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IMPACTO DE DIFERENTES TIPOS DE COBERTURAS NO CRESCIMENTO E DESENVOLVIMENTO DE ALFACE IRRIGADA

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1 RESUMO

O objetivo do trabalho foi avaliar o impacto de diferentes tipos de coberturas em momentos distintos, no ciclo produtivo, em relação ao crescimento e desenvolvimento da alface, sem restrição hídrica. Foi adotado delineamento experimental de blocos ao acaso, com três tipos de coberturas (sem cobertura, cobertura plástica dupla face branca e preta e cobertura vegetal com palha de arroz), e quatro períodos de avaliação (14, 21, 28 e 35 dias após o transplantio), com 4 repetições. Para implantação da cultura foram utilizadas mudas comerciais de alface (híbrido BS-068), sendo transplantadas em canteiros (3 x 0,5 x 0,5 m) previamente adubados. Durante os períodos de avaliação, foram realizadas medições para caracterizar o desenvolvimento das plantas: número de folhas, altura, diâmetro das plantas, área foliar, massa fresca e seca da parte aérea, variação da temperatura do solo, e resposta espectral da alface. A reflectância da condição sem cobertura foi significativamente maior em comparação com as plantas sob as coberturas. O cultivo sem cobertura apresentou variação de temperatura com maior amplitude em comparação com os tratamentos com cobertura. Os tratamentos que incluem cobertura demonstraram desempenho superior em quase todos os períodos do crescimento, evidenciando os benefícios dessas práticas para o desenvolvimento da alface.

Keywords: *Lactuca sativa* L, manejo hídrico, horticultura.

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IMPACT OF DIFFERENT TYPES OF MULCHES ON THE GROWTH AND DEVELOPMENT OF IRRIGATED LETTUCE

2 ABSTRACT

The objective of this study was to evaluate the impact of different types of mulch applied at distinct stages of the production cycle on the growth and development of lettuce under nonlimiting water conditions. A randomized block design was adopted, with three mulch types (no mulch, black-and-white dual-sided plastic mulch, and organic mulch with rice

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straw) and four evaluation periods (14, 21, 28, and 35 days after transplanting), with four replications. Commercial lettuce seedlings (hybrid BS-068) were used for crop establishment and transplanted into previously fertilized beds (3 × 0.5 × 0.5 m). During the evaluation periods, plant development was assessed by measuring the number of leaves, plant height, canopy diameter, leaf area, shoot fresh and dry mass, soil temperature variation, and spectral response of the lettuce. The reflectance of the plants in the no-mulch treatment was significantly greater than that of the plants in the mulch treatment. Compared with the mulch treatments, the mulch treatments resulted in greater soil temperature fluctuations. The treatments with mulch showed superior performance in almost all growth periods, highlighting the benefits of these practices for lettuce development.

Keywords: *Lactuca sativa* L., water management, horticulture.

3 INTRODUCTION

Vegetable production is an essential agricultural activity that plays a fundamental role in food security and human health (Pereira; Franceschini; Priore, 2020). Among the most popular and widely consumed vegetables worldwide is lettuce (*Lactuca sativa* L.), a member of the Asteraceae family. In Brazil, lettuce occupies a prominent position as the most commercialized leafy vegetable (Silva *et al.*, 2020) and is grown on small rural properties throughout the country. This gives the crop great economic and social importance (Kapoulas; Koukounaras; Ilić, 2017).

To maximize the yield, quality, and sustainability of these crops, farmers and researchers have been constantly seeking innovative techniques and practices. Two promising strategies are the use of plastic mulch and mulch for vegetables, particularly for lettuce production (Gastl Filho *et al.*, 2020).

Double white and black plastic mulch has emerged as an effective and versatile option. The white layer reflects sunlight, reducing heat accumulation in the soil and minimizing heat stress in plants (Francera; Mabesa, 2016). This phenomenon is especially beneficial for lettuce, as high temperatures can negatively affect its development and quality. On the other hand, the black layer of plastic mulch prevents weed growth, reducing competition for nutrients, water, and light. This unique combination contributes to a more favorable growing environment, resulting in higher lettuce productivity and quality (Jahan). *et al.*, 2018).

In addition to plastic mulch, plant cover is also a sustainable and efficient alternative for protecting vegetables. Mulching with plant material can be associated with no-till farming or the application of residues to the soil. Rice straw, in particular, has properties that make it an attractive option, such as its abundant availability in some regions, slow decomposition, and potential to enrich the soil with organic matter (Hachmann *et al.*, 2017).

The objective of this work was to evaluate the impact of different types of coverage, applied at different times during the production cycle, on the growth and development of lettuce under conditions without water restriction.

4 MATERIALS AND METHODS

The study was carried out at the Irrigation Technical Center (CTI), belonging to the State University of Maringá (UEM), located in the municipality of Maringá - PR (23°25'S, 51°57'W, 542 m altitude). A randomized complete block experimental design was adopted, with three types of cover (no cover, double-sided white and black plastic cover, and rice straw cover) and four evaluation periods (14, 21, 28, and 35 days after transplanting - DAT), with four replicates. For ease of reference, the growth periods were named A (14 days DAT), B (21 days DAT), C (28 days DAT), and D (35 days DAT).

The experiment was conducted in a protected environment, whose structure is 25 m long, 7 m wide and 3.5 m high, with the sides covered with white anti-aphid mesh and the arched roof covered with low-density polyethylene film (150 µm thick).

Commercial lettuce seedlings (hybrid BS-068) were used to plant the crops, which were subsequently transplanted into beds (3 × 0.5 × 0.5 m) previously fertilized according to soil chemical analysis and crop recommendations (Pauletti; Motta, 2019). The plants were placed in beds with a spacing of 0.30 m between them.

A drip irrigation system was used for water management. Crop evapotranspiration rates were determined via constant water table lysimeters, as described by Andrean *et al.* (2022), with readings taken daily at 8 am.

During the evaluation periods, measurements were taken to characterize plant development. Leaf counts were performed manually. The plant height and diameter were measured via a graduated ruler. The leaf area was quantified with an LI-3100 integrator. Fresh shoot mass was measured on a digital scale. To obtain the dry mass, the samples were dried in a forced-air circulation oven at 65°C until a constant weight was achieved. Soil temperature variations were monitored at a depth of 5 cm throughout the lettuce growth cycle via a thermometer placed next to the plants, with measurements taken every two days.

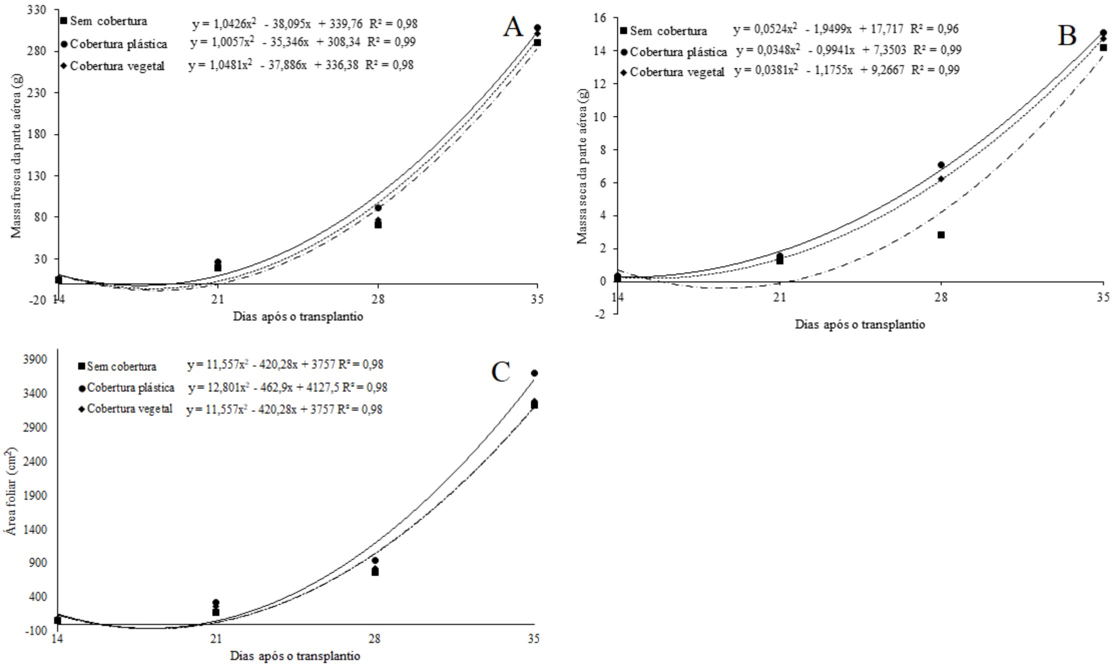
FieldSpec 3 equipment (ASD Inc.®), connected to the Plant Probe Reader, was used to obtain the spectral response of lettuce in the wavelength range between 350 and 2500 nm. Readings were taken from an intermediate leaf of the plants.

Finally, the collected data were subjected to analysis of variance via the F test and ANOVA, and the means were compared via the Tukey test at 5% significance via SISVAR statistical software (Ferreira, 2019).

5 RESULTS AND DISCUSSION

The variables fresh mass of the aerial part, dry mass of the aerial part and leaf area were significantly influenced ($p<0.05$) by the evaluation period, with quadratic regression models being adjusted and significant at the 5% probability level, as shown in Figure 1.

Figure 1. Fresh mass of the aerial part (A), dry mass of the aerial part (B) and leaf area (C) of the lettuce crop under different soil covers according to the evaluation periods.

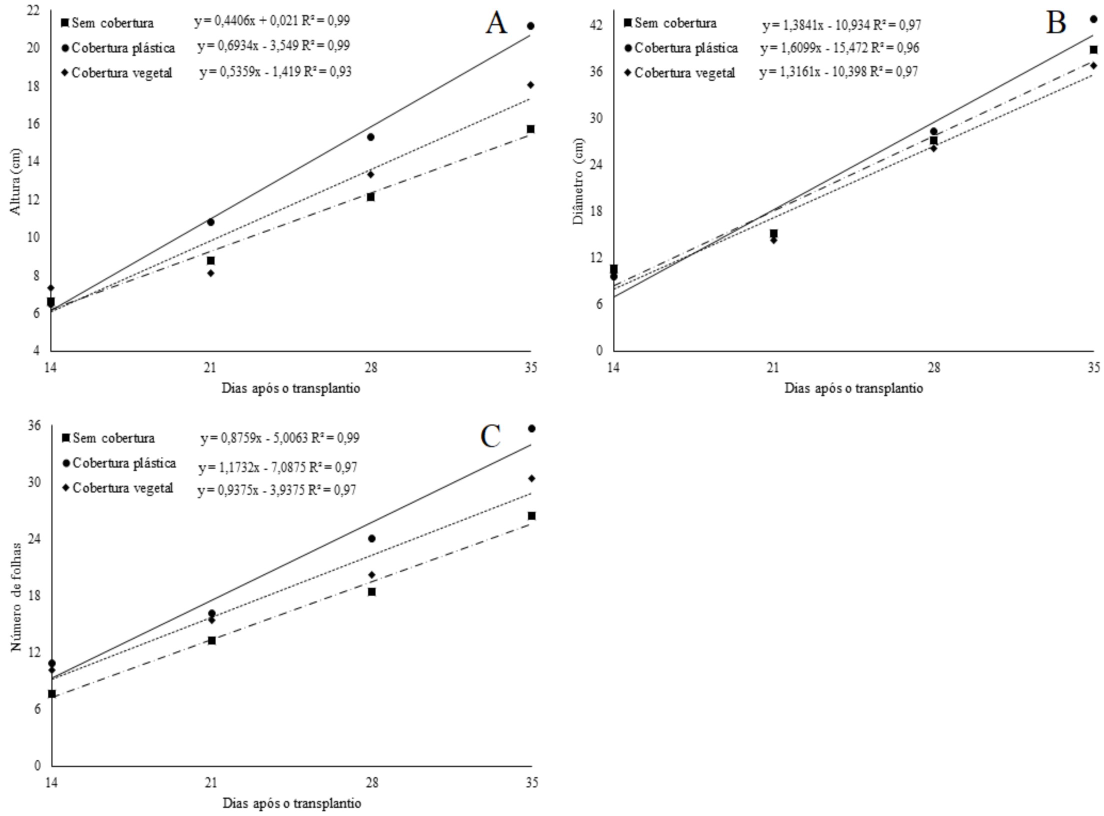


The results regarding the fresh and dry weights of the lettuce shoots throughout the evaluation periods clearly indicate the consistent superiority of the double-sided white and black plastic mulch treatment (Figure 1A and B). This treatment provided more favorable conditions for lettuce growth, resulting in greater biomass accumulation in the plants. This performance can be attributed to the specific properties of this mulch, such as its ability to reflect sunlight, reduce heat stress in plants, and inhibit the growth of weeds, which compete for essential resources (Siwek; Kalisz; Wojciechowska, 2007). This observation is in line with studies that highlight the effectiveness of plastic mulch in maintaining a more stable microclimate and protecting plants from environmental stresses.

In a study conducted by Gastl Filho *et al.* (2020) on lettuce cultivation in Ituiutaba, Minas Gerais, which uses various types of mulch—such as double-sided plastic, kraft paper, forage peanut straw, and Brachiaria straw—double-sided polyethylene mulches resulted in higher yields in terms of fresh and dry mass of the shoot, plant diameter and height, and number of leaves. Similarly, Farias *et al.* (2017), when evaluating four different types of mulch (black plastic, black and white plastic, black and silver plastic, and no mulch), reported that the fresh mass of the shoot and the total number of leaves were significantly greater in the treatment with black and white plastic mulch.

The height, plant diameter and number of leaves significantly varied throughout the different evaluation periods, enabling the application of linear regression models, which were statistically significant at the 95% confidence level, as shown in Figure 2.

Figure 2. Height (A), plant diameter (B) and number of leaves (C) of lettuce crops under different soil covers according to the evaluation periods.



The results clearly revealed that, compared with the other soil cover conditions, the double-sided white and black plastic mulch promoted significantly greater growth in terms of lettuce fresh weight (Figures 1 and 2). This difference was especially significant compared with that in the treatment without mulch, in which growth was lower.

The plant height and diameter followed the same trend, with plants grown under the double-sided white and black plastic mulch showing more vigorous growth (Figures 2A and 2B). These results can be attributed to the ability of mulch to moderate soil thermal conditions, creating a more favorable environment for plant growth. The significant difference in these variables highlights the positive impact of this management practice.

Leaf area and leaf number also increased under the double-sided white and black plastic mulch conditions (Figure 1C and Figure 2C). Greater leaf expansion and increased leaf number indicate greater photosynthetic capacity, resulting in greater biomass accumulation. Studies conducted by Souza *et al.* (2020), Vieira *et al.* (2020), and Volpato *et al.* (2021) corroborate these results, demonstrating that the regulation of microclimatic conditions provided by mulch benefits plant growth.

The mulch with plant residue, which was composed of rice straw, also significantly increased the lettuce fresh weight, although its performance was lower than that of the double-sided plastic mulch. These data highlight the effectiveness of mulch in promoting growth and creating favorable environments for crops.

Table 1 presents the significant differences between the cultivation treatments (without cover, with plastic cover and with vegetal cover) in the four different growth periods (A, B, C and D), considering the variables height, diameter, number of leaves, dry mass and fresh mass.

Table 1. Morphological development of lettuce under different soil covers in different growing periods.

Period	**Condition**	**Height**	**Diameter**	**NF**	**MFPA (g)**	**MSPA (g)**
THE	No coverage	6.60 a	10.60 to	8.00 b	4.40 b	0.23 c
	Plastic cover	6.48 a	9.66 a	11:00 a.m.	5.18 a	0.35 to
	Vegetation cover	7.32 a	10.07 a	10.00 to	4.72 ab	0.27 b
	CV (%)	16.76	20.71	9.82	5.87	3.4
B	No coverage	8.76 ab	15.23 a	13:00 to	18.71 c	1.28 b
	Plastic cover	10.80 to	15.08 a	16:00 to	25.87 a	1.52 a
	Vegetation cover	8.10 b	14.33 a	15.00 to	23.11 b	1.35 b
	CV (%)	11.73	21.72	15.57	3.62	5.44
W	No coverage	12.15 b	27.15 a	18.00 b	71.39 c	2.84 b
	Plastic cover	15.33 a	28.35 a	24.00 a	90.84 a	7.10 a
	Vegetation cover	13:35 ab	26.18 a	20.00 ab	77.22 b	6.20 a
	CV (%)	11.57	19.65	11.26	3.66	9.14
D	No coverage	15.75 b	38.93 a	26.00 b	290.05 c	14.16 b
	Plastic cover	21.15 a	42.80 a	36.00 a	308.65 a	15.09 a
	Vegetation cover	18.08 ab	36.83 a	30.00 b	301.05 b	14.74 ab
	CV (%)	10.16	9.07	6.97	0.72	1.99

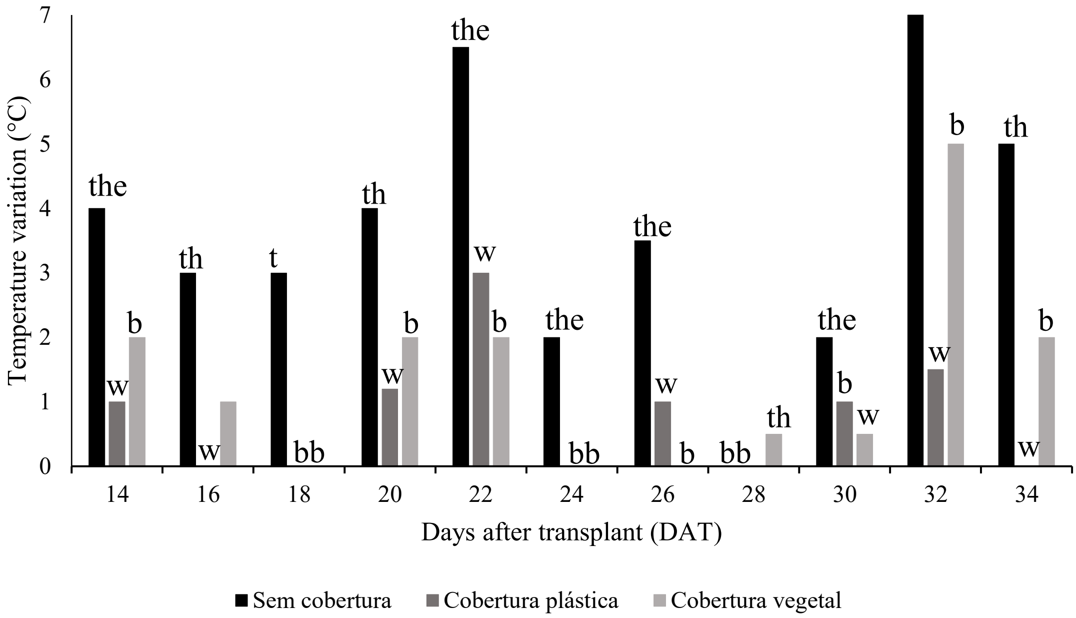
NF, number of leaves; MFPA, fresh mass of the aerial part; MSPA, dry mass of the aerial part.

Table 1 presents information on the influence of soil cover on lettuce growth during different periods of the growing season, highlighting the observed patterns and significant statistical disparities. The cover treatments demonstrated superior performance in almost all the periods evaluated, demonstrating the benefits of these practices for crop development.

These results (Table 1) have important implications for farmers and researchers involved in lettuce production. Choosing the right mulch type can increase productivity and improve the quality of the final product, generating both economic and environmental benefits. Double-sided white and black plastic mulch emerged as the most efficient option, followed by rice straw mulch.

Figure 3 shows the soil temperature variation at a depth of 5 cm throughout the crop cycle, with measurements taken every two days. Compared with the mulch treatment, the unmulched treatment resulted in a greater temperature range, demonstrating the ability of mulch to promote greater thermal stability in the growing environment.

Figure 3. Variation in soil temperature at a depth of 5 cm.



As shown in Figure 3, mulch on the soil surface, whether plastic or vegetal, acts as a thermal regulator, providing a more stable and balanced environment for plant development. The smaller temperature variation observed in covered crops suggests that these techniques help mitigate thermal fluctuations in the growing environment (Musie *et al.*, 2015).

According to Taiz *et al.* (2017), plant temperature is strongly influenced by solar radiation, but it is also influenced by relative humidity and wind speed. Because they lack active thermal regulatory mechanisms, their metabolism becomes quite vulnerable to external environmental conditions. Thus, temperature variations can significantly impact growth, development, and various physiological processes.

Excessively high or low temperatures can cause heat stress, impacting vital functions such as transpiration, nutrient absorption, and photosynthesis. The smaller temperature range provided by roof cover helps prevent these stresses, ensuring milder conditions for plant growth (Meneses *et al.*, 2016).

The use of mulching, owing to its different types and colors, directly influences soil temperature according to its ability to reflect, absorb, and transmit solar radiation (Franquera; Mabesa, 2016). Dark-colored mulches tend to increase the soil temperature because of their greater heat absorption, whereas light-colored mulches reflect more solar radiation, resulting in lower temperatures and increasing the amount of light available under the plant canopy (Jahan *et al.*, 2018).

The development of roots, stems, leaves, and even flower and fruit production can occur more uniformly when plants are exposed to smaller temperature fluctuations, promoting more consistent growth. Environments with extreme temperature variations force plants to adjust their physiological processes, reducing their efficiency in using resources such as water and nutrients. On the other hand, more stable thermal environments favor the absorption and utilization of these resources (Cardoso *et al.*, 2020).

With respect to the development cycle, in the first period (A), the differences between treatments are less pronounced, indicating that, at this initial stage, the growing conditions are relatively similar. However, as the cycle progresses, especially in periods B, C, and D, the use of plastic mulch becomes more prominent, with significantly superior results compared with the other conditions. This pattern suggests a positive cumulative effect of plastic mulch over time, promoting a more stable environment conducive to lettuce growth. In addition to maintaining ideal temperatures, this mulch also helps reduce competition for natural resources with weeds, maximizing the production potential of plants.

In addition to the biometric variables, a differentiation in the spectral behavior of lettuce crops was also observed under different growing conditions. The visible spectrum (VIS), with wavelengths between 400 and 700 nm, is strongly associated with the photosynthesis process, resulting in greater absorption of visible electromagnetic radiation (REM) (Ponzoni; Shimabukuro; Kuplich, 2012). *Near*-infrared (NIR) light, which ranges from 720 to 1300 nm, presents the highest reflectance rates on plant surfaces, interacting with the leaf mesophyll and causing internal light scattering (Ustin; Jacquemoud; Govaerts, 2001; Falcioni *et al*., 2020). Wavelengths between 1300 and 2500 nm correspond to *shortwave* infrared (SWIR) *infrared*, whose reflectance is inversely related to the amount of water present in the leaves (Ponzoni; Shimabukuro; Kuplich, 2012).

The differences in the spectral behavior of lettuce depending on the growing conditions are shown in Figure 4.

Figure 4. Spectral behavior of lettuce under different soil surface coverage conditions during cultivation.

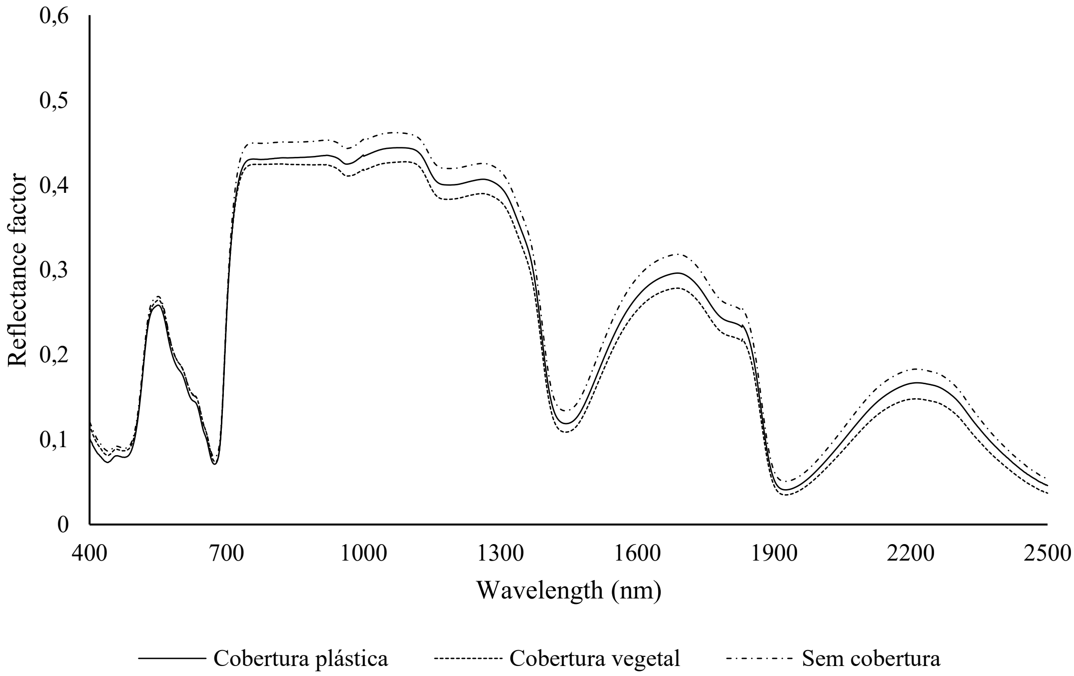


Figure 4 shows the variations in the reflectance values in the near-infrared (NIR) and shortwave infrared (SWIR) regions, indicating that the treatment without mulch had higher reflectance values than did the treatments with black and white double-sided plastic mulch or rice straw mulch. These differences can be attributed to the irrigation management adopted. All plants were irrigated daily at

8:00 a.m., with a water supply equivalent to 100% crop evapotranspiration (ETc). However, owing to the different moisture retention capacities and variations in evapotranspiration rates provided by the different mulches, the amounts of water actually used by the plants varied among the treatments. Compared with bare soil, plastic and mulch reduce evapotranspiration, which reduces the water demand required to achieve 100% ETc.

Despite the same irrigation criteria, plants grown in bare soil experienced greater moisture loss between irrigation intervals because of high evapotranspiration. Spectral analysis performed before daily irrigation revealed that these plants presented signs of temporary water stress, even under adequate water management, resulting in increased reflectance in the NIR and SWIR bands (Figure 4). This behavior may be related to changes in the cellular structure of the leaves and reduced water content in the plant tissues. Damm *et al.* (2018) reported that plants under water stress have higher leaf reflectance values than those with adequate water availability.

On the other hand, plants under both plastic mulch and rice straw mulch maintained a more favorable environment, with less thermal and water variation, which prevented significant water stress. These conditions resulted in lower reflectance values in the NIR and SWIR regions, reflecting the better physiological state of the plants and higher water content in the leaves. These results corroborate previous studies that demonstrated the positive influence of ground cover on modulating the microclimate around plants, promoting more vigorous growth and reducing the impacts of water and heat stress (Gheshm; Brown, 2020; Jahan *et al.*, 2018; Coelho *et al.*, 2013; Longhini *et al.*, 2019; Ranjan *et al.*, 2017; Franquera; Mabesa, 2016).

From an economic perspective, although implementing ground cover crops represents a greater initial investment, the long-term benefits can outweigh the costs. Increased productivity, improved vegetable quality, and reduced herbicide use for weed control can increase producers' profitability (Barros; Cavalcante, 2021). Furthermore, ground cover contributes to the sustainability of agricultural systems by promoting moisture conservation and reducing evapotranspiration, aspects that are especially important in regions with limited water resources.

The results obtained in this study highlight the effectiveness of ground covers in lettuce cultivation, with an emphasis on double-sided white and black plastic mulch, which is highly effective at promoting plant growth, resulting in greater biomass and improved physiological performance. The ability of this mulch to reflect sunlight, reduce heat stress, and suppress weed growth contributed to the creation of a more stable and productive growing environment.

Thus, ground cover crops represent an important management tool in lettuce cultivation, improving the efficiency of water and nutritional resource utilization. The ability of these practices to mitigate the effects of temperature and water variations by creating a more favorable microclimate reinforces their relevance in the context of more sustainable, efficient, and resilient agriculture. Choosing the right cover crop can not only maximize productivity but also contribute to the economic and environmental viability of horticultural production systems.

6 CONCLUSION

Under the conditions in which this study was conducted, considering the equipment used, the analyses performed and the discussions presented, the following conclusions can be drawn:

The lettuce crop showed superior agronomic performance throughout almost all the growth periods in the treatments with soil cover, demonstrating the benefits of these practices for crop development.

Compared with treatments with double-sided plastic cover (black and white) and plant cover (rice straw), growing lettuce without cover resulted in a greater soil temperature range, which demonstrates the role of cover in regulating soil temperature.

Compared with plants grown under mulch, those grown without mulch presented higher reflectance values in the near-infrared (NIR) and shortwave infrared (SWIR) regions. This result suggests that temporary water stress, even with adequate water management, reinforces the role of mulch in maintaining soil moisture and favors plant physiological conditions.

These findings demonstrate the importance of using mulch, especially double-sided plastic mulch, in lettuce cultivation. In addition to providing gains in productivity and quality, these practices contribute to the sustainability of the production system**,** optimizing the use of water resources and promoting a more stable microclimate for crop development.

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