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Chlorophyll content in plants and fruit yield of strawberry plants grown on mulching

Teores de clorofila nas plantas e produtividade de frutos de morangueiros cultivados sobre mulching

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ABSTRACT

This study aimed to evaluate productive characteristics and levels of photosynthetic pigments in two strawberry cultivars on different types of mulching, in an open cultivation system. The experiment was a 2 x 4 factorial completely randomized block design, with 2 varieties (Camarosa and Camino Real) and 4 ground covers (black low-density polyethylene, silver low-density polyethylene, non-woven and no mulching), with three replications. The cultivars were analyzed for chlorophyll a and b content, total chlorophyll, and chlorophyll a/b ratio, number of fruits per plant, yield (ton ha^{-1}), weight fruit mass, soluble solids (ºBrix), total acidity, pH and soluble solids/total acidity ratio. The Camarosa showed higher yield than cv. Camino Real. The silver low-density polyethylene and non-woven mulching treatment exhibited negative results, and are not recommended for the cultivation of Camarosa and Camino Real strawberries. The black low-density polyethylene mulching was the most recommended for growing such cultivars. Among the types of mulchings evaluated, the black low-density polyethylene achieved the best results and it is recommended for the Camarosa and Camino Real strawberry cultivars.

KEYWORDS: *Fragaria*, ground cover, varieties.

RESUMO

Para se ter frutos de qualidade e êxito no cultivo de morangos, os tratos culturais tornam-se necessários, como a utilização de coberturas de solo. Diante do exposto, objetivou-se com o presente trabalho avaliar as características produtivas e teores de pigmentos fotossintéticos de duas cultivares de morangueiro, sobre tipos de mulching, em sistema de plantio a céu aberto. O delineamento experimental utilizado foi em blocos casualizados, em esquema fatorial 2 x 4, sendo 2 cultivares (Camarosa e Camino Real) e 4 coberturas de solo (polietileno de baixa densidade preto, polietileno de baixa densidade prata, tecido não tecido branco e ausência de mulching), contendo três repetições. Avaliaram-se os teores de clorofilas a e b, clorofila total e relação a/b nas plantas; número de frutos $planta^{-1}$, produtividade (ton ha^{-1}), massa de frutos, sólidos solúveis (°Brix), acidez total, pH e relação sólidos solúveis/acidez total. A cv. Camarosa apresenta maior produtividade que Camino Real. O mulching de polietileno de baixa densidade prata e tecido não tecido apresentaram resultados negativos, não sendo recomendados no cultivo das cvs. de morangueiro Camarosa e Camino Real, sendo indicado o mulching polietileno de baixa densidade de cor preta. Dentre os mulchings utilizados no presente trabalho o polietileno de baixa densidade preto foi o que obteve resultados mais significativos sendo recomendado o seu uso para as cultivares Camarosa e Camino Real.

PALAVRAS-CHAVE: *Fragaria*, cobertura de solo, cultivares.

INTRODUCTION

Strawberry is the most representative among small fruits, and its cultivation is justified by the high profitability of the crop, consumer acceptance and diversity of marketing and processing options. In Brazil, the commercial production of strawberry is performed in different states due to the adaptability of the different cultivars used (FACHINELLO et al. 2011).

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Among several factors that favor the increased production and marketing the use of cultivars adapted to the climate conditions in southern Brazil stands out. The most common strawberry cultivars used in these regions correspond to Aromas, Camarosa, Diamante, Oso Grande, Ventana, Dover and Sweet Charlie (OLIVEIRA & SCIVITTARO 2006).

The cv. Camarosa is a short-day cultivar, with vigorous characteristics, early maturing and high production capacity (PASSOS et al. 2015). Its fruits are large, firm in texture, bright red color, of subacid flavor, suitable for fresh consumption and industrialization (OLIVEIRA et al. 2011). The cv. Camino Real has been used by Brazilian producers for demonstrating high production capacity. Its fruits have a pleasant taste, are large, firm, and recommended for fresh consumption and industrialization (SILVA et al. 2015).

In order to produce high quality fruit and to achieve a successful strawberry cultivation, cultural practices become necessary, mainly because it is a crop sensitive to pests and diseases. In this context, the use of ground cover has been highlighted through the use of materials, such as plastic films, given the easy application (OLIVEIRA et al. 2011).

This ground cover technique is known as mulching and is employed to avoid contact of the fruit with the ground, so as to harvest fruit free of impurities, which reduce the quality and post-harvest shelf life (MORAIS et al. 2008). This technique influences the maintenance of soil temperature, acts as thermoregulatory, prevents soil compaction, and takes action on invasive plants (MEDEIROS et al. 2007).

The materials used as ground cover include low-density polyethylene, found in various colors (LIMA JUNIOR & LOPES 2009). Another material also used is nonwoven, polypropylene used by horticulturists as floating cover over the plants (DALLA ROSA et al. 2014).

The use of mulching in strawberry crops has been extensively analyzed, but, conflicting results have been presented in relation to the cultivars studied and crop performance under particular soil and climate conditions and physicochemical characteristics of fruits (SCHNEIDER et al. 2013). And so, this study aimed to evaluate the production characteristics and chlorophyll content in two strawberry cultivars on different types of mulching, in the open planting system.

MATERIAL AND METHODS

The geographical coordinates of the experimental unit are 24°32'09''S latitude and 54°01'11''W longitude, at an average altitude of 420 m. The climate, according to Köppen (IAPAR 2012), is Cfa, subtropical climate; with average minimum temperature of 18 °C (mesothermal) and average maximum temperature of 22 ºC, with hot summer, infrequent frosts and rainfall concentrated in the summer months with average annual rainfall of 1,800 mm (ALVARES et al. 2013). The predominant soil classification is Yellow oxisol (EMBRAPA/CNPS 2012).

Strawberry Seedlings (Camino Real and Camarosa variety) were acquired from a nursery with varietal qualities. In May, seedlings were transplanted into beds, spaced 0.30 x 0.30 m. Before planting, soil was collected for chemical analysis. According to the chemical analysis of the soil, there is no need for lime application and topdressing with phosphorus and potassium. Only 200 kg ha^{-1} of nitrogen (urea form) was applied, a half five days before planting and another half 15 days after planting.

The experimental area consisted of three beds, each 1.20 m wide, 14.40 m long, spaced 0.40 m apart, totaling 63.4 m². Each site was a block and each block had eight plots each of 1.8 m. Eighteen plants were transplanted in each plot, arranged in three rows with six plants each. Beds were made with a rotary tiller at the height of 0.20 m.

The experiment was a 2 x 4 factorial randomized complete block design [2 strawberry cultivars, Camino Real and Camarosa x 4 mulching, black LDPE (low-density polyethylene), silver LDPE, TNT (non-woven) and no ground cover], with 3 replications. Each experimental unit consisted of three rows, with six plants each, and 0.30 m x 0.30 m spacing.

During the first month after transplantation, we used irrigation to completely wet the area. When the seedlings were adapted, we used drip irrigation with two lines per bed and drippers every 0.30 m, with a flow rate of 1.7 L h^{-1}. Soil was covered after a period of 30 days after transplanting.

To control pests and diseases, we applied the fungicide (azoxystrobin) and acaricide (abamectin) for the control of *Mycosphaerela* and mites, respectively, in accordance with recommendations for the strawberry crop.

80 days following the transplantation, harvest

began, extending to mid-December. Fruit harvests were performed every two days. We harvested fruits with about 75% of the epidermis in red, discarding the fruit with physiological, nutritional damages or attacked by pests and diseases. The selection of these was based on the guidelines of the Horticultural Quality Center of CEAGESP (ALVARENGA 2006).

For physical and chemical analysis, we considered as a working plot, three central plants randomly chosen, keeping one plant at each end of the rows as surround. In each harvest, we evaluated the average fruit mass; average mass per plant and average number of fruit per plant.

Every 30 days, five fruit samples were taken per plot, harvested at dawn and packed in labeled plastic bags, according to the corresponding plot, and subsequently transported to the Food Technology Laboratory at Unioeste for chemical analysis, including soluble solids (SS), total acidity (TA), SS/TA ratio and pH, according to the Adolfo Lutz Institute (IAL 2008).

For physiological assessment, samples were analyzed for chlorophyll a and b content of the leaves. Five disks of the central leaves of a plant chosen randomly in each plot were collected. Leaf material was collected 110 days after the start of harvest, and subsequently wrapped in aluminum foil and transported under refrigeration to the laboratory, where the samples were weighed on an analytical scale and physiologically evaluated.

The determination of chlorophyll a and b content was performed by using the method described by SIMS & GAMON (2002). Samples were macerated in liquid nitrogen and 5 mL solution containing 80% acetone p.a. and 20% 0.02 M Tris-HCl (pH 7.8) was added. The suspension was homogenized and centrifuged for 15 minutes at 2000 rpm (4 °C). Supernatant was read in a spectrophotometer at 663 nm (chlorophyll a), 647 nm (chlorophyll b) and 470 nm (carotenoids). The control consisted of the extraction solution. The values of absorbance were applied to the equations below:

$$Cl_a = 0.01373\ A_{663} - 0.004305\ A_{537} - 0.005507\ A_{647}$$
$$Cl_b = 0.02405\ A_{647} - 0.004305\ A_{537} - 0.005507\ A_{663}$$

The results (µmol ml^{-1}) were corrected according to their molecular weights proposed by LICHTENTHALER (1987), thereby obtaining Cl_a = 893.5 g mol^{-1}, Cl_b = 907.5 g mol^{-1} and total carotenoids = 550 g mol^{-1}, later expressed in mg gpf^{-1}. Data were tested by analysis of variance followed by Tukey's test at 5% probability.

RESULTS AND DISCUSSION

There was a significant interaction between variety and types of mulching for chlorophyll a. By the effect of mulching within each variety, it was observed that the Camarosa showed no significant difference. Better results for the Camino Real were found in the absence of mulching (Table 1).

There was also a significant interaction for chlorophyll a+b, wherein the breaking down the effect of mulching within each variety demonstrated that cv. Camarosa showed no difference between the studied types of mulching. For cv. Camino Real, the absence of mulching caused better results when compared with TNT and silver LDPE, which showed the worst results for chlorophyll a+b.

The effect of variety within each type of mulching for chlorophyll a+b revealed a difference for the silver LDPE mulching, in which Camino Real was superior to Camarosa. The other types of mulching showed no difference between the two varieties (Table 1).

The negative effect of silver LDPE on the content of chlorophyll a and chlorophyll a+b can be because this material reflects more sunlight. According to HENDRY & PRICE (1993), chlorophylls tend to be photooxidized under high photoirradiation. Photooxidation is an irreversible process and directly involves the light receptor pigments, which, by absorbing a great deal of light, remain excited longer and interact with O_2, producing free radicals, such as superoxide (O_2^-), which may destroy the pigments (TAIZ & ZEIGER 2013).

Allied to this, the maximum monthly average temperature during the production months was very high (Figure 1), primarily enhanced by the silver LDPE because of the reflection of sunlight.

The observation that only the cultivar Camino Real have shown differences in chlorophyll a+b content can be explained by the smaller size of the plant, as described by OLIVEIRA & SCIVITTARO (2011), thus having a lower shading that increases the radiation reflected by the silver LDPE. The cultivar Camarosa has greater vigor, as reported by OLIVEIRA et al. (2011), with greater shading and reflecting less irradiation.

Table 1. Chlorophyll a, total chlorophyll, soluble solids (SS) and SS/AT ratio according to cultivars and types of mulching.

Strawberry variety	Types of mulching			
	No mulching	nonwoven	silver LDPE	black LDPE
	Chlorophyll a (mg gpf^{-1})			
Camarosa	0.0228 aA*	0.0224 aA	0.0232 aA	0.0227 aA
Camino Real	0.0236 aA	0.0216 aAB	0.0210 aB	0.0229 aAB
Mean	0.0225			
CV(%)	3.69			
	Chlorophyll a+b (mg gpf^{-1})			
Camarosa	0.0384 aA	0.0371 aA	0.0379 aA	0.0372 aA
Camino Real	0.0390 aA	0.0361 aB	0.0354 bB	0.0376 aAB
Mean	0.0373			
CV(%)	2.43			
	Soluble solids (°Brix)			
Camarosa	7.28 aAB	6.50 aC	6.72 aBC	7.73 aA
Camino Real	7.30 aAB	6.83 aAB	7.46 aA	6.66 bB
Mean	7.06			
CV(%)	4.52			
	SS/AT			
Camarosa	5.53 aAB	4.83 bC	5.08 bBC	5.75 aA
Camino Real	5.80 aA	5.65 aAB	5.86 aA	5.32 bB
Mean	5.06			
CV(%)	3.71			

*Means followed by different uppercases in the same row and different lowercases in the same column are statistically different from each other, by Tukey's test at 5% probability.

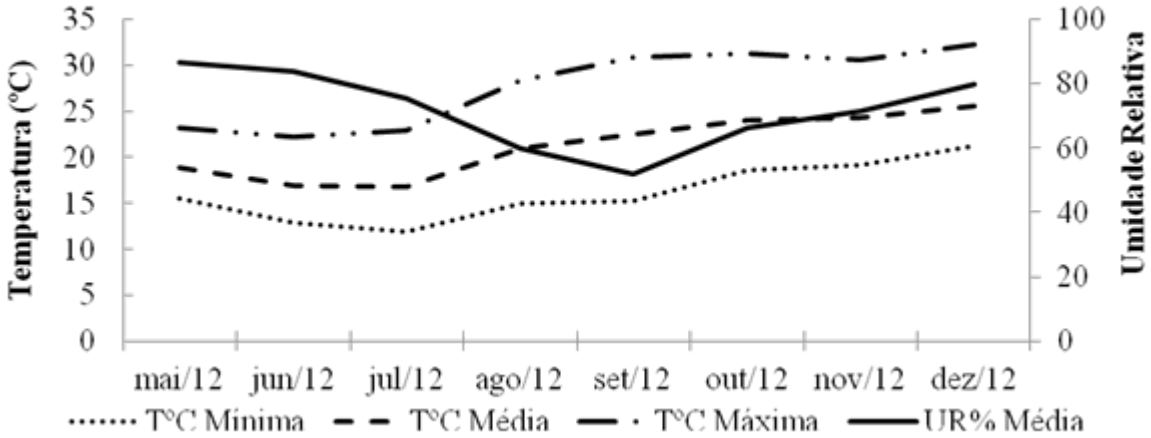

Figure 1. Relative humidity (%), maximum, minimum and average temperature in the experimental area, from May through December 2012.

In relation to soluble solids (SS), an interaction was found and by the effect of type of mulching within each variety indicated that the black LDPE (7.73 °Brix) showed a better value when compared with the TNT (6.50 °Brix), which presented the lowest result for the Camarosa. The Camino Real exhibited no difference between the types of mulching for soluble solids (Table 1). MANGNABOSCO et al. (2008) Six strawberry variety in three municipalities in the southwestern region of the Paraná State were examined, Brazil (Pato Branco, Verê and São Jorge D'Oeste) and similar values of soluble solids, ranging from 6.31 to 7.70 °Brix.

The SS/TA ratio in the types of mulching within variety revealed that black LDPE differed from TNT, but was similar to silver LDPE and no mulching for the Camarosa. In turn, for the Camino Real, there was no difference. The variety within types of mulching demonstrated that only within black LDPE was there difference, in which Camarosa was superior to Camino Real (Table 1).

MANGNABOSCO et al. (2008) obtained higher values in SS/TA ratio for the cv. Camarosa and Camino Real, which is due to the level of maturity of the evaluated fruits: with advancing maturity stage the TA tends to be lower, thus decreasing the SS/TA ratio. This variable is of great importance as it indicates a better balance between sweet and acid, promoting a more pleasant flavor, making fruit more attractive (KROLOW et al. 2007). YURI et al. (2012) reported that the use of black mulching provides greater heat absorption, and therefore higher soil temperature, favoring plant development and concentration of SS and AT, essential for fruit flavor.

The chlorophyll b presented a significant effect, separately, only for the types of mulching used. The absence of ground cover led to higher values of chlorophyll b than nonwoven, silver LDPE and black LDPE. For the chlorophyll a/b ratio, there was no significance in the tested treatments (Table 2).

For TA, pH, MMF, average yield and MFP, in Tables 2 and 3, there was no significant interaction between treatments, being analyzed separately. For TA, the cv. Camarosa presented a higher mean value than Camino Real, similarly to the results verified by MANGNABOSCO et al. (2008), representing a characteristic of the cultivars studied. For the types of mulching, there was no significant difference. For pH, there was no difference between treatments (Table 2).

The Camino Real variety showed better results than Camarosa for average fruit mass (MMF) with 14.645 against 12.734 g fruit^{-1}, respectively. RADIN et al. (2011), in Caxias do Sul and Eldorado do Sul, similar values were recorded for the Camarosa variety. The difference between the two cultivars for MMF, in this study, had already been found in Pelotas by OLIVEIRA et al. (2008), who attributed the result to the fact that the cv. Camino Real has larger fruit than cv. Camarosa.

Table 2. Titratable acidity (TA), pH, chlorophyll a and chlorophyll a/b ratio according to cultivars and types of mulching.

Variety	TA	pH	Chlorophyll b (mg gpf^{-1})	a/b (mg gpf^{-1})
Camarosa	1.33a*	3.78	0.0149	1.529
Camino Real	1.25b	3.80	0.0148	1.505
Types of mulching				
No mulching	1.29	3.79	0.0155a	1.497
Nonwoven	1.28	3.78	0.0146b	1.507
Silver LDPE	1.30	3.78	0.0146b	1.514
Black LDPE	1.30	3.81	0.0147b	1.551
Mean	1.29	3.79	0.0148	0.660
CV (%)	2.78	0.81	3.11	4.95

*Means followed by different lowercase letters in the same column are statistically different from each other, by Tukey's test at 5% probability.

Table 3. Average fruit mass (MMF), yield (ton ha^{-1}), average number of fruit per plant (NMFP) according to cultivars and types of mulching.

Variety	MMF (g fruit^{-1})	Yield (ton ha^{-1})	NMFP
Camarosa	12.734b*	25.487a	31.806a
Camino Real	14.645a	20.453b	22.124b
Types of Mulching			
No mulching	14.573ab	25.637	28.498
TNT	14.933a	25.882	27.860
Silver LDPE	12.380b	19.897	26.028
Black LDPE	12.872ab	20.465	25.473
Mean	13.690	22.970	26.965
CV(%)	7.92	19.75	14.07

*Means followed by different lowercase letters in the same column are statistically different from each other, by Tukey's test at 5% probability.

The TNT treatment showed better results for MMF, being superior to the silver LDPE treatment (Table 3). The observed results can be related to the data listed in Table 1, for chlorophyll and total chlorophyll, in which the mulching silver LDPE achieved the worst results. This relationship may be because chlorophylls are pigments that absorb solar energy. In agreement with CRUZ et al. (2007), each chlorophyll molecule can absorb only one quantum of energy each time. Thus, the lower the chlorophyll content, the lower plant development, and subsequently, the fruit.

The Camarosa was more productive under the conditions of the present study. Regarding the mulching, we suggest conducting further studies employing techniques that can minimize the effect of high temperatures during the production months for the development of the culture in the western region of the State of Paraná. Due to the high temperatures, LDPE had a negative effect when compared with TNT and bare soil. Considering TNT, it was not resistant to damage caused by the open cultivation system, and it did not prevent the development of weeds.

With respect to yield, the Camarosa was superior with 25.487 ton ha^{-1} against 20.453 ton ha^{-1}. The same was observed for NMFP, where the Camarosa showed better results and higher yield than the cv. Camino Real (Table 3). Corroborating OLIVEIRA et al. (2008), who compared the Camarosa and Camino Real in a tunnel system and obtained higher values of MMF for Camino Real. For NMFP, we found inverse values, i.e., higher number of fruit per plant for the cv. Camarosa. This is related to the very characteristic of the cv. Camino Real of producing few and small fruit, and only one fruit per inflorescence. The difference between the values registered by OLIVEIRA et al. (2008) and those found herein is explained by the planting environment. The cultivation of strawberries under tunnel is significantly superior compared to the production in the field (RESENDE et al. 2010).

Few studies on the use of alternative materials have been carried out to replace the polyethylene plastic in strawberry beds (VAILATI & SALLES 2010). Such a situation leaves some doubts about the use of materials that can replace polyethylene plastic. Therefore, studies comparing the performance of strawberries cultivated in beds covered with other materials are required to make more profitable the production process of this crop.

CONCLUSIONS

The Camarosa has higher yield than Camino Real under the evaluated conditions.

Nonwoven is not recommended as mulching, because it did not survive to the cultivation period, and was not effective in controlling weeds.

Black LDPE mulching achieved the best results for growing the Camarosa and Camino Real varieties.

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