiá samples are shown in Figure 3. For this sample group, twenty-two samples classified with scores below 86 and five classified with scores equal to or greater than 86 were found.

These results show that samples classified with scores below 86 and with scores equal to or greater than 86 were separated due to differences in the profile of organic acids and bioactive compounds (Figure 3).

Table 4 shows the weights of the compounds analyzed for the first three principal components of Acaiá samples processed using the wet method.

Among the compounds, citric acid, 5-CQA and trigonelline made the highest contributions to the three principal components. In relation to the other organic acids, lactic acid showed the lowest weights. Among the other bioactive compounds, 4-CQA made the lowest contributions.

3.4 Dry processed Acaiá samples

The scores for the profile of organic acids and bioactive compounds of dry processed Acaiá samples are shown in Figure 4. Overall, twenty samples had scores below 86 and seven received a final score equal to or greater than 86 in this group.

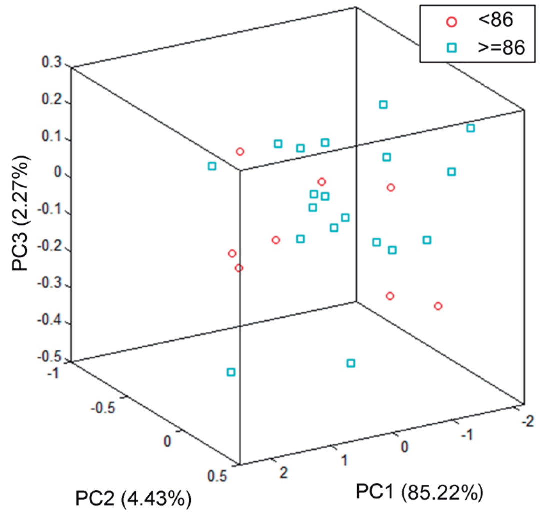

FIGURE 2 - Scores of the three principal components for organic acids and bioactive compounds of dry processed Bourbon Amarelo samples. Note: Final scores: samples classified with scores below 86 (<86); Samples classified with a score equal to or greater than 86 (>=86).

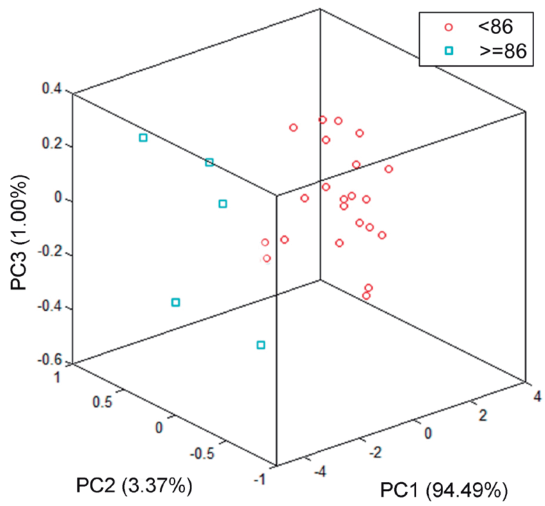

FIGURE 3 - Scores of the three principal components for organic acids and bioactive compounds of wet processed Acaiá samples. Note: Final scores: samples classified with scores below 86 (<86); Samples classified with a score equal to or greater than 86 (>=86).

Samples scored below 86 and samples classified with scores equal to or greater than 86 were not differentiated (Figure 4). Therefore, the results show that the differences in the profile of organic acids and bioactive compounds were not determining for final quality.

The results found for coffee samples processed by the dry method do not evidence the contribution of organic acids and bioactive compounds present in raw beans to the description of coffee quality by themseves. In addition, this phenomenon does not occur consistently between the combinations involving both genotypes and the dry method that were comprised in this study.

It is clear that the explanation for this phenomenon depends directly on processing method, so that when the coffees are mechanically pulped and demucilaged, there is a well defined separation between samples, according to the final scores considered.

TABLE 4 - Weights of organic acids and bioactive compounds for the first three principal components of Acaiá samples processed using wet method.

Parameter		PC1 (94.49%)	PC2 (3.37%)	PC3 (1.00%)
Organic acids	Citric	-0.707	0.501	-0.634
	Malic	-0.110	0.137	-0.207
	Quinic	-0.016	0.183	-0.370
	Succinic	-0.020	0.159	-0.289
	Lactic	0.002	0.017	0.012
	Acetic	0.002	0.088	-0.145
Bioactive compounds	3-CQA	-0.274	0.103	-0.166
	4-CQA	0.080	0.053	-0.029
	5-CQA	-0.672	-0.526	0.635
	Caffeine	-0.182	0.215	0.203
	Trigonelline	-0.796	0.623	-0.680

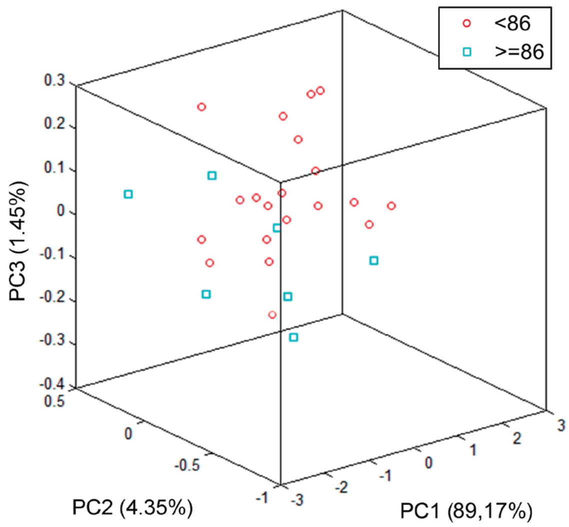

FIGURE 4 - Scores of the three principal components for organic acids and bioactive compounds of Acaiá samples processed using the dry method. Note: Final scores: samples classified with scores below 86 (<86); Samples classified with a score equal to or greater than 86 (>=86).

However, for genotypes Bourbon Amarelo and Acaiá, the formation of distinct groups was not observed when the dry process was adopted.

According to the results found by Borém (2012), coffees with scores above 85 for the group of yellow fruit varieties (Bourbon Amarelo) and coffees with scores above 86 for the group of red fruit varieties (Acaiá) occur when the wet processing method is adopted. Thus, the results found in this study allow to associate the organic acid and bioactive profile found in raw beans of coffee samples of both genotypes processed wet.

The strong impact of processing on the final chemical composition of raw coffee beans is recognized in the literature. Some studies prove differences in seed metabolic activity among processing methods (VÁZQUEZ-RAMOS; SANCHEZ, 2003; ZHANG et al., 1993). It is also believed that these differences lead to variations in chemical composition through degradation mechanisms activated during processing.

From the physiological point of view, the removal of parts that constitute the fruit favors embryo germination (BYTOF et al., 2005). It is believed that germination occurs differentially in seeds during pulping, due to the removal of inhibitors present in the exocarp and mesocarp. Thus, coffee pulping and demucilaging would trigger various reactions related to germination, such as reserve mobilization, resulting in different metabolic profiles, compared to the dry method. However, in addition to the compounds that are part of the coffee reserve mechanism, compounds present at lower concentrations, such as organic acids and those bioactive, may also show significant variations as a function of transformations resulting from processing (LELOUP et al., 2004; RIBEIRO, et al., 2016).

On the other hand, one of the hypotheses for the variability in the final coffee bean composition is the longer drying time, associated to the lower water removal rate, as possible factors responsible for the occurrence of reactions that degrade different compounds, observed with greater intensity in coffees processed using the dry method, compared to those processed using the wet method (LELOUP et al., 2004). This implies the possible changes in the chemical matrix of the natural coffee, resulting in coffees with variable sensory profiles. The results found in this study reinforce the effect of these factors, since it was not possible to find a defined profile for the analyzed compounds in dry processed samples, capable of associating with differences in beverage quality. In samples whose fruit was mechanically pulped and demucilaged, it was possible to associate beverage quality with the profile of organic acids and bioactive compounds present in raw beans.

Ripe fruits show the highest manifestation of all biochemical steps required for seed or bean formation (DAMATTA et al., 2007). However, shortly after plant removal, the chemical matrix does not represent the same found after drying (BYTOF et al., 2005; KLEINWÄCHTER; SELMAR, 2010; KNOPP; BYTOF; SELMAR, 2006). Therefore, considering the effect of the environment on the chemical constituents of freshly harvested coffee and all changes that occur during processing and after drying, some questions can be asked, such as which method represents the greatest impact on the original chemical matrix of beans? Based on the analysis of organic acids and bioactive compounds performed in this study, the observed results allow to infer that the removal of the exocarp and mesocarp from the fruits provided the smallest changes in the dry matter chemical matrix, in relation to fresh beans. On the other hand, the chemical matrices described in natural coffees were completely different for genotypes Bourbon Amarelo and Acaiá.

From the point of view of chemical aspects related to quality, organic acids at low concentrations are responsible for many fragrances found in coffee. There is also the relationship of each acid with the taste revealed in the beverage. As for example, the characteristic lemon flavor due to citric acid, the buttery flavor of lactic acid, as well as the apple flavor from malic acid. However, these sensations are frequently more noticeable in the form of pleasant odors found in roasted and ground beans than in coffee flavors (LINGLE, 2011). Furthermore, organic acids also contribute to the formation of acidity in the beverage. Although they do not present the highest content among the acids present in coffee, organic acids tend to produce higher amounts of hydrogen ions. This increase in the concentration of hydrogen ions is associated with the acidity perceived in the beverage (LINGLE, 2011).

In the search for a better understanding of the relationship between organic acid composition and sensory characteristics of coffee, Borém et al. (2016) found that the mean contents of lactic, acetic, malic and citric acids did not allow coffee differentiation in terms of sensory quality.

In the literature, there is a large number of studies aiming to establish a relationship between the bioactive compounds, caffeine, trigonelline and 3,4 and 5-CQA present in raw beans, with the sensory profile of coffee (BERTRAND et al., 2008; CAMPA et al., 2004; FARAH et al., 2006). Among these compounds, trigonelline has been indicated as a strong candidate to explain the reasons for coffee quality. However, trigonelline, as well as other bioactive compounds, is not able to determine the final beverage quality in isolation. For this study, the joint analysis of the organic acid profile, associated with the main bioactive compounds, was essential in the quality description of mechanically pulped and demucilaged coffee.

The description of differences among coffee genotypes, processing methods, and the final beverage quality concerning chemical composition is still a challenge for researchers (BORÉM, 2012; BYTOF et al., 2005). Therefore, this study is important to contribute to elucidate the phenomena of coffee quality.

From the point of view of beverage quality description, according to the protocol for the analysis of specialty coffees (SCAA, 2009), coffees classified with scores below 85 are described as premium, and coffees with scores equal to or above 85 are described as specialty origin, representing two distinct coffee categories. Thus, based on these descriptions and the results found in this study, it is possible to infer that there are marked differences in the sensory profile of coffee among the categories, representing a transition of quality standard. In this study, this transition was revealed through the SCAA methodology, using the final score as the main parameter. Although this type of methodology is of commercial and non-scientific application, it effectively represents the observations on the concept of quality practiced in the specialty coffee market.

4 CONCLUSION

Based on the results found in this study, it is concluded that:

It is possible to differentiate the sensory quality of mechanically pulped and demucilaged coffee from the organic acid profile, associated with bioactive compounds caffeine, trigonelin and chlorogenic acids (3,4 and 5-CQA), determined in raw beans.

It is not possible to differentiate the sensory quality of natural coffee through the analysis of organic acids and bioactive compounds present in raw beans.

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ADAPTATION OF PROGENIES/CULTIVARS OF ARABICA COFFEE (*Coffea arabica* L.) IN MOUNTAINOUS EDAFOCLIMATIC CONDITIONS

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ABSTRACT: Brazil is known for production and worldwide export of coffees. Study of adaptation of new progenies/cultivars of Arabica coffee (*C. arabica* L.) with resistance to rust in mountainous edaphoclimatic conditions is important for crop renewal and also for new plantations. This study was performed in the mountainous region of the Espírito Santo state, Brazil, with 30 progenies/cultivars of Arabica coffee planted at 2.5 x 0.7 m spacing with four replicates and seven plants/plot. The objective of the study was to evaluate the adaptation of rust-resistance coffee genotypes and compare them with the standard cultivars (Yellow and Red Catuaís), with regards to the characteristics of productivity, rust infection, productivity, sieve, aspect, plant vigor and yield according to the different maturity periods of the fruits. The results show that there are progenies/cultivars available with yields superior to Red and Yellow Catuais for the five different maturation periods. The progenies/cultivars present tolerance/resistance to rust, high plant vigor and good agronomic characteristics of the beans. These are options for new plantations or for renovation of crops for high harvest yield and do not required the use of pesticides.

Index terms: Productivity, rust, plant vigor, yield, sieve.

ADAPTAÇÃO DE PROGÊNIES/CULTIVARES DE CAFÉ ARÁBICA (C*offea arabica* L.) EM CONDIÇÕES EDAFOCLIMÁTICAS DE MONTANHAS

RESUMO: O Brasil tem destaque na produção e exportação mundial de cafés. O estudo da adaptação de novas progênies/cultivares de café arábica (*C. arabica* L.) com resistência à ferrugem nas condições edafoclimáticas das Montanhas é importante para renovação de lavouras e também para novos plantios. O estudo foi realizado na Região de Montanhas do Espírito Santo com 30 progênies/cultivares de café arábica plantados no espaçamento de 2,5 x 0,7 m com quatro repetições com sete plantas/parcela. O objetivo do estudo foi avaliar a adaptação dos genótipos com resistência à ferrugem do cafeeiro, comparando-as com as cultivares padrão (Catuaís Amarelo e Vermelho), nas características de produtividade, infecção de ferrugem, rendimento, peneira graúda, aspecto, vigor vegetativo e rendimento de colheita conforme as diferentes épocas de maturação dos frutos. Os resultados evidenciam que existem à disposição dos cafeicultores progênies/cultivares com produtividades superiores aos Catuaís Vermelhos e Amarelo nas cinco diferentes épocas de maturação. As progênies/cultivares apresentam tolerância/resistência à ferrugem, alto vigor vegetativo e boas características agronômicas dos grãos e são opções para novos plantios ou para renovação de lavouras para alto rendimento de colheita e podendo dispensar o uso de agrotóxicos.

Termos para indexação: Produtividade, ferrugem, vigor vegetativo, rendimento, peneira.

1 INTRODUCTION

Arabica coffee (*Coffea arabica* L.) is cultivated in several producing-regions throughout Brazil with variable edaphoclimatic characteristics that play an important role in adaptation of the cultivars. The genotype x environment interaction determines the recommendation of the cultivar for each specific region (NASCIMENTO et al., 2010, MATIELLO et al., 2016).

Genetic breeding studies of coffee cultivars by several research organizations have promoted advances in coffee activity and its practical application by coffee growers (CARVALHO et al., 2008; PARTELLI et al., 2009), seeking an increase in productivity (MARTINEZ et al., 2007; CARVALHO et al., 2010; MATIELLO et al., 2016) and greater resistance to rust. Rust is the main disease of Arabica coffee and depending on the spacing, cultivar and crop management can cause significant production losses (ZAMBOLIM et al., 2005; FAZUOLI et al., 2007; ANDREAZI et al., 2015).

Currently most of Brazil's coffee production is composed of cultivars presenting excellent agronomic characteristics, however with no resistance to rust. Utilization of rust-resistant cultivars avoids the use of agrochemicals, which reduces the risks of intoxication of the applier, environmental contamination, and reduces production costs (OLIVEIRA, et al. 2015; MATIELLO et al., 2016). It is also important

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to highlight that the Brazilian coffee agriculture faces high costs and lack workers of manual labor (SERA et al., 2015; MATIELLO et al., 2016).

The existing cultivars are classified into very early, early, middle, late and very late maturity cycles, which is a polygenic characteristic influenced by the environmental conditions, such as the region, local edaphoclimatic conditions, exposure direction, nutrition and biotic agents (GUERREIRO-FILHO et al., 2008; CARVALHO, 2008; RODRIGUES et al., 2014; RODRIGUES et al., 2016; MARTINS et al., 2017). Therefore, varieties with different maturation periods allow harvest scheduling, and those that increase the crop yield and have desirable agronomic characteristics should be prioritized when selecting the crop for implementation.

Several Arabica coffee cultivars were recently introduced and registered for use by coffee growers, however there are few studies on the behavior of these new genotypes in the field (PAIVA et al., 2010), especially when considering a period of 10 consecutive harvests in mountainous conditions. However, we know that prior to the use of these cultivars in commercial areas it is recommended that adaptability studies be done in the different coffee producing regions to evaluate their behavior in local soil and climate conditions for productivity and resistance to rust, and other characteristics.

The objective in this study was therefore to evaluate the adaptation of new progenies/cultivars of Arabica coffee (*C. arabica*) with resistance/ tolerance to coffee rust in edaphoclimatic conditions of the mountainous region of the state of Espírito Santo during 10 consecutive harvests. Comparisons were made with the standard cultivars (Red and Yellow Catuaí) with regards to the characteristics of productivity, rust infection, yield, sieve, aspect, plant vigor and harvest yield, according to the maturation times of the fruits.

2 MATERIAL AND METHODS

Description of the study area, Cultivars and Cultural Treatments

The study was carried out at the farm "Sítio Santa Maria" (coordinates: Lat: -20.4425 S, Long: -40.7796 W and elevation of 717 m), located in the municipality of Marechal Floriano, in the mountainous southeastern region of the Espírito Santo state. The soil is classified as Red Yellow Latosol (RYL) (EMBRAPA, 2013) and the climate is tropical with dry winter and summer rains, of the Aw type and subtype, according to the Köppen classification (Table 1).

The experiment was set up in a randomized block design with 30 treatments (progenies/ cultivars), four replicates and seven plants/plot planted in April, 2003 at a spacing of 2.5 x 0.7 m (densified). The thirty progenies/cultivars and selections used were thus classified according to the three maturation seasons (Table 2).

Cultural treatments of the crop during the study included liming and fertilization according to the soil analysis conducted every two years and the expected productivity, according to recommendations (PREZOTTI et al., 2007). Two foliar fertilizations with Boron (B), Manganese (Mn) and Zinc (Zn) micronutrient salts were performed per year, two foliar applications of Copper hydroxide (Cu) (45% Cu metal) were associated with the salts and an annual application of the insecticide thiamethoxan applied via soil drenching at the dose of 1.0 kg/ha of the commercial product Actara WG for control of leaf miner. Management of the weeds was conducted manually with one mowing and two chemical treatments with the active ingredient Glyphosate at the dose of 1.0 L/ha of the commercial product Roundup. No specific rust control or irrigation was used. All evaluations were carried out in the five central plants of the four plots described below.

Productivity, Yield, Sieves and Aspect

Harvest was always performed manually on a sieve or canvas. Mean samples of 2.0 kg of harvested coffee were obtained from each plot and taken to pre-drying in a drying oven and final drying on a cement yard according to the climatic conditions of the season until reaching the moisture content between 11.5 and 12%. Once dry, the samples were weighed, pulped and the yield (kilograms of processed coffee/kilograms of coffee beans) and productivity in processed coffee bags/hectare (sc/ha) were determined. The productivity yield was calculated for the 10 years of study and also the averages of the five biennia, i.e., 2005-2006, 2007-2008, 2009-2010, 2011-2012 and 2013-2014.

Next, 100 gram samples were classified on a set of sieves specific for the classification of coffee with regards to size of the raw beans, which were classified into only two groups: sieve 17 and above for the coarse flat type beans (BRAZIL, 2003). Aspect of the beans was evaluated by grading on a scale of 5 to 10 by three coffee buyers from the region with experience in the coffee trade.

TABLE 1 - Climatic characteristics (2003-2014), including: Precipitation (mm), Relative Humidity (R.H.) (%) and maximum and minimum Temperature (°C) according to the mini meteorological station of the brand La Crosse and model Pro WS at the "Sítio Santa Maria" farm, Marechal Floriano, ES.

Year	Precip. (mm)	R.H. (%)		Temperature (°C)	
		Max	Min	Max	Min
2003	1279.0	93.2	54.3	25.6	16.4
2004	2138.0	92.5	55.3	25.4	16.2
2005	1990.0	91.7	53.1	25.8	16.7
2006	1568.0	92.6	54.8	25.4	16.3
2007	1351.0	91.5	55.6	26.1	16.6
2008	2409.0	93.8	55.3	25.4	16.2
2009	2308.0	91.1	56.1	25.3	16.5
2010	1716.0	93.2	54.3	25.9	16.6
2011	1843.6	93.1	57.5	25.3	16.6
2012	2126.9	90.8	52.9	26.4	16.7
2013	1888.0	91.4	55.8	25.5	16.1
2014	1304.0	94.2	53.9	26.0	16.4
Mean	1826.8	92.4	54.9	25.7	16.4

TABLE 2 - Progenies/cultivars of *Coffea arabica* L. and their respective characteristics of genealogy, maturation period, expected reaction to rust and vigor in the experiment installed at the "Sítio Santa Maria" farm, in Marechal Floriano, ES.

Progenies/ cultivars	Genealogy	Maturation Period	Reaction to rust	Vigor
Catucaí V. 785 Cv.15	Icatu x 'Catuaí" (natural cross)	Very early	++	High
Tupi IAC 1669-33	Vila Sarchi' x Híbrido de Timor CIFC 832/2	Early	+	Medium
Katipó	Catimor (245-3-7)- derivado	Early	++	Medium
Caturra A. Colombiano	Caturra x Hibrído de Timor	Early	++	Medium
Iapar 59	Villa Sarchi (CIFC 971/10) x Híbrido de Timor (CIFC 832/2)	Early	+	Medium
Caturra A. Seleção CAK	Bourbon' (natural mutation)	Early	+++	Medium
Caturra A. Seleção Nanicão	Bourbon' (natural mutation)	Early	+++	Medium
Catucaí A. 2 SL	Icatu x 'Catuaí" (natural)	Medium	++	High
Sabiá Cv. 708	Catimor UFV 386 x Acaiá'	Medium	++	High
Catucaí A. 24/137 Cv. 250	Icatu x 'Catuaí" (natural)	Medium	++	High
Catucaí V. 24/137	Icatu x 'Catuaí" (natural)	Medium	++	High
IBC-Palma 2 (Fruto grande)	Catuaí Vermelho IAC-81 x 'Catimor UFV 353'	Medium	++	High
Catucaí-açú (Fava grande)	Icatu x 'Catuaí" (natural cross)	Medium	++	Medium
Catucaí A. 24/137 - CAK	Icatu x 'Catuaí" (natural)	Medium	++	High
Catucaí A. (Fava grande)	Icatu x 'Catuaí" (natural)	Medium	++	High

Catucaí V.20/15 Cv. 626	Icatu x 'Catuaí" (natural)	Medium	++	High
Topázio MG 1190	Catuaí Amarelo x Mundo Novo	Medium	+++	High
Rubi MG 1192	Catuaí x Mundo Novo	Medium	+++	High
Catucaí V. 36/6	Icatu x 'Catuaí" (natural)	Medium	++	High
Catucaí A. Cv. 07 - SSP	Icatu x 'Catuaí" (natural)	Medium	++	High
Mundo Novo 379-19	Sumatra x Bourbon Vermelho	Medium	+++	High
Paraíso A. MG H 419-1	Catuaí Amarelo IAC-30 x Híbrido de Timor UFV 445-46	Medium	+	Medium
Catucaí V. 19/08 Cv. 380	Icatu x 'Catuaí" (natural)	Late	++	High
Sarchimor Amarelo	Catuaí Amarelo x Obatã V. IAC 1669-20	Late	+	Medium
Catuaí A. IAC-39	Caturra A. IAC 476-11 x 'Mundo N. IAC 374-19'	Late	+++	High
Catuaí V. IAC-99	Caturra A. IAC 476-11 x 'Mundo N. IAC 374-19'	Late	+++	High
Catuaí V. IAC-81	Caturra A. IAC 476-11 x 'Mundo N. IAC 374-19'	Late	+++	High
Catuaí V. IAC-44*	Caturra A. IAC 476-11 x 'Mundo N. IAC 374-19'	Late	+++	High
Acauã	Mundo N. IAC 388-17' x Sarchimor IAC 1668	Very late	+	High
Obatã V. IAC 1669-20	Villa Sarchi x Híbrido de Timor (CIFC 832/2)	Very late	+	High

*Progeny/Cultivar used as a control. Highly resistant (+); Moderately resistant (++) and Susceptible (+++) (CARVALHO, 2008).

Rust infection

Evaluation of the incidence of rust on coffee leaves was carried out in the years 2010 to 2014, in the middle third and in the 3rd and 4th pair of leaves of the five central plants always at the time of harvest. Eight leaves were randomly collected per plant from the productive plagiotropic branches of 05 plants/plot, consisting of four leaves from two branches on the north face and four leaves from two branches on the south face, for a total of 40 leaves per plot (LIMA, 1979). The incidence of rust was assessed visually in the field by quantifying the percentage of leaves presenting pustules in relation to the total.

Plant vigor

The evaluation of plant vigor of the cultivars was carried out in the field, where scores from 1 to 10 were attributed, in which 10 corresponded to plants with the best development and greatest plant vigor. The scores were based on the general aspect of plant vigor, including: plant height, foliage, branch and crown growth, diameter of the orthotropic and plagiotropic branches (SHIGUEOKA et al., 2014).

Harvest yield

The harvest yield was evaluated only in 2009 during the fifth harvest, when the plants were at the peak of production, i.e., the highest average of the 10 years. The time spent to manually harvest the five (%) central plants of the plot by two (2) well-trained harvesters in carried sieves was measured, one at the top and the other at the bottom of the plots. The coffee was measured and the number of 80 liter sacs/day that a worker was able to harvest for each progeny/cultivar was calculated.

Statistical analysis of the data

For analysis of productivity data of the years and biennials, the rust infection percent, yield, sieve 17 and above, aspect and plant vigor, an ANOVA was performed along with the Scott-Knott test at 5.0% significance by the program SISVAR (FERREIRA, 2011). The Principal Component Analysis (PCA) was used to evaluate the characteristics of productivity, rust infection, yield, sieve 17 and above, plant vigor and harvest yield (sacks/day) by the program Fitopac 2.1.2.85.

3 RESULTS AND DISCUSSION

Yield

Significant differences were observed between the progenies/cultivars evaluated for productivity (both for the years and the bienniums), rust percentage, yield, sieve 17 and above, aspect and vigor, indicating genetic variability among the studied materials (Table 3).

The average yields of the five biennia increased significantly from 19.36 sc/ha in biennium 1 to 59.27 sc/ha in biennium 3 (Table 3). Mean productivity of the 10 harvests evaluated in this study was 45.66 sc/ha, greater than that found by Costa et al., (2013) when evaluating the productivity of 14 progenies/cultivars of Arabica coffee during four harvests in southern Minas Gerais (37.6 sc/ha). The mean productivity of the progenies/cultivars evaluated over the years increased significantly from 2005 (18.2 sc/ha) to reaching its maximum in the fifth harvest in 2009 (76.8 sc/ha). After this point there was a stabilization of the mean productivities that always remained above 40.0 sc/ha (Table 3).

When analyzing the mean productivity from biennium to biennium, the formation of different groups (from 4 to 9 groups) was observed by the Scott-Knott test, and in the average of the 10 harvests nine groups were formed (Table 4). Costa et al., (2013) evaluated the productivity of fourteen Arabica coffee progenies/cultivars during four harvests in the southern region of Minas Gerais, observing the formation of four groups by the Scott-Knott test at 1% probability.

In groups nine (a), eight (b) and seven (c) the less productive varieties are present, namely: Paraíso A. MG H 419-1 with medium maturation period and yield of 27.4 sc/ha, variety Caturra A. (Sel. Nanicão) with early maturity and yield of 33.3 sc/ha and the Caturra A. (Sel. CAK) variety with early maturity and yield of 35.9 sc/ha.

In group six (d) are the cultivars Iapar 59 and Mundo Novo 379-19 with mean productivities of 37.7 and 39.2 sc/ha, with early and medium maturation, respectively. Group five (e) includes cultivars Caturra A. Colombiano and Katipó, both with early maturation and averages yields of 41.9 and 42.0 sc/ha, respectively, as well as the progeny Catucaí A. Cv.07-SSP with average yield of 42.6 sc/ha and medium maturity.

In group four (f) there are six progenies/cultivars, including the cultivars Catuaí V. IAC-44 of late maturation and Catucaí A. (Fruto grande), Catucaí V. 36/6, Rubi MG 1192, Topázio MG 1190 and Catucaí V. 20/15 Cv. 626 of medium maturity. The yield ranged from 44.4 sc/ha to 45.9 sc/ha.

Group three (g) included seven progenies/cultivars: Tupi IAC 1669-33 of early maturation, the progenies/cultivars Catucaí A. 24/137 (Seleção CAK) and Catucaí-açú (Fruto grande) of medium maturity, Catuaí V. IAC-81, Catuaí V. IAC-99 and Catuaí A. IAC-39 of late maturation time and Obatã V. IAC 1669-20 of very late maturation time. The productivity of this group ranged from 47.2 sc/ha to 48.6 sc/ha. Costa et al. (2013), when evaluating the agronomic behavior of progenies/cultivars in Varginha (southern Minas Gerias, Brazil), verified the average yield in four harvests of 42.7, 41.4 and 41.1 sc/ha for the progenies IBC-Palma 1, Catucaí V. 24/137 and Sabiá Tardio, respectively. Matiello et al. (2007) studied progenies with resistance to rust also in the southern region of Minas Gerais and verified after five harvests that Sabiá Tardio and Catucaí V. 24/137 stood out with yields of 39.6 and 31.8 sc/ha, respectively. Paiva et al. (2010), also in southern Minas Gerais, after six harvests observed the dominance of the cultivar Sabiá Tardio with a yield of 40.89 sc/ha.

The present study showed that progenies/cultivars were highly resistant to rust (Tupi IAC 1669-33 and Obatã V. IAC 1669-20), moderately resistant (Catucaí A. 24/137-CAK and Catucaí-açú) and susceptible (Catuaís V IAC-81 and IAC-99 and Catuaí A. IAC-39) did not differ significantly for the average yield of 10 harvests; Which can be explained by the good agronomic management of the crop.

In the second (g) group are seven progenies/cultivars, including the progeny/cultivar Catucaí 785 Cv. 15 with red fruits of very early maturation; medium maturity progenies/varieties: IBC- Palma 2 (Fruto Grande); Catucaí V. 24/137; Catucaí A. 24/137 Cv. 250 and Sabiá Cv. 708; late maturation Arara (Sarchimor A.) and the very late maturation Acauã. Productivity of this group ranged from 49.5 sc/ha to 51.9 sc/ha. Carvalho et al. (2012) obtained an average yield during four harvests close to 45.0 sc/ha for the genotypes Catucaí A. 24/137, Sabiá Cv. 398 and IPR 103.

TABLE 3 - Summary of the analysis of variance, means and coefficients of variation of productivities over ten years, for the five biennia and the average of 10 harvests, rust infection (%) of 05 harvests, yield, sieve 17 and above and plant vigor of the progenies/cultivars of Arabica coffee in the experiment installed at the "Sítio Santa Maria" farm, in Marechal Floriano, ES.

		MEDIUM SQUARE - Productivity (sc/ha)									
Sources of variation	DF	2005*	2006*	2007*	2008*	2009*	2010*	2011*	2012*	2013*	2014*
Progenies/ Cultivars	29	166.3	159.3	267.9	1302.0	2257.3	306.1	713.6	371.0	609	700.5
Residual	120	3.4	4.2	6.3	24.1	96.6	17.8	31.8	29.2	56.6	31.3
Mean		18.2	20.5	28.1	52.7	76.8	41.8	53.7	48.0	63.3	53.6
C.V. (%)		10.2	10	8.9	9.3	12.8	10.1	10.5	11.3	11.9	10.4

		MEDIUM SQUARE - Productivity (sc/ha)					
Sources of variation	DF	Biennium 1*	Biennium 2*	Biennium 3*	Biennium 4*	Biennium5*	10 harvests*
Progenies/Cultivars	29	103.87	408.04	678.7	344.75	384.73	188.68
Residual	120	1.96	7.91	27.52	16.08	18.61	3.48
Mean		19.36	40.4	59.27	50.86	58.43	45.66
C.V. (%)		7.24	6.97	8.85	7.88	7.38	4.09

		MEDIUM SQUARE				
Sources of variation	DF	% Rust*	Yield*	Sieve 17 & above*	Aspect*	Vigor*
Progenies/Cultivars	29	2.637.72	4.095	417.14	1.460	2.892
Residual	90	5.89	0.003	1.27	0.010	0.004
Mean		23	17.91	55.94	7.770	7.698
C.V. (%)		10.56	0.32	2.02	1.42	0.85

* Significant at 5% probability by the Scott-Knott test. n=5. A % Rust, Yield, Sieve 17 and above and Aspect of the grains was performed in harvests (2005, 2006, 2007, 2008 and 2009) and Plant Vigor for the 10 harvests.

TABLE 4 - Mean productivity (sc/ha) of Arabica coffee progenies and cultivars during five biennia (2005 to 2014), the mean of 10 harvests (Mean sc/ha) and the relative percentage (%) in the experiment installed in the farm "Sítio Santa Maria", in Marechal Floriano, ES.

Progenies/Cultivars	Maturation time	Productivity per Biennia (sc/ha)					Mean (sc/ha)	% Relative
		1°	2°	3°	4°	5°		
Catucaí 785 Cv. 15	Very early	19.1 e	48.8 f	71.7 e	63.5 d	56.2 c	51.9 h	116.9
Tupi IAC 1669-33	Early	15.2 c	49.8 f	58.7 c	50.8 c	61.8 d	47.2 g	106.3
Katipó	Early	16.9 d	34.0 b	56.2 b	46.3 b	56.9 c	42.0 e	94.6
Caturra A. Colombiano	Early	21.3 f	46.2 e	50.4 b	48.4 b	43.2 a	41.9 e	94.4
Iapar 59	Early	16.2 d	34.4 b	61.8 c	37.3 a	38.7 a	37.7 d	84.9
Caturra A. (Sel. CAK)	Early	29.5 i	37.7 c	30.2 a	39.1 a	43.4 a	35.9 c	80.9
Caturra A. (Sel. Nanicão)	Early	14.6 c	36.3 c	36.9 a	34.4 a	44.2 a	33.3 b	75.0
Catucaí A. 2SL (Sel. CAK)	Medium	24.6 g	52.4 f	71.5 e	59.9 d	65.4 e	54.7 i	123.2
Sabiá Cv. 708	Medium	23.2 f	63.3 g	75.2 e	39.6 a	55.6 c	51.4 h	115.8

Catucaí A. 24/137 Cv. 250	Medium	21.7 f	39.9 d	81.1 f	51.0 c	62.7 d	51.3 h	115.5
Catucaí V. 24/137	Medium	27.3 h	41.6 d	61.2 c	57.1 c	66.3 e	50.7 h	114.2
IBC-Palma 2 (Fruto grande)	Medium	16.8 d	41.5 d	67.2 d	61.2 d	61.0 d	49.5 h	111.5
Catucaí-açú (Fruto grande)	Medium	17.7 e	52.4 f	61.7 c	55.5 c	52.3 b	47.9 g	107.9
Catucaí A. 24/137 (Sel. CAK)	Medium	27.2 h	35.5 c	59.9 c	53.5 c	60.5 d	47.3 g	106.5
Catucaí V.20/15 Cv. 626	Medium	15.2 c	35.0 c	68.0 d	45.5 b	66.1 e	45.9 f	103.4
Topázio MG 1190	Medium	22.2 f	41.3 d	54.2 b	48.4 b	62.5 d	45.7 f	102.9
Rubi MG 1192	Medium	19.4 e	41.9 d	51.0 b	53.1 c	62.8 d	45.6 f	102.7
Catucaí V. 36/6	Medium	20.4 f	36.6 c	55.9 b	51.8 c	62.6 d	45.5 f	102.5
Catucaí A. (Fruto grande)	Medium	20.2 f	45.0 e	54.0 b	48.3 b	56.5 c	44.8 f	100.9
Catucaí A. Cv. 07 - SSP	Medium	17.2 d	36.7 c	51.7 b	53.7 c	53.9 c	42.6 e	95.9
Mundo Novo 379-19	Medium	11.2 b	33.1 b	50.4 b	44.9 b	56.1 c	39.2 d	88.3
Paraíso A. MG H 419-1	Medium	7.7 a	14.0 a	34.7 a	38.2 a	42.2 a	27.4 a	61.7
Catucaí V. 19/08 Cv. 380	Late	21.6 f	39.0 d	74.4 e	66.7 d	66.4 e	53.8 i	121.2
Arara (Sarchimor A.)	Late	18.5 e	33.9 b	66.1 d	57.2 c	75.7 f	50.3 h	113.3
Catuaí A. IAC-39	Late	21.4 f	49.0 f	58.5 c	54.4 c	59.5 d	48.6 g	109.5
Catuaí V. IAC-99	Late	21.9 f	37.2 c	65.3 d	54.7 c	59.8 d	47.8 g	107.7
Catuaí V. IAC-81	Late	19.6 e	51.3 f	55.6 b	47.8 b	61.7 d	47.2 g	106.3
Catuaí V. IAC-44*	Late	17.8 e	33.2 b	61.7 c	42.8 b	66.3 e	44.4 f	100.0
Acauã	Very late	16.9 d	40.8 d	65.5 d	62.9 d	68.8 e	50.9 h	114.6
Obatã V. IAC 1669-20	Very late	18.3 e	30.3 b	67.6 d	57.6 c	63.9 e	47.6 g	107.2

* Progeny/Cultivar used as control. Means followed by the same letter on the same line do not differ at 5% probability by the Scott-Knott test (n=5)

A study carried out by Dias et al. (2005) with 25 coffee progenies also verified a high productive performance of the progeny Sarchimor IAC-4361 with yield of 44.7 sc/ha. A study by Costa et al. (2012) confirmed that after four harvests the progeny Arara planta 418 (Sarchimor A.) obtained an average of 50.2 sacks/ha. The progenies / cultivars of the present study can reach very close productivities and up to 50.0 beneficiated sacks / hectare, regardless of the maturation period. This is very important for coffee growers in order to better manage and scale the harvesting workforce and the physical postharvest structure, as well as to obtain a larger volume of peeled cherry coffee.

In the first (i) group the Catucaí V. 19/08 Cv. 380 progeny was highlighted with productivity of 53.8 sc/ha, being that of greatest productivity for the late maturation time, and the progeny Catucaí A. 2 SL (selection CAK) with productivity of 54.7 sc/ha which was the progeny of greatest productivity for the medium maturation period.

Comparing the yield of the control variety/ progeny (44.4 sc/ha) with the others, it was possible to observe that 21 varieties/progenies were superior, namely: very early maturation Catucaí 785 Cv. 15; early maturation Tupi IAC 1669-33; medium maturation Catucaí A. 2 SL (Sel. CAK), Sabiá Cv. 708, Catucaí A. 24/137 Cv. 250, Catucaí V. 24/137, IBC-Palma 2 (Fruto grande), Catucaí-açú (Fruto grande) and Catucaí A. 24/137 (Sel. CAK), Catucaí V.20/15 Cv. 626, Topázio MG 1190, Rubi MG 1192, Catucaí V. 36/6 and Catucaí A. (Fava grande); late maturation Catucaí V. 19/08 Cv. 380, Arara (Sarchimor A.), Catuaí A. IAC-39, Catuaí V. IAC-99 and Catuaí V. IAC-81and very late maturation Acauã and Obatã V. IAC 1669-20 (Table 4).

The maturation period does not influence productivity since the varieties/progenies of the same maturation periods were present in different groups, where the varieties of group nine (a) were the less productive and those of group one (i) the most productive. This shows a collection of materials with genetic diversity of yellow and red fruits available to coffee growers with adaptation to conditions at elevations exceeding 700 m and cold climate.

Rust

The progenies/cultivars with the lowest percentage of rust were: Acauã, Catucaí V. 19/08 Cv. 380, IBC-Palma 2 (Fruto grande), Iapar 59, Katipó, Arara (Sarchimor A.), Sabiá Cv. 708, Tupi IAC 1669-33, Caturra A. Colombiano, Catucaí 785 Cv.15, Catucaí V. 24/137 and Obatã V. IAC 1669-20. These varieties are distributed among the five different maturation seasons, which is very important for coffee growers to be able to stagger crops, lower production costs and increase profitability, as well as avoid using chemical control of the disease. Among the 30 progenies/cultivars evaluated, three cultivars were highlighted: Tupi IAC 1669-33 and Iapar 59 of early maturation and O Obatã V. IAC 1669-20 of very late maturation; and the progenies Katipó of early maturation; Catucaí V. 19/08 Cv. 380 and Arara (Sarchimor A.) of late maturation and Acauã of very late maturation that showed no incidence of rust. The greatest incidences of rust were the found in the progenies Caturra A. (Sel. CAK) and Mundo Novo 379-19 with mean incidences of rust of 80.15% and 85.5%, respectively (Table 5).

The severity of rust can vary in Arabica coffee genotypes even when grown under the same environmental conditions, with different levels of fungus resistance, classifying the genotypes as tolerant or susceptible (REUBEN & MTENGA, 2012); resistance is controlled by the SH gene and also by other genes, but with less effect (FAZUOLI et al., 2007). In fields competing with Arabica cultivars, certain cultivars present complete resistance to rust, while others may lose resistance due to local environmental conditions (SHIGUEOKA et al., 2014), a fact that is proven in this study. Because densified cropping favors the attack of rust, Paiva et al. (2010) indicated that care must be taken in the recommendation of cultivars for densified systems. According to Cabral et al. (2016), the inoculum source is easily dispersed by wind across great distances, which allows for dispersion of the pathogen among coffee growing areas in Brazil, and it is therefore difficult to predict the durability of resistance sources to coffee rust. For this reason it is recommended that breeding programs therefore incorporate multigene resistance as a control strategy.

Plant vigor

The progenies/cultivars with the lowest plant vigor scores were Caturra A. (Sel. CAK), Caturra A. (Sel. Nanicão) and the cultivar Mundo Novo 379-19, with values of 5.06, 5.89 and 6.65, respectively. The highest scores for vigor with average greater than 9.0 were the progenies Catucaí V. 19/08 Cv. 380 of late maturity with score of 9.01, Arara (Sarchimor A.) with score of 9.08 and Acauã with score of 9.15, both of late maturation (Table 5). One of the characteristics observed in the field for plant vigor is defoliation caused by the incidence of rust attack. It was observed that the progenies presenting the best scores for vigor are grouped with the lowest percentages of rust attack incidence, those with averages of 10 harvests presented 0.00% disease attack. Genetic materials with high plant vigor are correlated with increased productivity of the cultivars (SEVERINO et al., 2002), which may improve nutrient uptake, reduce suffering under unfavorable edaphoclimatic conditions (PETEK et al., 2002) and increase the longevity of crops in the field associated with the cultivars “Sarchimor” and “Catimor” (MATIELLO et al., 2005).

Yield, Sieve and Appearance

The lowest average yield of the coffee progenies/cultivars was that of Paraíso A. MG H 419-1, with average yield of 15.35 kg of processed coffee/36 kg sac of coffee beans, while cultivar Tupi IAC 1669-33 presented the maximum of 19.84 kg. Sieve 17 and above (coarse flat) is a required feature in the international coffee trade. For this attribute it was also observed that the lowest average was for the cultivar Paraíso A. MG H 419-1 with only 32.68% of sieve 17 and above. The progeny Catucaí A. 24/137 (Sel. CAK) presented 68.48% of the grains classified presenting this characteristic (Table 5).

The aspect of green coffee beans is widely used by coffee traders on the national and international market. Of the progenies/cultivars studied, 11 genetic materials had the worst scores, varying between 7.05 and 7.12 and the best cultivars Catucaí A. 2 SL (Sel. CAK), Mundo Novo 379-19 and Catucaí A. 24/137 (Sel. CAK)) presented scores of 8.85, 8.97 and 9.07, respectively (Table 5).

The commercial quality of coffee is based on characteristics such as appearance, color and cupping (Carvalho et al., 1994), in which current world demand is for coffees of both the best visual appearance and high sensorial quality, with preference for genotypes with higher percentage of coarse flat grains and better sensorial quality of the drink (PEROSA & ABREU, 2009; GICHIMU et al., 2012).

TABLE 5 - Mean rust infection (%), Yield, Sieve 17 and above and Aspect of 05 growing seasons (2005 to 2009) and Plant vigor of 10 seasons (2005 to 2014) of the Arabica coffee progenies/cultivars installed at the experimental farm "Sítio Santa Maria", in Marechal Floriano, ES, Brazil.

Progenies/Cultivars	Maturation period	Rust (%)	Vigor	Yield	Sieve 17 and above	Aspect
Catucaí 785 Cv. 15	Very early	3.55 a	8.11 h	17.75 h	65.60 k	8.10 c
Tupi IAC 1669-33	Early	0.00 a	7.94 g	19.84 r	65.24 k	8.08 c
Katipó	Early	0.00 a	7.55 e	17.72 h	58.80 h	7.08 a
Caturra A. Colombiano	Early	3.20 a	7.89 g	18.62 n	32.76 a	8.07 c
Iapar 59	Early	0.00 a	6.73 d	17.94 j	60.96 i	8.05 c
Caturra A. (Sel. CAK)	Early	80.15 i	5.06 a	19.71 q	42.84 b	7.12 a
Caturra A. (Sel. Nanicão)	Early	60.20 h	5.89 b	18.40 m	52.16 e	7.07 a
Catucaí A. 2 SL (Sel. CAK)	Medium	21.55 d	8.16 h	18.79 o	62.92 j	8.85 d
Sabiá Cv. 708	Medium	1.80 a	7.71 f	18.96 p	64.68 k	7.85 b
Catucaí A. 24/137 Cv. 250	Medium	15.00 c	8.08 h	18.99 p	62.56 j	7.78 b
Catucaí V. 24/137	Medium	3.65 a	7.89 g	18.78 o	54.04 f	7.12 a
IBC-Palma 2 (Fruto grande)	Medium	0.00 a	7.94 g	18.09 k	56.92 g	7.07 a
Catucaí-açú (Fava grande)	Medium	12.65 c	7.93 g	18.01 j	47.16 d	7.07 a
Catucaí A. 24/137 (Sel. CAK)	Medium	43.50 f	7.75 f	17.84 i	68.48 l	9.07 e
Catucaí V.20/15 Cv. 626	Medium	15.00 c	7.78 f	17.85 i	56.12 g	7.08 a
Topázio MG 1190	Medium	52.70 g	8.03 g	17.08 e	42.64 b	8.08 c
Rubi MG 1192	Medium	45.90 f	7.78 f	17.85 i	45.16 c	8.08 c
Catucaí V. 36/6	Medium	8.85 b	7.83 f	18.01 j	61.20 i	7.05 a
Catucaí A. (Fava grande)	Medium	24.45 d	8.08 h	17.46 g	66.16 k	8.05 c
Catucaí A. Cv. 07 - SSP	Medium	8.70 b	7.98 g	15.75 b	60.68 i	7.08 a
Mundo Novo 379-19	Medium	85.50 j	6.51 c	18.61 n	63.04 j	8.97 e
Paraíso A. MG H 419-1	Medium	6.75 b	6.65 d	15.35 a	32.68 a	8.05 c
Catucaí V. 19/08 Cv. 380	Late	0.00 a	9.01 i	17.69 h	56.72 d	7.12 a
Arara (Sarchimor A.)	Late	0.00 a	9.08 i	17.47 g	57.04 g	7.85 b
Catuaí A. IAC-39	Late	41.50 e	7.48 e	17.32 f	63.88 j	8.05 c
Catuaí V. IAC-99	Late	54.70 g	7.54 e	18.32 l	66.60 k	8.10 c
Catuaí V. IAC-81	Late	51.75 g	7.51 e	18.32 l	65.56 k	8.07 c
Catuaí V. IAC-44*	Late	39.20 e	7.69 f	17.71 h	65.00 k	8.07 c
Acauã	Very late	0.00 a	9.15 k	16.77 d	43.88 b	7.07 a
Obatã V. IAC 1669-20	Very late	0.00 a	8.26 i	16.15 c	64.72 k	8.03 c

Means followed by the same letter in the same column do not differ at 5.0% probability according to the Scott-Knott test (n=5). *Progeny/Cultivar used as the control. A % Rust, Yield, Sieve 17 and above and Aspect of the grains was assess in the growing seasons (2005, 2006, 2007, 2008 and 2009) and Plant Vigor in 10 seas

Because the bean size is directly related to coffee quality and improves the visual aspect, this is one of the criteria for selection of genotypes of a new cultivar and should be used in coffee breeding studies (PAIVA et al., 2010; PEDRO et al., 2011).

With the difficulty and high costs of the labor force that Brazilian coffee producers are facing, the harvest yield is an important aspect when considering manual harvest, a technique practiced by the great majority of small-scale agricultural producers. It was observed that the highest yield is obtained for short and conical sized plants, as is the case of Catucaí A. 2 SL and Catucaí V. 19/08 (Japi) of medium and late maturity, respectively.

In relation to the set of desirable agronomic characteristics that a progeny/cultivar should have, including: productivity, vigor, yield, high sieve and low susceptibility to rust, it is observed in Figure 1 that producers have access to good genetic material for the 05 different maturation periods. For example, the progeny / cultivar Paraíso A. MG H 419-1 present tolerance / resistance to rust, but doesn't show good productivity when compared to Catucaí A. 2 SL (Sel. CAK) and Tupi IAC 1669-33 that show good productivity, good sieve 17 and above, good yield and good harvest sacks / day besides presenting resistance to rust. Moreover, the progeny / cultivar Caturra A. (Sel. CAK); Caturra A. (Sel. Nanicão); Mundo Novo 379-19, should be avoided because they are susceptible to rust. (Figure 1).

According to Carvalho et al (2011), the progeny / cultivar Paraíso A. MG H 419-1 presenting high resistance to rusty and good productivity, however this progeny presented low productivity in relation to the other progenies evaluated in this present work.

4 CONCLUSIONS

When relating productivity with the maturation period we can highlight the progenies/cultivars: i) of very early maturation: Catucaí 785-15; ii) of early maturation: Tupi IAC 1669-33; iii) of medium maturation the progenies: Catucaí A. 2 SL (Sel. CAK), Sabiá Cv. 708, Catucaí A. 24/137 Cv.250, Catucaí V. 24/137, IBC-Palma 2 (Fruto grande), Catucaí-açú (Fruto grande) and Catucaí A. 24/137 (Sel. CAK); iv) of late maturation: Catucaí V. 19/08 Cv. 380 and Arara (Sarchimor A.) and v) of very late maturation Acauã and Obatã V. IAC 1669-20.

Coffee progenies/cultivars with tolerance and/or resistance to rust are excellent options for planting in new or renewal areas in humid and high elevation conditions to obtain high productivity and high plant vigor, potentially eliminating the need for chemical control of rust.

Therefore, this study shows that for the 5 different maturation periods studied, in areas of crop renewal or even for the conditions of new experimental areas, coffee growers have several options with specific characteristics of each progeny/cultivar superior to the standard Catuaí most commonly cultivated in the region.

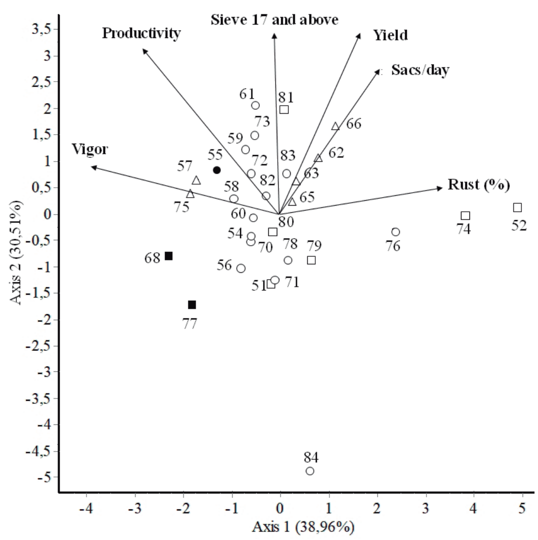

FIGURE 1 - Principal Components Analysis (PCA) relating the progenies/cultivars to the variables Plant vigor, Productivity (sc/ha), Sieve 17 and above, Harvest yield (sacs/day) and Rust (% infection). Different symbols indicate different maturation periods: ● very early; □ early; ○ medium; Δ late; ■ very late. The numbers represent the varieties: 51) Caturra A. Colombiano; 52) Caturra A. (Sel. CAK); 54) Catucaí-açú (Fruto grande); 55) Catucaí 785 Cv. 15; 56) Catucaí A. Cv. 07 - SSP; 57) Catucaí V. 19/08 Cv. 380; 58) Catucaí V. 24/137; 59) Catucaí A. 24/137 Cv. 250; 60) Catucaí V. 36/6; 61) Catucaí A. 2 SL (Sel. CAK); 62) Catuaí V. IAC-81; 63) Catuaí A. IAC-39; 65) Catuaí V. IAC-44; 66) Catuaí V. IAC-99; 68) Acauã; 70) Catucaí V.20/15 Cv. 626; 71) Topázio MG 1190; 72) IBC-Palma 2 (Fruto grande); 73) Sabiá Cv. 708 ; 74) Caturra A. (Sel. Nanicão); 75) Arara (Sarchimor A.); 76) Mundo Novo 379-19; 77) Obatã V. IAC 1669-20; 78) Rubi MG 1192; 79) Iapar 59; 80) Katipó; 81) Tupi IAC 1669-33; 82) Catucaí A. (Fruto grande); 83) Catucaí A. 24/137 (Sel. CAK); 84) Paraíso A. MG H 419-1

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CHARACTERIZATION OF BEVERAGE QUALITY IN *Coffea canephora* Pierre ex A. Froehner

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ABSTRACT: Differentiation of coffee according to its quality can result in added value. Both the coffee genotype and the environment influence beverage quality. The main species grown in the Amazon region is *C. canephora*, which includes two distinct botanical varieties: Conilon and Robusta. The aim of this study was to characterize beverage quality in *C. canephora* and distinguish the Conilon and Robusta botanical varieties and intervarietal hybrids. We evaluated the beverage quality of 130 superior clones from samples of hulled coffee collected in the experimental field of Embrapa Rondônia in the municipality of Ouro Preto do Oeste, RO, Brazil. The beverage was classified according to the Robusta Cupping Protocols, which also considers the nuances of the beverage, described as neutral, fruit-like, exotic, refined, and mild. The final mean values classified the Robusta botanical variety and the intervarietal hybrids as coffees with a premium beverage, and the Conilon botanical variety as usual good quality. The nuances of the Conilon botanical variety were found to be predominantly neutral (78%), as compared to the Robusta botanical variety and the intervarietal hybrids, which exhibited 50% and 44% of their beverages, respectively, with fruit-like, exotic, or mild nuances. The genetic parameters indicate that the genetic component was more important than the environmental in expression of coffee quality attributes. Genetic variability was observed in the population evaluated, except for the Uniform Cup and Clean Cup beverage attributes.

Index Terms: Specialty coffees, plant breeding, genetic parameters, conilon, robusta.

CARACTERIZAÇÃO DA QUALIDADE DA BEBIDA DE *Coffea Canephora* Pierre ex A. Froehner

RESUMO: O café de qualidade diferenciada proporciona um aumento no valor da saca. A qualidade da bebida é uma característica influenciada tanto pelo genótipo quanto pelo ambiente. A principal espécie cultivada na região Amazônica é *C. canephora* que apresenta duas variedades botânicas distintas: o Conilon e o Robusta. O objetivo neste trabalho foi caracterizar a qualidade da bebida de *C. canephora* discriminando as variedades botânicas Conilon, Robusta e híbridos intervarietais. Para isso foi avaliada a qualidade da bebida, de 130 clones superiores a partir de amostras de café beneficiado coletadas, no campo experimental da Embrapa Rondônia do município de Ouro Preto do Oeste - RO. A classificação da bebida foi realizada conforme o Protocolo de Degustação de Robusta Finos, que também considera os nuances da bebida descrita como neutro, frutado, exótico, fino e suave. As médias finais classificaram a variedade botânica Robusta e os híbridos intervarietais como cafés de bebida Prêmio, e a variedade botânica Conilon como Boa qualidade usual. Observou-se que os nuances da variedade botânica Conilon foram predominantemente neutros (78%), em comparação com a variedade botânica Robusta e de híbridos intervarietais que apresentaram 50% e 44% respectivamente de suas bebidas divididas entre os nuances frutado, exótico ou suave. Os parâmetros genéticos indicam que o componente genético foi mais importante que o ambiental na expressão dos atributos de qualidade do café. Observou variabilidade genética na população avaliada, exceto para os atributos uniformidade e limpeza da bebida.

Termos para indexação: Cafés especiais, melhoramento de plantas, parâmetros genéticos, conilon, robusta.

1 INTRODUCTION

Coffee is growing of great economic importance; coffee was the second largest agricultural commodity crop in terms of revenue for Brazil in 2016, behind only soybean (CONAB, 2017). Although the *Coffea* genus is composed of more than 120 species, only two are grown in a significant way, *C. arabica* L. and *C. canephora* (DAVIS et al., 2011). In the Amazon region, Rondônia is the main coffee-producing state, and the second largest producer of the species *C. canephora* in Brazil, with approximately 95,000 hectares of coffee under cultivation and production of 1.6 million bags of hulled coffee in 2016 (COMPANHIA NACIONAL DE ABASTECIMENTO-CONAB, 2017).

In general, in the North region of Brazil, coffee quality is not yet recognized through variation in price, and this discourages more suitable harvest and post-harvest practices

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(SCHLINDWEIN et al.,2013).According to Souza et al. (2015), many producers end up harvesting coffee fruit in the green or cane green stage because they need financial resources.

C. canephora is characterized by two distinct botanical varieties that are commercially grown (RAMALHO et al., 2016; ROCHA et al., 2013).The Conilon botanical variety is characterized by plants with bush-like growth, early flowering, branched stems, elongated leaves, greater susceptibility to diseases and higher tolerance to water deficit when compared to the Robusta variety. The Robusta variety, for its part, is characterized by greater vegetative vigor, upright growth, larger leaves and fruit, later maturation, less tolerance to water deficit, and greater tolerance to pests and diseases (FERRÃO et al., 2009; MONTAGNON; LEROY; YAPO, 1992). The natural intervarietal hybrids of 'Conilon' x 'Robusta' can be observed in the field (RAMALHO et al., 2016; MARCOLAN; ESPINDULA, 2015). Both genotype and environment affect beverage quality; coffee bean aroma and flavor are also influenced by soil and climate characteristics (SUNARHARUM; WILLIAMS; SMYTH, 2014).

Characterization of the beverage quality of *C. canephora* is a fundamental activity performed for scientific and commercial purposes. In 2010, the Robusta Cupping Protocol was developed, which presents specific evaluation criteria for *C. canephora* beverages, standardizing the beverage classifications upon considering the characteristic variations of this species (UGANDA COFFEE DEVELOPMENT AUTHORITY - UCDA, 2010). The main organoleptic attributes of the *C. canephora* beverages are Fragrance/Aroma, Flavor ,Aftertaste, Salt/Acid Aspect Ratio; Bitter/Sweet Aspect Ratio; Mouthfeel; Balance; Uniform Cup; Clean Cup, and Overall attributes. The means of the scores of all the attributes are used to obtain a final score that is used to classify a beverage according to its quality (BRASIL, 2011; MARCOLAN; ESPINDULA, 2015).

C. canephora accessions from the Conilon and Robusta botanical varieties represent important sources of variability for development of new varieties with differentiated beverage quality (ROCHA; et al., 2015; VENEZIANO, 1993) since each botanical variety has different amounts of soluble solids, which influence the body, aroma, acidity, and astringency of the beverage (ESQUIVEL;JIMÉNEZ, 2012; MENDONÇA, PEREIRA; MENDES, 2005). In Rondônia, Veneziano (1993) evaluated the quality of coffee from seven accessions of Conilon and nine accession of Robusta and observed that 14% of the genotypes of the Conilon botanical variety and 50% of the Robusta botanical variety had full-bodied coffee.

In this context, the aim of this study was to characterize the beverage quality of 130 clones of the Conilon and Robusta botanical varieties and of intervarietal hybrids to assist in development of new varieties that have a series of favorable characteristics.

2 MATERIALS AND METHODS

Samples

Were evaluated 130 samples of *C. canephora,* collected in 2015, originating from clones (genotypes) under evaluation in clone competition trials in the experimental field of Embrapa-Rondônia in the municipality of Ouro Preto do Oeste, RO (10°37'03'' S, 62°51'50'' W). The samples were composed of selected fruits, which were in the M3 maturation phase, light red and physiologically mature. Drying was performed in a batch-type, solar-heated air drier with mechanical system of unloading after approximately 140 hours when they reached 12% moisture (ALVES et al., 2014).Fourteen percent of the samples were discarded due to fermentation occurred during the drying process.

The clone competition trial was set up in 2011 at plant spacing of 3x2m for evaluation of 130 genotypes: 84of the Conilon botanical variety, 26 of the Robusta botanical variety, and 20 intervarietal hybrids. The experiment was managed according to the recommendations of Marcolan et al. (2009).

Climate in the municipality is Aw (Köppen classification), defined as humid tropical with a rainy season (October to May) in the summer and well-defined dry period in the winter (BRASIL, 1992).The mean annual amplitude of temperature ranges from 21.2ºC to 30.3ºC, and the highest temperatures occur in July and August. Mean annual rainfall is 1,939 mm, with mean relative humidity of 81% and altitude of 254m. The soil is a red eutrophic oxisol with a well drained clay texture (SANTOS, 1999). According to the soil analysis performed in 2016, the available phosphorus was 4 mg.dm^{-3} (Melich^{-1}), potassium 0.19 cmolc.dm^{-3}, calcium 2.66 cmolc.dm^{-3}and magnesium 0.54 cmolc.dm^{-3}. The sum of the aluminum and hydrogen was 2.97 cmolc.dm^{-3}, the organic matter was 20.2 g.kg^{-1} and the base saturation was 53%.

Sensory analysis of the samples was performed in the laboratory of the Conilon Brasil company in Jaguaré, ES, by three judges /cuppers (R Grader), according to the international method of beverage classification for *C.canephora*, i.e., the Robusta Cupping Protocol of the Coffee Quality Institute - CQI (Uganda Coffee Development Authority - UCDA, 2010).

During cupping, nuances of the beverage can be quantified (FERREIRA et al., 2012), which were classified as neutral, fruit-like/exotic, refined, and mild. Detailed descriptions of the nuances are used to characterize the market potential of the product for production of specialty coffees (SALVA;LIMA, 2007).

To evaluate the hypothesis that there are significant differences among the coffee samples derived from the Conilon and Robusta botanical varieties and intervarietal hybrids, the F test of analysis of variance was interpreted in a completely randomized design according to the following model (CRUZ; CARNEIRO; REGAZZI, 2014):

$$Y_{ij} = u + G_i + e_{ij}$$

in which: Y_{ij} = observation of the i-th botanical variety in the j-th replication, u = overall mean, G_i = i-th botanical variety (Conilon, Robusta botanical varieties and intervarietal hybrids), e_{ij} = random error associated with the i-th botanical variety in the j-th replication. To quantify the difference between the botanical varieties and the hybrid genotypes, the Tukey test was used at the level of 5% probability.

Among the genetic parameters most important for characterization of genetic control and efficiency of the selection process are heritability, repeatability, and selection accuracy (CRUZ; CARNEIRO; REGAZZI, 2014). Broad-sense heritability measures the relative proportion between the genotypic and environmental effects on expression of the characteristics. According to Vencovsky and Barriga (1992), this can be estimated by:

$$h^2 = \frac{\sigma_g^2}{\sigma_g^2 + \sigma_e^2}$$

in which h^2 is the broad-sense heritability, σ_g^2 is the genotypic variance, and σ_e^2 is the environmental variance.

3 RESULTS AND DISCUSSION

Of the 130 samples evaluated, 14% were discarded because the coffee had a fermented flavor caused by deficiencies in the drying process, which led to undesirable fermentation in the coffee fruit and, consequently, the impossibility of characterization of the organoleptic attributes of the beverage (MARCOLAN; ESPINDULA, 2015) (Table 1).

Analysis of variance indicated a significant difference between the botanical varieties for all the sensory analysis characteristics, except for Uniform Cup and a Clean Cup beverage, at 1% and at 5% probability (Table 1). The Clean Cup and Uniform Cup atributes refer to the absence of defects in the cup, in which the cupper evaluates five replications of the same sample, and the beverage is considered uniform when all the replications exhibit the same attributes, flavors, and nuances (Uganda Coffee Development Authority - UCDA, 2010). Similarity among these attributes is desirable and indicates that the post-harvest procedures were carried out in a uniform manner for the samples under evaluation.

The estimates of the experimental coefficient of variation observed for all the attributes evaluated can be considered low (CV<20%) (Table 1)**.**In comparison to field evaluations, variations from 19% to 30% in the estimate of the coefficient of variation for production of hulled coffee indicate that the experiment was well conducted (FERRÃO et al., 2008). Other studies that quantified the coefficient of variation of the attributes of the *C. canephora* beverage were not found in the literature.

The mean final score of 68.41 indicates a good quality beverage, classified as Usual Good Quality. The classification and mean value of the attributes of the beverage produced by *C. canephora*are of good quality beverages, with potential for sale of 100% *C. canephora* coffees, as well as mixtures with *C. arabica* (RIBEIRO et al., 2014). For the coffee industry, the greater concentration of soluble solids of *C. canephora* in relation to *C. arabica* provides higher industrial yield in the production of blends (FONSECA; FERRÃO; FERRÃO, 2013).

For the rural producer, the production of specialty coffees can be profitable, encouraging production of quality coffees (ALVES et al., 2011). According to the Brazil Specialty Coffee Association – BSCA (2017), differentiation of coffee according to its quality can result in up to 40% additional value of the bag.

TABLE 1 - Estimate of the F test of analysis of variance (ANOVA) of the following attributes: Fragrance/Aroma, Flavor, Salt/Acid Aspect Ratio, Bitter/Sweet Aspect Ratio, Mouthfeel, Balance, Aftertaste, Uniform Cup (Unifor.), Clean Cup, and Overall attributes among the Conilon and Robusta botanical varieties and the intervarietal hybrids.

S.V.	D.F.	Fragrance	Flavor	Acidity	Bitter	Mouthfeel
Botanical Var.	2	4.82**	5.16**	6.65**	7.10**	4.41**
Residue	109	-	-	-	-	-
Total	111	-	-	-	-	-
Mean	-	6.42	6.18	6.14	6.16	6.21
CV(%)	-	12.55	13.47	13.34	12.98	12.4
S.V.	D.F.	Balance	Aftertaste	Unifor.	Clean	Overall
Botanical Var.	2	5.27**	3.59**	1.14 ^{NS}	1.14 ^{NS}	6.14**
Residue	109	-	-	-	-	-
Total	111	-	-	-	-	-
Mean	-	6.19	6.15	9.51	9.51	6.19
CV(%)	-	12.37	12.1	15.69	15.69	13.26

** Significant at 1% probability according to the F test of ANOVA, ^{NS}: not significant, S.V.: source of variation, D.F.: degree of freedom, CV(%): coefficient of variation.

In Brazil and outside Brazil, the specialty coffee trade grows at a rate of about 15% a year (ROHDE; CASTAGNA, 2016; TONETTI; PAVAN; DALBOSCO, 2015).

Beverage quality is defined by the genotype and by the environment because they are factors that determine the formation of the organoleptic properties of the beverage (SCHOLZ et al, 2011). The magnitudes of genotypic and environmental variances indicate that the genetic component was more important than the environmental component in the expression of coffee quality attributes, except for Uniform Cup and a Clean Cup; which did not exhibit genetic variability in the evaluated population (Table 2). According to Falconer and Mackay (1996) heritability estimates higher than 0.80 indicates genetic progress with plant selection.

The Conilon and Robusta botanical varieties and the intervarietal hybrids exhibited different final beverage quality according to the Tukey test at 5% probability (Table 3). The scores showed differences between the type of beverage produced by the Conilon botanical variety compared to the type of beverage produced by the Robusta botanical variety and by the hybrid; the last two were placed in the same group due to their similarity. According to Verdin Filho et al. (2016) and Silva et al. (2009), the difference observed between Conilon and Robusta is the result of the chemical composition of the coffee beans, which was shown in the differentiation of the attributes.

Uniform Cup, Clean Cup, Aftertaste, and Mouthfeel are attributes of quality that did not exhibit significant differences between the botanical varieties (Table 3). According to Aguiar et al. (2005), the amount of chlorogenic acid ranges from 5.70% to 5.99% in the botanical varieties of the *C. canephora* species, and no significant difference was observed by the Tukey test at 5% probability. The concentration of chlorogenic acid in the coffee beans maintains the chemical constitution of the coffee bean after roasting, and affects the Uniform Cup of the organoleptic attributes (FAGAN et al., 2011). Aftertaste and Mouthfeel are attributes associated with the taste perceived by the taste buds, and are similar among the C. canephora botanical varieties. According to Verdin Filho et al. (2016), a high quality coffee should have a pleasant finish, with a residual effect of good duration adequate for the final taste in the mouth.

The attribute of Balance and the Overall attributes of the Conilon botanical variety differed from those of the Robusta botanical variety and from the intervarietal hybrids. The scores of these attributes are associated with other evaluations because Balance is interaction between the attributes, just as evaluation of the Overall attributes is, which is evaluated in a holistic manner in the sample according to the perception of the cuppers. According to Verdin Filho et al., (2016), Balance is responsible for determining the pleasant flavor sensation during consumption and after cupping, and this is an important characteristic for both specialty coffees and for preparation of blends.

TABLE 2 - Estimates of genetic parameters estimated for the attributes evaluated according to the Robusta Cupping Protocols: Fragrance/Aroma (Frag), Flavor, Salt/Acid Aspect Ratio(S/A), Bitter/Sweet Aspect Ratio(B/S), Mouthfeel (MF), Balance (Bal.), Aftertaste (After.), Uniform Cup (Unifor.), Clean Cup (Clean), and Overall.

Genetic Parameter	Frag.	Flavor	S/A	B/S	MF
σ^2_g	0.08	0.09	0.12	0.13	0.06
σ^2_e	0.02	0.02	0.02	0.02	0.02
σ^2_p	0.10	0.11	0.14	0.15	0.08
h^2	79.29	80.63	84.97	85.93	77.35
$\hat{\rho}$	11.03	11.87	15.47	16.51	9.96
$CV_{g\,(\%)}$	4.42	4.95	5.76	5.78	4.12
CVr (%)	0.35	0.37	0.43	0.44	0.33

Genetic Parameter	Bal.	After.	Unifor.	Clean	Overall
σ^2_g	0.08	0.04	0.01	0.01	0.13
σ^2_e	0.02	0.02	0.07	0.07	0.02
σ^2_p	0.1	0.06	0.08	0.08	0.11
h^2	81.02	72.15	12.97	12.97	83.71
$\hat{\rho}$	12.14	7.74	0.48	0.48	14.26
$CV_{g\,(\%)}$	4.6	3.51	1.09	1.09	5.41
CVr (%)	0.37	0.29	0.07	0.07	0.41

σ^2_g :genotypic variance, σ^2_e : environmental variance, σ^2_p : phenotypic variance, h^2: heritability for selection between botanical varieties, $\hat{\rho}$: intraclass correlation, CV_g : coefficient of genetic variation, CVr%: $CV_r = CV_g / CV_e$

It was also observed that the scores of the Fragrance/Aroma and Flavor attributes of the Conilon botanical variety were less than those of the Robusta botanical variety and the hybrid (Table 3). The fragrance defined as the smell of coffee when still dry and the aroma when the coffee is diluted in hot water is directly reflected in final beverage quality (UGANDA COFFEE DEVELOPMENT AUTHORITY - UCDA, 2010). Some chemical characteristics, such as lipid content of the coffee beans, have a beneficial effect on aroma and on flavor because, during roasting, they concentrate on the external areas, protecting the bean from possible losses of the component during this process (MARTINEZ et al., 2014). Aguiar et al. (2005) observed a significant difference between the amount of lipids in the Robusta botanical variety (10.91 g / 100 g) and in the Conilon botanical variety (7.33 g / 100 g).

Salt/Acid Aspect Ratio also differentiated Robusta and the intervarietal hybrids from the Conilon botanical variety (Table 3).

TABLE 3 - Scores given for each one of the attributes from classification of beverage quality for clones of the Conilon botanical variety (68), intervarietal hybrids (18), and Robusta botanical variety (26).

Attribute	Maximum Score[1]	Conilon Mean	Hybrid Mean	Robusta Mean
Fragrance/Aroma	10	6.2[b]	6.6[a]	6.7[a]
Flavor	10	6.0[b]	6.4[a]	6.6[a]
Salt/Acid Aspect Ratio	10	5.9[b]	6.4[a]	6.6[a]
Bitter/Sweet Aspect Ratio	10	6.0[b]	6.4[a]	6.6[a]
Mouthfeel	10	6.1[a]	6.4[a]	6.5[a]
Balance	10	6.0[b]	6.4[a]	6.5[a]
Aftertaste	10	6.0[a]	6.4[a]	6.4[a]
Uniform Cup	10	9.2[a]	9.5[a]	9.8[a]
Clean Cup	10	9.2[a]	9.5[a]	9.8[a]
Overall	10	6.0[b]	6.5[a]	6.5[a]
Slight defects[2]	0	0.1	0.1	0.1
Serious defects[2]	0	0.0	0.0	0.0
Mean of the Final Scores	-	66.5[b]	70.4[a]	71.8 [a]

[1]Maximum score that can be attributed in evaluation of the beverage characteristics according to the Robusta Cupping Protocols. [2]The defect score is subtracted from the sum of the individual scores given for each one of the primary attributes, obtaining the final score. [a,b] Means followed by the same letter do not differ according to the Tukey test at 5% probability.

This attribute is associated with the pleasant flavor that is possible to distinguish in the acidity and sweetness qualities of the beverage (SUNARHARUM; WILLIAMS; SMYTH et al., 2014). According to Moura et al. (2007) and Nascimento et al. (2008), high acidity of the *C .canephora* beverage is due to the large quantity of soluble solids, which are also responsible for the dark color and body of the beverage. Aguiar et al. (2005) observed a significant difference between the amount of soluble solids of Conilon and Robusta; however, Veneziano (1993) found similar values for these botanical varieties.

A total of 78% of the samples of the Conilon botanical variety were classified as neutral beverages (Table 4). The final score is estimated summing the individual scores of each beverage quality attributes. This score is used to classify the beverage quality in a range of 0 to 100 points, in which, scores below 50 points characterize commercial beverage, from 50-70 points usual good beverage, from 70-80 points premium classification and above 80 fine quality beverages. This result is in agreement with the score for its attributes because the Conilon attributes maintained similar scores, which expressed a beverage with neutral flavor of good quality (Table 3). Using protocol adapted from *C. arabica*, Veneziano (1993) characterized the beverage from genotypes of the Conilon botanical variety as neutral (86%) and light bodied (14%). The neutrality of coffees is desirable for the blends and soluble coffee industry (RIBEIRO et al., 2014). However, specialty coffees or differentiated coffees are those that have superior quality (BRESSANELLO et al.,2017) or those that have some kind of certificate of sustainable practices (NAVARINI; RIVETTI, 2010), serving different segments of the market.

The hybrid provides a beverage with predominantly neutral characteristics, though with a significant percentage of fruit-like, fine, and mild coffees, with characteristics of the two botanical varieties, Conilon and Robusta. Its quality classification was predominantly premium, showing potential for specialty coffees with greater sweetness and mildness.

Beverages originating from the Robusta botanical variety exhibited a greater incidence of fruit-like, exotic, fine, and mild nuances, for 50% of all samples; its predominant classification was of the premium type (Table 4).

TABLE 4 - Percentage of nuances in the samples and classification according to ROBUSTA CUPPING PROTOCOLS in five levels: fair: commercial; fair: usual good quality (fair-UGQ); average –usual good quality (average-UGQ); premium; and fine, in evaluation of 130 clones of the botanical varieties Conilon and Robusta, and intervarietal hybrids.

Botanical Var.	Neutral	Fruit-like	Exotic	Fine	Mild
Conilon	78%	15%	4%	1%	2%
Hybrids	67%	11%	0%	21%	1%
Robusta	50%	15%	12%	22%	1%
Botanical Var.	Commercial	Fair-UGQ	Average-UGQ	Premium	Fine
Conilon	2%	13%	46%	38%	1%
Hybrids	0%	6%	11%	83%	0%
Robusta	4%	0%	30%	62%	4%

Characterization and selection of specialty coffees with the fruit-like, exotic, mild, and fine nuances is important for development of new varieties.

Prior to the Robusta Cupping Protocols for classification of fine *C. canephora* varieties, beverage quality classification was required only for the *C. arabica* species because marketing of the *C. canephora* species was only a classification of ‘kind’ (grain defects and impurities) and sieve size (VERDIN FILHO et al., 2016); there was thus no appreciation of the beverage quality of *C. canephora*. In classification according to Normative Instruction no. 8 of June 11, 2003 (BRASIL, 2003), coffees originating from *C. canephora* with neutral flavor are adequate for production of commodity coffees; nevertheless, the Robusta botanical variety shows potential for production of specialty coffees.

The divergent beverage attributes among Conilon, Robusta botanical varieties and their intervarietal hybrids subsidy the characterization of new coffee organoleptic profiles and selection of plants with special beverage characteristics.

4 CONCLUSION

In expression of the attributes of the beverage from the Conilon and Robusta botanical varieties and from the intervarietal hybrids, the genetic parameters indicated that the genetic component is predominant in relation to the environmental for all the characteristics, except for the Uniform Cup and Clean Cup attributes of the beverage. The attributes Fragrance/Aroma, Flavor, Salt/Acid Aspect Ratio, and Bitter/Sweet Aspect Ratio are different between the Conilon and Robusta botanical varieties and define the nuances of the beverages. The intervarietal hybrids exhibit attributes similar to the Robusta botanical variety. In terms of coffee quality, the Conilon botanical variety exhibited a beverage with neutral nuances, and the Robusta botanical variety and the intervarietal hybrids exhibited a beverage with neutral, fruit-like, exotic, and mild nuances. All the samples evaluated were considered adequate for consumption; however, Robusta and the intervarietal hybrids exhibited higher proportions of classification as premium coffee.

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Characterization of resistance response of *Coffea canephora* genotypes to *Meloidogyne incognita* (Est I2) root-knot nematode

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ABSTRACT: Meloidogynose is prominent among the factors that limit yield in *C. canephora* in the western Amazon, Brazil. It is caused by species of "root-knot nematode"; the most important and aggressive of these species for coffee is *M. incognita*. The aim of this study was to assist the selection of resistant genotypes by characterizing the reaction of 32 *C. canephora* clones to *M. incognita* (Est I2). These genotypes are selected plants from the Germplasm Bank of Embrapa Rondônia of the botanical varieties Conilon, Robusta and intervarietal hybrids. The experiments were conducted under greenhouse conditions by inoculating six seedlings for each clone with 10 ml of suspension containing 5000 eggs of a pure inoculum of *M. incognita*. At 150 days after inoculation, evaluations were made of fresh weight of roots (FWR), total number of galls (NG), total number of eggs (NE), and the nematode reproduction factor (RF=final population/initial population). In contrast with the susceptible controls of arabica coffee (RF=1.2) and tomato plants (RF=31.3), six clones of the Conilon botanical variety, five clones of the Robusta botanical variety and eight intervarietal hybrids reacted as resistant to *M. incognita*, exhibiting RF<1 and a reduced number of galls (NG_{mean} = <10). The clones identified as resistant in this study were integrated in the coffee breeding program in Rondônia for development of cultivars resistant to the root-knot nematode adapted to tropical conditions.

Index terms: Coffee, meloidogynose, plant selection, plant breeding, Rondônia.

Caracterização da resposta de resistência de genótipos de *Coffea canephora* ao Nematoide-das-Galhas *Meloidogyne incognita* (Est I2)

RESUMO: Entre os fatores que limitam a produtividade do *C. canephora* na Amazônia Ocidental destaca-se a meloidogynose, causada por espécies do "Nematoide-das-Galhas", dentre as quais a mais importante e agressiva ao cafeeiro é *M. incognita*. O objetivo desse trabalho foi caracterizar a resistência à *M. incognita* (Est I2) de 32 genótipos das variedades botânicas Conilon, Robusta e híbridos intervarietais provenientes do Banco de Germoplasma da Embrapa Rondônia. Os experimentos foram realizados em casa de vegetação com a inoculação de seis mudas para cada clone com 10 ml de suspensão contendo 5000 ovos de inóculo puro de *M. incognita*. Cento e cinquenta dias após a inoculação foram avaliados o peso fresco (PF), o número de galhas (NG), o número de ovos (NO) e o fator de reprodução do nematoide (FR= população final/população inicial). Em comparação com as testemunhas suscetíveis de café arábica e do tomateiro (FR=1,2 e 31,3, respectivamente), os clones da variedade botânica Conilon (694, 160, 837, 46, 909, 890), da variedade botânica Robusta (1111, 8152, 8192, 10141, 8152) e os materiais híbridos (844, 1005, 169, 54, 453, 120, 193, 636) reagiram como resistentes à M. *incognita*, apresentando FR<1 e reduzido número de galhas ($NG_{médio}$ = <10). Os clones identificados como resistentes foram integrados ao programa de melhoramento genético do cafeeiro visando o desenvolvimento de cultivares resistentes ao nematoide-das-galhas e mais adaptados às condições edafoclimáticas regionais.

Termos para indexação: Café, meloidogynose, seleção de plantas, melhoramento genético, Rondônia.

1 INTRODUCTION

Brazil is the main worldwide exporter of coffee (*Coffea* spp.), with a 33.48% share of total exports in 2015, followed by Vietnam with 18.23%. In the 2016 crop season, Brazil had production of 51.37 million bags of hulled coffee, which represents growth of 18.8% compared to the previous year (ABIC, 2017). Two commercially profitable species of the *Coffea* coffee genus are grown in Brazil, *Coffea arabica* L. and *Coffea canephora* Pierre ex Froehner (DAVIS et al., 2011).

Phenotypic, isoenzymatic, and molecular analyses distinguish two botanical varieties in *C. canephora* species, named Conilon and Robusta Conilon (ROCHA et al, 2013). The Conilon coffee is characterized as having plants with bushy growth, early flowering, branched stems, elongated leaves, drought resistance, and greater susceptibility to diseases (RAMALHO et al., 2016, RODRIGUES et al., 2012). The Robusta coffee has greater

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vegetative vigor, upright growth, larger leaves and fruit, later maturation, less tolerance to water deficit, and greater tolerance to pests and diseases, especially to coffee rust (*Hemileia vastatrix*) and to the root-knot nematode (*Meloidogyne incognita*). In the Robusta botanic variety there is the cultivar 'Apoatã', which due to its resistance to *Meloidogyne* spp. have served as an alternative in management of areas infested by the root-knot nematode (PAIVA et al., 2012).

Among the factors that can limit coffee yield, pests and diseases is one of the most important. Some species of plant-parasitic nematodes cause serious damage in plantations, destroying up to 80% of the root system within five years of planting (BARROS et al., 2014; SILVA et al., 2013). Plant-parasitic nematodes have a substantial economic impact on coffee in most coffee-producing countries. Among these nematodes, those of the genus *Meloidogyne* spp. (GÖLDI, 1887), commonly known as "root-knot nematodes", lead to economic losses in the crop. In coffee fields, the damage caused by *Meloidogyne* spp. vary according to the species, the population density and the susceptibility of the host cultivar (SALGADO et al., 2014; SILVA et al., 2007).

According to Amorim et al. (2011), *Meloidogyne* spp. cause damage to the root system, which is manifested externally by gall symptoms, splitting, and scaling in cortical tissues, causing high disorganization of root tissues. Root deformations, known as root galls or knots, are the result of excessive multiplication and growth of cells affected by the "secretions" produced by the dorsal esophageal glands of the nematodes. Other symptoms are arrested growth of the root tip, cracks, and detachment of the cortex. In the shoots, there are symptoms of chlorosis, leaf drop, and slow decline. This is reflected in the field as plant wilting during the hottest hours of the day, premature leaf drop, lower production, and symptoms of mineral deficiencies (VIEIRA JÚNIOR et al., 2015, CASTRO et al., 2008).

Five species of root-knot nematode have been reported in Brazilian coffee fields: *M. coffeicola* Lordello and Zamith, *M. exigua* Goeldi, *M. hapla* Chitwood, *M. incognita* (Kofoid & White) Chitwood, and *M. paranaensis* Carneiro (SALGADO et al., 2015; SILVA et al., 2009). *M. incognita* is considered the most important species attacking coffee fields in Brazil, not only through its aggressiveness to coffee, but also through its wide range of hosts, which makes it difficult to control and makes it the most significant enemy of the crop (BRASS, 2008).

With the objective of selecting resistant genotypes to the root-knot nematode *M. incognita*, genotypes with greater productive potential of the Conilon and Robusta botanical varieties and of interspecific hybrids were characterized in regard to reaction to the root-knot nematode *M. incognita* (Est I2).

2 MATERIALS AND METHODS

Genetic Resources

Thirty-two genotypes were selected in the Germplasm Bank of Embrapa Rondônia based on the evaluation of the following morphological and productive traits: plant height (PHt), number of productive plagiotropic branches (NPLAG), distance between rosettes of the plagiotropic branch (DROS), number of coffee beans per rosette of the intermediate part of the plagiotropic branch (BROS), number of rosettes per plagiotropic branch (NROS), length of plagiotropic branch (LPLAG), length and width of leaves (LL, WL), number of days for fruit ripening (NDAYS), and coffee bean size (SIEVE). The genotypic value of production (GVProd) was estimated based on production of hulled coffee using the BLUP (Best Linear Unbiased Prediction) method (RESENDE, 2016) (Table 1).

The climate of the municipality of Ouro Preto do Oeste – RO is Aw type (Köppen classification), defined as humid tropical with a rainy season (October to May) in the summer and well-defined dry season in the winter (accumulated water deficit from June to September (DEF = 175 mm) and accumulated water excess from November to April (EXC = 781 mm) for 100 mm of water retention. Mean annual temperature amplitude ranges from 21.2ºC to 30.3ºC, and the highest temperatures occur in July and August. Mean annual rainfall is 1,939 mm and mean relative humidity is 81% according to the Climatological Normals (BRASIL, 1992).

Evaluation of resistance of *C. canephora* genotypes to *M. incognita*

The *M. incognita* inoculation agent was extracted from 15 g samples of roots taken from under the canopy of diseased coffee plants that had been naturally infested in crop fields in the municipality of Ji-Paraná, RO (10°52'53"S, 61°30'45"W, altitude 159 m).

TABLE 1 - Identification of genotypes (clones) of *C. canephora* according to the botanical varieties of the genotypic value of coffee production (GVProd), mean sieve and maturation cycle evaluated in the crop years 2013-2014 and 2014-2015 in the experimental field of Embrapa Rondônia in the municipality of Ouro Preto do Oeste, RO, Brazil.

Genotypes	Botanical variety[$]	GVProd (bags.ha^{-1})	Mean sieve (inches^2.64^{-1})	Classification[#]
890	C	101.6	13.4	EMC
453	H	90.5	13.4	EMC
968	C	90.0	14.6	EMC
193	H	87.3	14.9	EMC
160	C	85.7	15.5	EMC
1111	R	85.0	16.1	IMC
837	C	85.0	12.9	EMC
694	C	84.7	14.5	EMC
8152	R	82.0	15.8	LMC
8152	R	82.0	15.8	IMC
657	H	80.3	13.9	IMC
772	C	80.0	14.0	EMC
8192	R	78.0	14.4	LMC
10141	R	76.0	16.5	IMC
703	C	75.0	15.9	EMC
535	H	73.1	15.5	IMC
56	H	68.2	16.7	IMC
46	C	68.0	15.8	EMC
909	C	66.7	14.8	EMC
54	H	66.0	14.1	EMC
482	H	59.9	16.6	IMC
796	C	59.2	15.3	EMC
844	H	57.0	14.8	EMC
120	H	56.4	15.0	EMC
169	H	56.0	15.5	EMC
792	C	55.6	14.6	EMC
799	C	53.3	16.0	IMC
723	C	52.8	13.5	EMC
750	H	51.6	15.1	EMC
636	H	51.0	14.9	EMC
1005	H	50.0	14.8	EMC
729	C	49.3	12.9	EMC

[$]C: Conilon botanical variety, R: Robusta botanical variety, H: Conilon x Robusta hybrid genotype. [#] EMC: early maturation cycle, IMC: intermediate maturation cycle, LMC: late maturation cycle.

In laboratory conditions, the egg mass of a single female nematode at an advanced stage of oviposition was extracted under a stereoscopic microscope and transferred to an Eppendorf tube containing 0.1 ml of 1% saline solution. Immediately after the suspension with the egg mass was transferred to a test tube containing 10 mL of sterilized distilled water, which was placed in a vortex shaker for approximately 15 seconds, until the eggs were separated from the ootheca and the suspension was homogeneous. An automatic pippetor was used to individually inoculate 3.3 mL of the suspension containing nematode eggs on three cv. Santa Clara tomato plants (*Solanum lycopersicum* L.) with an age of 20 days after germination kept in 8 liter pots with sterilized substrate.

To facilitate nematode infection on the roots, a perforation of approximately 3 cm into the substrate was made near the base of each plant using a glass rod; at this point, the suspension was pipetted. In the first week after inoculation, the plants were irrigated with 50 mL of sterilized distilled water so that the nematode eggs would not be leached by the irrigation. After that, the tomato plants were irrigated for 80 days in a greenhouse until the nematodes multiplied sufficiently to set up the resistance trials.

In order to identify the species of the root-knot nematode, enzymatic characterization of the esterase profile was performed in the Embrapa Temperate Climate Plant Pathology Laboratory - RS through electrophoresis of isoenzymes coming from one of the infected tomato plants, according to the methodology of Carneiro & Almeida (2001). Females of *Meloidogyne javanica* (Treub) Chitwood, 1949 were used as control samples. The esterase profile observed was of a single typical pattern of *M. incognita* (Est I2).

The trial for evaluation of resistance of the coffee genotypes to root-knot nematode was carried out from July to December 2015 in Ji-Paraná, RO, in the experimental field of the Centro Universitário Luterano de Ji-Paraná - CEULJI/ULBRA (10º52'53''S and 61º30'45''W and altitude of 159 meters).

Seedlings of 32 genotypes of *C. canephora* (Table 1) at six months of age were transplanted to 8-liter pots containing sterilized substrate composed of sand, vermiculite, natural soil, and organic compost (1:1:1:1) and arranged on benches in a gable roof greenhouse. Each one of the 32 genotypes of *C. canephora* (Table 1) were inoculated with *M. incognita* represented a treatment using six replications for each clone, which were arranged in a completely randomized design and kept in a greenhouse. Clones of *C. canephora* of the Apoatã cultivar, identified by the numbers "1322", "1326", and "1327", were evaluated as resistant controls. The *C. arabica* IAC Obatã 1669-20 cultivar was used as a susceptible control, as already described for the other inoculated seedlings. Tomato plants cv. Santa Clara at 20 days after germination were also used for this purpose and were grown in 8-L pots with the same substrate cited for the coffee seedlings; they were inoculated at the same time to evaluate the quality of the inoculum and to ensure maintenance of the inoculum for other studies in process.

For inoculation of the *C. canephora* genotypes two weeks after transplanting the seedlings, nematode eggs multiplied on tomato roots were extracted according to Hussey & Barker (1973). Each coffee plant was inoculated separately by irrigation of the substrate in the pot with 10 ml of suspension containing 5,000 eggs + second stage juveniles (J2) of *M. incognita* (Est I2). Tomato plants were evaluated regarding reaction to *M. incognita* (Est I2) at 90 days after inoculation (DAI). The evaluation of coffee plants was at 150 DAI. For this evaluation, the roots of each plant were separated from the shoots, washed, and weighed, and the number of galls were counted. After that, the roots were processed according to the methodology of Hussey & Barker (1973) to determine the number of eggs and the reproduction factor (RF) of *M. incognita* (RF = final population / initial population) in the different genotypes evaluated. To calculate RF, the final population is considered as the total number of nematode eggs extracted from each coffee plant; the number of eggs were counted on a Peter's slide under an optical microscope. The initial population is that which was inoculated (5000 eggs + J2). The treatments that had $RF < 1.00$ were considered resistant, those with $RF = 0.00$ as immune, and those with $RF > 1.00$ as susceptible (OOSTENBRINK, 1966). The RF values were used to classify reaction of the coffee plants to *M. incognita* by the criteria of Seinhorst (1967), in which plants with $RF<1$ are considered poor hosts (PH), with $RF\geq1$ are considered good hosts (GH), and $RF=0$ are considered non-hosts (NH). Susceptibility of the plants was also classified, considering resistant plants as those with scores

1, 2, and 3 and susceptible plants as those with scores 4, 5, and 6, based on criteria modified from SASSER et al. (1984), who classified plants as resistant (R) that had a root system with number of galls less than or equal to 10, whereas those with higher values were considered susceptible (S).

Statistical methods

To quantify the reaction of the genotypes (clones) of *C. canephora* to *M. incognita* (Est I2), the data collected from each variable were interpreted considering the following model:

$$Y_{ij} = u + G_i + e_{ij}$$

in which Y_j = observation of the i-th clone in the j-th replication, u = overall mean, G_i = effect of the i-th clone, and e_j = random error associated with the i-th clone and in the j-th replication. The Scott-Knott test at 5% probability was used to test the equality hypothesis between the means of groups.

The estimates of genotypic, environmental, and phenotypic variance were obtained to quantify the proportion of total variance due to the effects of genotypes and environments (CRUZ, 2016). The genetic parameters, broad sense heritability, genotypic and environmental coefficients of variation, and intraclass correlation were estimated from the variance components. The significant estimates of the Pearson correlation coefficient were used to interpret the association between the reproduction factor (RF) and morphological and productive traits. The statistical analyses were performed using the GENES software (CRUZ, 2016).

3 RESULTS AND DISCUSSION

According to the F test of analysis of variance, the effects of clones, controls, and the contrast of clones vs. control were significant at 1% probability for fresh weight of roots (FWR), number of galls (NG), number of eggs (NE), and reproduction factor (RF) of the *M. incognita* nematode (Table 2).

As expected, the tomato cv. Santa Clara is a very susceptible host to *M. incognita*, exhibiting RF = 31.3 and NG = 731 at 90 DAI. As most *Coffea arabica* cultivars are hosts susceptible to *Meloidogyne* spp. (KANAYAMA et al., 2009), the *C. arabica* cultivar Obatã was considered a good host (GH) of *M. incognita* at 150 DAI, with RF = 1.2 by the classification of Seinhorst (1967) and susceptible (S) by the classification of Sasser (1984), exhibiting a high number of galls (NG = 11). These results furthermore attest to the quality of the inoculum of *M. incognita* (Est I2) used in the coffee plant genotype inoculation trial. In contrast, the three *C. canephora* resistant controls of the Apoatã cultivar were classified as non-hosts (NH) for *M. incognita* (RF = 0), according to the classification of Seinhorst (1967), or as resistant (NG = 0.0, 0.0, and 0.87), according to Sasser (1984), in the evaluations made at 150 DAI. At that time, few gall symptoms among the plants known as resistant were observed, only on clone 1326 (NG = 0.87) (Table 4). Such results confirm the resistance of the cultivar Apoatã which has been used as an alternative in control of root-knot nematodes. The clone Apoatã "IAC 2258" is recommended as rootstock resistant to *Meloidogyne* spp. in São Paulo for planting grafted seedlings in areas infested with the nematodes *M. exigua* and *M. incognita* (Kofoid & White) Chitwood and *M. paranaensis* (RAMALHO et al., 2009). In São Paulo, the mean yield of the ungrafted susceptible genotypes was an average of 55% lower than the yield of the same genotypes grafted on the cv. IAC Apoatã 2258 (BARBOSA et al., 2014).

The characteristics that have the higher coefficients of variation were RF>NG>NE>FWR (Table 3). Santos et al. (2017) evaluated the reaction of the *C. canephora* cultivar 'BRS Ouro Preto' to *M. incognita* (Est I2) and observed an experimental coefficient of variation of 26,94% to the reproduction factor (RF). Santos and Gomes (2011), evaluating the reaction of castor bean cultivars to six species of *Meloidogyne*, observed an experimental coefficient of variation of 36.6% and 47.7% for RF and NG respectively. Although the resistance trials are conducted in a controlled environment, they are biological experiments that are influenced by environment factors. The experimental coefficient of variation of 36.06 for NG and 36.74 for FR are comparable to the estimates obtained in other studies (CONTARATO et al., 2014).

The heritability measures the relative proportion between the genotypic and environmental effects in expression of the resistance (CRUZ, 2016). The heritability estimates of 94,94 for FWR, 96,12 for NG, 97,99 for NE, and 96,78 for RF may be considered high and indicates predominance of the genotypic component in expression of root knot resistance (Table 3). The larger influence of the genotype effect on the expression indicates the genetic progress through plant selection.

TABLE 2 - Results of analyses of variance of the characteristics of fresh weight of roots (FWR), number of galls (NG), number of eggs (NE), and reproduction factor (RF) of the nematode *M. incognita* (Est I2) in 32 genotypes of *Coffea canephora* evaluated at 150 days after inoculation.

SV	DF	FWR	NG	NE	RF
Treatments	36	19.13**	86.42**	146.39**	474.07**
Clones	31	19.78**	25.78**	49.82**	31.05**
Controls	4	11.45**	497.46**	874.40**	3440.66**
Clones vs Control	1	29.72**	177.94**	228.28**	2341.20**
Residue	185				
Total	221				
$Mean_{Overall}$		45.82	37.15	7.89	1.59
$Mean_{Clones}$		47.15	17.81	4.14	0.83
Apoatã 1322[#]		51.51	0.00	0.00	0.00
Apoatã 1326[#]		45.09	0.87	0.00	0.00
Apoatã 1327[#]		42.10	0.00	0.00	0.00
IAC Obatã 1669-20[$]		23.13	11.00	6.00	1.20
Tomato cv. Santa Clara[&]		24.59	791.00	156.67	31.33

[#] resistant cultivar [$] *Coffea arabica* susceptible cultivar; [&] Tomato susceptible cultivar, **:significant at 1% probability.

TABLE 3 - Genetic parameter estimates of fresh weight of the roots (FWR), number of galls (NG), number of eggs (NE), and the reproduction factor (RF) of the nematode *M. incognita* evaluated in 32 genotypes of *C. canephora* of the Conilon and Robusta botanical varieties and interspecific hybrids evaluated at 150 days after inoculation.

Genetic parameter	FWR	NG	NE	RF
σ^2_g	266.06	6.99	1.63	1.70
σ^2_e	14.16	0.28	0.03	0.05
σ^2_p	280.22	7.28	1.66	1.75
h^2	94.94	96.12	97.99	96.78
$\hat{\rho}$	75.79	80.51	89.05	83.35
CV_g	34.59	84.14	81.85	155.62
CV_e	20.11	36.06	25.73	36.74
CV_g/CV_e	1.76	2.03	2.85	2.23

Estimates of the coefficient of genetic variation (CVg) above the coefficient of environmental variation (CVe) characterize a favorable condition to obtain gains with the selection of resistant plants. The CVg/CVe ratio showed an amplitude of 1.76 for FWR and 2.85 for NE indicating that the first trait had higher environmental influence than the first one.

Although *C. canephora* is considered a species more resistant to root-knot nematode, the clones of *C. canephora* 750, 703, 772, 729, 799, 792, 796, 968, and 723 were considered good hosts of *M. incognita*, with levels of susceptibility greater than the *C. arabica* cultivar Obatã susceptible control (Table 4). Therefore, the clones cited above can be used as susceptible comparisons in new trials of reaction of the coffee plant to *M. incognita* (Est I2) in Rondônia. Among these materials, the clone hybrid 750 stood out through its high susceptibility to *M. incognita*, with RF = 5.68.

In contrast, of the 32 genotypes of *C. canephora* evaluated in this experiment, 23 (71%) were poor hosts (PH) of *M. incognita* because at 150 DAI, they had a reproduction factor less than 1 (RF<1) (Table 4). All five clones of the Robusta botanical variety were classified as poor hosts of *M. incognita* (RF<1) at 150 DAI, with a mean reproduction factor of 0.25. These data corroborate other studies involving the resistance of *C. canephora* to *Meloidogyne* spp., especially within accessions of Robusta coffee (BARBOSA et al., 2014).

The intervarietal hybrids, with the exception of clone 750 which was classified as a good host (RF = 5.68), all the others (844, 1005, H56, 169, 657, H54, 453, 120, 193, 535, 482, and 636) were classified as poor hosts (PH), with RF<1 (Table 4). Six genotypes of the Conilon botanical variety (890, 837, 046, 909, 694, and 160) were poor hosts (PH) of *M. incognita* (RF<1) and eight clones of the Conilon botanical variety (703, 772, 729, 799, 792, 796, 968, and 723) were considered good hosts (GH) of *M. incognita* at 150 DAI (RF_{mean} = 1.24) (Table 5).

According to the number of gals (NG), the genotypes characterized as poor hosts (PH) were also classified as resistant (R) (NG<10), except for the clones 1005 (NG = 12.16) and 657 (NG = 13.5), that were classified as susceptible (SASSER, 1984). Concerning the genotypes classified as good hosts (GH) to the nematode (RF>1), only clone 797 of Conilon coffee was considered resistant (NG = 8.6) (Table 4). According to Amorim et al. (2011), the presence of galls is one of the symptomatological aspects of the disease, and plant resistance refers to its capacity to supress multiplication of the pathogen. Evaluation of the presence and of the number of galls alone should not be considered in evaluation of resistance because resistant plants can form galls in the presence of few nematodes and susceptible plants might not produce galls. Santos et al., 2017, evaluating the resistance of *C. canephora* to *M. incognita* (Est I2), found that part of the clones considered resistant (RF<1) responded as susceptible when considering only the number of galls. This suggests that although the nematode induces formation of galls in *Coffea* spp., few were reproduced in the clones evaluated.

Of the nine clones classified as good hosts (GH) of *M. incognita* at 150 DAI, except for genotypes 750 and 796, which had reduced fresh weight of roots (FWR), the seven remaining clones of Conilon coffee 703, 772, 729, 799, 792, 968, and 723 had FWR results similar or superior to the resistant controls of cv. Apoatã (var. Robusta) (Table 4). Although these genotypes allowed multiplication of the nematode (RF>1), there was not significant damage in their roots compared to the Apoatã controls (resistant), which have a voluminous root system (PAIVA et al., 2012). However, tolerance to damage may be separate from resistance because it refers to the ability of a given host plant to compensate or recover from adverse effects of attack from a determined nematode and, nevertheless, produce well (VANSTONE et al., 2008).

Of the 23 clones considered poor hosts (PH) of *M. incognita*, only seven (844, 1005, H54, 837, 909, 193, and 694) exhibited FWR lower than the plants of the resistant control Apoatã (Table 4). DAMATTA et al. (2007) report that selecting clones with a more voluminous root system may be successful to develop resistant cultivars, because this is a trait favorable to rootstock cultivars. Resistance of the *C. canephora* Apoatã cultivar is associated with its vigorous root system (BARBOSA, et al., 2014, VILLAIN et al., 2010). The hypersensitivity reaction and impediment to the formation of giant cells is the resistance mechanism most accepted for explaining the incompatibility of the coffee plant to the root-knot nematode (LIMA et al., 2015; SILVA et al., 2013).

The Conilon and Robusta botanical varieties and their interspecific hybrids exhibited significant differences in estimates of RF. The Robusta botanical variety exhibited higher resistance ($RF_{(Robusta)}$= 1.24) than the intervarietal hybrids ($RF_{(Hybrids)}$= 0.63) and the Conilon botanical variety ($RF_{(Conilon)}$= 0.16) (Table 5).

TABLE 4 - Means of fresh weight of roots (FWR), number of galls (NG), number of eggs (NE), and reproduction factor (RF) of the root-knot nematode *M. incognita* (Est I2) in coffee plant genotypes (*C. canephora*) obtained at 150 days after inoculation with 5000 nematode eggs.

Genotype	Botanical Variety	FWR	NG	C	NE[1]	RF	C
750	H	25.71d	130.06a	S	28.40a	5.68a	GH
703	C	69.86a	79.00b	S	22.71b	4.53b	GH
772	C	43.48c	63.33b	S	14.46c	2.90c	GH
729	C	68.35a	73.3b	S	11.4c	2.28c	GH
799	C	55.25b	13.17c	S	7.87d	1.58d	GH
792	C	69.7a	63.83b	S	7.53d	1.53d	GH
796	C	31.12d	8.60c	R	6.13d	1.23d	GH
968	C	69.16a	14.60c	S	6.11d	1.21d	GH
723	C	69.48a	19.33c	S	5.91d	1.20d	GH
844	H	32.15d	2.00d	R	2.33e	0.47e	PH
1111	R[2]	41.36c	2.33d	R	2.15e	0.45e	PH
1005	H	31.43d	12.16c	S	1.50e	0.30e	PH
8102	R	64.75a	1.50d	R	1.33e	0.27e	PH
H56	H	69.66a	5.00c	R	1.28e	0.26e	PH
169	H	59.08b	7.33c	R	1.26e	0.25e	PH
657	H	40.08c	13.50c	S	1.21e	0.25e	PH
H54	H	25.53d	5.83c	R	1.10e	0.23e	PH
8192	R	61.2a	0.66d	R	1.03e	0.23e	PH
453	H	63.82a	1.83d	R	1.00e	0.20e	PH
120	H	35.46c	6.83c	R	0.95e	0.20e	PH
890	C	51.31b	3.16d	R	0.86e	0.18e	PH
10141	R	50.45b	1.66d	R	0.85f	0.18e	PH
837	C	26.78d	8.20c	R	0.81f	0.18e	PH
46	C	46.85c	2.6d	R	0.78f	0.15e	PH
909	C	27.48d	4.33d	R	0.71f	0.15e	PH
8152	R	66.28a	2.50d	R	0.60f	0.13e	PH
193	H	18.98d	5.20c	R	0.51f	0.11e	PH
694	C	22.36d	8.20c	R	0.48f	0.10e	PH
160	C	53.15b	2.80d	R	0.38f	0.10e	PH
535	H	43.08c	1.66d	R	0.36f	0.08e	PH
482	H	35.63c	2.33d	R	0.31f	0.08e	PH
636	H	39.95c	3.16d	R	0.26f	0.06e	PH
Apoatã 1322	R	51.51b	0.00e	R	0.00g	0.00f	NH
Apoatã 1326	R	45.08c	0.87e	R	0.00g	0.00f	NH
Apoatã 1327	R	42.10c	0.00e	R	0.00d	0.00d	NH
Obatã 1669-20	-	23.10d	11.00c	S	6.00d	1.20d	GH
TomatoSta.Cruz	-	24.60	791.00	S	156.7	31.30	GH

[a, b, c:] Means classified according to the Scott-Knott test at 5% probability, R = resistant and S = susceptible according to Sasser et al. (1984); [2] NH = non host; PH = poor host, and GH = good host, according to Seinhorst

TABLE 5 - Estimates of correlation between the reproduction factor (RF) of *Meloidogyne incognita* (Est I2) and eleven morphological and productive traits of Conilon and Robusta botanical varieties and their intervarietal hybrids, belonging to the Germplasm Bank of Embrapa Rondônia, Brazil.

Variables	Correlation
PHt x RF	-0.25^{NS}
NPLAG x RF	0.04^{NS}
NROS x RF	-0.08^{NS}
LPLAG x RF	-0.32*
DROS x RF	-0.08^{NS}
BROS x RF	-0.33*
NDAYS x RF	-0.25^{NS}
GVprod x RF	-0.05^{NS}
LL x RF	-0.24^{NS}
WL x RF	-0.36*
SIEV x RF	-0.34*
Mean RF $_{(Robusta)}$	1.24^{a}
Mean RF $_{(Hybrids)}$	0.63^{b}
Mean RF $_{(Conilon)}$	0.16^{c}

NS: not significant, *: significant at 5% probability, $^{a, b, c:}$ Means classified according to the Scott-Knott test at 5% probability. PHt = plant height, NPLAG = number of productive plagiotropic branches, DROS = distance between rosettes of the plagiotropic branch, BROS = number of coffee beans per rosette of the intermediate part of the plagiotropic branch, NROS = number of rosettes per plagiotropic branch, LPLAG = length of plagiotropic branch, LL, WL = length and width of leaves, NDAYS = number of days for fruit ripening, SIEVE = coffee bean size, GVProd = genotypic value of production.

The larger leaf size, larger bean size, longer plagiotropic branches, and greater number of beans per rosette were inversely associated with the resistance factor (Table 5). These are typical traits of the Robusta botanical variety that corroborates the higher resistance of this germplasm. Important traits such as the coffee bean yield did not present significant correlation with resistance to nematodes.

In Brazil, the Robusta variety, represented by the cultivar Apoatã IAC 2258 (*C. canephora* cv. 2.258 from the CATIE germplasm collection, Turrialba, Costa Rica) is one of the most used as rootstock resistant to *Meloidogyne* for the purpose of planting in infested areas. In Central America, the “Nemaya” cultivar, derived from the cross between the clones of *C. canephora* T3561 and T3751, has allowed the survival and competitiveness of coffee growing in regions infested by *Meloidogyne* (ANTHONY et al., 2007). Both cultivars are derived from the clone T3561 and exhibit multiple resistance to *M. exigua*, *M. incognita*, and *M. paranaenses* (LIMA et al., 2015).

These *C. canephora* genotypes resistant to *M. incognita* selected in this study can constitute sources of resistance for development of Conilon coffee cultivars with superior traits adapted to the soil and climate conditions of Rondônia.

4 CONCLUSIONS

At 150 DAI, the *C. canephora* clones of the Conilon botanical variety 694, 160, 837, 46, 909, and 890 and the hybrid materials 844, 1005, 169, 54, 453, 120, 193, and 636, all considered as having an early cycle and fruit maturation, respond as resistant to *M. incognita* and can be used in plant breeding programs for the purpose of obtaining early cycle coffee cultivars that are resistant to this nematode in Rondônia. The five clones of *C. canephora* of the Robusta botanical variety 1111, 8152, 8192, 10141, and 8152 were confirmed as resistant to *M. incognita*. The clones Apoatã 1322, Apoatã 1326, and Apoatã 1327 belonging to the Robusta botanical variety were confirmed as immune (non-hosts) of *M. incognita* and can be used as rootstock, with a view toward planting in infested areas and as sources of resistance to *M. incognita*.

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THE PROFILE OF SMALL COFFEE PRODUCERS IN THE SOUTH OF MINAS GERAIS, BRAZIL

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ABSTRACT. Highly appreciated by all people worldwide, coffee is a commodity with great economical weight in Brazil. While underscoring analyses on coffee production by the scientific community, current assay deals with the profile of coffee producers in the rural regions of the towns Machado, Poço Fundo and others in the south of the state of Minas Gerais, Brazil. Field work with 225 small producers of the region comprised questionnaires which were analyzed and grouped statistically in discriminating clusters. The correlation of variables was assessed by Pearson´s methodology. Results show that schooling level had a positive correlation with regard to the adequate use of fertilizers and insecticides. Higher schooling level provided greater knowledge on normalizations and correct soil management.

Index terms: Soil management, producers´ schooling level, normalizations.

ANÁLISE DO PERFIL DOS PEQUENOS PRODUTORES DE CAFÉ DO SUL DE MINAS GERAIS

RESUMO: O café, produto muito apreciado e valorizado em todo o mundo, se destaca como uma *commodity* de grande representatividade econômica no Brasil. Considerando todo o destaque apresentado pela comunidade cientifica a produção de café, este trabalho objetiva apresentar o perfil dos produtores de café das regiões rurais das cidades de Machado, Poço Fundo e circunvizinhanças, localizadas no sul do estado de Minas Gerais. O trabalho se desenvolveu por meio de pesquisa de campo com 225 pequenos produtores da região estudada. Os questionários foram analisados e agrupados estatisticamente em clusters descriminantes. Avaliamos a correlação das variáveis segundo a metodologia de Pearson. Dentro do ambiente avaliado identificamos que o nível escolar apresentado pela amostra obteve uma correlação positiva quanto ao uso adequado dos defensivos. O grau de instrução propiciou, também, maior conhecimento de normatizações e no manejo correto da lavoura.

Termos para Indexação: Manejo da lavoura, nível escolar do produtor, normatizações.

1 INTRODUCTION

Food production receives huge investments yearly since industrialized and natural foods are constantly on demand. Consequently, several producers and entrepreneurs exert all efforts to warrant supply with reasonable quality standard (LIMA et al., 2016). The coffee market follows suite and actually the southern region of the state of Minas Gerais, Brazil, concentrates a type of coffee production attending to international quality parameters (RAMOS et al., 2016).In fact, the coffee market supplements the great agriculture market believed to be one of the most important props in Brazilian economy (BARRA; LADEIRA, 2016).

The southern region of the state of Minas Gerais, especially that which comprises the rural area of the towns Machado, Poço Fundo and neighboring areas, is highly suitable for coffee culture. In fact, most coffee producers (small-size farmers) in the region earn their living on coffee plantations (FREDERICO, 2013; FREDERICO; BARONE, 2015; VILELA; RUFINO, 2010).

Owing to technological progress demanded in the supply of the world market, several small farmers, in contrast to big producers, have been greatly impaired because of low investments in the application of technologies. The employment of several types of mechanization, differentiated managements and other technologies for harvesting and processing the product positively impacts production costs by decreasing them and by guaranteeing profit increase (MARQUES; CRIPA; MARTINEZ, 2013; SANTINATO et al., 2016; XIA et al., 2015).

Pest control in coffee production is another item to boost financial profitability. Several pest types decrease or even destroy whole plantations (PRADO et al., 2016). On the other

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hand, inadequate control reduces the efficacy of the pesticide. Taking into consideration several scenarios and working with correct variables, control may be executed without any chemical pesticides (LOPES et al., 2012; PRADO et al., 2016). In fact, several issues may affect the product´s quality and profits (ALVES et al., 2013; LOPES et al., 2012).

Inadequate management in the use of pesticides seems to derive from deficiency in knowledge and lack of instruction. Pesticides generally are a great risk to user´s health (DAMALAS; ABDOLLAHZADEH, 2016) and their management demands the mandatory use of personal protective equipment (PPE) to protect users. It is known that lack of information makes farm workers discard PPEs, with great risks for themselves and their family (ABREU; ALONZO, 2016; ZORZETTI et al., 2014).

Environment and health concern are high in a demanding market. It has been estimated that in 2030 the population increase of more than three billion middle class consumers will increase quality food demand, or rather, food that attends to specific requirements in their production (BOLTON; ARONOW, 2009).Further, several developed normalizations try to solve the requirements of the production process to meet the demands of such activities (BRASIL, 2005).

Current assay analyzes the profile of small coffee producers in the town of Machado, Poço Fundo and neighboring areas with regard to market advances and regulations to be complied with.

2 MATERIALS AND METHODS

Field work was based on a previously conducted bibliographical survey which identified relevant themes for the preparation of a questionnaire employed in the survey for data (GIL, 2017).Questionnaire, comprising 22 open and closed questions, was analyzed by the Ethics Committee of UNIFENAS (Universidade José do Rosário Vellano) and approved (Protocol 62778216.8.0000.5143) Considerations on data were compared to demands of the Regulation Norms for Safety and Health on Work, Agriculture, Cattle Breeding, Forestry and Aquiculture (NR31) (BRASIL, 2005).

After the above evaluation, the geographical area was delimited for current analysis. The region comprised the southern area of the state of Minas Gerais, Brazil, featuring the towns and cities of Alfenas, Andradas, Bandeira do Sul, Boa Esperança, Botelhos, Cabo Verde, Campestre, Carvalhópolis, Guaxupé, Jacutinga, Machado, Nepomuceno, Paraguaçu, Poço Fundo, Poços de Caldas, São João da Mata, Silvianópolis and Turvolândia (Figure 1). and cities where farms were assessed.

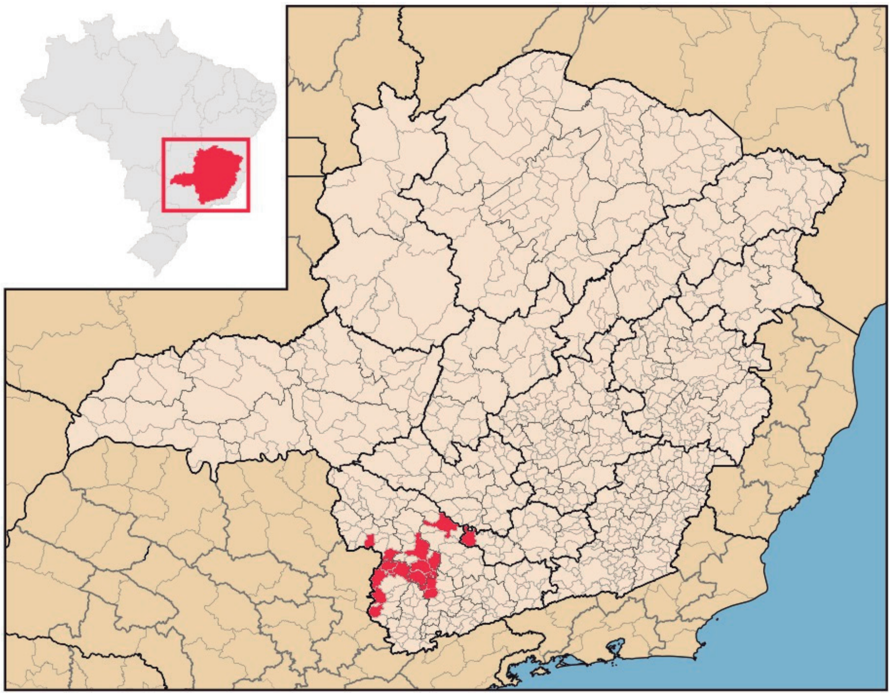

FIGURE 1- Map of Minas Gerais, Brazil, with town.

Analysis of discriminating cluster

Cluster analysis grouped sample themes in distinct groups so that each group would have the most similar items. Let each sample item j have a measurement vector Xj, with p = stored variables (MINGOTI, 2013).

$$X_j = \left[X_{1j}, X_{2j}, \dots X_{pj}\right] j = 1,2,3, \dots n$$

where, X_{1j} is the value of variable i measured in the sample item j. Data transformation is required according to Euclidian measurements (MINGOTI, 2013).Current research employed K-means hierarchical technique based on Krebs(1999)and Souza & Souza (2006).

Correlation analysis

Pearson´s correlation analysis, indicating positive or negative between two variables, was employed to investigate the relationship of the variables, at a significance rate of 5%.

3 RESULTS AND DISCUSSION

Analyses were performed from four different perspectives so that data could be clearly provided, or rather, independent initial analysis of the variables; Pearson´s correlation analysis; analyses of data classes; cluster analyses. Further, 225 responses were given.

INITIAL DATA ANALYSIS

Producer

Producers were characterized by age bracket, schooling level and technical formation in agriculture. Sample revealed that 32.44% of producers were over 54 years old; 16.44% were between 36 and 41 years old; 14.67% were between 42 and 47 years old; 13.33% were between 30 and 35 years old; 12.45% were between 48 and 53 years old; 10.67% were below 29 years old. It is highly significant to note the high percentage of farmers over 54 years old. The latter have already experienced different market changes, among which feature changes in regulations of coffee producing market (RAMOS et al., 2016).

In the case of schooling level, 47.56%of coffee producers received only basic schooling; 28% had a high school certificate; 14.22% had an undergraduate course; 10.22% had a postgraduate course. High rates in low schooling level according to age bracket indicate that they had to cope with difficulties during their schooling period. Small farmers normally involve all their family in the coffee plantation. Siblings in the labor force have little time for studies and education (FREDERICO; BARONE, 2015).

In the case of technical training in agriculture, 66.22% did not have the required formation in agriculture, whilst 33.78% had some sort of capacity. A highly relevant item is an in-depth knowledge in the area which is crucial for decision-taking. Among the several activities developed on the farm, the administrator´s decisions are relevant since they may define success or failure (BINOTTO; NAKAYAMA; SIQUEIRA, 2013).

Farm

The farms under analysis may be classified according to size, employment of external consulting board by the producer, connection with the internet, pest monitoring and its frequency. In fact, 44.44% of farms were over 9ha; 25.33% were between 3 and 6 ha; 17.33% were between 1 and 3ha; 12.9% were between 6 and 9ha.Each and every municipality has a Fiscal Module determining the farm´s category, namely, small, average and big. All farms under analysis were classified as "small" since they failed to comply with the four fiscal modules(INCRA, 2013).

Further, 53.78% of interviewed had resorted to specialized consulting service. As a rule, the region´s Cooperatives or the Technical Assistance and Rural Extension (EMATER – MG) make available any information required by the farmers. This activity is a great asset for the region´s farmers.

Further, 51.56% of farmers are not connected to the Internet, but 48.44% are. Due to technological progress, their number tends to increase. The Internet is a highly relevant tool for harvesting information for decision taking, such as market prices, temperature, past rainfall indexes, weather forecasts and others.

Further, 81% of farms periodically monitor pests. However, 16% do not undertake pest monitoring and 3% failed to answer this issue. Pest control is crucial since an infestation index above 30% requires urgent mitigation actions to avoid loss of the coffee harvest (DE SOUZA et al., 2014; PRADO; DORNELES JUNIOR, 2015). Moreover, 50% of farmers who monitored the crops stated that they did so every 3 to 6 months; 28% assessed the farm every 30 days; 21% once a year; 1% did not address this issue. Although there was a high monitor index, the 3 - 6 month option was not a good decision since, in case of pest infestation, the more rapid its identification, the more effective would be its control (DE SOUZA et al., 2014; PRADO et al., 2016; PRADO; DORNELES JUNIOR, 2015).

Work safety

Farm administration, especially the use of pesticides and fertilizers, requires specialized care and precaution. In fact, 72.89% of interviewed people use PPEs when applying pesticides; 13% did not answer the question; 10.22% occasionally used PPEs and 3.56% admitted not using PPE. In spite of the great number of people using PPEs, the 13% who failed to address the issue may not represent the truth. Following the farmers ´schooling level, the farmers´ conscience-awareness on the use of chemical products is still mandatory and relevant (DAMALAS; ABDOLLAHZADEH, 2016). Moreover, 82.22% stated that they never had any intoxication problem when they employed pesticides and fertilizers; 11.11% did not reply; only 2.67% reported some type of intoxication.

When the farmers were asked about disposal of empty pesticide packages, 83.11% answered they returned pesticide packages; 15.11% failed to answer the question; only 1.78% stated that did not return discarded packages. The latter category replied that they did not do so owing to forgetfulness and the reuse of packages on the farm. According to Brazilian legislation, return of empty packages is mandatory and instructions on the place of disposal are available at the buying outlet (BRASIL, 2005).

Knowledge on legislation, such as NR 31, was demanded. Results showed that 58.22% replied they knew the norm; 37.78% said they did not know its contents; 4% did not answer the question. The great number of people who were ignorant of the norm is a warning due to the co-relationship between knowledge and other items mentioned in the research given below.

RELATIONSHIP BETWEEN VARIABLES

Analysis following Pearson´s co-relationship methodology was undertaken (Tabela 1).

Knowledge on NR 31

Variable Agricultural Formation and Knowledge of Norm had a positive co-relationship ($r = 0.215; p < 0.001$). Result revealed that capacity level in agriculture is relevant to enhance knowledge and the possible application of the norm. Technical knowledge is important to foreground decision taking and actions on the farm (BINOTTO; NAKAYAMA; SIQUEIRA, 2013).

Within the context of producers´ information with regard to NR 31, there was a positive co-relation ($r = 0.255$; $p = 0.05$) with Access to the Internet and consequently with the application of specific activities, such as frequency in crop monitoring by farmers ($r = 0.159$; $p = 0.05$). According to the above data, pest monitoring was positively co-related ($r = 0.215$; $p = 0.05$) with proper dosage in pesticide application and the use of PPEs in the process ($r = 0.135$; $p = 0.05$).Data may be highlighted through the visualization of the negative co-relation between the knowledge of the norm ($r = 0.152$; $p = 0.05$) and the use of proper doses ($r = 0.219$; $p = 0.05$).

Farm size

With regard to the size of the farms analyzed, it has been perceived that increase in the farm´s size means a decrease in pest monitoring ($r = -0.164$; $p = 0.05$) and its frequency ($r = -0.229$, $p = 0.05$). Increase in farm size makes difficult the monitoring process, even though pest risk become greater since they occur on all farms (VILELA; RUFINO, 2010).

ANALYSIS OF CLASSES

Based on data harvested from the questionnaires answered by coffee producers in the south of the Minas Gerais state, the farmers´ profile was analyzed and results were classified into four classes.

Class 1: twenty-five coffee producers, aged between 36 and 41 years old, had basic education; they lacked agricultural training; they adopted tradition cultivation; they did not have any hired workers on their farms; they had automated harvest, coffee washer and drier, and coffee pulping machine; they monitored the crop between three and six months; they used PPEs and the recommended pesticide dosages; they applied the pesticide manually; they did not have any intoxication problems and returned the empty pesticide packages to the manufacturer.

TABELA 1 - Matrix of Pearson´s correlation with regard to the questions forwarded.

	Age	Area	Schooling	Agricultural Training	Consulting Service	Access to Internet	Crop System	Hired workers	Automated harvest	Coffee Drier	Coffee washer	Coffee Pulper	Pest Monitoring	Frequency of Monitoring	Recommended Dosage	Form of Application	PPEs usage	Intoxication Problem	Package return	Knowledge on NR31
Age	1	0,129	-0,109	0,186	-0,032	0,230	0,159	0,054	-0,066	0,101	0,019	-0,068	0,020	0,066	0,080	0,037	-0,042	-0,086	-0,012	0,070
Area	0,129	1	0,301	-0,055	-0,098	-0,083	0,055	0,463	-0,007	-0,360	-0,467	-0,203	-0,164	-0,229	-0,016	-0,073	0,030	-0,012	-0,081	-0,080
Schooling	-0,109	0,301	1	-0,438	-0,032	-0,142	0,028	0,463	-0,143	-0,192	-0,239	-0,194	-0,199	-0,157	0,009	-0,005	-0,015	0,065	-0,024	-0,131
Agricultural Training	0,186	-0,055	-0,438	1	-0,035	0,173	-0,080	-0,175	0,116	0,052	0,101	-0,003	0,110	-0,004	0,024	0,084	-0,024	-0,003	0,028	0,215
Consulting Service	-0,032	-0,098	-0,032	-0,035	1	0,114	0,089	-0,051	0,002	0,183	0,150	0,105	0,099	0,130	0,051	0,077	0,063	-0,056	0,076	0,127
Access to Internet	0,230	-0,083	-0,142	0,173	0,114	1	0,034	-0,098	0,017	0,144	0,107	0,062	0,050	0,057	-0,007	0,010	0,026	-0,103	-0,007	0,255
Crop System	0,159	0,055	0,028	-0,080	0,089	0,034	1	0,047	-0,075	0,002	-0,063	-0,030	-0,182	0,024	0,000	-0,045	-0,058	-0,145	-0,148	-0,037
Hired workers	0,054	0,463	0,463	-0,175	-0,051	-0,098	0,047	1	-0,303	-0,310	-0,420	-0,305	-0,168	-0,144	-0,019	-0,029	0,038	0,045	-0,014	-0,129
Automated harvest	-0,066	-0,007	-0,143	0,116	0,002	0,017	-0,075	-0,303	1	0,120	0,212	0,200	0,119	0,103	0,077	0,074	0,007	0,044	0,069	0,196
Coffee Drier	0,101	-0,360	-0,192	0,052	0,183	0,144	0,002	-0,310	0,120	1	0,495	0,233	-0,013	0,201	0,110	0,109	-0,025	-0,187	0,162	0,217
Coffee washer	0,019	-0,467	-0,239	0,101	0,150	0,107	-0,063	-0,420	0,212	0,495	1	0,394	0,090	0,122	0,033	0,180	-0,017	-0,117	0,100	0,212
Coffee Pulper	-0,068	-0,203	-0,194	-0,003	0,105	0,062	-0,030	-0,305	0,200	0,233	0,394	1	0,122	0,170	0,053	-0,133	0,057	-0,050	0,042	0,070
Pest Monitoring	0,020	-0,164	-0,199	0,110	0,099	0,050	-0,182	-0,168	0,119	-0,013	0,090	0,122	1	0,000	0,215	0,015	0,135	-0,085	0,134	0,116
Frequency of Monitoring	0,066	-0,229	-0,157	-0,004	0,130	0,057	0,024	-0,144	0,103	0,201	0,122	0,170	0,000	1	-0,017	0,081	-0,057	-0,054	0,113	0,159
Recommended Dosage	0,080	-0,016	0,009	0,024	0,051	-0,007	0,000	-0,019	0,077	0,110	0,033	0,053	0,215	-0,017	1	-0,047	0,020	-0,219	0,136	0,070
Form of Application	0,037	-0,073	-0,005	0,084	0,077	0,010	-0,045	-0,029	0,074	0,109	0,180	-0,133	0,015	0,081	-0,047	1	-0,025	-0,032	0,024	0,087
PPEs usage	-0,042	0,030	-0,015	-0,024	0,063	0,026	-0,058	0,038	0,007	-0,025	-0,017	0,057	0,135	-0,057	0,020	-0,025	1	0,020	0,154	0,041
Intoxication Problem	-0,086	-0,012	0,065	-0,003	-0,056	-0,103	-0,145	0,045	0,044	-0,187	-0,117	-0,050	-0,085	-0,054	-0,219	-0,032	0,020	1	0,027	-0,152
Package return	-0,012	-0,081	-0,024	0,028	0,076	-0,007	-0,148	-0,014	0,069	0,162	0,100	0,042	0,134	0,113	0,136	0,024	0,154	0,027	1	0,059
Knowledge on NR31	0,070	-0,080	-0,131	0,215	0,127	0,255	-0,037	-0,129	0,196	0,217	0,212	0,070	0,116	0,159	0,070	0,087	0,041	-0,152	0,059	1

* Rates in bold are different from zero, with a significance level of 0.05.

Class 2: fifteen coffee producers, aged between 30 and 35 years old, are the owners of farms over 9 ha; they had agricultural training and access to the Internet; they had automated harvest, coffee washer and drier and coffee pulping machine; they monitored the crop between three and six months; they used PPEs and the recommended pesticide dosages; they applied the pesticide manually; they did not have any intoxication problems and returned the empty pesticide packages to the manufacturer and were aware of NR.31.

Class 3: Twenty-four coffee producers, aged over 54 years old, were the owners of farms over 9 ha; they had basic education, employed specialized consulting service, but did not have access to the Internet; they did not have any hired workers; they had automated harvest, coffee washer and drier and coffee pulping machine; they monitored the crop every 30 days; they used PPEs and the recommended pesticide dosages; they applied the pesticide manually; they did not have any intoxication problems and returned the empty pesticide packages to the manufacturer and were unaware of NR.31.

Class 4: Twenty coffee producers, aged over 54 years old, were the owners of farms over 9 ha; they had a university degree, but no agricultural training; they had specialized consulting service and access to the Internet; they adopted conventional coffee cultivation and automated harvest and coffee pulping machine; they monitored the crop between three and six months; they used PPEs and the recommended pesticide dosages; they did not have any intoxication problems and returned the empty pesticide packages to the manufacturer and were aware of NR.31.

Analyses revealed the importance of basic education of the farmer for an in-depth knowledge of important normalizations. Based on low schooling levels, only older producers had any knowledge on the norm, perhaps due to experience.

ANALYSIS OF CLUSTERS

Group 1

Group 1 group comprised area, cultivation system, application of pesticide, intoxication issue. Farms with the biggest area cultivate conventional coffee which is the most cultivated crop in Brazil, according to Lopes *et al*. (2012). Farms with more than 9ha have 72.89% of interviewed using PPEs recommended during the application of pesticides. In fact, due to the above, 86.22% never suffered intoxication in the application of pesticides.

Group 2

The second group comprised schooling level, agricultural training, access to the Internet, knowledge on NR.31. The group was made up of 47.56% of the interviewed persons who have basic schooling; 66.22% with no agricultural training and 51.56% without access to the Internet. Binotto, Nakayama e Siqueira (2013) underscores knowledge to administer and be successful on the farm. In spite of lacking schooling and access to the Internet, 58.22% have knowledge on NR.31. This fact may be a reflection of communication with such institutions as Cooperatives and Emater. Although the institutions´ conscience-raising is highly relevant, it is still a warning of lack of farmer´s autonomy with regard to the farm´s administration tasks.

Group 3

The third group comprises Consulting Service and Monitoring frequency. Since Cooperatives and Emater provide free consulting service, 53.78% of interviewed producers have access to consultations and 81% monitor their crops for at least 3 to 6 months. According to Prado, Dorneles Junior (2015), monitoring is crucial: if pests reach 30% of the crop, urgent measures should be taken to avoid total loss of the coffee harvest(DE SOUZA et al., 2014; PRADO et al., 2016).

Grupo 4

The fourth group comprises hired workers, automated harvest, coffee drier, coffee washer, coffee pulping, pest monitoring, recommend dosage, use of PPEs and return of packaging. In a globalized world, technology is systematically progressing, with more machines and less workers, corroborated by current research. In fact, 71.56% of farms do not hire any workers and percentage in technology is high, although farms are small. The most important technology was the coffee drier found in 56.89% of farms, followed by the coffee washer with 31.56%, automated harvest with 22.22% and coffee pulping with 6.67%.

Further, 81% of the interviewed producers in the group monitor pests; 71.56% use the recommended pesticide dose; 72.89% use PPEs during applications; 83.11% return empty packages to manufacturer. The above reveals that producers who appreciate technology are also aware of the norms that should be complied with so that they could have a satisfactory financial return within the coffee production process.

4 CONCLUSION

Results reveal the importance of capacity of personnel in good practices in crop management. The higher the schooling level and specific capacity, the greater is knowledge on norms and consequently the implementation of adequate methodologies and the use of the required pesticides. Mechanization and speed generated by automation caused an increase in the monitoring index of crops.

The importance of specialized consulting services given by local cooperatives or regional offices should be underscored. In fact, the service establishes an equilibrium since it makes producers with low schooling level adopt the recommended good practices on their farm.

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INTERACTION OF K AND B IN THE INTENSITY OF COFFEE RUST IN NUTRIENT SOLUTION

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ABSTRACT: This study aimed at assessing the interaction of potassium (K) and boron (B) in the coffee rust intensity in a nutrient solution. The experiment which was performed in a greenhouse was set up in the randomized complete block design (DBC) with four replicates. The experimental unit involved a single vase with two *Catuaí Vermelho* (IAC 144) cultivars. The treatments included five doses of boron (0.05, 0.50, 1, 2 and 4 mg L^{-1}) and five of potassium (4.0, 5.0, 6.0, 7.0 and 8.0 mmol L^{-1}), totaling to 25 treatments in a factorial variance analysis. All the coffee seedling leaves were inoculated with *Hemileia vastatrix*. For the next 24 hours, the vases were covered with a black plastic bag, and left in the greenhouse to ensure favorable conditions for the fungal infection. A significant interaction was observed between the potassium (K) and boron (B) nutrients in coffee rust intensity. As the boron dose increased from 0.05 to 2.0 mg L^{-1}, the coffee rust intensity was observed to rise. From the 0.50 mg L^{-1} dose of B a drastic drop in the dry plant mass was observed, which reached zero index at the highest boron dose due to phytotoxicity.

Index terms: *Hemileia vastatrix*, plant nutrition, potassium, boron.

INTERAÇÃO DO K E DO B NA INTENSIDADE DA FERRUGEM DO CAFEEIRO EM SOLUÇÃO NUTRITIVA

RESUMO: Objetivou-se avaliar a interação do potássio (K) e do boro (B) na intensidade da ferrugem do cafeeiro em solução nutritiva. O experimento foi realizado em casa de vegetação. O delineamento experimental foi em blocos casualizados (DBC), com 4 repetições, sendo a unidade experimental constituída por um vaso, com duas mudas do cultivar Catuaí Vermelho (IAC 144). Os tratamentos consistiram de cinco doses de boro (0,05; 0,50; 1; 2 e 4 mg L^{-1}) e cinco doses de potássio (4,0; 5,0; 6,0; 7,0 e 8,0 mmol L^{-1}), totalizando 25 tratamentos em esquema fatorial de análise de variância. A inoculação foi realizada em todas as folhas das mudas de cafeeiro até o ponto de escorrimento. Posteriormente, os vasos foram cobertos com saco plástico preto por 24 horas, permanecendo na casa de vegetação com o objetivo de proporcionar condições adequadas para o fungo penetrar e iniciar o processo de infecção. Ocorreu interação significativa entre os nutrientes potássio (K) e boro (B) na intensidade da ferrugem do cafeeiro. A partir da dose de 0,05 até 2,0 mg L^{-1} de B foi observado aumento da intensidade da ferrugem do cafeeiro. A partir da dose 0,50 mg L^{-1} de B houve redução drástica da massa da planta seca, atingindo índice zero na maior dose de B, devido a fitotoxidez.

Termos para indexação: *Hemileia vastatrix,* nutrição de plantas, potássio, boro.

1 INTRODUCTION

Over the last 10 years in Brazil, the gross domestic product (GDP) revealed variations in responses to the economic moment. In light of this fact, agribusiness clearly emerged as the principal support of the economy and accounted for good outcomes in the trade balance. Coffee ranks high among the main agribusiness crops. The production for the 2016/2017 harvest was estimated at 45,5 million bags, with the southern state of Minas Gerais being the highest producing region, accounting for around 29% of the national production (CONAB, 2016). However, diseases are some of the main factors that reduce coffee productivity and the beverage quality. Coffee rust (*Hemileia vastatrix*, Berkeley & Broome) is one of the plant pathogens that causes up to 50% production loss.

Under field conditions however, the disease may vary in intensity based on the method of crop management, pending crop load, irrigation system, soil fertility, and mineral nutrition provided to the plants (LIMA et al., 2010; CUSTÓDIO et al., 2011). When the water, soil fertility and plant mineral nutrition are managed well and balanced accurately, it can be a complementary or alternative means of minimizing and managing diseases, as they play a crucial role in producing resistance barriers against disease (CARRE-MISSIO et al., 2009; PINHEIRO et al., 2011; DORNELAS et al., 2015; PEREZ et al., 2017), and the effect of the phytopathogenic activity of the plant.

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Potassium (K) and boron (B) are the important minerals that affect plant metabolism. Potassium is mainly responsible for the development of the root, controls the turgidity of plants, the transport of sugars and helps in the formation of enzymes and proteins (TAIZ & ZEIGER, 2013; PERDIGÃO et al., 2010). B influences the metabolism of phenols and ribonucleic acid (RNA), translocation of sugars, gibberellic acid activity and amylase action. Besides, the K is vital to cell wall structure, lignification and maintenance of higher stability of the plasma membrane, as well as lowers the extravasation of the K, sugars and amino acids, thus contributing towards a reduction in the intensity of diseases (DORDAS, 2008; MARSCHNER, 2012). In coffee, Carvalho et al., (1996) noted a higher incidence of rust at low N and K concentrations. In the case of nutrient B, no significant difference was reported for coffee rust. However, DORDAS (2008) and MARSCHNER (2012) recorded that the deficiency of B interfered with the incidence of diseases.

Then, this study aimed at evaluating the effect of the K and B nutrients on the intensity of coffee rust in nutrient solution.

2 MATERIAL AND METHODS

Employing the randomized complete block design (DBC) for the experiments, four replicates were done. Each experimental unit was a single vase with two plants. A total of 25 treatments were done, involving five doses of B (0.05, 0.50, 1, 2 and 4 mg L^{-1}) combined in a factorial analysis of variance with five doses of K (4.0, 5.0, 6.0, 7.0 and 8.0 mmol L^{-1}). Under greenhouse conditions, the mean temperature and relative humidity were maintained at 21 ° C and 78%, respectively, during the time of the experiments.

To prepare the seedlings, the *Catuai Vermelho* (IAC 144) was immersed in tap water for 3 hours. They were then disinfested first with 50% alcohol for 50 seconds, and with 1% sodium hypochlorite for 1 minute and finally rinsed thrice in distilled sterilized water. Next, they were seeded in 0.50 m x 0.35 m x 0.15 m plastic trays containing washed sand. After the first pair of cotyledon leaves emerged, the seedlings were watered for 15 days, first with 20% of the solution strength followed by 50% ionic strength.

The seedlings were then subjected to the treatments calculated to supply the K doses, using NH_4NO_3, $Ca(NO_3)$ $2.4H_2O$, KNO_3, KCl, KH_2PO_4, $MgSO_4.7H_2O$ and $CaCl_2.6H_2O$ as the macronutrient sources. To provide the micronutrients 1.0 mL L^{-1} of the stock solution was used, composed of $ZnSO_4.7H_2O$ (0.22 mL L^{-1}), $MnSO_4.4H_2O$ (3 mL $L^{-}1$), $CuSO_4.5H_2O$ (0.08 mL L^{-1}), $H_2MoO_4.H_2O$ (0.02 mL L^{-1}) and Fe-EDTA solution (1.0 mL L^{-1}). The boric acid was later added, based on the treatments, in the established dosages. The nutrient solution was continuously aerated via an air compressor connected through hoses to the vases. The solution pH was monitored every week and maintained between 5.5 and 6.0 by add 0.1 mol L^{-1} HCl or 0.1 mol L^{-1} NaOH. Whenever required distilled water was added to fill up the vessel volume. The exchange of this solution was done in the different treatments, when the NO_3^- depletion monitored with the Horiba® Card for this anion achieved 70% of the initial concentration.

The *H. vastatrix* inoculum was obtained by first collecting the leaves of the *Catuai Vermelho* cultivar that exhibited signs of rust in the field. These leaves were then placed in the humid chamber for 24 hours. Next, were washed with deionized water using a brush, and the suspension was conditioned in a glass Becker. The concentration of the suspension was calibrated in a hemocytometer and adjusted to $1.5x10^4$ urediniospores mL^{-1}. All the coffee seedling leaves were inoculated up to drainage point just, when the night period began. After the inoculation, the plants were left covered with black plastic bag for 24 hours in the greenhouse to ensure total darkness as well as complete leaf wetness and enable fungal penetration, thus triggering the infectious process.

The assessments were done on the 48th day after inoculation (DAI) when the first disease symptoms were noticed. Every seven days assessments of the disease incidence and severity were done, for a total of nine evaluations. The incidence of the disease was calculated by the percentage of disease leaves compared with the total number of leaves on coffee seedlings.

The disease severity was assessment by the total number of lesions per leaf and the disease leaf area was determined with the diagrammatic scale proposed by Cunha et al. (2001).

The values thus arrived at for coffee rust evaluation were integrated in an area under the incidence of the disease progress curve (AUIDPC) and severity (AUDSPC) of the disease.

Once the assessments were taken, the roots and aerial organs, leaves and branches of the seedlings were collected and nutrition analysis was done. After washing the samples in distilled water, they were individually packed in paper bags and oven dried at 60 ° C until constant weight was achieved. Post drying, the plant material was weighed and then the root and shoot materials were ground. The results were expressed in mass (kg) of dry roots (MR), dry aerial parts (MPA) and total (MR + MPA). After the aerial portions of the samples were weighed they were sent to the laboratory for analysis to determine the K and B concentrations.

To perform the statistical analysis and compare the treatments, the SAS® v. 93 statistical program was employed. The data on the AUIDPC, AUDSPC, root mass, dry and total aerial parts and nutrient contents drawn from the leaf analyses were subjected to the analysis of variance. The variables in the F test ($P <0.05$) showing significance were then submitted to an adjustment of the linear regression models. When the interaction showed significance, the Sigmaplot ® program was used to plot the response surface graphs.

3 RESULTS AND DISCUSSION

A significant ($p <0.05$) interaction between the K and B nutrients for the area under the incidence of the disease progress curve (AUIDPC) and severity (AUDSPC) of the coffee rust (Figure 1 and 2) was observed.

The lowest AUIDPC and AUDSPC values were seen up to B doses of 1 mg L^{-1}. Above that dosage an exponential increase in the disease was observed, but with a sharp drop from the B dose of 2 to 4 mg L^{-1}. The highest AUIDPC was obtained between the 6.0 and 7.0 mmol L^{-1} dose of K and 2.0 mg L^{-1} dose of B.

No significant interactions were seen between K x B in the dry root mass (MR), shoot (MPA) and total (MR + MPA) variables. However, the B nutrient alone was seen to affect these variables (Figure 3). As the B doses increased, the mass (kg) of both the roots and shoots decreased. At the 0.05 and 0.50 mg L^{-1} doses, the highest total masses of the dry plant were observed at values of 8.51 and 8.07 g, respectively. At the highest B dose, which induced plant death, the mass was close to zero, and consequently no disease was evident.

Nable et al., (1997) reported that the B present in excess in the plant tissues can cause leaf death and consequently the death of the entire plant. In this study, the dramatic decrease in the plant dry mass was due to the B-induced phytotoxicity. The plants revealed reduced growth due to necrosis occurring in the apical meristems, exhibiting symptoms similar to those caused by B deficiency, resulting in death at the highest dose. In the young plants, the symptoms are more severe because of the dose being applied at the higher concentration level compared with the smaller leaf area. Thus, no pathogenic infection was evident in the necrotic areas.

The analysis of the aerial plant parts revealed no significant interaction between the K and B. However, the supply of B in the nutrient solution significantly affected the concentration of B and K in the leaf (Figures 4A and 4B, respectively). From the lowest B dose (0.05 mg L^{-1}) provided via the nutrient solution up to 1 mg L^{-1}, an increase in B was seen in the leaves, after which a decline was seen and zero content was reached. Whereas for the leaf content of K, the highest K concentration was evident when the B dose was at its least, and there was a remarkable drop in the K content in the coffee leaves.

Some studies report the direct influence of B on pathogen growth and development beyond their functions in plant metabolism. Shi et al., (2012) in their work with the *Colletotrichum gloeosporioides* pathosystem in mango culture recorded the borate treatment produced an accumulation of the reactive oxygen species (ROS) in the fungal spores, damaging the mitochondria. Besides, the B could also be possibly linked with the disruption of the pathogen cell membrane (QIN et al., 2010), which in turn could inhibit the pathogen spore germination. Earlier, Quin et al., (2010) in their study of the *Botrytis cinerea* fungus in the grape cultivation reported boron exerting an effective control of the gray mold on the grape berries.

Coffee is most sensitive to deficiency and more highly responsive to B application (BROWN & SHELP, 1997). This implies that the coffee plant has a narrow sufficiency range of B, ranging between 40 and 90 mg kg-1 in the leaves (MARTINEZ et al., 2003). Besides, the excess boron which causes both the deficiency and toxicity induces a decrease in the root system caused by the death of the root ends (NABLE et al., 1997), which minimizes its water and nutrient absorbing efficiency.

The B-induced toxicity, accompanied by a decrease in the root and shoot mass, triggered a nutritional imbalance in the plant, affecting the K absorption. Power & Woods (1997) reported that the potassium absorption rises with the addition of Boron and almost ceases to occur when it is absent; in fact, in several instances the apparent lack of potassium may in reality be boron deficiency.

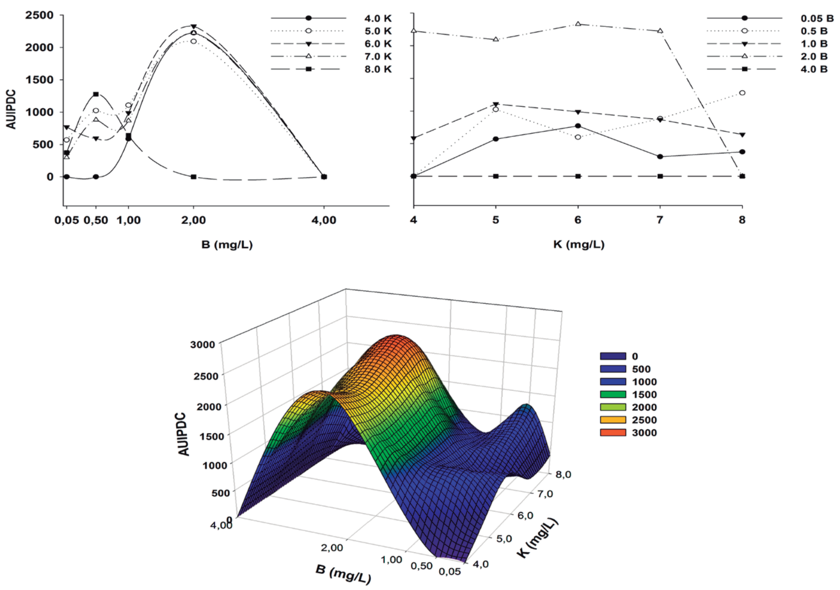

FIGURE 1 - The area under the incidence of the disease progress curve (AUIDPC) of coffee rust (*Hemileia vastatrix*) in response to the potassium and boron doses in nutrient solution. UFLA, Lavras, MG, 2017.

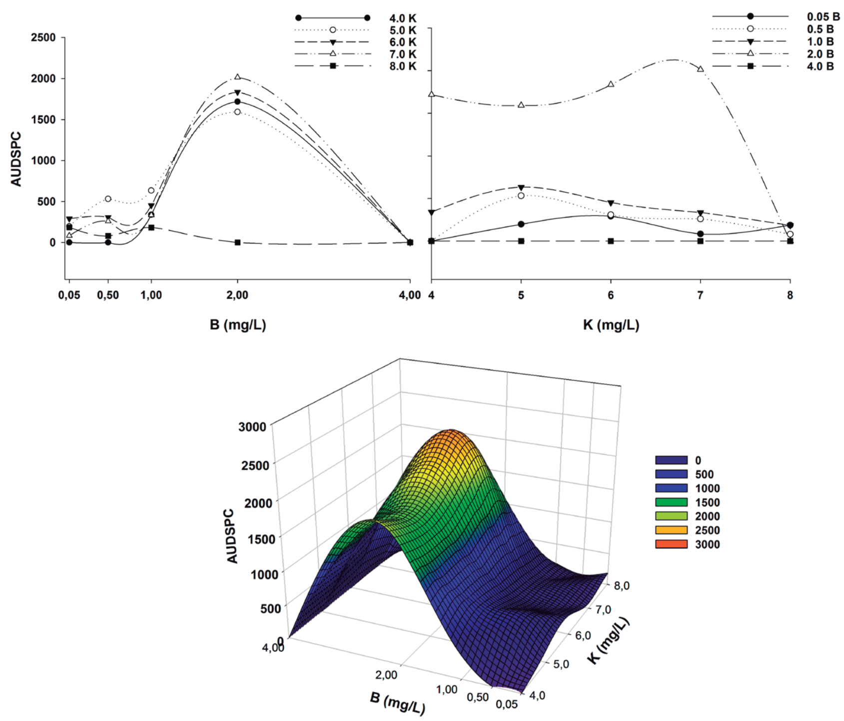

FIGURE 2 - The area under the severity of the disease progress curve (AUDSPC) of coffee rust (*Hemileia vastatrix*) in response to the potassium and boron doses in nutrient solution. UFLA, Lavras, MG, 2017.

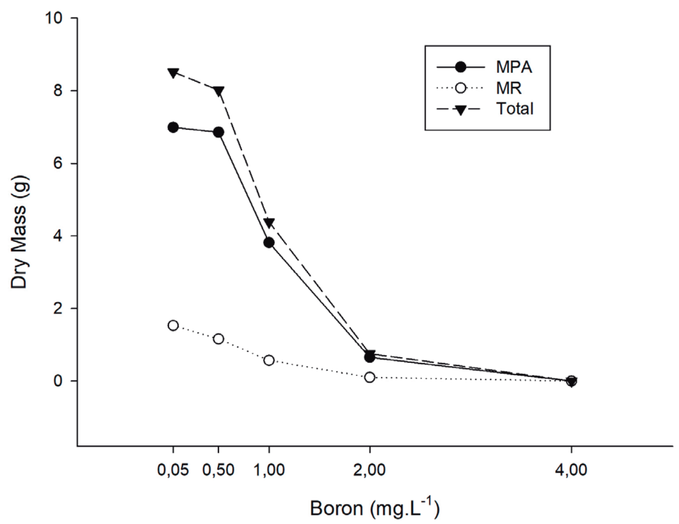

FIGURE 3 - Dry Root Mass (MR), shoot (MPA) and total (MR + MPA) as a result of the boron doses in the nutrient solution. UFLA, Lavras, MG, 2017.

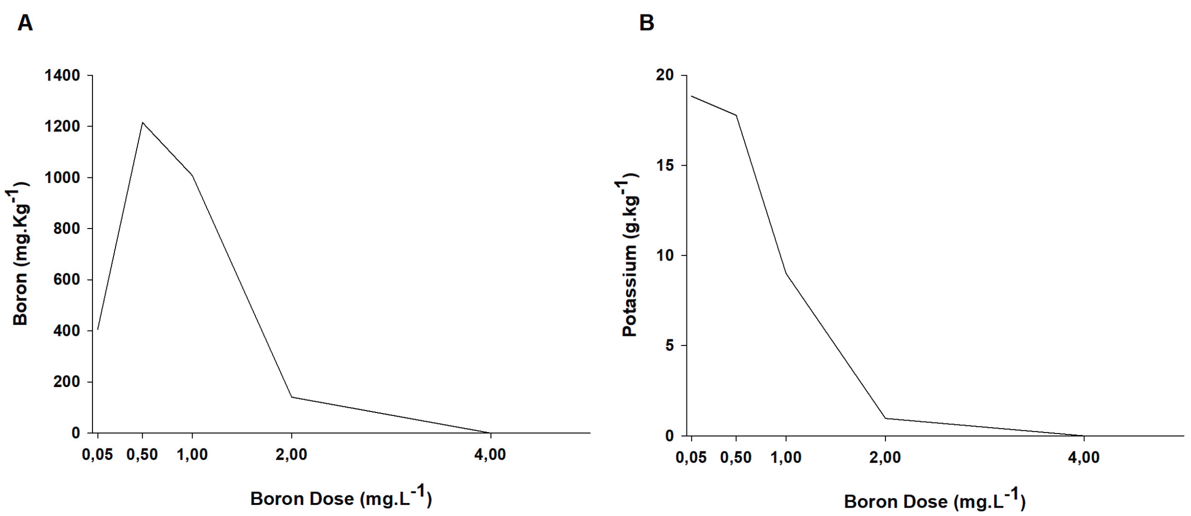

FIGURE 4 - Nutritional levels of B (A) and K (B) resulting from the boron doses in the nutrient solution. UFLA, Lavras, MG, 2017.

Thus, the lower K concentration contributed towards a decrease in the total mass of the plant, because the role of this element is to maintain cellular osmotic equilibrium (MARSCHNER, 2012), as well as activate the enzymes influencing the respiratory and photosynthetic processes, vital to plant growth and development.

Apart from these functions, Brown et al., (2002) reported that plants having ideal boron levels, decrease the extravasation of K, sugars and amino acids, as they play a significant part in the middle lamella formation, endowing the cell wall with a higher degree of resistance to the fungal penetration and colonization, thus lowering the disease severity. Besides, the ideal boron concentration in the plant may be linked to the rise in the production of the reactive oxygen species (ROS) (QIN et al., 2007), which in turn inhibits the fungal growth and development. However, the precise mode of action of boron on fungi remains unclear, and only limited data is available on the effects of boron on fungal metabolism. In this work the inadequate or unbalanced fertilization of these nutrients, resulted in the deficiency of

K, causing excess sugars in the cytoplasm as well as in the intercellular spaces and on the leaf surface, due to osmotic imbalance, contributing to its accumulation in the plant and serving as a source of energy for plant pests and pathogens (MARSCHNER, 2012). These conditions make leaf tissue susceptible to infection by pathogens. Therefore, it is not possible to generalize the effect of nutrients on plant disease, these can vary depending on the host, the pathogen and the interaction with the nutrients (PEREZ et al., 2017).

4 CONCLUSIONS

The interaction of the nutrients potassium (K) and boron (B) in the intensity of coffee rust was observed, under controlled conditions.

The dosage of B in 0.05 to 2.0 mg L^{-1} was observed to cause an increase in the intensity of coffee rust. From the 0.50 mg L^{-1} dose of B, a dramatic drop in the dry plant mass was noted, which reached zero at the highest B dose induced by phytotoxicity.

5 ACKNOWLEDGMENTS

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CONDUCTIVITY TO RUST IN COFFEE UNDER DIFFERENT WOODEN AND FRUIT TREE INTERCROPPING SYSTEMS

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ABSTRACT: The coffee intercropping with fruit and wooden species of economic value has been presented as a viable alternative for coffee cultivation in order to mitigate adverse environmental conditions for coffee trees, among other factors. Adapting the crop management to the new conditions stablished by the system is fundamental to obtain success on intercropping. One of the most serious diseases for the crop is the rust caused by *Hemileia vastatrix*., which may have its severity increased in function of the microclimate conditions provided by the trees. In this sense, the disease behavior under different intercropping systems and consequent different need to adapt the control measures when compared to the cultivation in full sun should be investigated. The present study was conducted aimed to verify the impact of tree systems composed by three wooden species, Cedar (*Acrocarpos fraxinifolius*), African mahogany (*Khaya ivorensis*), Teak (*Tectona grandis*) and two species of fruit trees, avocado (*Persea Americana*) and macadamia (*Macadamia integrifolia*) planted in different spacing over the occurrence and evolution of rust.It was possible to observe that coffee rust began to progress in the coffee plants from the month of February reaching a peak in September in all the treatments. Differences were observed in the progress curves of the disease, especially in the species that presented larger canopy such as avocado. Further studies are suggested with the purpose of establishing the microclimatic changes provided by the cultivation of different wooden and fruit species in intercropping with coffee, according to the dynamics of the climate and their development.

Index terms: Climate changes, shade-grown, sustainability.

CONDUTIVIDADE À FERRUGEM EM CAFÉ SOB DIFERENTES SISTEMAS DE CONSÓRCIO

RESUMO: A arborização com espécies frutíferas e madeireiras de valor econômico tem se apresentado como uma alternativa viável para a cafeicultura visando, entre outros fatores, atenuar condições ambientais adversas aos cafeeiros. Para que o sistema de consórcio seja bem sucedido torna-se necessário adaptar o manejo da cultura para as novas condições estabelecidas para o sistema de cultivo. Com relação às doenças, entre elas a ferrugem (*Hemileia vastatrix*.), uma das doenças mais graves para a cultura, pode ter a sua severidade aumentada devido às condições de microclima proporcionadas pelo cultivo arborizado. Dessa forma o conhecimento do comportamento da doença sob diferentes sistemas de consorciação e consequente necessidade de adaptação das medidas de controle em relação ao cultivo a pleno sol, devem ser pesquisadas. A presente pesquisa objetivou verificar o impacto de sistemas de arborização com três espécies madeireiras, Cedro (*Acrocarpos fraxinifolius*), Mogno Africano (*Khaya ivorensis*), Teca (*Tectona grandis*) e duas espécies de frutíferas,*abacateiro (Persea americana)*e macadâmia (*Macadamia integrifolia*), plantadas em diferentes espaçamentos sobre a ocorrência e evolução da ferrugem. Foi possível observar que a ferrugem começou a progredir nos cafeeiros a partir do mês de fevereiro, atingindo um índice máximo no mês de setembro para todos os tratamentos. Diferenças foram observadas nas curvas de progresso da doença, especialmente nas espécies que apresentavam maior copa como o abacateiro. Estudos adicionais são sugeridos com a finalidade de estabelecer as mudanças microclimáticas proporcionadas pelo cultivo de diferentes espécies arbóreas e frutíferas consorciadas ao café, em função da dinâmica do clima e do desenvolvimento das mesmas.

Termos para indexação: Mudanças climáticas, sustentabilidade, consórcio.

1 INTRODUCTION

The coffee introduced in Asia and Latin America was initially cultivated under shade to retain the physiological attributes of shade plants. In the 1950s, the use of shade was abandoned as a regular practice to increase production in Brazil (DAMATTA and RODRÍGUEZ, 2007) and control of diseases and pests, especially the coffee rust *Hemileia vastratix* (Berk. & Br.) and the coffee berry borer (DAMATTA, RENA, 2002).

The model of coffee cultivation adopted in Brazil since the beginning of the 19th century is characterized by monoculture in full sun and therefore with low level of biological diversity, disregarding the idea that coffee can be cultivated below the forest canopy, as in the case of coffee trees from Colombia, Venezuela, Costa Rica, Mexico, Nicaragua, and Panama (AGUIAR-MENEZES et al., 2007). In this sense, Brazilian research has been driven to find more ecological and economically feasible solutions, especially for

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small and medium-sized farmers, with the aim to adapt crops to climatic changes.

The main effects of shading on coffee cultivation are associated with nutrient cycling; the presence of natural pest and disease controllers; better use of labor in the off-season, attenuation of the damaging action of wind, decrease of air temperature fluctuations around 2-3°C and wind velocity and increase of air humidity (VALENTINI et al.2010; OVALLE RIVERA et al., 2015). As a reflection of the shading on the coffee trees, one can observe the production of longer internodes, fewer but larger leaves, obtainment of soft drink coffees (slower maturation), increased coffee production capacity and reduction of biennial production, lower incidence of pointer drought and cercosporiosis, reduction of mechanical damages and injuries that facilitate the penetration of pathogens, reduction of defoliation, low attack of miner, lower incidence of scald and frost, additional income for the use of the tree species and reduction of infestation of weeds in the crop. In addition, there is a growing appreciation of shaded coffee plantations due to their contributions to biodiversity conservation and ecosystem service providence (TSCHARNTKE et al. 2011, IDOL, HAGGAR, COX, 2011; DE BEENHOUWER et al. 2013; MANCUSO et al. 2013). However, intercropping involves a number of aspects to be considered, such as the shadow level, diversity and nature of the shadow of species, number of extracts and horizontal distribution, which effects are in need to be clarified for the development of new "Good Systems" to deal with climate changes and the complex effects on the potential attack of pests and diseases (AVELINO et al. 2007; BOTELHO et al.2015).

The shadow effects on coffee pests and diseases are usually not clear, since the shade can be conducive to a particular process in the life cycle of a harmful organism and hamper another process at the same time. Higher incidences of coffee borer (SANCHEZ et al.,2013) and coffee rust (LOPEZ-BRAVO et al., 2012) have already been reported in shaded coffee plantations. Damage caused by cercosporiosis (*Cercospora coffeicola*), a disease that can cause total defoliation in coffee plants, is elevated in unshadowed coffee plantations (STAVER, 2001), probably because of the greater susceptibility of plants under water or nutritional stress. (WRIGLEY, 1988).

In the case of coffee rust, a disease that has relevant importance for Brazilian and world coffee production, the balance of these antagonistic effects is variable and sometimes controversial. A high percentage of shade can reduce rust attack by reducing production. However, the shade also softens the temperature variation, intercepts light and probably increases the humidity in the crop, although these effects favor the increase of rust (LOPEZ-BRAVO et al., 2012).

Chemical control is the mode of control of coffee rust predominant in full sun cropping systems. Cultivars tolerant to the disease, adapted to the different cultivation regions, are being made available to the coffee growers, so far there has been a low level of substitution of the coffee tree for the new cultivars.(CARVALHO et al. 2012).

Avelino et al. (2015) studied the crisis promoted by the worsening of coffee rust in Colombia and Central America (2008-2013), its impact, probable causes and proposed solutions, mentioning that shade management also affects rust. In Central America, coffee rust intensities were high both in coffee plots under shade and total exposure to the sun. However the impacts in terms of defoliation and dead branches, which are the main factors affecting yield, are not clear. They believe the impacts should have been greater at full sun exposure where coffee plants were particularly stressed due to the rainfall in 2012. The effect of shade on host defoliation due to rust deserves further investigation.

The intercropping of coffee with tree and fruit species is often cited as an option to improve the ability of family coffee growers to adapt to climatic risks (LASCO et al., 2014), as well as to provide alternative sources of income from coffee products, such as fruits, wood, coal, latex, thus freeing the producer from the cyclical variations of coffee quotations (PEZZOPANE et al., 2010; GOVINDAPPA; ELAVARASAN, 2014). Intercropping presents an alternative income for small producers to plant coffee in the absence of bank credits, while for large producers it may represent an additional income. Therefore, when planning the intercropping, its goals must be considered to define the species to be planted.

The present research aimed to define the effect of using the fruit specie avocado (*Persea Americana*) and macadamia (*Macadamia integrifolia*) and the wooden trees Cedar (*Acrocarpos fraxinifolius*), African mahogany (*Khaya ivorensis*), Teak (*Tectona grandis*) planted in different spacing, on the occurrence and evolution of coffee rust in order to define the adequate management of both intercropped and coffee crops, so that both can produce satisfactorily.

2 MATERIAL AND METHODS

The assay was conducted in a private property called Fazenda da Lagoa, located in the municipality of Santo Antônio do Amparo, state of Minas Gerais, a coffee producing region in the south of Minas Gerais State, which coordinates are 20 ° 54 '58.1 "S and 44 ° 51 '13.7 ° W. The region presents altitude of 1089 m, average temperature of 19.8 °C and precipitation 1670 mm/year.

Three wooden species and two fruit trees were planted concomitantly with the coffee crop on December 2012 (cultivar Catuaí - IAC 99). The wooden species Cedar (*A. fraxinifolius*), African mahogany (*K.ivorensis*), Teak (*T. grandis*) and the fruit trees avocado (*P. americana*) and macadamia(*M. integrifolia*) were planted between the plants in the row of the coffee trees using two spacing. For the wooden species, the spacing were established in 9.0 x 13.6 m and 18 x 13.6 and for the fruit species the spacing of 7.0 x 13.6 m and 14.0 x 13.6 m were established for avocado and 5.0 x 13.6 and 8.0 x 13, 6 for macadamia. The control is in full sun.

In the spacing between the rows, three lines of coffee trees were intercalated with the shade species, in total and 13.6 m between the intercropped lines. The incidence of rust was determined by collecting 100 leaves per plot at each 30 days and counting the number of leaves with symptoms of the disease. Subsequently, the rust ,progress curves were defined for the studied period. According to Shaner and Finney (1977), the area below the disease progress curve can be calculated as follows:in which:

$$AACPD = \{\sum_{j=1}^{n-1} [(y \ + y \ )/2] * (t_{i+1} - t_i)\}$$

Yi: severity of disease (note per plot in%) at the ith observation;

Yi + 1: disease severity at the time of the i + 1 evaluation;

Xi: time (days) in the ith observation;

Xi + 1: evaluation period i + 1;

n: total number of observations.

The statistical design was randomized blocks in subdivided plots, considering plots as the different species of wooden and fruit plants tested in consortium with the coffee trees and subplots as the different spacing.

For all variables, a 5% probability was adopted for the F test. The analyzes were performed using the Sisvar computer program developed by Ferreira (2011). When significant differences were detected, the means were grouped by the Scott-Knott test, at 5% probability.

3 RESULTS AND DISCUSSION

The results concerning rust evolution curves in the intercropping and control treatments from November 2015 to November 2016 are presented on Figures 1 and 2.

The levels of rust began to rise from the month of February, but to a lower extent in the treatment with Teak, which provided lower rates of rust in relation to the other treatments. This may be explained by the characteristics of the plant, which belongs to a species considered shading, but lose the leaves during the dry season, therefore presenting a lower shading effect than the other species tested. The rust indexespresented a peak on September, when they were significantly higher in the macadamia and cedar species at smaller spacing and in the avocado, macadamia and cedar at larger spacing.

The area under the disease progress curve was calculated to evaluate the behavior of the disease throughout the studied period, which results are presented on Table 1.

The analysis of results presented on Table 1 demonstrated a significant interaction between the two spacing only for the treatment with avocado in consortium with coffee trees. Therefore, the different treatments were compared within each spacing used.

In the spacing 1, the treatments with species teak and mahogany did not promote elevation in areas below the coffee rust curve even being inferior to the control, whereas the treatments with cedar and avocado provided area similar to the control and macadamia an area significantly higher in relation to treatments and control.

Regarding the spacing 2, the treatments related to intercropping of coffee with teak, mahogany and cedar presented areas below the coffee rust curve similar to the control in full sun, while the treatments of coffee intercropped with avocado and macadamia presented the highest areas below the coffee rust curve. The results observed agree with other results relating that shade mitigates temperature variation, intercepts light and probably increases moisture in the crop, and these effects favor the increase of rust, depending on the species used (MANCUSO et al., 2013).

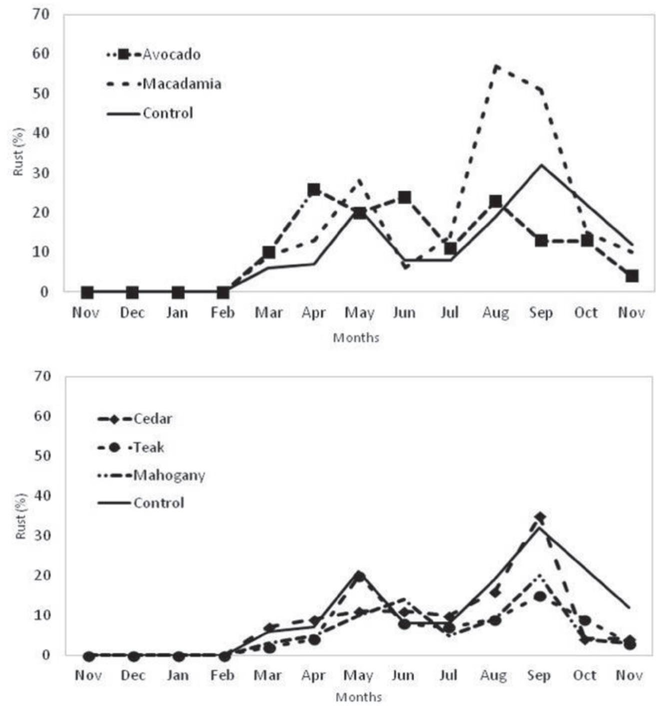

FIGURA 1 - Evolution of rust in trees with wooden species at spacing 9 x 13.6 m (A); fruit species at spacing 7 x 13.6 m for avocado and 5x 13.6m for macadamia (B). Santo Antonio do Amparo, Minas Gerais.

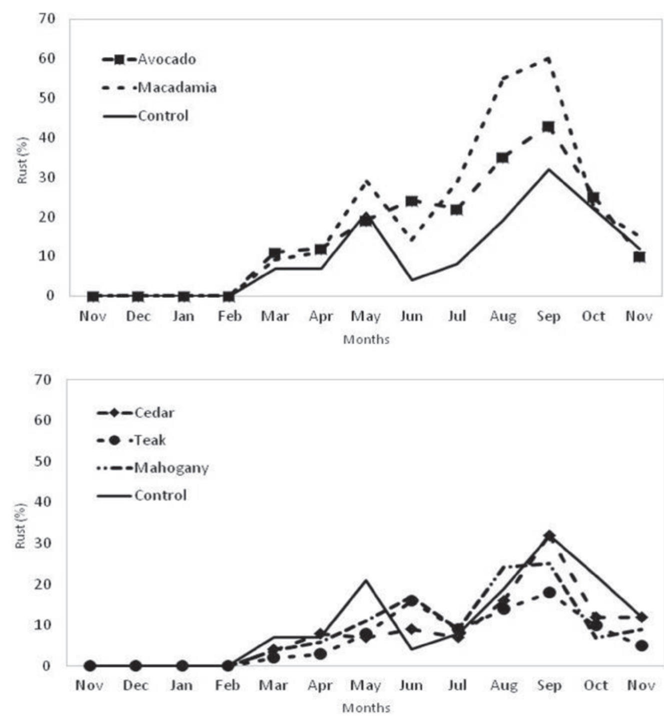

FIGURA 2 - Evolution of rust in trees with wooden species planted at spacing 14.0 x 13.6 m (A); Fruit trees planted at spacing 18.0 x 13.6 m for avocado trees and 8.0 x13 m for macadamia (B). Santo Antonio do Amparo, Minas Gerais. 2015/16.

On the other hand, there was no significant effect between treatments and spacing, except for the treatment with avocado that presented a larger area below the coffee rust curve in the larger spacing.

Considering that avocado is a good option for intercropping with coffee due to its high adaptability to environmental conditions and the possibility of generating additional income, especially for small coffee farmers (MANCUSO et al. 2013), further studies are necessary in order to shed light on the effect of different spacing over the incidence of rust observed in the present study.

One of the possible causes would be the competition exerted by some species used in the intercropping and consequent reduction of its productivity (GOVINDAPPA; ELAVARASAN, 2014). If there is competition of avocado with coffee trees and consequent reduction of productivity, the lowest rust index is justified, since the plant with less production becomes less susceptible to the incidence and severity of the disease.

In relation to the influence of climate (Figure 3) on the evolution of rust (Figs 1 and 2), it was observed that in all treatments the disease began to evolve from the month of February reaching a peak in the month of September, varying the intensity of rust among treatments with higher rust indices in species that presented higher canopy development, such as fruit species avocado and macadamia. In this way future research will be developed aiming to determine changes in the microclimates provided by the different species used in the consortium system.

TABLE 1 - Areas below the coffee rust curve in plantations intercropped with wooden and fruit species at different spacing. Santo Antonio do Amparo, Minas Gerais. Period of November 2015 to November 2016.

Treatments	Spacing 1 **	Spacing 2 ***
Teak	61.00 a A*	76.00 a A
African mahogany	71.50 a A	115.00 a A
Cedar	105.00 b A	112.50 a A
Avocado	121.00 b A	195.50 b B
Macadâmia	199.50 c A	236.50 b A
Control	132.00 b A	132.00 a A
CV (%)	27.36	31.31

* Means followed by the same lowercase letters in the columns and upper case in the rows belong to the same group by Scott-Knott's test at 5 % of probability.

** Spacing 1: 9.0 x 13.6 m for wooden species; 7.0 x 13.6m for avocado and 5.0 x 13.6 for macadamia.

*** *** Spacing 2: 18.0 x 13.6m for wooden species; 14.0 x13.6 m for avocado and 8.0 x 13.6 for macadamia.

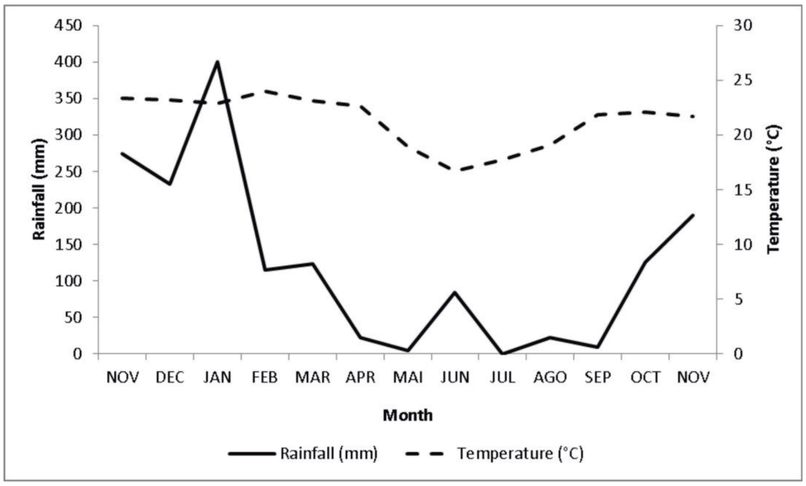

FIGURA 3 - Rainfall and temperature data during the period of November of 2015 to November of 2016.Santo Antonio do Amparo - MG.

4 CONCLUSIONS

Coffee intercropping were favorable for the development of coffee rust in the conditions of the research developing. The continuity of the research will allow the verification of the consistency of the results, considering the dynamics of the environmental conditions and the development of the fruit and tree species tested in intercropping system with coffee.

5 AKNOWLEDGMENTS

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CHEMICAL CONTROL OF *Conyza canadensis* (L.), IN MIXTURES OF HERBICIDES WITH GLYPHOSATE IN COFFEE CROP

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ABSTRACT: The plants invasion of *Conyza* genus has occurred in several regions in Brazil and in the world, due to the selection caused by the continuous use of herbicides with the same active, causing losses in production. This work aims to evaluate the association of herbicides in the control of *C. canadensis***.** The trial was carried out on a farm, in MG, in a Mundo Novo coffee plantation, in a randomized block design (RBD), with 7 treatments and 4 replications, totalizing 28 plots. The treatments were composed by CTU (no application), Glyphosate 1440g i.a ha^{-1}, Glyphosate 1440g i.a ha^{-1} + Ethyl Chlorimuron 25g i.a ha^{-1}, Glyphosate 1440g i.a ha^{-1} + Methyl Metsulfuron 6g i.a ha^{-1}, Glyphosate 1440g i.a ha^{-1} + Flumioxazine 100g i.a ha^{-1}, Glyphosate 1440g i.a ha^{-1} + Ethyl Carfentrazone 32g i.a ha^{-1}, Glyphosate 1440g i.a ha^{-1} + Saflufenacil 56g i.a ha^{-1}. In all treatments, non-ionic Dash adjuvant was used in the proportion of 1% of the application volume. Ten evaluations were carried out using the scores criterion, where 1 means efficiency between 0 and 20%; 2 from 21 to 40%; 3 from 41 to 60%; 4 from 61 to 80%; 5 from 81 and 100%. It is concluded the treatment Glyphosate 1440g i.a ha^{-1} + Saflufenacil 56g i.a ha^{-1} presented superior results from the first evaluation, evolving until the conclusion of this experiment.

Index terms: Horseweed, herbicide, saflufenacil, weed, tank mix.

CONTROLE QUÍMICO DA *Conyza canadensis* (L.), EM MISTURAS DE HERBICIDAS COM GLIFOSATO EM CAFEEIRO

RESUMO: A invasão de plantas do gênero Conyza, tem ocorrido nas mais diversas regiões produtoras de café do Brasil, e no mundo, devido à seleção causada pelo uso contínuo de herbicidas com o mesmo princípio ativo, causando grandes prejuízos na produção. Portanto, este trabalho, tem por objetivo avaliar a associação de herbicidas no controle da *C. canadensis*. O experimento foi conduzido na Fazenda Cava, município de Carmo do Rio Claro, MG, em uma lavoura de café Mundo Novo, no delineamento em blocos casualizados (DBC), com 7 tratamentos e 4 repetições, totalizando 28 parcelas. Os tratamentos foram compostos pela Testemunha, Glifosato 1440g i.a ha^{-1}, Glifosato 1440g i.a ha^{-1} + Clorimuron Etílico 25g i.a ha^{-1}, Glifosato 1440g i.a ha^{-1} + Metsulfuron Metilico 6g i.a ha^{-1}, Glifosato 1440g i.a ha^{-1} + Flumioxazina 100g i.a ha^{-1}, Glifosato 1440g i.a ha^{-1} + Carfentrazona Etílica 32g i.a ha^{-1}, Glifosato 1440g i.a ha^{-1} + Saflufenacil 56g i.a ha^{-1}. Em todos os tratamentos foram utilizados adjuvante Dash® na proporção de 1% da calda. Foram realizadas dez (10) avaliações utilizando-se o critério de notas, onde 1 significa eficiência entre 0 a 20%; 2 eficiência entre 21 a 40%; 3 eficiência entre 41 a 60%; 4 eficiência entre 61 a 80%; 5 eficiência entre 81 a 100%. Conclui-se que o tratamento Glifosato 1440g i.a ha^{-1} + Saflufenacil 56g i.a ha^{-1}, apresentou resultados superiores desde a primeira avaliação até a conclusão deste trabalho.

Termos para indexação: Buva, herbicidas, saflufenacil, plantas daninhas, mistura de tanque.

1 INTRODUCTION

Brazil stands out as the world's largest producer, exporter and consumer of coffee, with a planted area around 2.209 hectares between the Arabica and Conilon species with an estimated production of 49.67 million bags, of which Minas Gerais is the largest producer with an area around 1.180 hectares and an estimated production of around 28.5 million bags (CONAB, 2016).

Among the main problems for the production of coffee stands the weed competition, especially in the period from October to March (grain filling stage) and in plantations in formation when located in the projection of the cup of the coffee tree, requiring an efficient management system of weeds (FIALHO et al., 2010; FIALHO et al., 2011). The presence of these plants can reduce the macronutrient content by up to 50% and the development of young coffee plants by up to 41% (CARVALHO et al., 2013).

Among the most diverse harmful invaders to the coffee crop, stands out the plant known as Horseweed, for its tolerance to the main herbicides available in the market. The genus *Conyza* includes approximately 50 species which are distributed in almost worldwide (KISSMANN; GROTH, 1999).

The damages caused by Horseweed are not only those caused by the competition for light, water, nutrients and space, but for the coffee grower the damages of this species can still cause difficulties in cultural dealings, for example,

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during the sweeping of the grains under the coffee tree cup after the harvest and also, problems with the heating of the cooling system of the tractors caused by the feathers produced by the flowers of this plant.

Therefore it is necessary to control this weed, with mechanical or chemical method. The main control of *Conyza spp.* is the chemical method with herbicides but satisfactory results have not been observed.

The main herbicide used in coffee cultivation, glyphosate, was not successful in the control of *Conyza spp*., because this species shows resistance to this active principle and with a greater global distribution (HEAP, 2014).

According to Yamauti et al. (2010), the control of the Hairy fleabane (*Conyza bonariensis* L.) is not satisfactory, even with sequential applications of glyphosate at the dose of 720 g e.a. ha^{-1}, since it reached only 54.8% of control.

The weed resistance to herbicides is defined as the natural and inheritable ability of certain biotypes within a population to survive and reproduce after exposure to herbicide doses that would be lethal to normal (susceptible) individuals of the same species (CHRISTOFOLETTI et al., 1994).

Due to the rapid selection and dispersion of resistance, the control of this plant became inefficient when using only glyphosate, requiring the adoption of new control strategies, such as the combination with another herbicide (CULPEPPER, 2006; WILSON et al., 2007).

Martins et al. (2012) observed that tank mixtures with Carfentrazone + Glyphosate or 2,4-D + Glyphosate and 2,4-D isolated application presented the best control percentagens of *Commelina benghalensis.* The same authors also evidenced the synergism in the mixture between Carfentrazone + Glyphosato when observed that these products applied alone did not provide satisfactory effects in the control of *C. benghalensis.*

Due to the increasing resistance to glyphhosate, alternatives of tank mixtures for control of this species appear as etyl chlorimuron and metyl metsulfuron, with action mechanism belonging to the chemical group ALS (acetolactate synthase) inhibitors; etyl carfentrazone and flumioxazine, both of the chemical group PROTOX inhibitors, in addition to a new molecule, saflufenacil, with an action mechanism inhibiting the protoporphyrinogen IX oxidase enzyme (PPO or PROTOX). (CARVALHO; LOPEZ-OVEJERO, 2008).

The objective of this work was to evaluate the herbicidal effect of mixing Glyphosate with the different active ingredients Saflufenacil, Ethyl Chlorimuron, Methyl Metsulfuron, Flumioxazine and Ethyl Carfentrazone, applied on Horseweed in coffee plantations.

2 MATERIAL AND METHODS

The experiment was installed on the Cava Farm, in the municipality of Carmo do Rio Claro, MG. The used cultivation to establish the plots was Mundo Novo 379/19, with pruning at 50 cm in height in 2013, and currently with a productivity estimate of 53.33 ha^{-1} bags. The crop spacing is 3.0 m between row and 1.0 m between plants, giving a population of 3,333 plants per hectare. The average altitude is around 843 m, average annual temperature is 20ºC, accumulated annual rainfall 1,564 mm, latitude 20º58'31" S and longitude 46º17'36" W.

The experimental design was a randomized block design (RBD) with seven treatments and four replicates totalizing 28 plots. The treatments consist of mixing the following herbicides: T1-Control Treatment Unit - CTU (just water); T2-Glyphosate (Roundup® 360g L^{-1}) - 1440g a.i. ha^{-1}; T3-Glyphosate (Roundup® 360g L^{-1}) + Ethyl Carfentrazone (Aurora® 400g L^{-1}) - 1440g a.i. ha^{-1} + 32g a.i. ha^{-1}; T4-Glyphosate (Roundup® 360g L^{-1}) + Saflufenacil (Heat® 700g kg^{-1}) - 1440g a.i. ha^{-1} + 56g a.i. ha^{-1}; T5-Glyphosate (Roundup® 360g L^{-1}®) + Flumioxazine (Flumyzin® 500g kg^{-1}) - 1440g a.i. ha^{-1} + 100g a.i. ha^{-1}; T6-Glyphosate (Roundup® 360g L^{-1}) + Methyl Metsulfuron (Zartan® 600g kg^{-1}) 1440g a.i. ha^{-1} + 6g a.i. ha^{-1} e T7-Glyphosate (Roundup® 360g L^{-1}) + Ethyl Chlorimuron (Clorin® 250g kg^{-1}) 1440g a.i. ha^{-1} + 25g a.i. ha^{-1}. In all treatments, 1% non-ionic Dash mineral oil was used. The meteorological conditions during the applications were: minimum temperature of 18ºC and maximum of 31,1ºC, minimum relative humidity of 59%, and winds with velocity between 0,0 and 0,8 km h^{-1} (Source: Cooxupé Weather Station, Carmo do Rio Claro Center).

The meteorological data were provided by the Cooxupé Weather Station in the city of Carmo do Rio Claro, through the Vantage Pro 2 station, with updated data every 15 minutes for 24 hours.

The treatments application were carried out on April 1st, 2016, using a hand-held back sprayer with spear and ADI 11002 jet spray tip calibrated with *Gate* valves (Guarany) with 150 kPa providing an output 250L ha^{-1} of application volume. The application speed was 2.62 km h^{-1}. The plots were 3.5 m by 1.33 m (4,55m²).

At the application time, the coffee plants rows were heavily infested with weeds and with a clear predominance of Horseweed.

The evaluations were performed at 3, 6, 9, 12, 15, 18, 21, 24, 27 and 30 days after application of the treatments - DAA. The herbicide efficiency was carried out through a systematic of scores on the plots by three evaluators: score 1: efficiency between 0 to 20%; score 2: efficiency between 21 and 40%; score 3: efficiency between 41 to 60%; score 4: efficiency between 61 and 80% and score 5: efficiency between 81 and 100%.

The collected data were submitted to analysis of variance by the SISVAR 4.3 program (FERREIRA, 2011), and the averages were submitted to the Scott-Knott test at 5% probability.

3 RESULTS AND DISCUSSION

The results obtained after the application of herbicides to control Horseweed (*C. canadensis*) are exhibited in Table 1.

It was verified that the mixture Glyphosate + Saflufenacil, on *C. canadensis*, was classified with score 5 showing efficiency greater than 80% already at 3 DAA. This result remained until 30 DAA, according to the table below, and in this period there was no incidence of regrowth.

This result coincides with the conclusions of Eubank et al. (2013) that affirmed that Saflufenacil associated with Glyphosate with added adjuvant caused an increase in the absorption (6%), and reduction in the translocation (6%), of the herbicide Glyphosate in plants of *C. canadensis*. And the same authors add that although it caused a reduction in the translocation, the presence of Saflufenacil provided an equivalent increase in the absorption of Glyphosate, which may have contributed to the occurrence of synergism.

The systemic distribution can be explained by its weak acid character and also by the metabolic stability in dicotyledonous plants (GROSSMANN et al., 2013).

The mixture of Metsulfuron and Glyphosate at 3 DAA had lower results than glyphosate and equal to the CTU, but in the course of evaluations this herbicide treatment was consistently higher than score 3 up to 30 DAA.

Although the regrowth date was not accurately assessed in this study, it was observed that the treatment of glyphosate + metsulfuron re-emerged after 24 DAA, and the other treatments around 21 DAA. It was not observed regrowth in the glyphosate + saflufenacil treatment.

The association of Glyphosate + Carfentrazone presented satisfactory results reaching at 15 DAA control index above 80%, however, at 30 DAA this index fell to less than 70%, being classified with score 4. For plants at an advanced stage of development, the control levels tend to reduce, as observed by Constantin et al. (2013).

According to the Table 1, it turns out that the association of Glyphosate with Chlorimuron presented satisfactory results in the evaluations from the 15 DAA, receiving a score 4 with an equivalent efficiency at the average of 70% (61-80%), after which it presented regrowth mainly at 30 DAA. Similar result was observed by Fornarolli et al. (2010), where Glyphosate (2.0 L g pc ha^{-1}) + Chlorimuron (80 g pc ha^{-1}) provided 80% control at 90 DAA when applied in 4 to 6-leaf plants. Santos et al. (2010), observed a 75% control at 80 DAA in the treatment where Glyphosate + Chlorimuron (80 g pc ha^{-1}) was applied.

Moreover, observing the results in table 1, it is evidenced that the treatment Glyphosate + Flumioxazine did not stand out in any of the evaluations receiving score 2 varying efficiency between 21 and 40% in the control of *Conyza canadensis.*

The control results of *C. canadensis* by Glyphosate applied in isolation did not present a result superior to 20% receiving score 1 as it is evidenced in Table 1, presenting only intoxication of the apical parts. These results are in agreement with those of Moreira et al. (2007), that in citrus production areas, identified biotypes of the two species of *Conyza* (*C. bonariensis* L. – Hairy fleabane and *C. Canadensis* L. – Horseweed) resistant to Glyphosate.

The unsatisfactory control of Hairy fleabane with the use of Glyphosate led to the suspicion that species of this genus could acquire resistance to this herbicide molecule (VARGAS et al., 2007). This information corroborates with the selectivity observed in the test conducted on the Cava Farm. Another important point perceived in this work are the results obtained from the treatments Glyphosate + Carfentrazone and Glyphosate + Chlorimuron that from 15 DAA to 27 DAA remained control above score 4 (61 to 80%), which leads us to admit that although the plant does not die, this paralyzed plant impairs the appearance of new plants around it by the suppression effect of sowing, competing mainly by light, during a considerable period (27 days).

TABLE 1 - Control efficiency of Conyza canadensis with mixtures of herbicides to glyphosate and evaluations every 3 DAA. - Carmo do Rio Claro, MG, 2015/2016.

Treatment	Days after application DAA									
	3	6	9	12	15	18	21	24	27	30
1. CTU	1,00 e	1,00 d	1,00 d	1,00 e	1,00 d	1,00 f	1,00 d	1,00 c	1,00 e	1,00 e
2. Glif.	1,50 d	1,50 d	2,50 c	1,50 d	2,00 c	1,87 e	1,75 c	2,12 b	2,12 d	1,75 d
3.Glif.+Carf.	4,00 b	3,87 b	3,75 b	3,37 b	4,75 a	4,50 b	4,25 b	4,37 a	4,25 b	3,50 b
4.Glif.+Saf.	5,00 a	5,00 a	5,00 a	5,00 a	5,00 a	5,00 a	5,00 a	5,00 a	5,00 a	5,00 a
5.Glif.+Flum.	2,00 c	2,50 c	3,50 b	2,62 c	3,75 b	2,81 d	1,87 c	2,87 b	2,15 d	2,50 c
6.Glif.+Met.	1,00 e	3,87 b	3,25 b	3,50 b	3,75 b	3,75 c	3,75 b	4,00 a	3,50 c	3,50 b
7.Glif.+Clori.	2,25 c	3,50 b	3,50 b	3,50 b	4,00 b	4,00 c	4,00 b	4,25 a	4,00 b	3,75 b
CV (%)	11,48	15,77	18,49	9,19	7,71	8,64	14,09	17,00	12,24	13,28
F	0,00**	0,00**	0,00**	0,00**	0,00**	0,00**	0,00**	0,00**	0,00**	0,00**

Averages followed by the same lowercase letter in the column belong to the same group by the Scott - Knott test at 5% significance.

CTU – Control Treatment Unit

It is important to mention that the treatment with glyphosate + saflufenacil herbicides causes selection pressure in favor of genotypes resistant to these molecules. Therefore, the results that are not 100% efficient but still greater than efficiency 80% can be used as herbicide management to try to break this selection pressure while maintaining a satisfactory control for weed control. In this work, it can be observed that Carfentrazone or Chlorimuron associated to Glyphosate can be used in the management of herbicides for Horseweed control because they have a high control, however, without causing selection pressure in the same way as the Glyphosate + Saflufenacil mixture.

For Lopez Ovejero et al., (2008) a possible decrease in the ecological adaptability of the resistant biotype has direct consequences in the competitiveness of the same and, therefore, in its dynamics within the population, directly affecting weed management techniques. Thus, when the selection pressure factor is eliminated (herbicide), the gene frequency of the resistant biotype decreases rapidly in the seed bank due to its lower adaptability, facilitating its management.

4 CONCLUSIONS

Glyphosate + Saflufenacil show to be highly efficient on *C. canadensis*.

Chlorimuron or Carfentrazone associated with Glyphosate obtains scores superior to 4 (61-80% of control) until the 27 DAA.

Glyphosate + Saflufenacil provide high selection pressure to Horseweed.

Chlorimuron or Carfentrazone associated to Glyphosate can be used in Horseweed resistance management.

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SENSORY PROFILE OF BRAZILIAN COFFEES BASED ON CONSUMER PERCEPTION AS AN ALTERNATIVE TO THE CONVENTIONAL METHODS

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ABSTRACT: Consumer-based methodologies for sensory characterization of foods have been widely discussed and are satisfactory, when compared to the results of trained panelists. However their efficiency in the description of complex foods rich in sensory attributes (flavor and aroma) such as coffee still needs to be explored. Polarized sensory positioning (PSP) is an innovative methodology for sensory characterization, based on the comparison of samples with reference products. In this study, roasted and ground coffees with different quality ratings according to the Coffee Quality Program (PQC) of the Brazilian Coffee Industry Association (ABIC) – Traditional, Superior and Gourmet – were evaluated by this method, applied to consumers. The beverage was presented to 100 consumers, who quantified the degree of global difference between the samples and the chosen references, using unstructured scales, followed by the verbal description of the sensory characteristics perceived in each sample evaluated. The samples were described for 30 attributes related to visual appearance, aroma, flavor, texture and hedonic terms. The method presented a good discriminative capacity, since it was able to differentiate the samples according to the PQC classification. In addition it allowed to identify the main sensory characteristics responsible for similarities and differences between the samples. The results indicate that consumers were able to infer about a quality classification based on their own perception and vocabulary, and the Brazilian traditional coffee was considered inferior to specialty coffees increasingly available in the market.

Index Terms: Sensory description, polarized sensory positioning, coffee quality, consumer science.

PERFIL SENSORIAL DE CAFÉS BRASILEIROS ATRAVÉS DA PERCEPÇÃO DO CONSUMIDOR COMO ALTERNATIVA AOS MÉTODOS CONVENCIONAIS

RESUMO: Metodologias baseadas na percepção do consumidor para obter a caracterização sensorial de alimentos vêm sendo amplamente discutidas apresentando-se satisfatórias quando comparadas aos resultados de avaliadores treinados. Porém, a eficiência delas na caracterização de alimentos complexos e ricos em atributos sensoriais de sabor e aroma, como o café, ainda deve ser explorada. O posicionamento sensorial polarizado (PSP) é uma metodologia inovadora para a caracterização sensorial que se baseia na comparação entre amostras e um conjunto de produtos de referência. Neste estudo, cafés torrado e moído com diferentes classificações segundo o Programa de Qualidade do Café (PQC) da Associação Brasileira da Indústria do Café (ABIC) – Tradicional, Superior e Gourmet – foram avaliados utilizando esta metodologia aplicada com consumidores. As bebidas foram avaliadas por 100 consumidores que quantificaram o grau de diferença global entre as amostras e as referências escolhidas utilizando escalas não estruturadas, seguido da descrição verbal das características sensoriais percebidas em cada amostra avaliada. As amostras foram descritas por 30 atributos relacionados à aparência visual, ao aroma, ao sabor, à textura e a termos hedônicos. O método apresentou uma boa capacidade discriminativa, tendo em vista que conseguiu segmentar as amostras de acordo com a classificação do PQC. Além disso, permitiu identificar as principais características sensoriais responsáveis pelas semelhanças e diferenças entre as amostras. Os resultados indicaram que os consumidores foram capazes de inferir sobre uma classificação de qualidade segundo sua percepção e linguagem, sendo o café tradicional brasileiro considerado inferior aos cafés especiais, que estão cada vez mais acessíveis no mercado.

Termos para indexação: Descrição sensorial, posicionamento sensorial polarizado, qualidade de café, estudo de consumidor.

1 INTRODUCTION

Information on the sensory characteristics of food and beverage is essential for successful product development and marketing. Those informations are obtained mainly by trained panelists through descriptive sensory methods and consumers are asked about preference and acceptance, not providing information on how they perceive the sensory characteristics of products. In addition to that, most existing descriptive techniques require the maintenance of trained panelists and the use of unstructured scales to evaluate products. It makes analyses time-consuming and costly due to exhaustive training sessions, so that the problems with the use of scales are minimized (LAWLESS; HEYMANN, 2010).

In order to reduce the analysis time and costs inherent to conventional descriptive tests, recent research has sought to develop methodologies that can be applied to consumers and allow the rapid description of foods, making it possible

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for the industry to use them. These innovative methodologies have rapidly gained popularity and become one of the most active and dynamic areas of sensory science research in recent years. Besides being quicker and easier to understand by participants, when using consumers for product descriptions, these techniques are also intended to bring products to the market that actually have the characteristics expected by the target audience, and are useful for providing valuable information during the development of new products or in the design of marketing campaigns (ARES et al., 2010; ARES et al., 2011; DOOLEY et al., 2010; JAEGER et al., 2015; LAAKSONEN et al., 2016; REINBACH et al., 2014; ROUSSEAU, 2015; VEINAND et al., 2011). Besides providing sensory configurations similar to those obtained by conventional descriptive analysis, the methods presented have shown efficiency in sample differentiation, even using consumers in the evaluation (ARES et al., 2014; BRUZZONE et al., 2012; CADENA et al., 2014; FLEMING et al., 2015; JAEGER et al., 2013; LADO et al., 2010; REINBACH et al., 2014; VARELA; ARES, 2012; VARELA et al.; 2014).

Coffee is one of the most consumed beverages worldwide. The association between coffee consumption and a variety of conditions and diseases has been examined extensively. Besides its economic importance, coffee consumption has been currently encouraged by health experts, since research indicates that coffee is a reducing agent for the risk of some types of cancer, due to antioxidant and anticarcinogenic substances naturally present in coffee, or those formed during its processing (ARRUDA et al., 2009). Grosso et al. (2017) evaluated the associations between coffee and caffeine consumption and various health outcomes in an umbrella review of the evidences from meta-analyses of observational studies and randomized controlled trials (RCTs). This study showed that there is probable evidence of the beneficial effects of coffee consumption for a number of chronic diseases, including some cancers (endometrial, prostate, colorectal, and liver), cardiovascular disease and metabolic-related outcomes (such as type-2 diabetes and metabolic syndrome), and neurological conditions (such as Parkinson's disease, Alzheimer's disease, and depression).

Although the use of some methodologies based on consumer perception such as sorting, check-all-that-pply, projective mapping and polarized sensory positioning is already established as a way to obtain reliable sensory characteristics more quickly than with a trained panelists, little is known about their efficiency in the characterization of complex foods, rich in sensory attributes (flavor and aroma), such as coffee, wines, chocolate, spirits and beers. Physical aspect and cup-tasting are the main procedures to evaluate coffee quality commercially. In the literature, the most used sensory tools for this beverage description in recent years are: cup-tasting by a small number of experts (two or three) certified by the Specialty Coffee American Association - SCAA (ALVES et al., 2017; ISQUIERDO et al., 2012; Lópes-Gracía et al., 2016;SILVA et al., 2014), Brazil Specialty Coffee Association - BSCA (SILVEIRA et al., 2016) and in accordance to Resolution SAA-37 (PINO et al., 2017); and quantitative descriptive analysis with trained panelists (DELLA MODESTA et al., 1999; MONTEIRO, 2002; MONTEIRO et al., 2005; SANTOS et al., 2013; SILVA, 2003). On the other hand, few consumer studies have been using hedonic scale and multivariate data analysis, reporting on acceptability, emotions, perceptions and consumer behavior in different consumption contexts (FRANCISCO; et al., 2014; OLIVEIRA, 2008; OSSANI et al., 2017).

In Brazil, the Coffee Quality Program (PQC) launched in 2004 by the Brazilian Coffee Industry Association (ABIC) certifies the quality of the final beverage obtained through roasted and ground coffee, using a sensory analysis methodology validated by the ABIC, which classifies and differentiates coffees into categories. The evaluation of coffee quality is performed by trained panelists in accredited laboratories and takes into account aroma of ground coffee, aroma, acidity, body, astringency and bitterness, among other beverage characteristics. The coffee quality category is determined according to the Global Quality score, obtained by the product on a scale of 0 to 10. The minimum score of a recommended beverage corresponds to 4.5 points and, according to the received score, coffee is classified as Extra Strong, Traditional, Superior or Gourmet (ABIC, 2017). Specialty coffees are evaluated and certified by the BSCA. They are certified in batches and analyzed by three panelists of the association. Roasted and ground beans are evaluated for the aspects: clean drink, sweetness, acidity, body, taste, residual taste and overall balance. To be certified, the coffee must score greater than or equal to 80 and no parameter can be equal to zero (BSCA, 2017).

Polarized sensory positioning (PSP) is a new methodology based on consumer perception that consists in comparing the samples with a set of fixed references, called poles (TEILLET, 2014). This methodology allows assessors to quantify the overall degree of difference between each sample and each of the chosen poles using scales, ranging from “exactly the same” to “totally different” (TEILLET et al., 2010). The usual number of poles used in studies with PSP is three and, in pole selection, the main sensory characteristics responsible for similarities and differences between samples should be considered (ANTÚNEZ et al., 2015; ARES et al., 2015; CADENA et al., 2014; DE SALDAMANDO et al, 2013; TEILLET, 2014).

In this study, the sensory description of roasted and ground coffee with different ratings according to the Coffee Quality Program (PQC) of the Brazilian Coffee Industry Association (ABIC) was obtained, using consumer perception through polarized sensory positioning (PSP).

2 MATERIAL AND METHODS

Samples

Seven samples of roasted and ground coffee – 3 classified as Traditional, 2 as Superior and 2 as Gourmet – were purchased from the local market in the city of Rio de Janeiro, selected from companies certified by the ABIC Coffee Quality Program (PQC). The traditional and superior coffees were selected from among the 14 largest associated coffee industries of the ABIC, according to a report published in October 2014 (ABIC, 2014). The samples codes and characteristics of the coffees regarding the quality shown in the label, bean species, classification of the beverage and roasting are presented in Table 1. These characteristics were obtained from the packages.

Samples T3, S1 and G1 were chosen as poles (references). Poles were selected taking into account the main sensory characteristics responsible for differences among samples, based on results from preliminary study with trained panelists.

The samples were prepared in Britânia coffee machines (NCB27) with a large paper filter No. 4, using mineral water and coffee powder at a proportion 100 g of powder/L of mineral water, according to the preparation recommendation by the ABIC (2004). They were served in 40-mL portions at 70°C in white porcelain cups kept in an oven at 70°C and coded with random three-digit numbers. Samples were evaluated in two distinct sessions of 4 and 3 samples, per consumer, at intervals of at least 4 hours. Consumers were instructed to sweeten or not samples according to their regular consumption way. Sucrose and sucralose were offered to sweeten bevareges according to the assessor’s preference (SANTOS, 2010). Mineral water at room temperature was offered to the consumer to eliminate taste interference between tastings. The beverage was kept in the coffeemaker and considered appropriate for consumption within a maximum time of 30 minutes (FERIA-MORALES, 1989), after which they were discarded.

Consumers

A total of 100 consumers (68% women; 18-65 years) participated in this study. Participants were recruited among Embrapa Agroindústria de Alimentos employees and trainees who showed interest in the study, time availability, affinity for the product and good health conditions. Study was approved to local research ethics committee (CAAE 54935116.9.0000.5284). The participants signed a Free and Informed Consent Term and received a small gift for their participation.

Polarized Sensory Positioning

Consumers received three poles and one sample, served in 40-mL portions at 70°C, in white porcelain cups kept in an oven at 70°C. The poles, denominated as R1, R2 and R3, were presented simultaneously in this order from left to right. The samples were coded with random three-digit numbers and were presented in a balanced order (MACFIE et al., 1989).

Participants were asked to taste the poles and try to memorize their sensory characteristics. They were then invited to try each of the samples, monadically, and evaluate the overall difference between the sample and each pole using a 10-cm unstructured scale anchored with the terms “exactly the same” to the left and “totally different” to the right. Consumers were informed that they had to perform the task according to their own criteria, and that there were no right or wrong answers. In addition, they were advised to try the poles as many times as they thought necessary. After comparing each sample with the poles, consumers were asked to write up to three words capable of describing the sensory characteristics of the sample in question.

TABLE 1 - Characteristics of the coffee samples used in the study

Samples	Classification PQC	Coffee specie	Classification Beverage*	Roast
T1	Traditional	Arabica	"Dura"	Medium
T2	Traditional	ND	ND	ND
T3	Traditional	ND	ND	ND
S1	Superior	Arabica	"Dura"	Medium
S2	Superior	ND	ND	ND
G1	Gourmet	Arabica	"Mole"	Light
G2	Gourmet	ND	ND	ND

ND - Not declared

*BRAZILIAN OFFICIAL COFFEE CLASSIFICATION – COB. CETCAF (2014)

This initial verbalization was preprocessed (grouping of synonyms, management of ambiguous words) to obtain the final descriptions used in data analysis.

The tests were performed at the Sensory Analysis Laboratory of Embrapa Agroindústria de Alimentos, in Rio de Janeiro, in individual booths, under white lighting. Data were collected using the Fizz software (Biosystemes, France).

Data analysis

Data were analyzed using Multiple Factor Analysis (MFA) in order to preserve individual data and to compensate individual differences when evaluating the similarities and differences between samples and poles (TEILLET, 2014). For each sample, the mean intensity scores was calculated, and a matrix containing samples in rows and poles in columns was constructed. MFA was performed, taking into account the data of each consumer as a separate group of variables. The descriptors provided by consumers were analyzed qualitatively and quantitatively. A qualitative analysis of the words elicited by consumers in the description step was performed. Those that were considered synonyms or inflections of the same word were merged into categories and their frequency of mention was determined by counting the number of consumers who used the terms within each category. Those terms mentioned by less than 10% of the consumers were excluded for further analysis (ARES et al., 2010). The frequency table, containing the frequency of terms of each category for the description of each of the samples, was constructed and considered as a group of supplementary variables in the MFA. The confidence ellipses were calculated using truncated total bootstrapping considering the first four dimensions of the configurations (DEHLHOLM et al., 2012).

All statistical analyses were performed using the FactoMineR package of the R language software (R CORE TEAM, 2014).

3 RESULTS AND DISCUSSION

The sensory description of coffee was carried out in four 6-hour sessions, totaling 24 hours for application and data collection.

Consumers characterized the samples through 30 attributes, 3 related to appearance, 7 to aroma, 14 to flavor, 3 to mouthfeel and 3 to hedonic attributes (Table 2). Each consumer generated an average number of 15 attributes (1 for visual appearance, 2 for aroma, 10 for flavor, 1 for body and 1 hedonic). These attributes were: dark, light, without oiliness, characteristic aroma, weak aroma, pleasant aroma, strong aroma, burnt aroma, sweet aroma, mild aroma, strong flavor, bitter taste, burnt flavor, weak flavor, mild flavor, characteristic flavor, sweet taste, cereal flavor, residual flavor, non-characteristic flavor, acid taste, metal flavor, bitter residual, tasteless, full-bodied, thin, astringent, pleasant, tasty, bad.

PSP enabled the identification of sensory characteristics of the beverages through consumer vocabulary. It was also observed that consumers used some hedonic terms (pleasant, tasty, bad - Table 2) in beverage description that are not obtained when descriptive analysis were performed with trained panelists. The description obtained by PSP using sensory and hedonic terms was also reported in other studies (ARES et al., 2011; VEINAND et al., 2011).

TABLE 2 - Attributes used by consumers to describe coffee beverages.

Attribute	Number of mentions	Attribute	Number of mentions
Appearance		*Aroma*	
Dark	55	Characteristic	32
Light	13	Weak	26
Without oiliness	10	Pleasant	25
Flavor		Strong	19
Strong	183	Burnt	13
Bitter	173	Sweet	12
Burnt	80	Mild	13
Weak	56	*Mouthfeel*	
Mild	45	Full-bodied	61
Characteristic	44	Thin	37
Sweet	31	Astringent	14
Cereal	22	*Hedonic*	
Residual	17	Pleasant	35
Non-characteristic	17	Tasty	33
Acid	16	Bad	20
Metal	12		
Bitter Residual	9		
Tasteless	9		

Cadena et al (2014) considered the use of hedonic terms a limitation on the sensory characterizations obtained from the consumer, although this information can be used to identify sensory characteristics relevant to consumers in the design of marketing and communication strategies.

The sensory configuration of coffee samples is presented in the dimensional space obtained through MFA (Figure 1). The first two dimensions accounted for 50.43% of the variance in the experimental data. The evaluated beverages were clearly differentiated into three groups of samples similar to each other. Within each distint group, confidence ellipses of samples overlaped in the first and second dimensions, showing that were considered similar on their sensory characteristics. A group formed by the traditional beverages T1, T2 and T3 and by the gourmet beverage G2; a second group formed by the superior beverages S1 and S2; and a third group formed by the gourmet sample G1; they were therefore classified, according to the classification proposed by the ABIC, except sample G2. This fact indicates a good differentiation capacity of the PSP method in this study. Despite being classified with a gourmet label, sample G2 were positioned at sensory configuration together traditional beverages, possiblly because it had sensory characteristics similar to the traditional certified coffees selected for this study Moreover, this fact is linked with sensory dimension generated by the set of samples avaliated. De Saldamando et al. (2013) indicated that different sets of poles could affect conclusions regarding similarities and differences among products to some extent. It means that chosen poles could affect discrimination in specific dimensions so that some sensory dimensions could be more interesting than others (not necessarily the main sensory dimensions), as suggested by Ares et al. (2015). In other words, discriminative conformation obtained in the present study is dependent of the sensory dimension generated by the set of products avaliated: poles and samples.

The results are in agreement with those reported by Varela et al. (2014), who demonstrated the good differentiation capacity of this methodology. In fact, PSP has the additional advantages such as enabling the comparison of sample configurations from different sessions, which cannot easily be achieved using the other two rapid methodologies (ANTÚNEZ et al., 2015; ARES; VARELA, 2014; CADENA et al., 2014; VARELA; ARES, 2012).

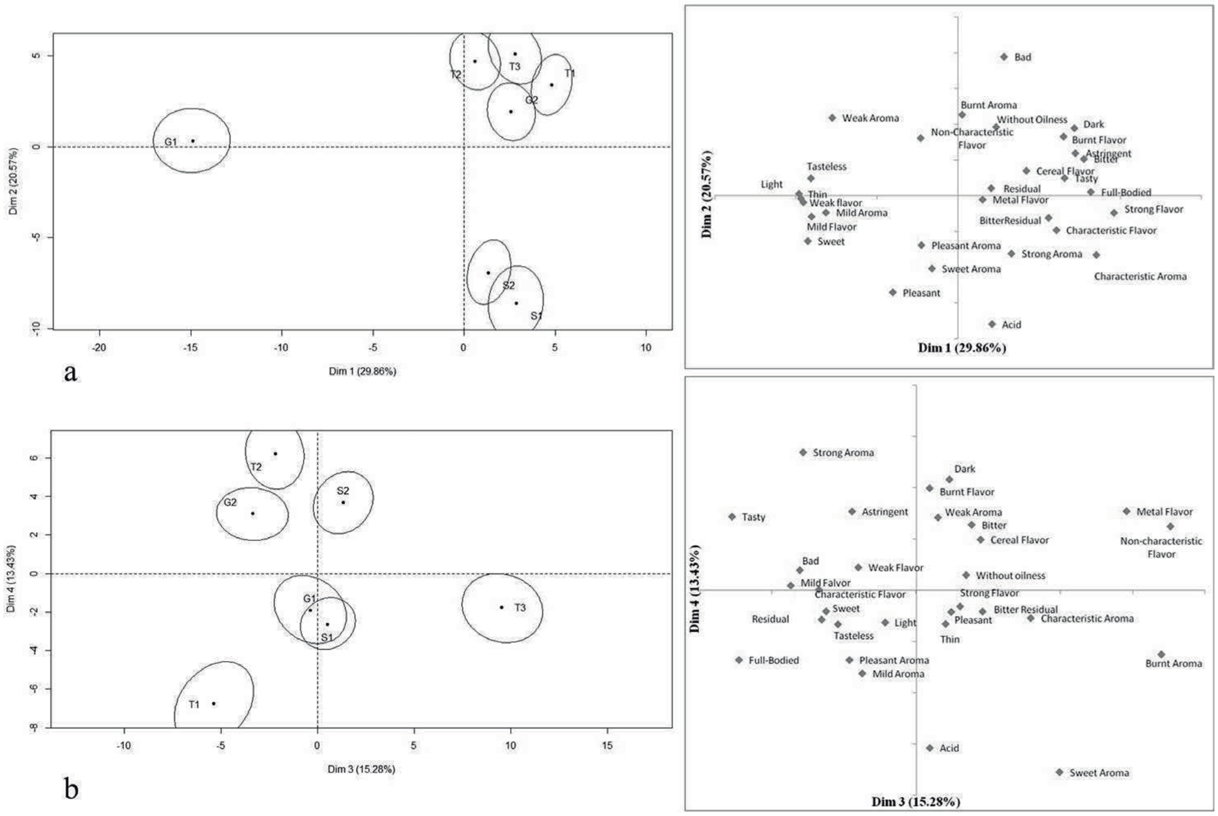

FIGURE 1 - Representation of samples and terms in the first and second dimensions of multiple factorial analysis (MFA) on polarized sensory positioning data. T1, T2 and T3 – Traditional; S1 and S2 – Superior; G1 and G2 – Gourmet.

Antúnez et al. (2015) confirmed that data aggregation of data collected in different sessions with different assessors using PSP provides similar information to the evaluation of samples in a single session. This characteristic of PSP makes it a particularly interesting alternative when using consumer-based characterizations for new product development (ANTÚNEZ et al., 2015; ARES; VARELA, 2014; CADENA et al., 2014). Besides, allowing the assessor to more easily identify the main sensory characteristics responsible for the similarities and differences between samples, due to the direct comparison with the references presented. This advantage is especially greater in relation to other sensory analysis techniques, where comparison is made monadically and depends on the panelist memory, among other factors that occur at the moment of the evaluation, such as concentration during the execution of the task (ANTÚNEZ et al., 2015).

Some authors reported that PSP seems to be a quick and interesting methodology for sensory characterization of products (DE SALDAMANDO et al., 2013; TEILLET, 2014; VARELA et al., 2014). De Saldamando et al. (2013) suggested that this method present a clear advantage over projective mapping and sorting tasks, particularly when working with samples with persistent flavours, or when a large number of samples should be evaluated over a long period of time or for quality control.

In addition to being able to differentiate beverages, it also allowed the identification of the main sensory characteristics of samples through consumer perception. Sample G1 was described mainly with the terms light, thin, mild aroma and flavor, weak and tasteless flavor. Samples S1 and S2 were mainly characterized by the attributes acid taste, strong and characteristic aroma. The samples T1, T2, T3 and G2 were associated to the attributes burnt aroma and flavor, dark, without oiliness and bad.

The sensory attributes used to characterize the samples were consistent with their type of roasting process (Table 1). The traditional samples T1, T2 and T3, of medium roast, were related to burnt aroma, while the gourmet sample G1, of light roast, was associated to the terms light color, thin, mild aroma and flavor, weak and tasteless flavor. A good consistency was also observed in the association of attributes burnt, dark, without oiliness with the term bad for taste and aroma, when consumers described traditional beverages, in the same way that they associated the attributes light, thin and mild to the terms pleasant aroma and taste for the description of the samples superior S1 and gourmet G1. These results indicate that main sensory characteristics that consumers consider when defining coffee as pleasant or bad are related with roasting conditions. In this case, the study also indicates the inferior quality of Brazilian traditional coffee when compared with especialty coffees. Consumers, who increasingly have access to superior and gourmet coffees, were able to discriminate and provide sensory characteristics of coffee beverages making an inference of a quality classification according to their perception and language.

Preprocessing of words generated by consumers may have led to loss of information during text interpretation, which may have contributed to the reasonable explanation of variance (50.43%) in the main dimensions of the sensory map. In the preprocessing of the words generated by the consumers of this study, there may have been a bias in the loss of information during the interpretation of the text. It is important to emphasize that the analysis of descriptive terms obtained through consumers in the description task is a time-consuming, laborious and difficult to perform and interpret (VARELA; ARES, 2012). Consumers write their comments without guidance, using their own writing style and sometimes with spelling and grammatical errors. Therefore, this initial verbalization needs to be preprocessed in order to obtain the final descriptions used in data analysis. Rostaing et al. (1998) mentioned the following steps necessary for the initial verbalization treatment: removal of errors, elimination of connectors and auxiliary terms, contextualization of sentences and terms that comprise them, lemmatization, regrouping of synonyms and management of ambiguous words. In most cases, this processing is done manually and, at some point, arbitrary decisions are made about synonymy, ambiguous terms and/or intensities. This decision-making is a crucial step in recovering reliable results without losing important information. As a way to minimize this risk, some authors (ARES et al., 2010; GALMARINI et al., 2013; NIEDOMYSL; MALMBERG, 2009) performed the classification and synonymy of words individually by more than one researcher. In this study, this treatment was manual, by a sensory analyst. There are recommendations for the use of some tools developed by these authors: Microsoft Excel macro, called “texttocolumn” (Microsoft Excel v. 2010), and some particular macros (available on request).

4 CONCLUSION

The PSP method was effective in the sensory characterization of coffee using consumer perception. The technique was adequate in both the differentiation aspect, including beverage classification according to the PQC of ABIC, and indicating the main sensory characteristics that direct beverage quality according to the consumer point of view, besides presenting advantages over the conventional descriptive profile regarding the time to perform the analysis. Despite being classified with a gourmet label, one of two gourmet sample were positioned at sensory configuration together traditional beverages, possiblly because they had similar sensory characteristics, and/or because sensory dimension generated is linked with the set of samples avaliated.

Main sensory characteristics that consumers consider when defining coffee as pleasant or bad are related with roasting conditions: attributes burnt, dark, without oiliness were assossiated with the term bad for taste and aroma, in the same way that they associated the attributes light, thin and mild to the terms pleasant aroma and taste.The results indicate that consumers were able to perceive the inferior quality of traditional Brazilian coffee, possibly due to the popularization of specialty coffees nationally marketed.

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NOTA PRÉVIA

DOES SULPHUR EXPEL THE COFFEE BERRY BORER FROM *Coffea arabica* L. FRUITS?

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ABSTRACT: Technicians and insecticide retailers recommend adding sulfur to the insecticide mixture to expel coffee borer females (*Hypothenemus hampei*) from the fruit. The objective in this study was to verify if sulfur expels the coffee borer from the fruit and what the cost associated with the use of sulfur in the insecticide mixture is. Perforated fruits were collected from coffee crops (Red Catuaí, IAC 144) during the granulation phase for the experiments and divided into two lots. The first lot was used to verify the effectiveness of sulfur to expel the borer, and the second to evaluate the effect of temperature x sulfur source x expelling effect on the borer. Sources of sulfur tested were: SK30 and Kumulus DF. The first experiment was the treatments: sulfur sources (two + control without sulfur), two plastic containers (open and closed), five repetitions (factorial: 3 x 2). The second were the treatments: sulfur sources, plastic containers and under two temperatures, factorial 3x2x2. The number of adult females that left the fruits within 24 and 48 h was evaluated. There was no difference in the number of females that abandoned the fruits between treatments with sulfur and control (P> 0.05). It was concluded that sulfur does not expel *H. hampei* from *C. arabica* fruits.

Index terms: Coffee, bored fruits, *Hypothenemus hampei*, temperature.

O ENXOFRE DESALOJA A BROCA-DO-CAFÉ DE FRUTOS DE *Coffea arabica* L.?

RESUMO: Técnicos e vendedores de inseticidas, recomendam adição de enxofre à calda para desalojar as fêmeas da broca do café (*Hypothenemus hampei*) do fruto. Objetivou-se com esse trabalho verificar se o enxofre desaloja a broca do café dos frutos e o custo associado ao uso do enxofre à calda. Frutos broqueados foram coletados em cafeeiro (Catuaí Vermelho, IAC 144) na fase de granação para dois experimentos. O primeiro objetivou verificar o efeito do enxofre como desalojante da broca, e o segundo para avaliar o efeito da temperatura x fonte de enxofre x efeito desalojante da broca. As fontes de enxofre testadas foram: SK30 e , Kumulus DF. Os experimentos foram em delineamento inteiramente casualizado, esquema fatorial duplo. O 1º experimento foram os tratamentos: fontes de enxofre (duas+ controle sem enxofre),dois recipiente plástico (aberto e fechado), 5 repetições (fatorial: 3 x 2). O 2º foram os tratamentos: fontes de enxofre, recipiente plástico e sob duas temperaturas, fatorial 3x2x2. Avaliou-se o número de fêmeas adultas que abandonaram os frutos com 24 e 48 h. Não houve diferença entre o número de fêmeas que abandonaram os frutos nos tratamentos com enxofre e a testemunha (P>0,05). Conclui-se que o enxofre não atua como desalojante de *H. hampei* dos frutos de *C. arabica* .

Termos para indexação: Café, frutos broqueados, *Hypothenemus hampei*, temperatura.

The coffee berry borer, *Hypothenemus hampei* (Ferrari, 1867) (Coleoptera: Scolytidae) is a monophagous species, which perforates the coffee fruit at various phenological stages, housing itself in the seed for a significant part of its life cycle (VEGA et al., 2015). Generally, a single female infests one coffee fruit, laying its eggs and generating larva that cause damage (CONSTANTINO et al., 2011; VEGA et al., 2015). The losses caused by the coffee bery borer in productive countries such as Uganda, Colombia, Jamaica, Tanzania, Malásia and Mexico vary between 50 to 90% (VEGA, 2004), affecting many families in the rural environment (VEGA et al., 2003).

Chemical controls are the most commonly used for this pest. However, they frequently fail, are toxic to humans and non-target organisms and contaminate the environment. With the removal of the insecticide endosulfan from the market, few control alternatives for coffee berry borer remain (U.S. ENVIRONMENTAL PROTECTION AGENCY, 2010). Despite the insecticide Benevia® 100 OD (SOUZA et al., 2013) being

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registered in the state of Minas Gerais, there are still few insecticide options. As a solution to this situation, technicians and retailers recommend the addition of sulfur to the insecticidal mixture to expel coffee berry borer females from the fruits. There are however, no studies which assess the use of sulfur for the borer and existing studies evaluate its application in relation to other pests such as *Rhyzopertha dominica* (Fabricius, 1972) (Coleoptera: Bostrichidae) and *Spodoptera frugiperda* (Smith, 1797) (Lepidoptera: Noctuidae) (GONÇALVES, 2007; GUERREIRO; CAMOLES; BUSOLI, 2013). Given the need to find ways to minimize damage during coffee cultivation, we sought to verify if sulfur applied on *arabica* coffee fruits expels the adult *H. hampei* females as well as determine the costs associated with the use of sulfur in the insecticide mixture.

The trials were carried out at the entomology laboratory of the Universidade Federal de Viçosa – *Campus* Rio Paranaíba. Red Catuaí variety coffee (IAC 144) in a phenological state of granulation, without insecticide application, was collected from a coffee crop. The female borers were obtained via rearing on a diet provided by the Institute de Pesquisa do Paraná – IAPAR. Prior to conducting the experiments, 1,000 fruits were arranged on a white plastic tray (30 x 40 x 10 cm) and infested with females obtained via breeding, at a ratio of one female/fruit. After 4 h of exposure, the females perforated and entered the fruits, which were therefore ready for use in the experiments.

In the first experiment, the experimental design was totally randomized, in a double factorial scheme (3 x 2) + control (water). Three sulfur sources (Kúmulus DF - 1 L ha-1, fertilizer SK30 - 1 L ha^{-1} and Sulfur 750 - 3 L ha^{-1}) were used in two types of environment (open and closed container), with five replicates. The fruits perforated by the borer were sprayed using a 350 mL spray bottle and dried in the shade for 30 minutes. Following this, 15 fruits per plastic container were added (TP 62 100-T of 200 ml), constituting the experimental unit (repetition: 15 fruits/pot, performed 450 perforated fruits/ treatment). The total was five closed and five open plastic containers containing fruits treated using the sulfur sources. The containers were sealed to verify if the sulfur sources had a fumigant effect. The open containers had their lids punctured (2 x 2 cm) and organza fabric was fixed over the top to allow gases to escape but prevent the escape of borers that left the fruits.

The second experiment was carried out using a factorial scheme (3 x 2 x 2), with three sulfur sources (as above), open and closed containers and two temperatures (25° C and 35° C) in BOD with 5 repetitions. After the preparation process of the fruits and exposure to the borer as in experiment 1, the containers were added in two BOD's, with a temperature of 25° C and the other at 35° C.

The number of female adults that abandoned the fruits was counted at 24 and 48 hours after spraying. The data were submitted to the Shapiro-Wilk and Bartlett tests with the aim of verifying the normality and independence of the residues and the homogeneity of the variance. To compare the data obtained, ANOVA (Analysis of variance) was performed and where necessary, the measures were compared using the Tukey test ($p>0.05$).

The sulfur sources (SK30 and Kúmulus DF) sold in the markets in the region of Alto Paranaíba was tested (Table 1). Data regarding dose and price were also collated to determine the cost of adding sulfur to the insecticide mixture.

Significant differences between the sulfur sources ($F= 0.09$, $p>0.05$) or type of container ($F= 2.97$, $p= 0.095$) were not observed, nor were they observed in the interactions between the sulfur sources x type of pot ($F= 0.56$, $p>0.05$). Additionally, significant differences between sulfur sources ($F= 0.13$, $p>0.05$), temperature ($F= 1.54$, $p= 0.215$), type of container ($F= 0.79$, $p>0.05$) or in the interaction between these ($F= 0.11$, $p>0.05$) were not observed in the experiment assessing the effect of temperature x sulfur sources on the number of females that abandoned the fruits (Table 1). Products with a sulfur base cost on average R$21.50 ha^{-1} (Table 2).

In the present research it was seen that under control conditions, sulfur does not affect the coffee borer, since the expected expelling effect was not observed in any of the treatments. Additionally, no effect by temperature on the action of the sulfur to expel the borer was observed. This result was different to what was claimed by the sulfur retailers/ consultants, who in an informal manner affirmed that sulfur would function at higher temperatures, given that it would become a gas and expel the borer from the interior of the fruit. The cases of success with the use of sulfur on pests are rare. The same applied for the control of coffee borer, given that the borers did not abandon the grains under laboratory conditions in sealed containers. In cafe producing areas, an effect by sulfur on coffee berry borers was not expected, given that sulfur is very stable and does not evaporate.

TABLE 1 - Average ± standard error for the number of females of *Hypothenemus hampei* that abandoned *Coffea arabica* fruits in the two experiments.

Treatments	Characteristics of pots	[1]Females expelled from the fruit/container		
		1st Experiment	2nd Experiment	
	24 hours		25 °C	35 °C
Kúmulus		0.21± 0.21a	0.50± 0.29a	0.25±0.29a
SK30	Open	0.11±0.09a	0.00±0.00a	0.00±0.00a
Control		0.22±0.28a	0.50±0.29a	0.00±0.00a
Kúmulus		0.24±0.23a	0.50±0.29a	0.25±0.29a
SK30	Closed	0.21±0.21a	0.00±0.00a	0.00±0.00a
Control		0.31±0.26a	0.50±0.29a	1.00±0.00a
	48 hours			
Kúmulus		0.20±0.20a	0.25±0.25a	0.00±0.00a
SK30	Open	0.20±0.20a	0.25±0.25a	0.25±0.29a
Control		0.00±0.00a	0.00±0.00a	0.75±0.48a
Kúmulus		0.60±0.24a	0.25±0.25a	0.25±0.25a
SK30	Closed	0.60±0.40a	0.25±0.25a	1.25±0.25a
Control		0.80±0.20a	0.00±0.00a	0.50±0.50a

[1]Averages followed by the same letter in the same column do not differ between themselves according to the Tukey test with 5% probability.

TABLE 2 - Characteristics of the main products with a sulfur base in Alto Paranaíba, MG.

Commercial name	Sulfur Concentration (%)	Dose (L or Kg ha^{-1})	Unit Costs (R$ L or Kg^{-1})	Costs (R$ ha^{-1})
SK30	80	1	35.00	35.00
Kúmulus DF	80	0.5	16.00	8.00
		Average	25.50	21.50

Therefore it does not penetrate the coffee grain in the liquid formula. The formation of the gas occurs when fossil fuels are burnt (CETESB, 2017). However, authors such as BELLETTINI et al. (2005) and OLIVEIRA et al. (2006) affirm that sulfur forms hydrogen sulphide gas without even testing this hypothesis. If gas formed however, and there was an effect on the borer in the experiment with the closed container, the borer would have left the coffee fruit. This did not occur though, leading to the certainty that sulfur can be used for other purposes, but not to control the coffee berry borer.

Sulfur has been recommended for use mixed with the insecticide chlorpyrifos to increase the efficacy of the control of the coffee borer and for use as an acaricide being effective through contact and ingestion (VAN LEEUWEN et al., 2005). It is a mining subproduct destined for the production of agricultural fertilizer (DEPARTAMENTO NACIONAL DE PRODUÇÃO MINERAL, 2014). It is not however recommended as a fumigant. The little research that exists is for other pests, such as *Spodoptera frugiperda* caterpillars (GREENLEE; HARRISON, 2005). These studies showed an expelling effect on *S. frugiperda*, mainly through the liberation of sulfhydric gases. These act as an insect bio-irritant, resulting in greater movement, and consequently, contamination, as well as greater exposure to natural enemies and mortality of caterpillars (GUERREIRO; CAMOLESE; BUSOLI, 2013).

In studies carried out with sulfur applied on soil for the control of crickets (*Quesada gigas*) in coffee crops, satisfactory results were obtained, and have as a hypothesis control through the utilization of sulfur and the compounds resultant from the oxidation of sulfur and inhibitors of acetylcholinesterase. Given this, we argue that sulfur applied on soil becomes a potent insecticide (REIS et al., 2015).

As seen in the results, the use of sulfur in the control of the borer increases application costs and, does not present a satisfactory result to help control the insect. A possible explanation could be a lack of contact between the borer and the sulfur, due to its habit of staying inside the fruit. In addition to not delivering results for control of the coffee borer, it can cause population imbalances with *Leucoptera coffeella* (Guérin-Méneville, 1842) Lepidoptera: Lyonetiidae and mites (VENZON et al., 2013; ANDRADE et al., 2011). It also causes environmental contamination due to leaching of sulfur into the soil profile (REN; ZHU, 2015). Sulfur in the air can also provoke harm to human health, such as exacerbation of asthma symptoms (MATHEW et al., 2015). Additionally, there are the necessary expenses (R\$21.50 ha^{-1}), taking into account the fact that the use of sulfur does not contribute to controlling the borer. This cost is variable depending on source and region, reaching higher values or not depending on the fluctuation of the prices of the products. However, the addition of sulfur to the insecticide mixture increases application costs.

We conclude that sulfur does not have the expected positive effect on the control of the borer. Consequently, it does not act to expel adult *H. hampei* females from *C. arabica* L fruits.

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