BÁRBARA NOGUEIRA SOUZA COSTA

BANANA 'BRS PLATINA' UNDER DIFFERENT MULCHES: YIELD, POST HARVEST AND MORPHOPHYSIOLOGICAL PARAMETERS

LAVRAS - MG
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Tese apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Agronomia/Fitotecnia, área de concentração em Produção Vegetal, para a obtenção do título de Doutor.

Prof. Dr. Moacir Pasqual
Orientador
Prof. Dra. Leila Aparecida Salles Pio
Coorientadora

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Aprovado em 28 de fevereiro de 2019.

Dra. Leila Aparecida Salles Pio	UFLA
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À minha mãe, Mara, e ao meu padrasto Carlos;

À minha avó Terezinha (in memoriam);

Às minhas irmãs Alexandra e Mariana;

Ao meu esposo Irton,

por tanto amor, carinho, incentivo e apoio.

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RESUMO

A bananicultura brasileira possui grande importância econômica e social. A banana uma das frutas mais apreciada pelos consumidores, fazendo parte da alimentação básica de todas as camadas sociais da população. O objetivo desse trabalho foi avaliar a influência dos diferentes tipos de cobertura do solo nos aspectos produtivos, fisiológicos e anatômicos da bananeira 'BRS Platina' não irrigada. O experimento foi conduzido no pomar da Universidade Federal de Lavras (UFLA). Mudas de bananeira micropropagadas da cultivar 'BRS Platina' foram plantadas no campo com espaçamento de 2,5 x 3,0 metros (1333 plantas ha^{-1}), sem irrigação. Cerca de 20 dias após o plantio, foram instaladas as coberturas, filmes de polietileno preto, filmes de polietileno de dupla face (branco e preto), cobertura orgânica (da própria cultura) e controle (solo nu). O delineamento experimental foi em blocos ao acaso, com quatro tratamentos, seis blocos e seis plantas por tratamento, totalizando 144 plantas. Dentre as seis plantas utilizadas em cada tratamento, duas constituíram a bordadura, portanto foram avaliadas quatro plantas. As análises realizadas na primeira e segunda safra foram: análise de crescimento, qualidade pós-colheita, produção e produtividade, anatomia, trocas gasosas, clorofila, índice relativo de clorofila, conteúdo relativo de água e tolerância protoplasmática. Tanto a cobertura orgânica quanto a inorgânica (filme plástico) proporcionam maior crescimento e rendimento de bananeira, e podem ser utilizadas no cultivo dessa cultura. As mesmas também proporcionam aumento no conteúdo de clorofila e nas características das trocas gasosas. Entretanto, não influenciam nas características anatômicas, teor relativo de água e tolerância protoplasmática, nas folhas de bananeira 'BRS Platina' não irrigadas.

Palavras-chave: Filme plástico. Anatomia. Trocas gasosas. Clorofila.

ABSTRACT

Brazilian banana farming has great economic and social importance. Banana is one of the fruits most appreciated by consumers, being part of the basic diet of all social levels of the population. The experiment was conducted in the farm of the Federal University of Lavras (UFLA). Micropropagated banana plants of the cultivar 'BRS Platina' were planted in the field with a spacing of 2.5 x 3.0 meters (1333 plants ha^{-1}), without irrigation. About 20 days after planting, different mulches was installed: black polyethylene films; double-sided polyethylene films (white and black), organic mulch (from the own crop), and control (bare soil). The experimental was set up in a randomized block design with four treatments, six blocks and six plants per treatment, totaling 144 plants. Among the six plants used in each treatment, two constituted the border, therefore four plants were evaluated. The analyzes performed in the first and second crop were: growth analysis, post-harvest quality, production and productivity, anatomical analyses, gas exchanges, chlorophyll content, relative chlorophyll index, relative water content, and protoplasmic tolerance. Both the organic and inorganic cover (plastic film) provide greater growth and yield of banana, and can be used in the cultivation of this crop. They also provide an increase in the chlorophyll content and in the characteristics of the gas exchanges. However, they do not influence the anatomical characteristics, relative water content and protoplasmic tolerance in non-irrigated 'BRS Platina' banana leaves.

Keywords: Plastic film. Anatomy. Gas exchange. Chlorophyll.

SUMÁRIO

CAPÍTULO 1

1 INTRODUÇÃO GERAL

A banana é a fruta mais consumida no mundo e o alimento básico de milhões de pessoas nos trópicos, e a bananicultura é uma das atividades de grande importância econômica e social do agronegócio mundial e brasileiro (FERREIRA et al., 2015). Estima-se que o consumo nacional aparente per capita da banana esteja em torno de 27,5 kg hab^{-1} ano^{-1}, sendo a média mundial igual a 12,4 kg hab^{-1} ano^{-1}, podendo-se considerar o brasileiro o maior consumidor de banana do mundo (FÁVARO, 2003).

A bananicultura brasileira possui grande importância econômica e social, sendo que o Brasil vem destacando-se no cenário mundial como o quarto maior produtor da fruta em 2016, com produção de aproximadamente 6,8 milhões de toneladas em uma área cultivada de 469,71 mil ha, sendo os maiores produtores Índia, China, e Indonésia respectivamente (AGRIANUAL, 2019).

A cobertura (mulching) é o processo de cobrir a superfície do solo ao redor das plantas com um material orgânico ou sintético para criar condições adequadas para o crescimento, desenvolvimento e produção eficientes das plantas (BAKSHI et al., 2015). No entanto, existem diferentes tipos de coberturas, tais como inorgânico (cascalho, seixos ou filme de polietileno) (BLACK et al., 1994) orgânico (madeira, casca ou folhas, usado individualmente ou em misturas) (NI et al., 2016).

O crescimento das plantas é grandemente influenciado pelo uso de diferentes materiais de cobertura orgânicas e inorgânicas. Elas conservam a umidade do solo na zona de raízes das frutíferas. A água desempenha um papel importante no crescimento e desenvolvimento das plantas. A presença de umidade adequada no solo é vital para o crescimento das plantas e processos fisiológicos (BAKSHI et al., 2015).

Devido à escassez de chuvas dos últimos anos, a cobertura do solo pode ser uma ferramenta importante na eficiência do uso de recursos hídricos, já que a utilização do filme plástico tem potencial para a redução das perdas de água por evaporação, o que pode reduzir o consumo de água de 5 a 30% pela cultura (ALLEN et al., 1998).

Devido a numerosas vantagens da cobertura do solo, necessidade de utilização de técnicas que façam melhor aproveitamento dos recursos hídricos e falta de pesquisas sobre a utilização de filmes plásticos na fruticultura, há necessidade de pesquisas nessa área, demonstrando que esse estudo tem grande relevância. Assim, o objetivo desse trabalho foi avaliar a influência dos diferentes tipos de cobertura do solo nos aspectos produtivos, fisiológicos e anatômicos da bananeira 'BRS Platina' não irrigada.

2 REFERENCIAL TEÓRICO

2.1 Importância Econômica da Bananeira

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O cultivo da banana é uma das atividades agrícolas mais antigas do País, merecendo destaque em todos os Estados brasileiros. Em 2018 as principais regiões produtoras eram Sudeste com 34,22% e Norte com 31,56% da produção nacional, seguidos das demais regiões Nordeste com 15,11%, Sul com 14,97 % e Centro Oeste com 4,13% da produção (AGRIANUAL, 2019).

Em 2018, os estados de São Paulo, Minas Gerais, Bahia e Santa Catarina, eram os principais produtores, e representavam 50,07% da produção nacional. Atualmente, o Brasil apresenta produção de 6.826,212 toneladas numa área de 461,354 ha (AGRIANUAL, 2019). Em 2018, as regiões Nordeste e Sudeste foram responsáveis por 65,78 % da produção nacional, com estimativas de 173,398 e 131,709 hectares de área colhida, respectivamente, e o estado da Bahia é o maior produtor nacional (AGRIANUAL, 2019).

2.2 Características da Cultura

A bananeira (*Musa* spp.) é uma planta herbácea, tipicamente tropical, pertencente à classe das Monocotiledôneas, família *Musaceae*, gênero *Musa* cujo centro de origem é o Continente Asiático. Para seu bom desenvolvimento e sua produção, exige calor constante, elevada umidade e boa distribuição de chuvas. Essas condições favoráveis são registradas na faixa compreendida entre os paralelos de 30ºde latitude Norte e Sul, nas regiões onde as temperaturas se situam entre os limites de 10ºC e 40ºC. Entretanto, existe a possibilidade de seu cultivo em latitudes acima de 30º (até 45ºC), desde que a temperatura seja adequada (MOREIRA, 1987).

As cultivares comerciais evoluíram a partir das espécies selvagens *Musa acuminata* Colla e *Musa balbisiana* Colla. Além da origem biespecífica (A = acuminata, B = balbisiana), a classificação desses grupos de banana comestível se baseia também, na combinação de cromossomos, resultando nos grupos diplóides (AA, BB e AB), triplóides (AAA, AAB e ABB) e tetraplóides (AAAA, AAAB, AABB e ABBB) (BALLESTERO, 1992; DANTAS & SOARES FILHO, 1997).

As temperaturas ideais para a bananeira situam-se entre os limites de 10ºC e 40ºC, estando a temperatura ótima para seu cultivo em torno de 28ºC (MELO et al., 2010). Considera-se a faixa de 15ºC a 35ºC de temperaturas como os limites extremos para a exploração racional da cultura e abaixo de 15ºC a atividade da planta é paralisada. Temperaturas inferiores a 12ºC provocam o distúrbio fisiológico conhecido como *chilling* ou "friagem", que prejudica os tecidos dos frutos, principalmente os da casca, devido à coagulação da seiva na região subepitelial da casca. Quando atinge 0ºC, ocorre a geada, que provoca graves prejuízos, tanto na safra pendente com na seguinte. As baixas temperaturas, também aumentam o ciclo de produção das bananeiras, provocam a compactação da roseta foliar, dificultando o lançamento da inflorescência ou provocando o seu "engasgamento". Por outro lado, em temperaturas acima de 35ºC o desenvolvimento da planta é inibido, em consequência principalmente, da desidratação dos tecidos, sobretudo das folhas (MOREIRA, 1987 ; MEDINA, 1995 ; BALLESTERO, 1992 ; BORGES et al., 2000).

O vento é outro fator climático que influencia no cultivo da banana, cujos prejuízos são proporcionais à sua intensidade e podem provocar: *chilling,*ou "friagem", no caso de ventos frios, desidratação da planta em consequência de grande evaporação, fendilhamento das nervuras secundárias, redução da área foliar e tombamento de plantas. Com relação à umidade relativa do ar, a bananeira apresenta melhor desenvolvimento em locais com médias anuais em torno de 80% (MEDINA, 1995). Contudo, quando associada às chuvas e a temperaturas elevadas, provoca doenças fúngica (BORGES et al., 2000).

O método de propagação da bananeira é exclusivamente vegetativo. A utilização de mudas convencionais, por exemplo, mudas de rizoma, contribui significativamente para a disseminação de pragas e doenças (SOUZA et al., 2000; ROELS et al., 2005). Com isso, A cultura de tecidos ou micropropagação vem sendo muito utilizada como uma alternativa viável de propagação da cultura em grande escala, produzindo mudas de alto vigor vegetativo, em curto espaço de tempo e isentas de problemas fitossanitários (KOZAI et al., 1997; SOUZA et al., 2000; ALVES et al., 2004).

Rizoma ou caule subterrâneo é a parte da bananeira onde todos os órgãos se apoiam direta ou indiretamente e na sua parte superior está implantado o pseudocaule que é formado pelas bainhas das folhas, dispostas concentricamente. A gema apical de crescimento encontra-se localizada no centro do colo da bananeira, porém, implantada no cilindro central do rizoma, ela é responsável pela contínua formação de folhas e das gemas laterais de brotação, e depois de gerar o total de folhas e gemas laterais de brotação da planta, ela cessa esta atividade e surge o fenômeno da diferenciação floral, onde se processa ,a partir daí , a transformação da gema apical em inflorescência da planta (que é o órgão de frutificação da bananeira, isto é, futuro cacho) (MOREIRA, 1987).

2.3 Cultivar BRS Platina

As cultivares Prata, 'Prata-Anã e Pacovan ocupam aproximadamente 60% da área cultivada com banana no Brasil. A 'Prata-Anã' predomina nos cultivos mais tecnificados , não obstante seja suscetível às principais doenças do bananal (DONATO et al., 2006). O uso alternativo de cultivares resistentes pressupõe que estas apresentem qualidade próxima a da Prata-Anã para aceitação do público e da cadeia produtiva (PIMENTEL et al., 2010). Neste sentido, a BRS Platina, lançada como cultivar em 2012, destaca-se pela resistência ao mal-do-panamá e sigatoka-amarela, maior precocidade e maior peso, comprimento e diâmetro do fruto, comparada à Prata-Anã (DONATO et al., 2006, 2009).

Com isso, uma das estratégias para solucionar a falta de cultivares “adequadas” é a criação de novos genótipos resistentes a doenças e pragas, que apresentem porte baixo, que sejam altamente produtivos e apresentem sabor semelhante às cultivares tradicionalmente aceitas pelos consumidores. Para isso, no Brasil, a EMBRAPA Mandioca e Fruticultura Tropical, Cruz das Almas (BA), utiliza-se do melhoramento genético para a obtenção de híbridos tetraploides superiores a partir do cruzamento das cultivares triploides tradicionais com diploides, que foram avaliados em diferentes ambientes nos Estados pelas instituições de pesquisa (SILVA et al., 2003a).

A BRS Platina (PA42-44) é um híbrido tetraplóide (AAAB) desenvolvido pela Embrapa Mandioca e Fruticultura Tropical a partir do cruzamento entre Prata-Anã (AAB) x M53 (AA). Apresenta bom perfilhamento, porte médio a baixo e características de desenvolvimento e de rendimento idênticas às da genitora. Embora evidencie menor número de pencas, sua produtividade é semelhante a da Prata-Anã e apresenta maior precocidade para florescimento e colheita (DONATO et al., 2006, 2009). As plantas possuem o pseudocaule arroxeado, e seus frutos são maiores, de coloração verde mais clara, com bom sabor e formato plano que lhe confere facilidade para embalar. Pimentel et al. (2010) observaram que os frutos da BRS Platina apresentam-se mais maduros em relação aos da Prata-Anã nos mesmos índices de coloração, à semelhança das variedades tipo *Cavendish*.

A utilização dessa cultivar é importante devido a mesma ser resistente às principais doenças da bananeira, pois será utilizada cobertura morta da própria cultura nesse estudo.

2.4 Cobertura do Solo

A cobertura de solo (“mulching”) é um sistema de proteção que utiliza materiais próprios para cobrir o solo, buscando oferecer melhores condições à planta protegida. Funciona como uma barreira entre solo e atmosfera, caracterizada pelo seu efeito isolante. É tão antiga e natural quanto as florestas, que deixam uma manta espessa de folhas sobre a superfície. As coberturas mais tradicionais são matérias orgânicas vegetais: capim, palha, bagaço, casca e outros que estejam disponíveis. Existem também materiais inertes, como pedra, cascalho, carvão, papel tratado etc. Entretanto, nenhum desses supera a aplicação do plástico, devido a sua diversidade na composição, disponibilidade no mercado, facilidade no manejo e custo acessível (FILGUEIRA, 2007).

Os filmes para a cobertura de solo são de polietileno, de baixa espessura e limitada largura, apresentando diversas cores: transparente, preta, branca, prateada, parda, verde etc. Os transparentes são mais utilizados nas regiões frias, por causa do efeito estufa sobre o solo, porém não controlam as plantas daninhas. Em oposição, o filme preto não causa o efeito estufa, porém controla as plantas daninhas e é mais resistente, sendo o mais utilizado no Brasil. Os filmes de outras cores apresentam característica intermediarias. Observa-se que o filme preto absorve muito calor recebido, aquecendo-se e podendo provocar queimaduras nas partes mais sensíveis da planta, com as quais esteja em contato direto. Uma opção interessante, já oferecida pelo mercado, é o filme de dupla face: preto na face interna – opaco e mais resistente – e branco ou prateado na externa – reflete a luz não se aquece tanto (FILGUEIRA, 2007).

Nas condições brasileiras, é mais difundida a aplicação do filme preto, principalmente em culturas de morango, alface, solanáceas-fruto e cucurbitáceas, conduzidas no campo, em casa de vegetação e também túnel. A cobertura plástica é de fácil instalação e relativamente de baixo custo, podendo trazer bons retornos econômicos (FILGUEIRA, 2007).

A cobertura do solo proporciona um ambiente favorável para o crescimento, o que resulta em uma planta mais vigorosa e saudável, que pode ser mais resistente a lesões por pragas. Mulching impede a evaporação da água da superfície do solo e também reduz o crescimento das ervas daninhas. As coberturas podem ser inorgânicas ou orgânicas. Tem vários efeitos no solo, como reduz a taxa de infiltração, conserva a umidade do solo, mantém a temperatura do solo, reduz a lixiviação de fertilizantes. Promove a colheita antecipada e melhora o rendimento e a qualidade dos frutos (AMAN et al., 2018).

O uso da cobertura plástica resultou em maiores produtividades em relação ao mulching com palhada nas culturas da alface crespa, tomateiro, repolho e feijão vagem (BRANCO et al., 2010). Carvalho et al. (2005) ao avaliarem o uso de cobertura morta do solo (capim, casca de arroz, palha de café ou serragem) no cultivo de alface, concluíram que, independente do tipo de cobertura morta, esta é eficaz no controle de plantas espontâneas resultando em maior produtividade da cultura devido à menor competição por água, nutrientes e luz.

Andrade Júnior et al. (2005) ao compararem diferentes tipos de cobertura do canteiro para cultivo de alface em Minas Gerais, não encontraram diferenças entre a cobertura com lona plástica preta e solo nu para variáveis produtivas, apenas o “mulching” com casca de café se mostrou superior.

Ferreira et al. (2009) ao realizarem experimento com a cultura da alface no Estado do Acre, obtiveram maior produtividade e maior controle de plantas espontâneas, quando utilizado casca de arroz ou plástico prateado para cobertura do solo, em relação ao solo descoberto ou plantio direto. Mógor et al. (2007), obtiveram maiores produtividades na cultura da alface com utilização de cobertura do solo com plástico preto em relação á cobertura morta ou solo nu.

Olinik et al. (2011) em experimento com a cultura da abobrinha obtiveram como resultado que o uso de filmes de polietileno em cobertura do solo proporcionou melhores resultados em relação ao solo desnudo, com uso de polipropileno ou casca de arroz na cobertura do solo.

A cobertura do solo possui inúmeras vantagens como exposto ao decorrer desse texto e a mesma tem sido muito utilizada na agricultura, principalmente na olericultura, com isso a importância de se realizar estudos da utilização de coberturas orgânicas ou inorgânicas em frutíferas já que os estudos são escassos.

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CHAPTER 2: ARTICLE 1

ARTICLE 1 - Yield and post harvest of 'BRS Platina' banana not irrigated under different types of soil mulches

ABSTRACT

Banana (*Musa* spp.) is a crop with outstanding economic and social expression throughout the world. The objective of this study was to investigate the effect of different mulches types in growth production, and post-harvest of banana 'BRS Platina' not irrigated. The experiment was conducted in the farm of the Federal University of Lavras (UFLA). Micropropagated banana plants of the cultivar BRS were planted in the field with a spacing of 2.5 x 3.0 meters (1333 plants ha^{-1}), without irrigation. About 20 days after planting, different mulches was installed: black polyethylene films; double-sided polyethylene films (white and black), organic mulch (from the own crop), and control (bare soil). The experimental was set up in a randomized block design with four treatments, six blocks and six plants per treatment, totaling 144 plants. Among the six plants used in each treatment, two constituted the border, therefore four plants were evaluated. The analyzes performed in the first and second crop were: growth analysis, post-harvest quality, production and productivity. Both organic and inorganic (plastic film) mulch provide greater growth and yield of banana 'BRS Platina' not irrigated, and can be used in the cultivation of this crop.

Keywords: Plastic film. Polyethylene. Organic mulch. *Musa* spp.

Produção e pós-colheita de bananeira 'BRS Platina' não irrigada sob diferentes tipos de coberturas do solo

RESUMO

A bananeira (Musa spp.) é uma cultura com expressividade econômica e social marcante em todo o mundo. O objetivo deste estudo foi avaliar o efeito de diferentes tipos de coberturas no crescimento, produção e pós-colheita da bananeira 'BRS Platina' não irrigadas. O experimento foi conduzido no pomar da Universidade Federal de Lavras (UFLA). Mudas de bananeira micropropagadas da cultivar 'BRS Platina' foram plantadas no campo com espaçamento de 2,5 x 3,0 metros (1333 plantas ha^{-1}), sem irrigação. Cerca de 20 dias após o plantio, foram instaladas as coberturas, filmes de polietileno preto, filmes de polietileno de dupla face (branco e preto), cobertura orgânica (da própria cultura) e controle (solo nu). O delineamento experimental foi em blocos ao acaso, com quatro tratamentos, seis blocos e seis plantas por tratamento, totalizando 144 plantas. Dentre as seis plantas utilizadas em cada tratamento, duas constituíram a bordadura, portanto foram avaliadas quatro plantas. As análises realizadas na primeira e segunda safra foram: análise de crescimento, qualidade pós-colheita, produção e produtividade. Tanto a cobertura orgânica quanto inorgânica (filme plástico) proporcionam maior crescimento e rendimento de bananeira 'BRS Platina' não irrigada, e podem ser utilizadas no cultivo desta cultura.

Palavras-chave: Filme plástico. Polietileno. Cobertura orgânica. *Musa* spp.

1 INTRODUCTION

Banana (*Musa* spp.) is a crop with outstanding economic and social expression throughout the world. It is an important source of food and one of the fruits with the highest production and consumption among tropical fruit trees (DONATO et al., 2006).

Mulching is the process of covering the soil surface around the plants with an organic or synthetic material to create congenial condition for plant growth, development and efficient production (BAKSHI et al., 2015). There are different types of mulches, such as inorganic (gravel, pebbles, or polyethylene film) (BLACK et al., 1994) organic (wood, bark, or leaves, used individually or in mixtures) (NI et al., 2016).

Plastic-film mulching has become a globally applied agricultural practice (STEINMETZ et al., 2016). In China, it is estimated that about 15–19% of its arable land is currently cultivated under plastic-film mulch (WANG et al., 2016; HE et al., 2017). Its use aims to improve the soil environment with the aim of improving the soil environment thus making it more beneficial to plant growth and increasing water use efficiency in semiarid regions (EKEBAFE et al., 2011), once it can reduce infiltration rate, conserve soil moisture, maintain soil temperature, reduce fertilizers leaching. Mulching can also promote early harvest of crop and improve yield and fruit quality (AMAN et al., 2018). Therefore, the current global usage of plastic mulch films is enormous and has been increasing in recent years (BRODHAGEN et al., 2017).

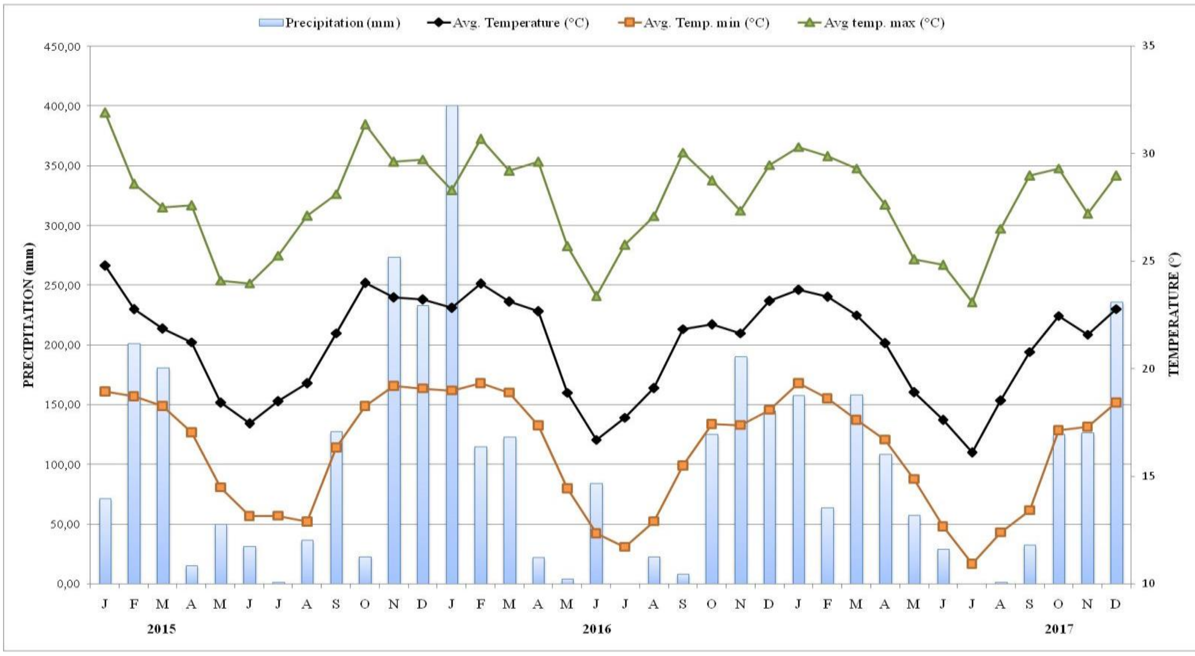
Technologies that optimize water resources are of extreme importance, since agriculture success is totally dependent on this resource. Several old techniques have been rescued, and optimized, as the use of mulches. Recent studies show the efficiency of the plastic-film mulch on the growth and yield of different cultures such as, mango, banana, papaya, and pineapple according to the National Committee on Plasticulture Application in Horticulture (BHATTACHARYA et al., 2018).

Therefore, the objective of this study was to investigate the effect of different mulches types in growth, production, and post-harvest of banana 'BRS Platina' not irrigated.

2 MATERIAL AND METHODS

The experiment was conducted at the farm of the Federal University of Lavras (UFLA), located in the city of Lavras, southern Minas Gerais, from 2015 to 2017 The Köppen climate classification for this region is Cwa - subtropical climate (21º14'S, 45º00'W and 918 metres of average altitude), i.e., a subtropical climate with cold and dry winters and warm and moist summers (KÖPPEN; GEIGER, 1928). The average annual temperature in 2015, 2016, and 2017 was 21.4°C, 21.1°C and 20.8°C with minimum average temperature 16.6°C in 2015, 16.2°C in 2016, and 15.8°C in 2017 and average temperature maximum 27.9°C in 2015, 27.9°C in 2016, and 27.6°C in 2017 (Fig. 1). The sum of rainfall was 1246.00 mm in 2015, 1240.60 mm in 2016, and 1097.00 mm in 2017.

Figure 1 – Climatic data from January 2015 to December 2017, Lavras, Minas Gerais, Brazil.



Source: Instituto Nacional de Meteorologia (INMET) - Banco de Dados Meteorológicos para Ensino e Pesquisa (BDMEP).

Soil preparation was carried out with a plowing and two harrowing, followed by the grooving in lines, with a depth of 20 cm. Later, micropropagated banana plants cultivar 'BRS Platina' were planted in the field in November of 2015 with a spacing of 2.5 x 3.0 meters (1333 plants ha^{-1}), without irrigation. About 20 days after planting, different mulches were installed: black polyethylene films; double-sided polyethylene film (white and black); organic mulch (from the own crop), and control (bare soil). The management practices of the crop were standardized, mainly regarding fertilization, thinning, defoliation, and phytosanitary control, using chemical products recommended for the crop.

The experimental was set up in a randomized block design with four treatments, six blocks and six plants per treatment, totaling 144 plants. Among the six plants used in each treatment, two constituted the border, therefore four plants were evaluated. The data was submitted to analysis of variance (ANOVA) and the means compared by Tukey's test at 5% of significance level using the statistical program SISVAR (FERREIRA, 2011).

The analyzes performed in the first and second crop were:

2.1 Growth analysis

The plants were evaluated for leaf number (unit), plant height (cm), pseudostem diameter (cm) and suckers number (unit) over 5 monthly evaluations.

2.2 Post harvest quality

Samples were taken (one hand) from the total of bunches harvested from the experiment at the maturation stage. The length and diameter (cm) were measured with a pachymeter, and the following physical-chemical parameter were analyzed on the fruit pulp:pH, determined by potentiometry; soluble solids (SS), in refractometer, with results were expressed in °Brix; titratable acidity (TA), was determined according to the AOAC expressed in % of citric acid per 50 mL of pulp, determined by titration with sodium hydroxide (0.1 N) using 1% phenolphthalein as indicator, the soluble solids/titratable acidity ratio (SS/TA).

2.3 Production and Productivity

The number of hands (NH) was obtained by the average number of hands obtained in the bunches collected in the plot. The number of fruits per hands (NFH) was obtained by the average number of bananas obtained in each plot harvested in the plot. The production was obtained from the average of the weights of hands collected in the plot and the productivity (Kg ha^{-1}) was obtained from the average weights of hands collected in the plot multiplied by the number of plants (1333 plants ha^{-1}).

3 RESULTS AND DISCUSSION

3.1 Growth analysis

Most of the growth characteristics did not differ significantly in the interaction between mulches and evaluations period. Therefore, these factors were evaluated separately (Table 1 and 2).

All the mulches increased plant height, pseudostem diameter, and suckers number in relation to control in the first crop. In the second crop the organic mulch provided higher plant height compared to the other treatments, and both plastic films increased the plant height compared to control. Besides, all the mulches provided increase in the pseudostem diameter. The plastics films increased in the leaf number in compared to the other treatments (Table 1).

The plant growth is greatly influenced by the use of different organic and inorganic mulching materials. They maintain soil moisture in the root zone of fruit trees. Water plays an important role in the growth and development of plants. The presence of adequate moisture in the soil is vital for plant growth and physiological processes (BAKSHI et al., 2015).

Haynes (1980) observed that mulching generally increased the growth and vigour of various fruit trees. This author found that different types of organic or inorganic mulch provided higher values in the growth characteristics in banana plants. Helaly et al. (2017) observed increase in plant length and stem diameter of husk tomato (*Physalis pubescens* L.) plants, using black plastic film, and white and black compared to the bare soil. Moreover, Santosh et al. (2017) concluded that the treatment 80% of fertilizer requirement application through drip and plastic mulch performed well in respect of growth parameters; maximum plant height, pseudostem girth of banana 'Grand Naine'.

However, Balkic et al. (2016) did not observe difference between the control (bare soil) and transparent plastic film for the pseudostem diameter of the banana 'Dwarf Cavendish'.

Table 1 – Plant height (PH), pseudostem diameter (PD), suckers number (SN), and leaf number (LN) of de *Musa* spp. of the first and second crop, under different mulches. (Lavras, 2019)

Mulches	PH (cm)	PD (cm)	SN (unit)
		First crop	
Control (bare soil)	1.38 b	44.12 b	1.66 b
Organic mulch	1.57 a	52.12 a	2.30 a
Plastic film (white and black)	1.53 a	49.81 a	2.18 a
Plastic film (black)	1.54 a	51.45 a	2.24 a
CV(%)	10.19	12.46	30.64
Mulches	PH (cm)	PD (cm)	LN (unit)
		Second crop	
Control (bare soil)	2.28 c	69.81 b	13.80 b
Organic mulch	2.69 a	80.99 a	14.19 b
Plastic film (white and black)	2.51 b	79.15 a	16.19 a
Plastic film (black)	2.45 b	77.38 a	17.02 a
CV(%)	8.05	6.96	13.86

*Means followed by the same letter within columns are not significantly different by Tukey's test ($p \leq 0.05$).

In the first and second crop the mulches were efficient for banana growth. This technique of protecting plants from adverse biotic and abiotic stresses and providing favorable environmental or growth conditions to the plants. Therefore, protected cultivation has significant plant multiplication enhancing vegetative and reproductive growth (AMAN et al., 2018), once the mulches provides a more favorable environment for the plants to growth. Both organic or inorganic mulches conserve soil moisture.

Kwambe et al. (2015) also observed higher values of plant height for organic mulch and lower height for control in bean (*Phaseolus vulgaris* L.) plants grown under organic and inorganic mulch. Helaly et al. (2017) reported an increase in stem diameter and leaf area of Phisalys plants, using black plastic film, and white and black compared to the bare soil.

An increase was observed during the evaluation days for plant height, pseudostem diameter, and leaf number in the first and second crop. The suckers number was greater at 150 days in the first crop (Table 2). This shows the normal growth of plants in the course of the days, reflecting the increase in these characteristics. Nevertheless, as for the suckers number, there was a decrease in the course of the days, that can be explained due to the common management practices of the banana farming that would be the removal of suckers, leaving only those of interest that serve to continue the next year of production of the crop.

Table 2 – Plant height (PH), pseudostem diameter (PD), suckers number (SN), and leaf number (LN) of de *Musa* spp. of the first and second crop, at evaluations period. (Lavras, 2019)

Evaluations period (days)	PH (cm)	PD (cm)	SN (unit)
		First crop	
60	0.85 e	29.04 d	0.00 e
90	1.24 d	40.57 c	2.20 c
120	1.60 c	53.62 b	3.58 b
150	1.87 b	60.48 a	4.10 a
180	1.97 a	63.15 a	0.61 d
CV(%)	4.95	12.53	26.75
Evaluations period (days)	PH (cm)	PD (cm)	LN (unit)
		Second crop	
120	1.84 d	58.64 b	13.18 c
150	2.28 c	72.52 b	14.70 b
180	2.70 b	82.44 a	16.14 a
210	2.83 a	85.45 a	16.22 a
240	2.83 a	85.76 a	16.36 a
CV(%)	4.31	5.40	7.80

*Means followed by the same letter within columns are not significantly different by Tukey's test ($p \leq 0.05$).

There was interaction between the evaluation days and mulches, contributing to an increase in leaf number in the first crop, at 180 days using the plastics films. The plastic film (black) provided higher in the leaf number than control and organic mulch at 150 days. All treatments provided increase in this characteristic at 150 and, 180 days (Table 3).

Balkic et al. (2016) did not observe difference between treatments for the leaf number of the banana 'Dwarf Cavendish'. However, Helaly et al. (2017) report an increase of the leaf area of husk tomato (*Physalis pubescens* L.) plants in plastic films, black, and (white and black) compared to control.

The increments in vegetative growth parameters of banana as a result of mulch treatments may be due to plastic mulches directly affect the microclimate around the plant by modifying the radiation budget of the surface and decreasing the soil water loss Liakatas et al. (1986).

Table 3 – Leaf number, and suckers number of *Musa* spp. of the first and second crop, under different mulches and evaluations period (Lavras, 2019)

Mulches	**Evaluations period (days)**				
	60	90	120	150	180
	Leaf number (unit)				
	First crop				
Control (bare soil)	11.13 aC	12.79 aB	13.96 aAB	14.67 bA	15.14 bA
Organic mulch	10.71 aC	13.04 aB	13.75 aB	15.29 bA	15.31 bA
Plastic film (white and black)	10.46 aD	13.92 aC	14.13 aC	15.79 abB	17.50 aA
Plastic film (black)	10.46 aC	13.92 aB	13.88 aB	16.75 aA	17.72 aA
CV(%)	5.67				
Mulches	**Evaluations period (days)**				
	120	150	180	210	240
	Suckers number (unit)				
	Second crop				
Control (bare soil)	5.50 aA	2.92 abB	4.85 bA	3.11 bB	3.04 bB
Organic mulch	5.61 aA	2.76 bB	5.67 abA	2.49 bB	2.49 bB
Plastic film (white and black)	5.88 aA	3.54 abB	6.25 aA	6.25 aA	6.25 aA
Plastic film (black)	6.61 aA	4.13 aB	6.31 aA	6.31 aA	6.31 aA
CV(%)	18.95				

*Means followed by the same letter within columns (mulches) and within rows (evaluations days) are not significantly different by Tukey's test ($p \leq 0.05$).

The interaction between the evaluation days and mulches was significant, contributing to an increase in suckers number in the second crop, at 210 and 240 days using the plastics films. For the organic mulch and control, the greatest suckers number was observed at 120 and 180 days, while for the plastic films the greatest suckers number was observed at 120, 180, 210, and 240 days (Table 3).

Santosh et al. (2018) observed that all the fertilizer treatments associated to the plastic mulch provided an increase in the number of suckers of banana 'Grand Naine'.

There was no significant difference between the treatments for the post harvest characteristics in the first and second crop (Table 4).

3.2 Post harvest quality

Table 4 – Length, diameter, pH, soluble solids (SS), titratable acidity (TA), and soluble solids/titratable acidity ratio (SS/TA) of fruits of *Musa* spp. of the first and second crop, under different mulches. (Lavras, 2019).

Mulches	Length (cm)	Diam (cm)	SS (ºBrix)	TA (%)	SS/TA
	First Crop				
Control (bare soil)	113.31 a	24.85 a	17.94 a	38.87 a	0.48 a
Organic mulch	114.76 a	25.31 a	16.82 a	39.01 a	0.51 a
Plastic film (white and black)	117.00 a	26.70 a	18.86 a	38.93 a	0.46 a
Plastic film (black)	177.99 a	28.23 a	19.63 a	38.26 a	0.43 a
CV(%)	10.65	9.63	11.16	1.83	11.85
Mulches	Second Crop				
Control (bare soil)	130.11 a	36.10 a	20.75 a	38.62 a	0.55 a
Organic mulch	125.74 a	35.68 a	21.39 a	38.76 a	0.54 a
Plastic film (white and black)	130.52 a	36.16 a	20.87 a	38.72 a	0.54 a
Plastic film (black)	141.62 a	37.59 a	21.19 a	38.61 a	0.55 a
CV(%)	8.46	4.93	2.56	0.79	2.48

*Means followed by the same letter within columns are not significantly different by Tukey's test ($p \leq 0.05$).

According to Aman et al. (2018), the plastic film mulch can promote early harvest of crop and improve yield and fruit quality. This was not observed in this work, but Helaly et al. (2017) observed increase in diameter, length, soluble solids, and titratable acidity of husk tomato (*Physalis pubescens* L.) fruits, cultivated using black plastic film, and white and black compared to the bare soil. Balkic et al. (2016) found that the clear plastic provided greater length of the banana fruits than control and white net; these same authors reported an increase in soluble solids in the banana fruits, grown in clear plastic and white net than control. However, they did not observe a significant difference in fruit diameter.

Santosh et al. (2017) concluded that the treatment with 80% of fertilizer requirement application through drip and plastic mulch provided higher levels of soluble solids but a lower titratable acidity of fruits of banana 'Grand Naine'.

In the first crop all the mulches provided an increase in the fruits number, and number of hands than bare soil. For the production and productivity of the hands weight the plastic films provided higher value for this characteristic than the control. However, the organic mulch provided increase in the number of fruits, number of hands, production, and productivity of hands weight, than the other treatments in the second crop (Table 5).

3.3 Production and Productivity

Table 5 – Number of fruits (NF), and number of hands (NH), production of hands weight (HW), and productivity of hands weight (HW) of *Musa* spp. of the first and second crop, under different mulches. (Lavras, 2019)

Mulches	NF (unit)	NH (unit)	HW (kg)	HW (kg ha^{-1})
	First crop			
Control (bare soil)	63.70 b	5.65 b	4.55 b	6083.81 b
Organic mulch	85.50 a	6.95 a	5.57 ab	7424.68 ab
Plastic film (white and black)	80.75 a	6.55 a	6.75 a	8994.27 a
Plastic film (black)	78.75 a	6.40 a	6.40 a	8534.27 a
CV(%)	8.82	6.43	17.41	17.42
Mulches	Second crop			
Control (bare soil)	121.70 b	8.46 b	16.11 b	21480.80 b
Organic mulch	140.67 a	9.25 a	20.47 a	27283.74 a
Plastic film (white and black)	120.08 b	8.33 b	15.87 b	21150.38 b
Plastic film (black)	120.13 b	8.08 b	16.13 b	21501.29 b
CV(%)	5.59	5.49	10.31	10.30

*Means followed by the same letter within columns are not significantly different by Tukey's test ($p \leq 0.05$).

Mulching is the process of covering the soil surface around the plants with an organic or synthetic material to create congenial condition for the plant growth, development and efficient production (BAKSHI et al., 2015). This was proven in this study, since the mulches provided an increase in the yield parameters of banana. Other authors also observed an increase in the yield parameters of several crops grown under different types of plastic films than to the control, such as blueberry (*Vaccinium corymbosum* L) grown in reflective plastic film (MUNEER et al., 2019), watermelon *Citrullus lanatus* (Thunb.) grown in plastic film (White and black) (LAMBERT et al., 2017), banana (*Musa* spp.) grown in white net and clear plastic (BALKIC et al., 2016) and husk tomato (*Physalis pubescens* L.) in plastic film black, and plastic film (White and black) (HELALY et al., 2017).

The mulching provides a favorable environment for growth which results in more vigorous and healthier plant which may be more resistant to pest injury. Mulching prevents evaporation of water from the soil surface also reduces the weed growth (AMAN et al., 2018). This causes the plants to growth in more favorable environments due to the high humidity of the soil and less competition between the crop and weed, thus increasing crop yields.

The results of this study show that the organic mulch provided higher yields of the banana plants. This may have occurred, because the organic mulches add nutrients and humus to the soil as they decompose, improving its moisture holding capacity, while inorganic mulches are inert materials originated from non living material, not adding nutrients and humus to the soil (BAKSHI et al., 2014).

Another explanation for different results from the first crop and the second crop was that the plastic mulch had already been somewhat deteriorated, leaving the soil a bit uncovered, so this may have influenced the results of the second crop.

4 CONCLUSION

Both organic and inorganic (plastic film) mulch provide greater growth and yield of banana 'BRS Platina' not irrigated, and can be used in the cultivation of this crop.

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CHAPTER 3: ARTICLE 2

ARTICLE 2 - Different types of soil mulches in the leaf anatomy and physiology of 'BRS Platina' banana not irrigated

ABSTRACT

Banana is among the world´s most popular fruits and it is consolidated in the international market. The objective of this study was to investigate the effect of different mulches types in physiological and anatomical characteristics of banana 'BRS Platina' not irrigated. The experiment was conducted in the farm of the Federal University of Lavras (UFLA). Micropropagated banana plants of the cultivar BRS were planted in the field with a spacing of 2.5 x 3.0 meters (1333 plants ha^{-1}), without irrigation. About 20 days after planting, the mulches were installed , black polyethylene films, double-sided polyethylene films (white and black), organic mulch (from the own crop), and control (bare soil). The experimental design was a randomized block design consisting of four treatments, six blocks and six plants per treatment, totaling 144 plants. Among the six plants used in each treatment, two constituted the border, therefore four plants were evaluated. The analyzes performed in the first and second crop were: anatomical analyses, gas exchanges, chlorophyll content, relative chlorophyll index, relative water content, and protoplasmic tolerance. Both organic and inorganic (plastic film) mulch are efficient in increasing chlorophyll content and gas exchange characteristics. However, they do not influence the anatomical characteristics, relative water content, and protoplasmic tolerance in banana leaves not irrigated.

Keywords: Plastic film. Organic mulch. Gas exchanges. Chlorophyll.

Diferentes tipos de coberturas do solo na anatomia foliar e fisiologia da bananeira 'BRS Platina' não irrigada

RESUMO

A banana está entre as frutas mais populares do mundo e consolidada no mercado internacional. O objetivo deste estudo foi avaliar o efeito de diferentes tipos de coberturas nas características fisiológicas e anatômicas da bananeira 'BRS Platina' não irrigada. O experimento foi conduzido no pomar da Universidade Federal de Lavras (UFLA). Mudas da cultivar 'BRS Platina' oriundas da cultura de tecidos foram aclimatizadas por 3 meses em casa de vegetação e depois foram plantadas no espaçamento de 2,5 x 3,0 metros (1333 plantas ha^{-1}), sem irrigação. Cerca de 20 dias após o plantio, foram instaladas as coberturas, filmes de polietileno preto, filmes de polietileno de dupla face (branco e preto), cobertura orgânica (da própria cultura) e controle (solo nu). O delineamento experimental foi em blocos ao acaso, com quatro tratamentos, seis blocos e seis plantas por tratamento, totalizando 144 plantas. Dentre as seis plantas utilizadas em cada tratamento, duas constituíram a bordadura, portanto foram avaliadas quatro plantas. As análises realizadas na primeira e segunda safra foram: análises anatômicas, trocas gasosas, teor de clorofila, índice relativo de clorofila, teor relativo de água e tolerância protoplasmática. Tanto a cobertura orgânica quanto a inorgânica (filme plástico) são eficientes no aumento do teor de clorofila e nas características de trocas gasosas. Entretanto, não influenciam nas características anatômicas, teor relativo de água e tolerância protoplasmática, em folhas de bananeira não irrigadas.

Palavras-chave: Filme plástico. Cobertura orgânica. Trocas gasosas. Clorofila.

1 INTRODUCION

Banana is among the world´s most popular fruits and it is consolidated in the international market (JAISWAL et al., 2014). India is the world´s largest producer. In 2016, India produced about 20.24 million tons of bananas. Brazil is the third largest producer (up from 6.45 million tons in 2016) (FAO, 2018).

Banana is a plant that has a great demand for water, and lack of water affects the physiological processes of the plant, which will affect its growth and development. Several innovative water-saving methods, such as straw and plastic film mulching (YIN et al., 2015), regulated deficit irrigation (CHAI et al., 2014; YANG et al., 2011).

Plants growth is greatly influenced by the use of different organic and inorganic mulching materials. They conserve soil moisture in the root zone of fruit plants. Water plays an important role in the growth and development of plants. The presence of adequate moisture in the soil is vital for plant growth and physiological processes (BAKSHI et al., 2015).

Within this context, according, Decoteau et al. (1988) The light environment around the plant is altered with the use of mulches. Kasperbeauer & Wilkinson (1995) stated that even small differences in Far red: Red ratio over various colored mulch surfaces could have significant effect on plant development.

Graham & Decoteau (1995) conducted an experiment to study the influence of mulches on bell pepper production in which they reported that black plastic had the greatest absorption of photosynthetic photon flux (PPF) and white flux had the greatest reflection of PPF and blue light. Other author, Decoteau (2008) mentioned that lighter color mulches reflected more light. Increase in light intensity can affect plant development and yield through greater photosynthetic rates and ratio of FR: R is important in phytochrome regulation of plant physiological processes and can affect internode length and stem elongation, chloroplast ultrastructure, and photosynthetic efficiency.

Recent studies show the influence of plastic mulching on photosynthesis and chlorophyll of some crops. Helaly et al. (2018) observed higher total chlorophyll content in husk tomato (*Physalis pubescens* L.) plants, in mulching treatments compared to control (bare soil), and the same authors reported that white and black mulching provided higher value of this characteristic with respect to black mulching. Muneer et al. (2019) found higher values of photosynthetic active radiation in blueberry (*Vaccinium corymbosum* L) plants grown in mulching compared to those not cultivated in mulching. Sun et al. (2018), observed higher values of chlorophyll SPAD and photosynthetic rate, in peanut (*Arachis hypogaea*) plants grown in different types of mulching (biodegradable films or Polyethylene film) with respect to the control (bare soil).

The objective of this study was to investigate the effect of different types soil mulches in leaf anatomy and physiology of banana 'BRS Platina' not irrigated.

2 MATERIAL AND METHODS

The experiment was conducted on the farm of the Federal University of Lavras (UFLA), located in the city of Lavras, southern Minas Gerais, from 2015 to 2017 The Köppen climate classification for this region is Cwa - subtropical climate (21º14'S, 45º00'W and 918 metres of average altitude), i.e., a subtropical climate with cold and dry winters and warm and moist summers (KÖPPEN; GEIGER, 1928).

Soil preparation was carried out with a plowing and two harrowing, followed by the grooving in lines, with a depth of 20 cm. Later, micropropagated banana plants cultivar 'BRS Platina' were planted in the field in November of 2015 with a spacing of 2.5 x 3.0 meters (1333 plants ha^{-1}), without irrigation. About 20 days after planting, different mulches were installed: black polyethylene films; double-sided polyethylene film (white and black); organic mulch (from the own crop), and control (bare soil). The management practices of the crop were standardized, mainly regarding fertilization, thinning, defoliation, and phytosanitary control, using chemical products recommended for the crop.

The experimental was set up in a randomized block design with four treatments, six blocks and six plants per treatment, totaling 144 plants. Among the six plants used in each treatment, two constituted the border, therefore four plants were evaluated. The data was submitted to analysis of variance (ANOVA) and the means compared by Tukey's test at 5% of significance level using the statistical program SISVAR (FERREIRA, 2011).

The analyzes performed in the first and second crop were:

2.1 Anatomical analyses

Fully expanded samples of the third leaf, counting from the apex of the plant, were collected and immediately fixed at FAA 50% samples were stored in 70% ethanol (JOHANSEN, 1940). These samples were standardized and collected in the central region of the leaf, without the main nervure. Then, the plant material was included in methacrylate

(Historesin-Leica), according to the manufacturer's recommendations and transversely sectioned on an automatic feed rotary microtome (model RM2155, Leicamicrosystems Inc., Deerfield, USA) 5μm thick, stained with toluidine blue (O'BRIEN et al., 1964).

The images for structural analysis were obtained under light microscope (model AX-70 TRF, Olympus Optical, Tokyo, Japan) coupled to a digital still camera (model ZeissAxioCamHRc, Göttinger, Germany) and microcomputer with the image capture program Axion Vision, having been digitized and stored. These images were measured in 10 different fields of each sample using Image-Pro® Plus software (version 4.1, Media Cybernetics, Inc., Silver Spring, USA). The thickness of the palisade and spongy parenchyma, epidermis and hypodermis of adaxial and abaxial were determined in the cross sections of the leaf.

2.2 Gas exchanges

The photosynthetic and transpiratory rate, stomatal conductance, intercellular carbon, and intercellular and external carbon ratio of leaf were evaluated with an infrared gas analyzer (IRGA) model LI-6400, using on fully expanded leaves, generally, the third leaf counting from plant apex, selected after 8:30 a.m., and the photon flux density photosynthetically active was fixed in the apparatus chamber for 500 μmol m^{-2} s^{-1}.

2.3 Chlorophyll content

The chlorophyll content assay was performed according to the simplified protocol by Scopel et al. (2011). Leaf tissue samples were collected and transported in a polystyrene box with ice. Leaf discs of 1 cm diameter were transferred, without need of maceration, to test tubes with a lid, containing 10 ml of 80% (v/v) acetone and stored for 24 h in a cold chamber protected from light. At the end of this period, the extracts were filtered and the resulting solution was placed in cuvettes. The white sample consisted of 80% (v/v) acetone solution. Absorbance readings were performed in a spectrophotometer at wavelengths 645, 652 and 663 nm for chlorophylls. With the readings, the chlorophylls *a*, *b* and total contents (WITHAM et al., 1971) were calculated and the results were expressed in mg per gram fresh mass of leaf tissue (mg g^{-1}).

2.4 Relative chlorophyll index (RIC)

RIC was determined using a portable meter, SPAD-502 (*Soiland Plant Analysis Development*) model from MinoltaCo., Osaka, Japan. The reading was performed in the morning, between 9 a.m. and 10 a.m. Before carrying out the readings, the instrument was calibrated with the reading tester, according to the recommendations of the manual (MINOLTA, 1989).

2.5 Relative water content (RWC)

To evaluate the RWC, leaf discs (from the newest fully expanded leaf) were taken from the center of the leaf blade of each plant, and its fresh mass (FM) was determined. The leaf discs were placed in Petri dishes, where they remained submerged in distilled water during 24 h in order to obtain their turgid mass (TM). Subsequently, the leaf discs were dried in a convection oven at 70 °C for 48 h in order to obtain their dry mass (DM). The RWC was obtained using the following formula: $RWC = \{[(FM-DM) / (TM-DM)] \times 100\}$ %, following the methodology of Barrs and Weatherley (1962).

2.6 Electrolyte leakage (protoplasmic tolerance)

Leaf protoplasmic tolerance was evaluated by the release of electrolytes from leaf discs (LEOPOLD et al., 1981) immersed in 30 ml of distilled water in test tubes. Primarily, the electrical conductivity was measured with an electrical conductivity meter (DIGIMED brand, model CD 21A), where the collected leaf discs has been immersed for 24 h. This first reading was considered as being the free conductivity (FC).

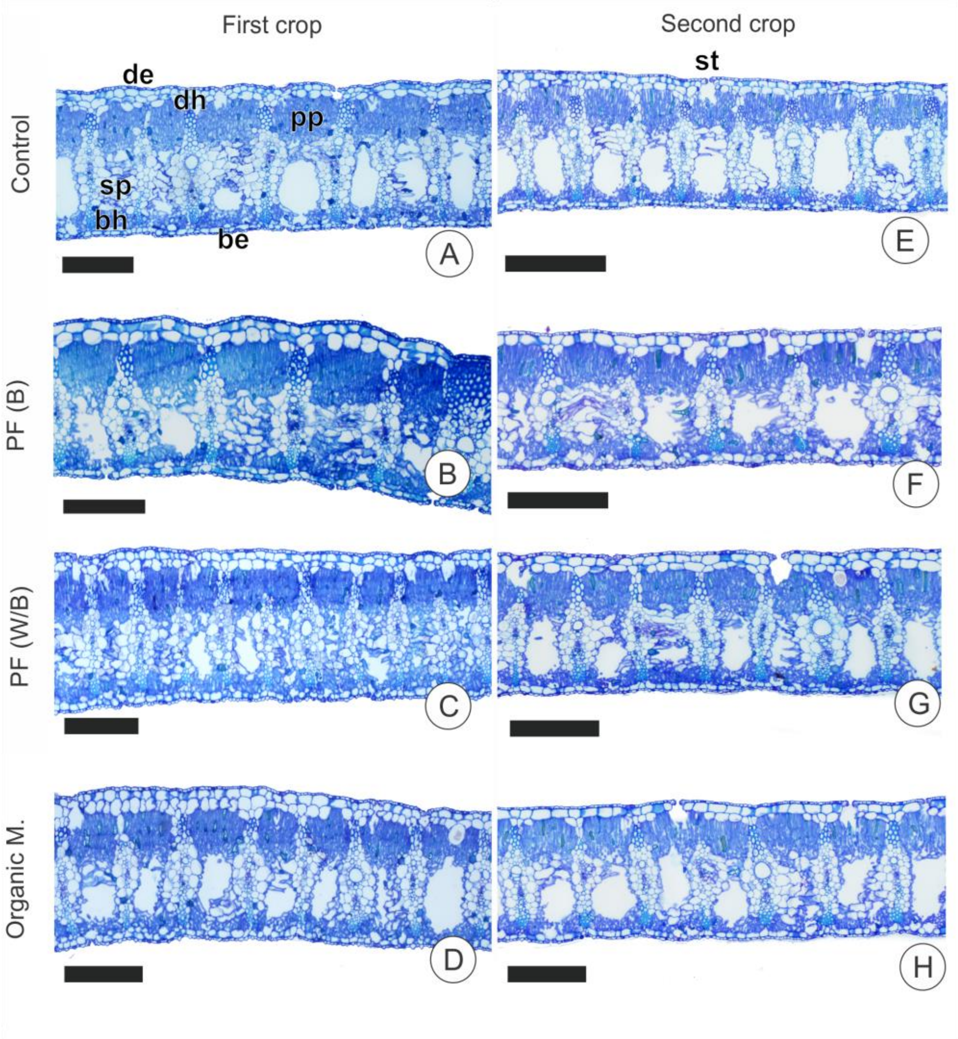
After this measurement, the same test tubes with the leaf discs immersed in distilled water were placed in a water bath at 100 °C for 1 h, and then measured again the electrical conductivity, which was called the total conductivity (TC). From these data, the absolute integrity percentage ($AIP = 1 - FC/TC$) was calculated according to the methodology described by Vasquez-Tello et al. (1990).

3 RESULTS AND DISCUSSION

3.1. Leaf Anatomy

With respect to characterization of the tissues, in all treatments it was observed that the banana leaf has a unistratified epidermis on the adaxial and abaxial faces. The mesophyll is characterized as dorsoventral, showing palisade parenchyma oriented toward the epidermis of the adaxial face just beneath the hypodermis of the adaxial face, and spongy parenchyma is oriented toward hypodermis of abaxial face (Figure 1). These results are in accordance with Sumardi and Wulandari (2010). The same authors report that the banana being classified as amphihypostomatic (stomata on both faces, however with greater quantity and stomata in the abaxial face).

Figure 1 – Photomicrographs of leaves from banana (*Musa* spp.) grown under different mulches. Adaxial epiderms (de), adaxial hypodermis (dh), parenchyma palisade (pp), spongy parenchyma (sp), abaxial hypodermis (bh), abaxial epiderms (be), and stomata (st). PF (B) - plastic film (black), PF (W/B) - plastic film (white and black). Bar = 300 μm. (Lavras, 2019)



There was no significant difference between the treatments for the anatomical characteristics to the first and second crop (Table 1).

Table 1 – Adaxial epidermis (DE), abaxial epidermis (BE), adaxial hypodermis (DH), abaxial hypodermis (BH), parenchyma palisade (PP), spongy parenchyma (SP) and leaf blade (LB) of *Musa* spp. grown under different mulches. (Lavras, 2019)

Mulches	DE	BE	DH	BH	PP	PL	LB
	μm						
	Firt crop						
Control (bare soil)	11.90a	9.81a	51.23a	19.63a	150.32a	231.78a	465.71a
Organic mulch	10.45a	9.31a	54.95a	19.84a	142.67a	254.02a	474.01a
Plastic film (white and black)	10.49a	10.07a	48.18a	19.79a	141.26a	213.19a	426.05a
Plastic film (black)	9.95a	9.25a	47.45a	17.53a	131.34a	216.42a	423.27a
CV(%)	10.15	8.87	25.20	10.89	13.64	14.63	13.81
Mulches	Second crop						
Control (bare soil)	10.18a	10.35a	39.73a	19.98a	129.88a	218.47a	401.64a
Organic mulch	9.94a	9.53a	36.87a	18.38a	158.81a	213.74a	455.73a
Plastic film (white and black)	11.06a	10.52a	48.71a	17.55a	158.98a	217.91a	448.89a
Plastic film (black)	10.20a	9.85a	39.32a	17.21a	145.36a	202.31a	414.22a
CV(%)	8.86	9.10	23.69	12.70	14.26	24.41	14.85

*Means followed by the same letter within columns are not significantly different by Tukey's test ($p \leq 0.05$).

The light environment around the plant is altered with the use of mulches (DECOTEAU et al., 1988). The influence of light on the leaf anatomy occurs both in the early stages of development and in the adult stage, because the leaf is a "plastic organ" and its internal structure adapts to ambient light conditions (WHATLEY; WHATLEY, 1982).

The palisade and spongy parenchyma are tissues that present great capacity of responses to the light stimulus, influencing, therefore, the foliar thickness (CASTRO et al. 2005). According to Taiz and Zeiger (2017), the properties of the palisade cells allow the direct passage of light, and the properties of the spongy parenchyma cells, which serve to disperse light, determining a more uniform absorption through the leaf.

This was not demonstrated in this experiment, since the changes in solar radiation produced by different mulches were not enough to cause anatomical changes or to affect the tissues.

Chavarria et al. (2012) observed increase in palisade parenchyma provided clear plastic film compared than control. However, the same authors did not find a significant difference between the treatments for adaxial and abaxial epidermal thickness, and spongy parenchyma in plants of grapevine.

3.2 Gas exchanges

According to the table 2, there was a significant difference to the characteristics of gas exchange for the first crop. However, there was no significant difference between the treatments for the characteristics of gas exchange for the second crop.

All the mulches provided increase in the photosynthetic rate, and stomatal conductance compared to control. The highest transpiration rate was provided by the plastic film (black), and the lowest by the control treatment. The plastic film (black) provided an increase in the intercellular carbon, and intercellular and external carbon ratio compared to control (Table 2).

Table 2 – Photosynthetic rate (A) (µmol CO_2 $m^{-2}s^{-1}$), transpiratory rate (E) (mmol H_2O $m^{-2}s^{-1}$), stomatal conductance (Gs) (mol H_2O $m^{-2}s^{-1}$), intercellular carbon (Ci) (µmol CO_2 mol^{-1} ar), and intercellular and external carbon ratio (Ci/Ca) of *Musa* spp. grown under different mulches. (Lavras, 2019)

Mulches	A	E	Gs	Ci	Ci/Ca
	First crop				
Control (bare soil)	3.27 b	0.001 c	0.024 b	154.07 c	0.39 c
Organic mulch	5.93 a	0.002 b	0.056 a	209.45 ab	0.53 ab
Plastic film (white and black)	6.37 a	0.002 b	0.077 a	174.08 bc	0.45 bc
Plastic film (black)	5.67 a	0.003 a	0.060 a	214. 79 a	0.55 a
.	14.93	19.60	26.77	12.34	12.08
Mulches	Second crop				
Control (bare soil)	21.93 a	0.005 a	0.50 a	304.91 a	0.80 a
Organic mulch	20.46 a	0.006 a	0.48 a	293.67 a	0.77 a
Plastic film (white and black)	20.28 a	0.005 a	0.44 a	288.65 a	0.76 a
Plastic film (black)	19.29 a	0.005 a	0.40 a	286.24 a	0.75 a
CV(%)	11.44	14.54	15.28	4.14	4.15

*Means followed by the same letter within columns are not significantly different by Tukey's test ($p \leq 0.05$).

Photosynthesis is one the major biochemical processes found in plants which directly involves with plant growth and development and photosynthetic activities are fluctuated according to light intensity and wave lengths (MUNEER et al., 2014).

The light environment around the plant is altered with the use of mulches. Light reflected from the surface of plastic mulch can have a phytoregulatory role in growth of young tomato plants (DECOTEAU et al 1988).

Liang et al. (2011), observed that the transparent plastic film provided higher values of, photosynthetic rate, transpiratory rate, and stomatal conductance than organic mulch, and control in plants of hot pepper (*Capsicum* spp.). The same authors found no difference between the treatments mentioned above for the internal carbon characteristic. Different from the results found in this experiment, where photosynthetic rate, and stomatal conductance was higher in all types of mulches.

Canul-Tun et al. (2017) found no difference between different mulch (Black, White/ black, Aluminum/black, and Silver/black) and control for photosynthetic rate, transpiratory rate, and stomatal conductance in plants bell pepper (*Capsicum annuum* L.).

Sun et al. (2018) observed higher value of photosynthetic rate, in peanut (*Arachis hypogaea*) plants grown in different types of mulching (biodegradable films or Polyethylene film) compared to control (bare soil).

Cai et al. (2007) and Dong et al. (2009) reported that mulches improved strongly leaf photosynthetic capacity. Liang et al. (2011) reported that the three compositions of mulches materials could increase leaf photosynthetic capacity.

Taiz and Zeiger (2017) affirm that stomata closure is a mechanism for adapting plant species to restrict water losses in water deficient conditions, thus reducing transpiration and consequently interfering with photosynthesis and accumulation of photoassimilates. This may explain the lower value of the photosynthetic and tranpiratory rate, provided by the control.

3.3 Chlorophyll content

There was a significant difference to the characteristics of chlorophyll content for the first crop. However, there was no significant difference between the treatments for the chlorophyll content to the first and second crop (Table 3).

According the table 3, all the mulches provided an increase in the chlorophyll a, *b*, total, and relative chlorophyll index compared to control. However, for chlorophyll *a* the organic mulch provided a higher value of this characteristic than to plastic film mulch (white and black)

Table 3 – Chlorophyll *a* (*a*), Chlorophyll *b* (*b*), total chlorophyll (TC), and relative chlorophyll index (RCI) of *Musa* spp. grown under different mulches. (Lavras, 2019)

Mulches	*a*	*b*	TC	RCI
	(mg.g^{-1} fresh matter)			(SPAD)
	First crop			
Control (bare soil)	0.022 c	0.007 b	0.033 b	55.972 b
Organic mulch	0.045 a	0.016 a	0.060 a	62.028 a
Plastic film (white and black)	0.037 b	0.012 a	0.049 a	64.765 a
Plastic film (black)	0.043 ab	0.013 a	0.56 a	64.888 a
CV(%)	13.02	25.02	18.42	5.32
Mulches	Second crop			
Control (bare soil)	0.038 a	0.012 a	0.050 a	55.317 a
Organic mulch	0.038 a	0.012 a	0.049 a	52.221 a
Plastic film (white and black)	0.032 a	0.007 a	0.039 a	56.200 a
Plastic film (black)	0.041 a	0.011 a	0.052 a	54.678 a
CV(%)	23.65	30.13	24.42	6.72

*Means followed by the same letter within columns are not significantly different by Tukey's test ($p \leq 0.05$).

While chlorophyll a participates directly in the photochemical stage (the first stage of the photosynthetic process - energy transfer), chlorophyll b and carotenoids constitute the so-called accessory pigments that aid in the light absorption (TAIZ; ZEIGER, 2017).

With the increase in chlorophyll content, there is an increase in light absorption and hence higher electron transmission in the photochemical phase of photosynthesis (TAIZ; ZEIGER, 2017). As observed in the experiment, since the different mulches provided higher values for the content of chlorophyll content, were the ones that also provided a higher photosynthetic rate of the banana plants.

Other authors also observed higher values in chlorophyll contents compared to the control treatment in some plants, such as Helaly et al. (2017), observed that plastic films (black, white and black) provided higher values for total chlorophyll content in relation to control in husk tomato (*Physalis pubescens* L.) plants. Ni et al. (2016), observed that different types of organic mulch provided an increase in chlorophyll *a* and total contents compared to the control in plants of tea olive (*Osmanthus fragrans*). However, the same authors didn't find significant difference between treatments for chlorophyll *b* content.

Sun et al. (2018), observed higher values of chlorophyll SPAD, in peanut (*Arachis hypogaea*) plants grown in different types of mulching (biodegradable films or Polyethylene film) compared to control (bare soil). However, Splawski et al. (2016) observed that organic mulch (Woodchips) provided higher value of relative index of chlorophyll in relation to the control, and the plastic film was equal to the control and organic mulch in plants of pumpkin

3.4 Relative water content and electrolyte leakage (protoplasmic tolerance)

There was no difference among treatments for the relative water content, and for electrolyte leakage, represented by free and total conductivity, and absolute integrity percentage for the first and second crop (Table 4).

Table 4 – Relative water content (RWC), free conductivity (FC), total conductivity (TC), and absolute integrity percentage (AIP), of leaves of *Musa* spp. grown under different mulches. (Lavras, 2019)

Mulches	RWA (%)	FC (μs cm^{-1})	TC (μs cm^{-1})	AIP (%)
	First crop			
Control (bare soil)	80.19 a	17.55 a	43.49 a	0.59 a
Organic mulch	81.20 a	19.72 a	53.89 a	0.63 a
Plastic film (white and black)	76.94 a	21.82 a	52.49 a	0.58 a
Plastic film (black)	77.52 a	19.14 a	46.37 a	0.59 a
CV(%)	4.84	16.43	13.67	6.14
Mulches	Second crop			
Control (bare soil)	84.02 a	61.08 a	475. 90 a	0.87 a
Organic mulch	88.21 a	72.09 a	503.05 a	0.88 a
Plastic film (white and black)	88.05 a	62.67 a	439.08 a	0.86 a
Plastic film (black)	87.94 a	61.56 a	458.54 a	0.87 a
CV(%)	4.71	12.20	9.97	1.34

*Means followed by the same letter within columns are not significantly different by Tukey's test ($p \leq 0.05$).

The release of electrolytes occurs in severe levels of water deficit due to the increase in the amount of active species of oxygen (superoxides), free radicals and lysing enzymes (ROY-MACAULEY et al., 1992) which resulted in the broken and increased membrane permeability and often in irreversible damages in organelles and molecules present inside the cells (ALONSO et al., 1997).

The present study aimed to observe, through the analysis of electrolyte leakage, if the plants suffered some type of stress because they were not irrigated. This analysis shows that plants reflect severe stress only under equivalent severe conditions. Therefore, these results were not verified in this experiment, since the rainfall index is high in the region where the experiment was developed.

Kirnak et al. (2003) and Kaya et al. (2005) observed that release of electrolytes was higher in the control treatment than black plastic film. However, the relative water content in the leaves was higher in the black plastic film compared to control treatment in bell pepper and cucumber plants, respectively under conditions of water stress. These results are different from those found in this experiment, where no significant difference was observed among the treatments for these characteristics.

4 CONCLUSIONS

Both organic and inorganic (plastic film) mulch are efficient in increasing chlorophyll content and gas exchanges characteristics. However, they do not influence the anatomical characteristics, relative water content, and protoplasmic tolerance, in banana leaves 'BRS Platina' not irrigated.

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