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Brown eye spot incidence during the vegetative stage of coffee grown in soil under sustainable management

Abstract – The objective of this work was to evaluate the influence of different soil coverings, fertilizer types, and soil conditioners on the incidence and severity of brown eye spot (*Cercospora coffeicola*) in coffee (*Coffea arabica*) during the vegetative stage. The experiment was carried out in a randomized complete block design, in a 3×2×5 factorial arrangement (soil coverings × fertilizer types × soil conditioners) in subdivided plots, with three replicates. Comparisons were made among: three soil covering (plastic film, *Urochloa decumbens*, and no covering) in the plots; two fertililizer types (conventional and controlled release) in the sub-plots; and four soil conditioners (coffee husk, agricultural gypsum, water retention polymer, and organic compound), as well as the control, in the sub-sub-plots. The area under the progress curve for disease incidence and severity showed the lowest mean without soil covering, whereas that for number of leaves was greater with the use of the controlled-release fertilizer. The plastic film provided a greater soil moisture and a lower soil resistance penetration. The chemical composition of the organic compound reduced coffee plants growth. Soil covering with plastic film or *U. decumbens* favors the high incidence of brown eye spot; however, it provides a greater soil moisture and, therefore, improves the growth of coffee plants in the vegetative stage.

Index terms: *Cercospora coffeicola*, *Coffea arabica*, controlled-release fertilizer, mulch, plastic film.

Incidência da cercosporiose na fase vegetativa de cafeeiro cultivado em solo submetido a manejo sustentável

Resumo – O objetivo deste trabalho foi avaliar a influência de diferentes coberturas de solo, tipos de fertilizantes e condicionadores de solo sobre a incidência e a severidade da cercosporiose (*Cercospora coffeicola*) em cafeeiro (*Coffea arabica*), em estádio vegetativo. O experimento foi realizado em delineamento de blocos ao acaso, em arranjo fatorial 3×2×5 (coberturas de solo × tipos de fertilizantes × condicionadores de solo) em parcelas subsubdivididas, com três repetições. Foram feitas comparações entre: três coberturas de solo (filme plástico, *Urochloa decumbens* e sem cobertura) nas parcelas; dois tipos de fertilizante (convencional e liberação controlada) nas subparcelas; e quatro condicionadores de solo (casca de café, gesso agrícola, polímero hidrorretentor e composto orgânico), bem como o controle, nas subsubparcelas. A área abaixo da curva de progresso da incidência e da severidade da doença mostrou as menores médias sem cobertura do solo, enquanto a do número de folhas foi maior com o uso do fertilizante de

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liberação controlada. O filme plástico proporcionou maior umidade do solo e menor resistência à penetração do solo. A composição química do composto orgânico reduziu o crescimento do cafeeiro. A cobertura do solo com filme plástico ou com *U. decumbens* favorece a alta incidência da cercosporiose; no entanto, proporciona maior umidade do solo e, consequentemente, melhora o crescimento do cafeeiro na fase vegetativa.

Termos para indexação: *Cercospora coffeicola*, *Coffea arabica*, fertilizante de liberação controlada, cobertura morta, filme plástico.

Introduction

Currently, Brazil exports about 32.8 million bags (60 kg) of *Coffea arabica* L., generating US$ 5.33 billion income and, therefore, being the largest producer and exporter in the world (Cecafe, 2021). Water deficit stands out among the limiting factors to this production, mainly in the current climate change scenario (Pozza & Alves, 2008), which is also capable of limiting the nutrient absorption, consequently favoring the susceptibility of plants to pests and diseases (Marschner, 2012).

One of the coffee diseases favored by nutritional imbalance is brown eye spot (BES) (Pozza et al, 2010; Silva et al., 2019), whose causal agent is the fungus *Cercospora coffeicola,* Berk. & Cooke. This disease can occur in coffee plants from seedling to crop in production, infecting leaves and fruit, generating production loss and quality depreciation of the drink (Pozza, et al., 2010; Lima et al., 2012).

Therefore, innovative cultivation techniques have been sought, such as soil covers that are capable of increasing water retention, maintaining soil temperature and humidity, thus reducing both the soil degradation and the potential for weed infestation (Partelli et al., 2010; Ragassi et al., 2013). Greater water availability promotes the uptake of nutrients, including N, P, K, Ca, and Mg, which are responsible for constituting the physical resistance barriers, such as the cell wall and the cuticle (Marschner, 2012).

Likewise, the soil fertility is extremely important for coffee to grow and develop. Thus, more efficient fertilizers are applied, as they are technologies capable of optimizing the use of nutrients by plants, by reducing losses through leaching and volatilization (Dominghetti et al., 2016). These fertilizers can contribute to the reduction of the brown eye spot incidence, since the disease is favored by nutritional imbalance (Chaves et al., 2018; Silva et al., 2019).

The use of soil conditioners is another promising technique, with emphasis on the use of superabsorbent polymers for soil-water retention, which are capable of increasing the water storage capacity in the soil, contributing to the growth and development of the crop, especially from the vegetative stage until the beginning of production (Azevedo et al., 2002).

Still, the agricultural gypsum is highlighted as a relevant practice to mitigate the effects caused by water scarcity, as well as for the management of diseases, due to its composition with up to 96.5% of calcium sulfate, provided it is applied at the correct dose according to technical recommendations (Serafim et al., 2013).

The use of coffee husks and organic compound as soil covers promotes the maintenance of organic matter content in the soil, the nutrient retention, and cycling, besides showing a positive influence on the biological activity, which turns the environment unfavorable to pathogenic organisms, due to the release of compounds which are toxic to them (Roscoe et al., 2006; Preethu et al., 2009). Because of this fact, the use of coffee husk extract at 116 g L^{-1} shows promising results in the management of brown eye spot, providing a reduction of up to 35% of the area under the progress curve for the number of lesions (Pereira et al., 2008). Moreover, soil conditioners are also known to improve plant growth. In a study involving water restrictions and different soil conditioners, the use of coffee husk favored greater plant height and greater number of leaves, even under conditions of water restriction at 40% field capacity (Castanheira et al., 2019).

Combined with a greater availability of nutrients in balance, these techniques are applicable in areas with water deficit of crops, in certain periods after planting the seedlings, mainly in plants in the vegetative stage. Due to the sensitivity of the crop to climatic fluctuations in the younger stages, the availability of water and temperature are critical limiting factors for the growth and development of coffee, in several Brazilian regions, before the beginning of fruiting, a stage when there is a great demand for these resources (Pozza & Alves, 2008; Martins et al., 2015). The crop stage before the start of production is little studied. It represents a short period of time, depending on the cultivar and can be a maximum of two years from planting. At this stage, coffee plants show a great growth of the root system and the plagiotropic and orthotropic branches, but still without production, which leads to the progress of diseases and pests, in a totally different way from the coffee tree at flowering and fruiting stages.

The objective of this work was to evaluate the influence of soil coverings, types of fertilizers, and soil conditioners on the incidence and severity of brown eye spot in coffee during the vegetative stage.

Materials and Methods

In January 2016, seedlings of *Coffea arabica* 'Mundo Novo 379-1', which is susceptible to brown eye spot, were planted in the field. The experimental area was located in the municipality of Lavras (21°13'36.47"S, 44°57'40.35"W, at 975 m altitude), in the state of Minas Gerais, Brazil. The local climate is classified as Cwa (humid subtropical), but it has Cwb characteristics with dry winters and rainy summers, according to the Köppen-Geiger's classification. The dry season occurs from April to September, while the rainy season occurs from October to March. The annual average temperature is 19.4°C, with 14.4°C as minimum and 21.6°C as maximum. The soil of the experimental area was classified as Latossolo Vermelho-Amarelo distrófico, according to the Brazilian Soil Classification System (Santos et al., 2018), i.e., Oxisol, with clayey texture, with the following composition 440 g kg^{-1} clay, 90 g kg^{-1} silt, and 470 g kg^{-1} sand (Curi et al., 2017).

Before the installation of the experiment, soil chemical characteristics at 0–20 cm soil depths were as follows: pH (water), 5.0; organic matter, 2.1 dag kg^{-1}; remaining phosphorus (P-rem), 27.1 mg L^{-1}; P (Mehlich-1), 4.5 mg dm^{-3}; K, 104 mg dm^{-3}; Ca^{2+}, 1.5 $cmol_c$ dm^{-3}; Mg^{2+}, 0.5 $cmol_c$ dm^{-3}; Al^{3+}, 0.2 $cmol_c$ dm^{-3}; H + Al, 3.5 $cmol_c$ dm^{-3}; cation exchange capacity (CEC) at pH 7.0 (T), 5.7 $cmol_c$ dm^{-3}; Al saturation (m%), 8.1%; and base saturation (V%), 39.6%. The soil chemical characteristics at 0–40 cm soil depths were the following: pH (water), 4.6; organic matter, 1.3 dag kg^{-1}; P (Mehlich-1), 1.4 mg dm^{-3}; K, 48 mg dm^{-3}; Ca^{2+}, 0.5 $cmol_c$ dm^{-3}; Mg^{2+}, 0.2 $cmol_c$ dm^{-3}; Al^{3+}, 0.5 $cmol_c$ dm^{-3}; H + Al, 4.4 $cmol_c$ dm^{-3}; CEC at pH 7.0, 5.1 $cmol_c$ dm^{-3}; V%, 15.9%; and m%, 37.8%.

A randomized complete block experimental design was carried out in a factorial arrangement of split split plot 3×2×5 (soil cover× types of fertilizers × soil conditioners), with 30 treatments, and three replicates, with a total of 90 experimental units. Each plot consisted of three rows of six plants, with four plants in the central row, which were used for measurements. The other rows and plants were borders. The comparisons were performed as follows: in the plots, three soil coverings were compared (plastic film, *U. decumbens* and no covering); in the subplots, two types of fertilizers (conventional and controlled release); and in the sub-sub-plots, four soil conditioners (coffee husk, agricultural gypsum, water retention polymer, organic compound) and the control without conditioner.

The spacing was 3.6 m between rows by 0.75 m between plants in the row. The experiment was carried out between April 2016 and September 2016, during the growth and vegetative stages of coffee seedlings, when they were already rooted, and the canopy was in full development, that is, established, and until its first flowering.

To evaluate the soil fertility before installing the experiment, 20 soil sub-samples were taken from this area, at 0–20 cm and 20–40 cm soil depths. The simple samples were homogenized in a bucket, constituting a compound sample, and then they were sent to the soil analysis laboratory for physicochemical characterization. According to the analysis results, liming was carried out in a total area, with 1.9 Mg ha^{-1} limestone with 90% PRNT, to correct the soil acidity. Subsequently, a complementary lime at 150 g m^{-1} was applied to the furrows and homogeneously incorporated into the soil. At 30 days before planting and at 60 days after the the lime application, 350 g per linear meter of simple superphosphate (18% P_2O_5) were incorporated into the soil in all treatments.

Soon after the planting of the coffee seedlings, the agricultural plastic film was installed on the planting row. This material is based on double-sided polyethylene. Its white face was exposed to the sun and the black face was in contact with the soil. To fix the sides of the film on the planting row, a pile of earth was put on its ends. The plastic film dimensions were 1.60 m wide, and the seedling was fixed in the middle of the agricultural plastic film. To apply fertilizers and soil conditioners, the sides of the film were raised and then fixed again.

Mulch was produced from *U. decumbens* planted in December 2015, before the coffee plantation, so that the *U. decumbens* was already established at the time of coffee planting. This grass was sown by broadcast, using 10 kg ha^{-1} seed (Souza et al., 2006), in the range of 1.60 m between rows of coffee trees. Mechanical mowing was performed before flowering. After drying, *U. decumbens* biomass was placed on the planting row under the canopies of coffee tree, using a rake. In the rainy season, grass was mowed from 5 to 10 cm height, at 35-45-day interval and, at the beginning of the dry period, it was mown at greater intervals to reduce the competition among the coffee trees, mainly for water and nutrients. In the planting row, weed control was performed with weeding and pre-emergent herbicides, at control intervals according to the weed growth.

In the treatment without covering, the 80 cm range on each side of the planting row was kept clean by means of weeding, and by the application of registered post- and pre-emergent herbicides indicated for the predominant target plants at the site. Between the rows, weed control was performed with a mechanical mowing.

Nitrogen and potassium were supplied to plants by the conventional fertilization formulated at 20-00-20 and, when necessary, this supply was complemented with conventional urea composed of 45% N. For the controlled-release fertilizer, two commercial products coated with elemental sulfur particles and organic polymers was used, one coated with urea (37% N), and the other, with potassium chloride (52% K_2O).

For the post-planting fertilization, 10 g N and K_2O per plant were applied, on a surface, in circles, 5 cm away from the stem. In the fertilization of the first year after planting, 30 g N and 10 g K_2O per plant were applied. These doses were determined to provide the same amount of nutrients to the plants, distinguishing only the fertilizers' type used and the form of application.

The conventional fertilization was carried out in installments, in coverage, at 30 and 60 days after planting. In the first year after planting, the recommended dose was divided into three times, at 45-day intervals, and the first application was carried out in November. The controlled-release fertilization was applied at once. Both liming and fertilization were calculated on the basis of the soil analysis results and the nutritional needs of coffee tree, described by Guimarães et al. (1999).

The organic compound and coffee husk were applied in coverage, in the projection of the coffee canopy at 10 L per plant, distributed in the 0.50 m range on each side of the plant (Guimarães et al., 1999). Coffee husk was prepared from the bean's pericarp, without undergoing a decomposition procedure. The organic compound contained residue from farm and food industry. The chemical characteristics of coffee husk were: N, 18.5 g kg^{-1}; P, 1.2 g kg^{-1}; K, 29.7 g kg^{-1}; Ca 3.9 g kg^{-1}; and Mg, 1.2 g kg^{-1}. The chemical characteristics of the organic compound were: N, 10.7 g kg^{-1}; P, 12.5 g kg^{-1}; K, 12.5 g kg^{-1}; Ca 23.8 g kg^{-1}; Mg, 3.5 g kg^{-1}; and Fe, 26.09 g kg^{-1}.

The agricultural gypsum was applied in 50 cm range on each side of plants, totaling 300 g m^{-2} (Guimarães et al., 1999). The applied product contained 18% calcium and 15% sulfur. The initial dose was calculated on the basis of the soil texture and on the analysis results of the soil from the 20−40 cm layer.

The water retention polymer was prepared by mixing 1.5 kg of this material in 400 L water and let to rest for 30 min. This gel was applied in the seedling planting pits and on the growing crop. For seedlings, 1.5 L of this mixture was applied per planting pit, incorporating the gel into the soil (Pieve et al., 2013).

The soil conditioners were applied at planting time. The control did not receive the application of the soil conditioners.

Using a nondestructive method, the incidence and severity of brown eye spot were evaluated in all plant leaves every two weeks, from April 2016 to September 2016, with a total of ten evaluations until the first flowering. The equation used to determine disease incidence, according to Campbell & Madden (1990), was: [Incidence (%) = (NLS/TNL)×100], where NLS is the number of leaves with symptoms per plant and TNL is the total number of leaves per plant.

The mean disease severity was evaluated on the basis of a diagrammatic scale, proposed by Custódio et al. (2011), for all leaves with incidence in the four plants in the plots, considering 0.1, 3, 6, 12, 18, 30, and 50% of affected leaf area.

The climate data were obtained from a climatological station located next to the experimental area, with Campbell Scientific datalloger and sensors (CM110; Campbell Scientific, Logan Utah, USA). The collected data were total precipitation (mm), average relative humidity (%), maximum, average, and minimum temperatures (°C), and insolation (W m^{-2}).

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In April and July/2016, the vegetative growth and soil resistance to penetration were evaluated. Vegetative growth was obtained by measuring the stem diameter (mm) with a digital pachymeter, and the plant height (m), with a graduated scale.

The soil resistance to penetration (kgf cm^{-2}) was determined with a hydromechanical penetrometer model MPC (Compacted-layer meter, Stara, Não-me-Toque, RS, Brasil). The pressure exerted on the soil was estimated by introducing the equipment into the soil up to 20 cm depth. The operation was performed at four points in each experimental plot.

Soil moisture was evaluated monthly, using the standard method (Claessen, 1997), with the soil sampling from 0–20 cm soil depths, in each experimental plot. The samples were placed in aluminum cans, which were immediately taken to the laboratory and weighed on a precision scale, to obtain the weight of the moist soil. After 24 hours in an oven at 110°C, the weight of the dry soil was determined. Subsequently, the gravimetric soil moisture was calculated in percentage (Claessen, 1997) as follows:

$$\mathrm{SM} = \left(\left(\mathrm{WSW} - \mathrm{DSW}/\mathrm{DSW}\right)\right) \times 100$$

in which: SM is the percentage of soil moisture, WSW is the wet soil weight, and DSW is the dry soil weight.

The incidence and severity of brown eye spot, the number of leaves, and soil moisture, over time, were integrated into an area under the incidence progress curve (AUIPC), severity (AUSPC), number of leaves (AUNLPC), and soil moisture (AUSMPC), according to Shaner & Finney (1977), in the following equation:

$$\mathrm{AUPC} = \sum_{i=1}^{n-1}\left(Y_i + Y_{i+1}\right)/2 \times \left(T_{i+1} - T_i\right)$$

in which: AUPC is the area under the incidence or severity progress curve (AUIPC or AUSPC), number of leaves (AUNLPC), or soil moisture (AUSMPC); Y_i is the proportion of the disease in the ith observation; T_i is the time in days of the ith observation; and n is the total number of observations.

The variance analysis assumptions were verified with the tests of normality (Shapiro-Wilk) and homogeneity (Bartlett). Subsequently, the data were subjected to the analysis of variance, and the significance was verified by the F-test, at 5% probability. If the F-test was significant, the Scott-Knott's test, at 5% probability, was used to compare the treatments. Data statistical analyses were performed using the R software version 3.6.3 (R Core Team, 2016).

From the average data on the brown eye spot incidence and severity in the leaf, and number of leaves, the progress curves over time were plotted, together with the climate data.

Results and Discussion

The brown eye spot (BES) incidence and severity progress curve were influenced by climatic conditions (Figures 1 and 2). BES occurred throughout the assessment period starting in April. The peak incidence of the BES occurred in July with the average of 35% infected leaves. This period was characterized by favorable conditions to the disease, with 22ºC average temperature, 69% relative humidity, low rainfall (1.6 mm) and high insolation (208.8 W m^{-2}). It is known that the BES intensity varies according to climatic conditions, and that it is favored by high insolation, low water availability and temperatures between 10 and 25ºC (Pozza et al., 2010; Silva et al., 2016, 2019; Chaves et al., 2018). This highest incidence in July may have occurred due to nutritional disorders as a consequence of low rainfall during this period, which caused the nutrient imbalance that favored the disease (Chaves et al., 2018). In addition, the peak of BES severity showed a behavior similar to the incidence, and it occurred under the same conditions and times also reported by Silva et al. (2016). These authors also found a greater disease severity at temperatures about 21ºC and high light intensity.

In September, the disease reduced, and there was also an increase of the number of leaves (Figure 1). The increase of rainfall, relative humidity, and temperature led to an increase of leaf emissions, causing greater leaf shading in the coffee canopy, thereby reducing the light intensity and disease, since the cercosporin toxin, associated with the pathogenicity, is activated at highly intense luminosity (Daub & Ehrenshaft, 2000; Daub et al., 2005; Chaves et al., 2018).

There was a significant effect of AUIPC and AUSPC for soil cover (Table 1). The treatment with no soil cover showed the lowest AUIPC (1,811.6) and AUSPC (1,321) averages, while coverings with *U. decumbens* and plastic film were similar. The largest AUIPC and AUSPC were observed in treatments with *U. decumbens* and plastic film. However, plants in

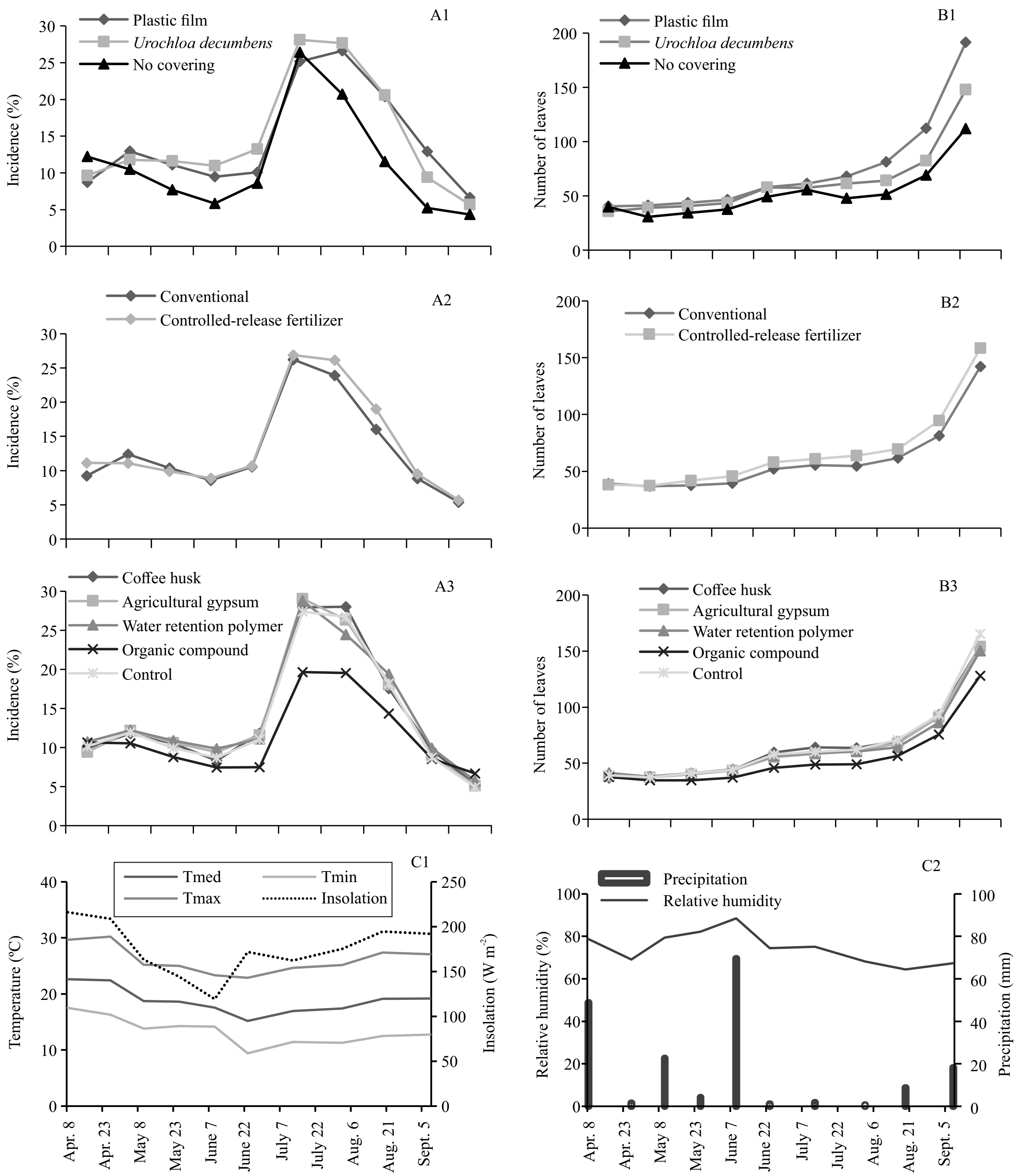

Figure 1. Progress curve for the brown eye spot incidence (%) (A1, A2, and A3) and number of leaves (B1, B2, and B3), and behavior of climatological variables from April to September 2016 (C1 and C2), according to data from the main weather station of Lavras, in the state of Minas Gerais, Brazil.

these treatments also showed higher number of leaves (Figure 1). In this context, a smaller number of leaves could contribute to the dilution of the disease incidence, as observed by Chaves et al. (2018), since infection by *C. coffeicola* causes the increase of ethylene synthesis, consequently increasing the abscisic acid, which favors the defoliation (Valencia, 1970). Therefore, less leafing treatments would also reduce the occurrence of diseases. The greatest plants growth and leafing occurred under the same amounts of nutrient supply, that is, the plants grew more and produced more, but with less availability and quantity of nutrients than those for smaller plants. Thus, the chance of nutritional imbalance or lack of nutrients in plants with greater growth and leafing led to a higher BES incidence. The greater availability of water and the consequent increase of soil fertility certainly provided the supply and balance of nutrients in these plants with greater growth, outside the standard recommended in the literature.

The AUNLPC shows a significant effect of types of fertilizers and an interaction between soil covering and conditioners (Tables 1 and 2). The AUNLPC also shows a higher effect (10440.7) of the controlled-release fertilizer than that of the conventional fertilizer (8830.8). Controlled-release fertilizers make nutrients gradually available, reducing losses and, consequently, increasing the efficiency of harvesting (Dominghetti et al., 2016). As to the soil cover with *U. decumbens*, the lowest AUNLPC was observed

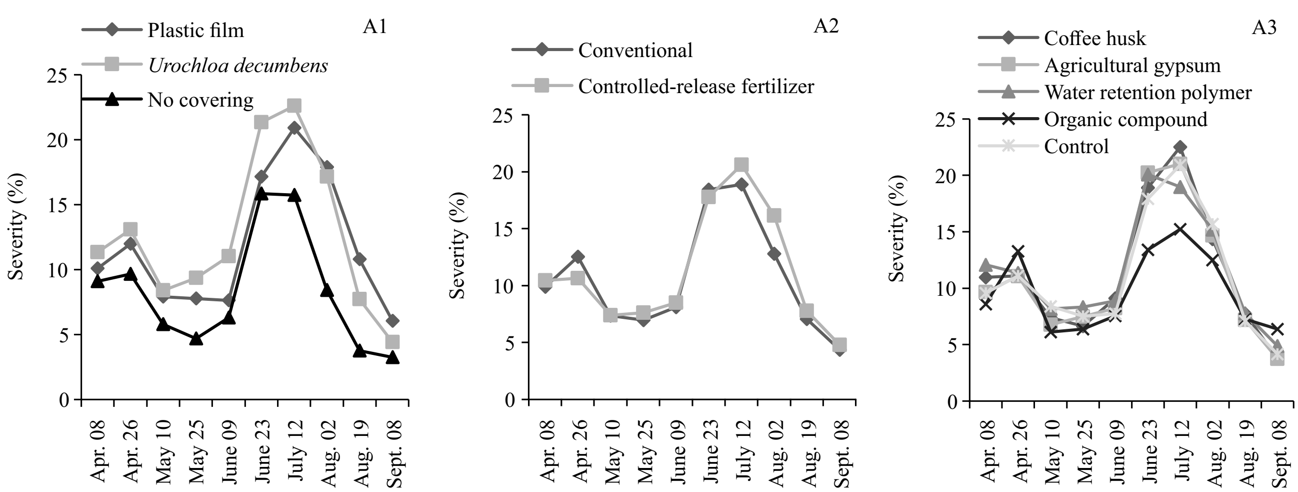

Figure 2. Progress curve of the brown eye spot severity in coffee plants (A1, A2, and A3) from April to September/2016.

Table 1. Area under the incidence progress curve of brown eye spot (AUIPC), severity (AUSPC), and number of leaves (AUNLPC) of coffee cultivated under soil coverings, with types of fertilizers, and soil conditioners(1).

Soil covering	AUIPC	AUSPC
No covering	1,812b	1,321b
Plastic film	2,375a	1,925a
Urochloa decumbens	2,439a	2,049a
Types of fertilizer	AUNLPC	
Controlled-release fertilizer	10,441a	
Conventional fertilizer	8,831b	

(1)Means followed by equal letters, do not differ by Scott-Knott's test, at 5% probability.

with the use of organic compound (5,505.4), while the other conditioners showed higher and statistically equal means. As to the soil cover with plastic film, the highest AUNLPC means were observed for the treatments with coffee husk (12,658.6) and the control (12,004.9); and the remaining conditioners showed lower and similar means. An even smaller AUNLPC was observed with the use of organic compound under soil covering with *U. decumbens*, which can be justified by the possibility that the compound used was toxic to plants due to excess iron (Jucoski et al., 2016).

As to the coverage with plastic film, the highest AUNLPC values were observed for the control and the coffee husk treatments. Possibly, these responses are related to a better use of water. In this sense, despite the higher BES incidence and severity on coffee trees covered with plastic film, there was a greater plant growth and leafing, due to the moisture in the soil and the more efficient absorption of nutrients, which favored the damage reduction caused by BES (Chaves et al., 2018; Silva et al., 2019).

As to AUSMPC, an interaction was observed between soil covering and soil conditioners (Table 2). The highest AUSMPC values in relation to the soil without cover was observed for coffee husk (2,606.2), while the other conditioners showed similar and lower means. For soil cover with *U. decumbens*, coffee husk (2,938.5), organic compound (2,908.5) and the water retention polymer (2,821.4) showed higher AUSMPC means. Soil moisture influences the nutrient uptake; and the maintenance of the soil cover and the organic residue can reduce the water loss through evaporation and soil temperature, which allows of increased infiltration and reduced runoff (Erenstein, 2002).

There was a significant effect of soil conditioners, in April, for soil resistance to penetration, and an interaction between soil covering and conditioners in July (Table 3 and 4). In April, the organic compound showed the lowest soil resistance to penetration than

Table 2. Area under soil moisture progress curve (AUSMPC), number of leaves (AUNLPC) of coffee cultivated under soil coverings, types of fertilizers, and soil conditioners(1).

Soil conditioner	AUSMPC			AUNLPC		
	Plastic film	No covering	*U. decumbens*	No covering	Plastic film	*U. decumbens*
Coffee husk	3,063Aa	2,606Ab	2,938Ab	8,013Ac	12,659Aa	10,099Ab
Organic compound	3,111Aa	2,410Bc	2,908Ab	8,133Ab	11,233Ba	5,505Bc
Agricultural gypsum	3,124Aa	2,363Bc	2,672Bb	7,693Ab	10,055Ba	10,893Aa
Water retention polymer	3,132Aa	2,262Bc	2,821Bb	7,528Ab	10,730Ba	11,177Aa
Control	3,051Aa	2,425Bc	2,694Bb	8,390Ab	12,005Aa	10,425Aa

(1)Means followed by equal letters, uppercases in the columns and lowercases in the lines, do not differ by Scott-Knott's test, at 5% probability.

Table 3. Plant height and soil resistance to penetration of coffee cultivated under soil coverings, with controlled-release fertilizer and conventional fertilizer, and soil conditioners(1).

Soil conditioner	Plant height (cm)		Soil resistance to penetration (kgf cm^{-2})		
	Controlled-release	Conventional	No covering	Plastic film	*Urochloa decumbens*
Coffee husk	26.20Ba	26.47Ab	18.26Cb	17.97Bb	20.05Aa
Organic compound	24.56Ba	24.16Ab	19.89Ba	17.85Bb	18.95Aa
Agricultural gypsum	24.83Ba	26.61Ab	23.21Aa	17.46Bc	19.88Ab
Water retention polymer	29.41Aa	25.26Ab	19.51Ba	18.08Bb	20.40Aa
Control	24.56Ba	25.87Ab	20.63Ba	20.00Aa	19.88Aa

(1)Means followed by equal letters, uppercases in the columns and lowercases in the lines, do not differ by Scott-Knott's test, at 5% probability.

the other soil conditioners. In July, in the treatment without covering, coffee husk had the lowest mean (18.3 kgf cm^{-2}), followed by the organic compound, the water retention polymer, and the control, with similar responses and, finally, the agricultural gypsum with greater soil resistance to the penetration (23.2 kgf cm^{-2}). However, in the soil covered with plastic film, the highest mean was found in the control, without the use of conditioners (20 kgf cm^{-2}).

The lower resistance of the soil to penetration may be correlated with the higher AUSMPC, as observed by Silveira et al. (2010). Soil covering, as well as the use of organic residue, promotes greater water retention in the soil and a consequent reduction of soil compaction (Montanari et al., 2012). Thereby, the greater availability of water in the soil enables a greater efficiency of nutrient absorption and contributes to the effectiveness of BES management (Chaves et al., 2018; Silva et al., 2019).

A significant difference was observed between the morphological variables evaluated in the two analyzed periods (April and July/2016) (Table 3 and 4). In April, there was a significant interaction between types of fertilizers and soil conditioners for plant height, and a significant effect for soil covering. The controlled-release fertilizer had a significant effect, and the highest plant height was observed in the treatment with the water retention polymer (29.4 cm). Regarding the soil covering factor, the highest plant height was observed with the use of plastic film (27 cm) than that of the other coverings. The techniques that allow the maintenance of soil moisture favor the conditions for the full growth of plants (Silveira et al., 2010).

In July, there was a significant difference between height and stem diameter for soil covering and conditioners (Table 4). The highest plant heights were observed in the treatment of soil covering with *U. decumbens* and plastic film, followed by the treatment without covering with the lowest average (32.1 cm). The largest stem diameter was observed in the treatment with plastic film (7.1 mm) in comparison with the other covers. Regarding the conditioners, the lower plant height (31 cm) and stem diameter (5.7 mm) were found in the treatment with organic compound, while the other conditioners resulted in higher averages for these parameters, without difference between them. The cultivation with *U. decumbens* provided the highest height combined with the smallest stem diameter. These results may be related to the plant etiolation which, in the search of light, grew excessively causing the reduction of the stem diameter, which was also observed in April (Tatagiba et al., 2010).

Therefore, techniques that allow of the water maintenance in the soil and improve the efficiency of nutrient absorption, in the early stages of coffee development, contribute to the nutritional balance of plants, which is essential for the coffee brown eye spot management, providing the best plant growth.

Table 4. Plant height, stem diameter, and soil resistance to penetration of coffee cultivated under soil coverings, fertilizer types, and soil conditioners(1).

Soil covering	April		July	
	Plant height (cm)	Stem diameter (mm)	Plant height (cm)	Stem diameter (mm)
No covering	25.16b	4.01b	32.1b	5.83b
Plastic film	27.03a	4.29a	36.0a	7.15a
Urochloa decumbens	25.20b	3.75c	35.3a	6.30b
Soil conditioner	Soil resistance to penetration (kgf cm^{-2})		Plant height (cm)	Stem diameter (mm)
Coffee husk	15.29a		35.49a	6.52a
Organic compound	13.51b		30.99b	5.67b
Agricultural gypsum	15.91a		35.43a	6.58a
Water retention polymer	16.14a		35.03a	6.58a
Control	15.73a		35.41a	6.78a

(1)Means followed by equal letters, uppercases in the columns and lowercases in the lines, do not differ by Scott-Knott's test, at 5% probability

Conclusions

1. Covering the soil with plastic film or *Urochloa decumbens*, favors the high incidence of brown eye spot (*Cercospora coffeicola*); however, it provides more soil moisture and growth of the coffee (*Coffea arabica*) plants in the vegetative phase.
2. The use of controlled-release fertilizers promotes a greater number of leaves and plant height of coffee than use of conventional fertilizers.
3. The use of plastic film provides greater soil moisture and lower soil resistance penetration.
4. The organic compound is prejudicial to coffee growth, due to its chemical composition.

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