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Uso de caulim processado como técnica sustentável de mitigação dos efeitos das mudanças climáticas na produção agrícola

Use of processed kaolin as a sustainable technique to mitigate the effects of climate change on agricultural production

Uso de caolín procesado como técnica sostenible para mitigar los efectos del cambio climático en la producción agrícola

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PALAVRAS-CHAVE
Café; sustentabilidade; inovação.

Resumo: O café é a segunda bebida quente mais consumida no planeta. O Brasil é reconhecido como o principal protagonista na produção e exportação de café; sendo assim a busca pelo aumento de produção sem expansão da área física plantada é um caminho da sustentabilidade e pilar das pesquisas agrícolas em regiões tropicais. Diante disso, o presente estudo tem como objetivo discutir à luz de uma revisão de literatura integrativa uma técnica sustentável e ecologicamente correta para a proteção de plantas cultivadas a pleno sol, a fim de assegurar o contínuo crescimento da produção do café no Brasil. Trata-se da pulverização do mineral caulim sobre plantas comercialmente cultivadas de café; um mineral inorgânico, natural, processado, purificado e formulado, disponível sob a marca comercial Surround®WP. Considerou-se como metodologia aplicada, a pesquisa descritiva e explicativa, com vistas à identificação da relação entre a temperatura do ar, temperatura sobre as plantas e seus danos causados às plantas através do procedimento técnico da pesquisa bibliográfica. De forma geral, a elevação da temperatura do ar causa estresse térmico no cafeeiro e favorece a queimadura das folhas, causada pelo excesso de radiação solar, deixando a planta vulnerável a insetos não desejáveis. Os resultados dos estudos revisados demonstraram que a aplicação do caulim contribuiu significativamente para o aumento da produtividade, melhoria na qualidade dos grãos e agregação de valor ao produto comercializado. Desta forma, o produto poderá ser importante aliado para o contínuo crescimento sustentável e economicamente viável da cafeicultura brasileira.

KEYWORDS
Coffee; sustainability; innovation.

Abstract: Abstract: *Coffee is the second most consumed hot beverage on the planet. Brazil is recognized as the main protagonist in coffee production and exportation. Therefore, the search for increased production without expanding the physical area planted is a path to sustainability and a pillar of agricultural research in tropical regions. In light of this, the present study aims to discuss, through an integrative literature review, a sustainable and ecologically correct technique for the protection of commercially grown coffee plants in full sun, in order to ensure the continuous growth of coffee production in Brazil. This technique involves spraying the mineral kaolin on commercially grown coffee plants, which is an inorganic, natural, processed, purified, and formulated mineral available under the commercial brand Surround®WP. The methodology applied was descriptive and explanatory research, aimed at identifying the relationship between air temperature, temperature on the plants, and the damage caused to the plants through the technical procedure of bibliographic research. In general, the increase in air temperature causes thermal stress in coffee plants and promotes leaf burning caused by excess solar radiation, leaving the plant vulnerable to unwanted insects. The results of the reviewed studies demonstrated that the application of kaolin contributed significantly to increased productivity, improved grain quality, and added value to the commercialized product. Thus, the product may be an important ally for the sustainable and economically viable growth of Brazilian coffee production.*

PALABRAS CLAVE
Café; sustentabilidad; innovación.

Resumen: *El café es la segunda bebida caliente más consumida del planeta. Brasil es reconocido como el actor principal en la producción y exportación de café; por tanto, la búsqueda de una mayor producción sin ampliar el área física plantada es un camino hacia la sostenibilidad y un pilar de la investigación agrícola en las regiones tropicales. En vista de eso, el presente estudio discute, a la luz de una revisión integrativa de la literatura, una técnica sostenible y ecológicamente correcta para la protección de plantas cultivadas en pleno sol, con el fin de garantizar el crecimiento continuo de la producción de café en Brasil. Es la pulverización del mineral caolín sobre plantas de café cultivadas comercialmente; un mineral inorgánico, natural, procesado, purificado y formulado, disponible bajo la marca comercial Surround®WP. Se consideró la investigación descriptiva y explicativa como metodología aplicada, con el fin de identificar la relación entre la temperatura del aire, la temperatura de las plantas y los daños que causan a las plantas mediante el procedimiento técnico de la investigación bibliográfica. En general, la elevación de la temperatura del aire provoca estrés térmico en el cafeto y favorece la quema de las hojas, provocada por el exceso de radiación solar, dejando a la planta vulnerable a insectos indeseables. Los resultados de los estudios revisados mostraron que la aplicación de caolín contribuyó significativamente a aumentar la productividad, mejorar la calidad del grano y agregar valor al producto comercializado. De esta manera, el producto podría ser un aliado importante para el crecimiento continuo, sostenible y económicamente viable del café brasileño.*

Introduction

It has been estimated that coffee consumption began in 1000 BC, but records show that the first cultivation and trade, on any scale, only began in 1400 AD (Specialty Coffee Association, 2019). In most coffee producing countries, more than 70% of production is destined for the international market, thus most of the value added to this commodity is captured by roasters and retailers in importing countries (International Coffee Organization, 2019).

According to companies associated with the Brazilian Coffee Industry Association (ABIC), the demand for coffee in Brazil is still expanding, following a trend that is seen globally (Vegro & Santos, 2018). Coffee shops have never been more popular. Large coffee shop chains have opened thousands of stores around the globe, including in young and promising markets such as China and India (Bureau of Coffee Competitive Intelligence, 2018). It was Brazil that launched soluble coffee to the world; supported by the best technology and competitiveness, Brazilian soluble coffee industries have more than twenty distinct types of socio-environmental and process management certifications (Guimarães, 2015).

Recognized as the main protagonist in world coffee production, with 57.2 million 60Kg bags, Brazil is the largest exporter of this commodity, considering the sum of green, soluble, and roasted and ground coffee (Companhia Nacional de Abastecimento, 2020). According to the International Coffee Organization, global consumption is expected to reach 209.47 million 60kg bags. Therefore, the increase in coffee production in Brazil is of fundamental relevance in face of the challenges for global supply, in addition to the fact that the flavor of Brazilian coffee is increasingly winning the taste of the population of consumer countries (Guimarães, 2015).

Considering the current demands regarding sustainable agriculture, the objective of this study is to discuss, based on the literature, the feasibility of spraying kaolin, an inorganic, natural, processed, purified, and formulated mineral on coffee plants - *Coffea arabica L*, with a view to arousing the attention of farmers and professionals of corporate coffee farming about a sustainable, accessible, innovative and environmentally correct alternative for the expansion of coffee production, disconnecting from the concept of increasing production with area expansion.

The various edaphoclimatic characteristics of coffee farming result in variations in production systems, cultivated species, quality and yield of production, and, consequently, in economic results (Camargo, 1985). Being Brazil the largest coffee producer and exporter, whose protagonism is projected in the coming decades, the search for increased production without, however, expanding the planted physical area is a path to sustainability and preservation of natural reserves, pillars of agricultural research in tropical regions. In this context, the present study aims to discuss, in the light of an integrative literature review, the use of kaolin as a sustainable and environmentally correct technique for the protection of full-sun coffee plants, to ensure the continuous growth of grain production in Brazil even in the face of the predicted climatic changes.

Theoretical foundation

Systematic research which identified the effects of processed, purified and formulated, sprayed kaolin on plants gained importance and visibility in the 1970s after demonstrating a 4.0°C reduction in the leaf temperature of orange trees, and up to 5.4°C in rubber trees. This same study also proved a 25% decrease in the transpiration rate of the plants (Abou-Khaled, Hagan, Davenport, 1970).

Evaluations of the plants that received the processed kaolin, when under unfavorable climatic conditions, showed that they became more productive when compared to sorghum, cotton, tomato, apple, and coffee plants without protection with the processed kaolin (Abreu et al., 2020; Glenn et al., 2001; Srinivasa Rao, 1985; Moreshet, Cohen, Fuchs, 1979; Stanhill, Moreshet, Fuchs, 1976).

The kaolin mineral consists of hydrated aluminum silicate, the theoretical chemical composition is 39.50% of aluminum oxide, 46.54% of silicon dioxide and 13.96% of water (Luz, Campos, Carvalho, Bertolino, Scorzelli, 2008). The kaolin rock, in nature, brings in its composition traces of undesired metals, such as red iron oxide, which must be removed to obtain high qualities of white shine, and titanium dioxide, which must be eliminated to meet industrial specifications (Harben, 1995).

Due to its set of positive characteristics, kaolin is versatile and applied in the ceramics industry, in formulations for medicinal products, cosmetics, toothpaste, food additives, and as a light diffuser in white incandescent lamps, among others. The largest volume of this mineral is used by paper industries during the paper bleaching process. Chemically inert in a wide pH range, it has low thermal and electrical conductivity, soft texture, non-porous, non-expansive, and non-abrasive, has high dispersion and homogenization capacity in water and, due to its white or nearly white color, it is used as a pigment. In addition, it acts as reinforcement in load applications (Glenn, Prado, Erez, McFerson, Puterka, 2002; Harben,1995; Luz & Damasceno, 1994).

In agriculture, it is characterized as multifunctional, ecological, and non-toxic to the environment and living beings. It acts on the plants as a minimizer of thermal stress when they are exposed to high solar radiation and high air temperatures, contributing to the improvement of fruit quality and increased production (Mphande, Kettlewell, Grove, Farrell, 2020; Sharma, Reddy, Datta, 2015; Glenn & Puterka, 2005).

In general, 120 minutes after being sprayed onto plant surfaces, the processed and purified kaolin forms a film of crystals, being called 'particle film', marketed under the brand 'Surround® WP'. The product was registered under patent protection in favor of Engelhard Corporation, acquired by BASF. In Brazil, this agricultural input is exempt from registration at the Brazilian Institute for Environment and Renewable National Resources (IBAMA), the Ministry of Agriculture, Livestock and Supply, and also at the National Health Surveillance Agency (ANVISA) (Ministério da Agricultura, Pecuária e Abastecimento, 2016).

Studies in several countries have demonstrated the beneficial effects of processed and purified kaolin particle film on different commercially cultivated plants. As pointed out by studies in the United States, the product acts as a filter and reflective agent of solar radiation, reduces water stress and providing thermal comfort to the surfaces of *Capsicum annuum peppers* in periods of high air temperatures (Creamer, Sanogo, El-Sebal, Carpenter, Sanderson, 2005). In Colombia, a reduction of 2.5°C in the leaf temperature of roses (*Rose spp*.) was observed (Sotelo-Cuitiva, Restrepo-Díaz, García-Castro, Ramírez-Godoy, Floréz-Roncancio, 2011). In the commercially grown apple tree species *Malus domestica*, grown in New Zealand, the product reduced leaf temperature by at least 17% (Wünsche, Lombardini, Greer, 2004), and also mitigated scald damage caused by high solar radiation in South Africa (Gindaba & Wand, 2007). In Egypt, in tomato plantations *Solanum lycopersicum*, it increased water use efficiency by 26.24% (Abdallah, 2019). Also in Italy, in tomato plants protected with processed and purified kaolin particle film, a reduction in leaf temperature of 1.1°C was observed, reducing sunburn symptoms in the fruits, improving quality, allowing additional profitability of up 900 €/ha (Boari, Cucci, Donadio, Schiattone, Cantore, 2014).

Pomegranate fruits *Punica granatum*, grown commercially in India,, had 47% less sunburn when protected with the product and, due to this benefit, the pomegranates marketed had a better quality than the existing standard (Sharma, Datta, Varghese, 2018). Thus, the kaolin particle film has been considered as the best method for preventing quality losses of pomegranates by sunburn, also in commercial crops in Turkey (Yazici & Kaynak, 2006). Studies on commercially grown apple trees in the United States showed an increase in photosynthetic carbon assimilation, and an increase in stomatal conductance leading to higher productivity (Glenn et al., 2001). An additional benefit was observed when the product provided repellency against the fruit fly *Rhagoletis pomonella*, an undesirable insect, which in the larval phase, punctures apple fruits depreciating them for commercialization (Leskey, Wright, Glenn, Puterka, 2010). It was also effective as a repellent against cicadas, carriers of the *Xylella fastidiosa* bacteria, which causes a lethal disease in apple, mango, orange, tangerine, lemon, and grape orchards (Joubert, Grové, De Beer, Steyn, 2004; Puterka et al., 2003).

In addition to these already-mentioned benefits, recent studies conducted in Brazil prove that the use of kaolin contributes to a repellency rate against the psyllid *Diaphorina citri* up to 80% (Franco & Fukuda, 2018). This undesirable, fearsome insect for citrus growers acts as the vector of transmission of the bacteria that cause greening (Huanglongbing/HLB), one of the most destructive diseases, capable of decimating citrus orchards of all ages, in Brazil and worldwide (Bassanezi et al., 2020). Considering the coffee crop, a beetle called *Hypothenemus hampei* (Coffee Broca) is pointed out as the most undesirable insect, due to its high capacity to damage the grains, depreciating them to the point of making them commercially unviable. It was observed that the processed and purified kaolin is a repellent agent against the presence of the coffee berry borer (Coffee Broca), whose presence rate remained below 2% throughout the fruiting period. Associated with the biological insecticide Mycotrol®ESO, it showed a repellent effect also against aphids, thrips and whitefly (Kawabata, Nakamoto, Curtiss, 2015; Reis, Souza, Santa-Cecília, Silva, Zacarias, 2010).

In Italy, in a sunflower crop *Helianthus annuus*, the efficiency of the processed and purified kaolin particle film as a repellent of undesirable insects has been proven (Salerno, Rebora, Kvalev, Gorb, Gorb, 2020). In India, the product reduced the incidence of the fruit borer by 50.3%, and the appearance of the disease called "bacterial blistering " in pomegranate crops (*Punica granatum*) by 40.2% by 40.2% less (Sharma et al., 2018).

Specifically with regard to coffee and considering the agroclimatic zoning in force in Brazil, correlated to the architecture of the coffee plant and the increase in air temperature, negative impacts on productivity may arise and, therefore, there may be reduction in areas suitable for cultivation of *Coffea arabica L* coffee, by up to 75% in Paraná and 95% in Goiás, Minas Gerais and São Paulo (Assad, Pinto, Zullo, Avila, 2004).

Scientific studies have shown that temperatures above 23ºC on the *Coffea arabica L* coffee plant, without forest shading, lead to flower abortion, commonly known as "starnets", which induce the plant to produce more leaves and fewer grains (Camargo, 2010). In this way, high temperatures on the coffee plant reduce grain production and extend the production cycle, making it so long that it coincides with the flowering of the next crop (Camargo, 2010).

Taking into account the Special Report of the Intergovernmental Panel on Climate Change, every effort should be made so that the Earth's environmental temperature does not exceed more than 1.5°C, because, among other consequences, there will be negative impacts on future cereals production in tropical and temperate regions (Intergovernmental Panel on Climate Change, 2014). Plant physiology research has shown that above 24ºC, there is a 10% decrease in the photosynthetic rate for each 1ºC increase in ambient temperature, with the rate approaching zero after 34ºC (Nunes, Bierhuizen, Ploegman, 1968).

Therefore, it is understood that the Brazilian coffee industry is committed to socio-environmental issues, which is why there is a concern to produce sustainably. Consequently, it has been supported by a set of rigorous laws in favor of biodiversity conservation and the welfare of people associated to coffee production (Associação Brasileira da Indústria do Café, 2020).

Methodology

The present study is a descriptive and explanatory research with the aim of identifying the phenomenon arising from the relationship between air temperature, the temperature on plants, and the consequent damages, as well as observing the factors that determine such phenomenon (Gil, 2010). The methodology used is bibliographic research. According to Gil (2010) the bibliographical research is developed from publications in articles, books or websites on the subject already studied.

This is an integrative literature review. The inclusion and exclusion criteria were accessed using the Google Scholar search engine, and the electronic library system, that have links to various databases, including those considered relevant to this study, such as SBICafé, Biblioteca do Café, BioOne, Capes, Scielo, Web of Science and Science Direct. The research was carried out in the first semester of 2020, prioritizing works published from 2009 to 2019, being analyzed, in total, about 60 articles.

Specifically, with regard to coffee culture, searches were conducted in all editions of the Brazilian Coffee Research Congress from 2007 to 2019. This is an exclusive scientific event on coffee cultivation, held for 45 years by the Procafé Foundation. It has long been the meeting point between research and agrotechnological dissemination for the coffee sector and is characterized by the presentation of scientific papers and seminars, as well as the realization of field demonstrations of innovations destined for the coffee production system.

Main results

Reduction in leaf temperature and effect on the physiology of agricultural crops

According to the bibliographic research undertaken, it is possible to state that processed kaolin, of the commercial brand Surround®WP, mechanically complements the defense/adaptation mechanisms of the plants cultivated in full sun, when these are insufficient to avoid injuries caused by the excess of solar radiation. Among the naturally protective mechanisms of plants, the increase in the flavonoid concentration, Ultraviolet-B absorbers, and the creation of an enzymatic antioxidant system, composed of the set of catalysis, superoxide dismutase, glutathione reductase, and ascorbate peroxidase, responsible for eliminating reactive oxygen species, stand out. They are considered key players in the production of non-enzymatic antioxidants, such as α-tocopherol, ascorbic acid, and carotenoids (Gonzalez-Villagra et al., 2020; Rippa, Ambrosone, Leone, Mormile, 2020; Kumari, Singh, Agrawal, 2009; Jansen, Hectors, O'brien, Guisez, Potters, 2008; Jain, Kataria, Guruprasad, 2003).

Sprayed on plants, kaolin acts as a reflective filtering agent of the sun's rays and softens the negative effects of excess solar radiation and high temperatures in the environment. Additionally, in synergy with the physiological defense mechanisms of plants, positive responses have been observed in varieties of commercially cultivated plants, enabling them to adapt to new environmental conditions, known as acclimation mechanism. Such responses, consistently, are attributed to the phenotypic plasticity of cells´ physical and morphological changes, all of them temporary, being reversed when there are changes in the environment (Tiaz, Zeiger, Moller, Murphy, 2017; Debat & David, 2001).

Particularly in Brazilian coffee production, the processed kaolin protective filter began to be sprayed on (or in) adult plants in the 2015/2016 harvest, demonstrating effective results in reducing the average leaf temperature by at least 2°C, reducing water stress by 39.25% and increasing the thermal index of stomatal conductance by 87.20% (Krohling et al., 2016, Abreu, Abreu, Krohling, Campostrini, 2017a). Protected *Coffea arabica L.* coffee plantations had a reduction in individual leaf temperature by 3.4°C, unfolding in gains in photosynthetic carbon assimilation by 71% (Steiman, Bittenbender, Idol, 2007). It was also observed an increase in the thermal index value of stomatal conductance by 116%, i.e. plants with higher respiration rate, lower temperature and better conditions to perform photosynthesis (Abreu *et al*., 2017a).

Studies of the adaptation capacity of young *Coffea arabica L*. coffee plants, transplanted from the nursery to the field, in full sun, in two seasons of the year (autumn and summer), demonstrated the protective effect of the kaolin filter on the leaves of *Coffea arabica L*. coffee, keeping them healthy, vigorous and free of symptoms of sunburn when compared the untreated ones. Furthermore, a reduction in the temperature of 7.5ºC was measured during autumn and up to 6ºC in summer (Abreu et al., 2020). One possible reason for the greater evaporative cooling of the leaf is the 26.24% increase in water use efficiency after application of the processed and purified kaolin (Abdallah, 2019).

Gains from the purified kaolinite particulate filter

The analyzed studies showed that coffee crops protected with this processed kaolin produced more perfect coffee fruits, with a larger size, resulting in increased productivity (Krohling et al., 2016; Santinato, Santinato, Eckhardt, Roda, Vieira, 2016). After harvesting, an increase of 7.63% in the sensory quality of the Catuaí Vermelho IAC44 coffee drink was observed. The sensory rating of the drink was 77.13 points compared to 71.66 points for unprotected coffee. As a result, there are financial gains for the farmer, who sells the coffee at higher prices due to the better quality than the standard (Abreu, Krohling, Abreu, Campostrini, 2017c).

Another scientific work proved an increase of 28.4% in the quality of the grains, and that each kg of dry grain in coconut with protection yielded 0.635 kg compared to 0.594 kg in unprotected plants (Abreu et al., 2017b). The coffee plants protected with Surround® WP produced 94 bags of 60 kg per hectare, compared to unprotected plants that produced in the same growing area 91 bags per hectare. Such a difference, considering that the price of the coffee bag at the time of the study was R$420.00, allowed the coffee grower to receive R$1,320.00 more per harvested hectare (Abreu et al., 2017b).

A summary of these results obtained in the analyzed studies is presented in Table 1.

Table 1
Use of processed kaolin particle film and its effects on coffee plants - *Coffea arabica and Coffea canephora*

Countries	**Author(s)**	**Results from Surround®WP**
	Coffea arabica	
United States (Hawaii)	Steiman & Bittenbender, 2007	Decrease in leaf temperature by 3.4°C compared to air temperature. Increase in photosynthesis rate by 71%.
Brazil	Santinato *et al*., 2016	Larger and more turgid, scald-free leaves compared to leaves without protection.
Brazil	Abreu *et al.*, 2020	Reduction of 7.5°C in leaf temperature compared to air temperature.
Brazil	Abreu *et al.*, 2017c	Increase of 5.47 points in coffee beverage quality.
	Coffea canephora	
Brazil	Abreu *et al.*, 2016	Reduction of leaf temperature by 2.0°C compared to air temperature.
Brazil	Krohling *et al*., 2016	Higher photosynthetic index. Higher proportion of full grains. Fewer malformed grains of the "boia" or shocked type.
Brazil	Abreu *et al.*, 2017b	Increase in farmer's income of R$1,200.00 per harvested hectare.
Brazil	Abreu *et al.*, 2017a	Less thermal stress on the leaves.

Source: Elaborated by the author.

Proposals to increase coffee production without expanding agricultural area

Brazil has gone from being an importer of technology and food on a large scale to becoming a generator of knowledge on tropical and sustainable agriculture; in addition to being one of the largest food producers in the world, capable of exporting to around 170 countries, with a huge impact on the trade balance (Embrapa, 2018). Parallel to this, there is a growing demand from society for the development of more sustainable production systems and a worldwide pressure for sustainability in social, economic and environmental aspects.

Grain production in 1990 was 58 million tons, cultivated in an area of 38 million hectares. 20 years later, production reached 155 million tons, using only 49 million hectares of land, thus grain production in Brazil grew 167%, while the cultivated area increased only 30% (Barison, 2012). Such efficiency is a positive consequence of the adoption of modern agricultural techniques and the inclusion of biotechnology. Even with the introduction of new technological packages incorporated into the production system, the dynamism of accepting the coffee drink on a global level has been vigorous. In order to meet the scenarios that point to increase in demand of around 2.0% per year until 2030, it is necessary to increase production (Vegro & Santos, 2018).

Research conducted by satellite sampling in a spatial domain in the Atlantic Forest ecosystem, dominated by a large tropical rainforest in southeastern Brazil, found that with 25% increase in deforested area there was a 1°C increase in the temperature of the Earth's surface, that is to say, areas without any forest cover had a temperature 4°C higher than forested areas. This study helps to understand the possible undesirable effects of replacing native vegetation with pasture, and other important and undesirable agricultural practices (Wanderley, Domingues, Joly, Rocha, 2019).

Research conducted in various tropical forest regions, records a warming in the average temperature of 0.26°C, which corresponds to ± 0.05°C per decade. This result corroborates with the global increase in air temperature, attributed to the greenhouse effect of anthropogenic action (Malhi & Wright, 2004). These anthropogenic disturbances are depleting natural resources, making it increasingly difficult to establish the coexistence between the growing demands of human population and ecological sustainability (Cumming et al., 2014). Once the predictions of air temperature increase by the IPCC (Intergovernmental Panel on Climate Change) are confirmed, the coffee tree agricultural zoning should migrate, compulsorily, to other regions (Assad et al., 2004).

The increase in air temperatures in the recommended zoning areas may cause a shift to other regions, causing social and economic impacts throughout the coffee production chain (Baca, Läderach, Haggar, Schroth, Ovalle, 2014), as for the good performance of *Coffea arabica L* plantations, the annual average temperatures should be between 18°C and 21°C (Alègre, 1959). The use of processed kaolin, acting as a filter and reflective agent of the excess solar radiation and reducer of leaf temperatures, is an ecologically sustainable, innovative, affordable, and easy-to-handle alternative that allows the plant to express its genetic potential when protected from high ambient temperatures and water stress by preventing damage caused by excessive solar radiation (Abreu et al., 2018). It is worth mentioning that Brazil has the second- largest reserve of kaolin rock in the world, on the order of 4.2 billion tons (Brazilian Mining Institute, 2012).

Final considerations

The air temperature is one of the important abiotic factors for plant development, considering that, in the areas defined as ideal edaphoclimatic zoning for coffee cultivation, temperatures are rising and may negatively impact the grain quality and productivity rates. The set of studies reviewed confirm that *Coffea arabica* and *Coffea canephora* coffee plants grown in full sun, sprayed and protected by the filtering and reflecting agent of the excess solar radiation based on processed and purified kaolin, showed a leaf temperature reduction from 2ºC to 7.5ºC, reduced of thermal stress, and additionally, less water stress.

Surround®WP is a natural and sustainable innovation for mitigating the effects of climate change, since it has contributed to the increase in the quality of coffee grains, productivity, and greater profitability for coffee growers. The increase in temperature in coffee-growing areas should be on the alert agenda of coffee growers, as if neglected, it may influence, at some point in the future the migration of crops compulsorily and involuntarily. As a result of this impact, there could be a reduction in jobs and rural exodus.

An interesting additional benefit of the application of processed and purified kaolin was observed due to its secondary effect of repelling some undesirable insects, contributing to the improvement of the plant and coffee grain quality. This characteristic entails the expansion of research in Brazil, in order to verify the possibility of this product becoming another tool for the rationalization of the use of pesticides.

According to the manufacturer, the processed and purified kaolin brand Surround® is being manufactured in Brazil, making it an accessible product and within the reach of producers whose production model ranges from large scale to family agriculture, including conventional as well as organic agriculture. In this way, this agricultural input, once sprayed on coffee plants, cam be an important ally for the continuous sustainable and economically viable growth of Brazilian coffee cultivation.

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