EFFECT OF STRAW MULCHING ON SOIL TEMPERATURE AND LETTUCE PRODUCTIVITY

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ABSTRACT: This study evaluated the effects of straw mulching on soil temperature and the productivity of two lettuce cultivars (*Lactuca sativa* L.) under a no-tillage system. The experiment was conducted in Três Passos, RS, Brazil, during the winter of 2024, using a randomized block design in a bifactorial arrangement. The variables analyzed included soil temperature, plant diameter, fresh mass, and dry mass. The results showed that straw mulching reduced soil thermal amplitude, providing a more stable environment for plant development. However, the presence of straw significantly reduced dry mass accumulation, possibly due to increased soil moisture retention. A significant effect was observed on the diameter of butterhead lettuce under straw mulch, whereas the crisphead cultivar showed no expressive variations. It is concluded that straw mulching represents a viable and sustainable alternative for lettuce cultivation, particularly in small-scale farming systems, by enhancing crop resilience to microclimatic fluctuations.

Key-words: Lettuce; No-tillage; Straw Mulching; Soil Temperature; Sustainable Agriculture.

EFEITO DA COBERTURA COM PALHADA NA TEMPERATURA DO SOLO E PRODUTIVIDADE DA ALFACE

RESUMO: Este trabalho avaliou os efeitos da cobertura do solo com palhada sobre a temperatura do solo e a produtividade de duas cultivares de alface (Lactuca sativa L.), sob sistema de plantio direto. O experimento foi conduzido em Três Passos, RS, durante o inverno de 2024, em delineamento experimental de blocos ao acaso com arranjo bifatorial. Foram avaliadas variáveis como temperatura do solo, diâmetro da planta, massa fresca e massa seca. Os resultados indicaram que a cobertura do solo com palhada contribuiu para a redução da amplitude térmica, proporcionando ambiente mais estável para o crescimento das plantas. No entanto, a presença de palha reduziu significativamente a massa seca das plantas, possivelmente devido à maior retenção de umidade. Constatou-se efeito significativo no diâmetro das plantas de alface lisa com palhada, enquanto a alface crespa não apresentou variações expressivas. Conclui-se que o uso de palhada pode ser uma alternativa viável e sustentável para melhorar a resiliência da cultura da alface, especialmente em sistemas de agricultura familiar.

Palavras-chave: Alface; Plantio Direto; Palhada; Temperatura do Solo; Agricultura Sustentável**.**

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INTRODUCTION

Lettuce (*Lactuca sativa*) is one of the most widely cultivated and consumed leafy vegetables worldwide, being extensively used in human diets due to its versatility and nutritional value (FILGUEIRA, 2013). Its cultivation can occur under different production systems, such as conventional, organic, and hydroponic, with the latter increasingly adopted in response to the need for greater efficiency in water use and the reduction of environmental impacts (SILVA et al., 2019).

Lettuce production is directly influenced by environmental factors such as temperature, humidity, solar radiation, and soil type. Extremely low or high temperatures may affect plant growth and development, interfering with leaf formation and the final quality of the product (TAKAHASHI et al., 2017). Furthermore, excessive humidity may favor the incidence of fungal diseases such as downy mildew (*Bremia lactucae*) and bottom rot (*Rhizoctonia solani*), directly affecting yield (RESENDE et al., 2014).

With the increasing environmental concerns and the need for sustainable production systems, practices such as intercropping, crop rotation, and the use of bio-inputs have been studied to minimize negative impacts and improve lettuce production efficiency (ALTIERI; NICHOLLS, 2013). These strategies can contribute to more resilient agricultural systems, reducing the dependence on chemical inputs and promoting soil and plant health.

In this context, proper soil management is also essential to ensure adequate crop development. The adoption of the No-Tillage System for Vegetables (NTSV) has proven to be an efficient strategy to improve soil structure, reduce erosion, and increase water retention, factors that are essential for lettuce cultivation (ZIECH et al., 2014). Soil mulching is one of the principles of NTSV, as it contributes to maintaining soil temperature, reducing weed incidence, and enhancing soil biological activity (GASPARIM et al., 2005).

Soil temperature is a determining factor for seed germination, root growth, and nutrient uptake by plants. Mulching has a significant effect on thermal regulation, reducing daily thermal amplitude and providing more stable conditions for vegetable development (TEIXEIRA et al., 2018). Studies have shown that mulching acts as a thermal insulator, lowering soil temperature during the day and minimizing heat loss at night, which can favor the growth of lettuce and other vegetables (OLIVEIRA et al., 2020).

In addition to thermal control, mulching also influences soil microbiota and nutrient availability. The decomposition of organic matter derived from mulch releases beneficial compounds that stimulate microbial activity, improve soil structure, and increase the availability of essential nutrients to plants (SANTOS et al., 2017). This effect may result in greater plant vigor and higher vegetable yields, while reducing the need for synthetic fertilizers (ROSA et al., 2019).

The indirect effects of mulching also include reduced water evaporation and improved water infiltration, contributing to more efficient irrigation use (CARVALHO et al., 2016). In crops such as carrot and tomato, the adoption of plant cover has proven effective in maintaining soil moisture and increasing productivity, suggesting similar benefits for lettuce (MENDONÇA et al., 2021).

Although the benefits of mulching have been reported in different crops (ABDUL-BAKI; TEASDALE, 1993; KADER et al., 2017), studies evaluating its specific effects on lettuce grown under the no-tillage vegetable system (NTSV) are still limited, particularly when considering the interaction with different cultivars. Thus, it is necessary to investigate how this management practice influences both soil temperature and crop productivity (SILVA et al., 2014).

In this context, the present study aimed to evaluate the productive performance of two lettuce cultivars under the No-Tillage System for Vegetables (NTSV), considering the presence or absence of mulch and its effects on soil temperature.

MATERIAL AND METHODS

The experiment was carried out in the municipality of Três Passos, Rio Grande do Sul, Brazil, in a Red Latosol soil, located in the Northwestern region of the state (coordinates 27°27'21" S, 53°55'55" W). The trial was conducted in the garden of Escola Municipal de Ensino Fundamental 25 de Julho, from June to August 2024. The experiment was established on June 7, 2024, and samples were collected for analysis on August 5, 2024.

Seedlings of crisphead and loose-leaf lettuce cultivars were purchased from a specialized horticultural company at the ideal developmental stage for transplanting, with five leaves per seedling. The seedlings were transplanted into two plots measuring 8 × 10 m, totaling 18 m² of experimental area. Plant spacing was 0.30 m between plants and 0.30 m between rows, corresponding to a population of approximately 111,000 plants per hectare. The study was conducted under a no-tillage system.

Irrigation was performed through natural rainfall and manually using a household watering can. A timer was used to control irrigation time according to the water requirements of the crop. Manual watering was applied during periods of low rainfall, as prolonged dry spells could impair plant development or even cause losses.

Mulch was applied using Tifton grass hay, uniformly distributed over the plots at a rate equivalent to 6 t ha^{-1} (675 g per plot). Organic fertilization consisted of 225 g of bovine manure applied in the planting row, corresponding to 2 t ha^{-1}. This rate is commonly used in vegetable production (BRITO et al., 2014; SAMINÊZ et al., 2002).

The experimental design was a randomized block design in a 2 × 2 × 4 factorial scheme (two soil cover conditions × two lettuce cultivars × four replications), totaling 16 plots. The treatments consisted of: T1 – loose-leaf lettuce in mulched soil; T2 – loose-leaf lettuce in bare soil; T3 – crisphead lettuce in mulched soil; and T4 – crisphead lettuce in bare soil, each replicated four times.

Lettuce performance was evaluated at harvest (58 days after transplanting) by measuring plant diameter with a measuring tape. After harvesting, plants were weighed using a digital balance with 0.1 g precision. Fresh matter and dry matter of the whole plant, excluding roots, were determined. After weighing, samples were oven-dried at 65 °C until constant weight.

Soil temperature was measured using a Zyhum GM320 Digital Infrared Laser Thermometer, previously calibrated. The device measures temperature by emitting an infrared beam to the soil surface, with a measurement distance of 0.5 m. Measurements were taken at approximately 3:00 p.m., at 48 h intervals. The practice of measuring soil temperature at this time and frequency is supported by scientific protocols that emphasize capturing diurnal thermal variations to better understand soil processes and their implications for agriculture (GLOBE, 2014; FRODELLA et al., 2020).

Temperature measurements were performed differently depending on soil cover: two measurements in lettuce plots without mulch, and four measurements in mulched plots. For mulched plots, two measurements were taken above the mulch layer and two below it, by temporarily removing the mulch. After each measurement, the mulch was replaced at the same location.

The data collected for soil temperature, fresh mass, dry mass, and plant diameter were tabulated and subjected to analysis of variance (ANOVA). Treatment means were compared using Tukey’s test at a 5% probability level.

RESULTS AND DISCUSSION

Soil temperature measurements during the lettuce cultivation period showed considerable variation across the different stages of the experiment, ranging from 7.5 °C to 30.6 °C, as illustrated in Figure 1.

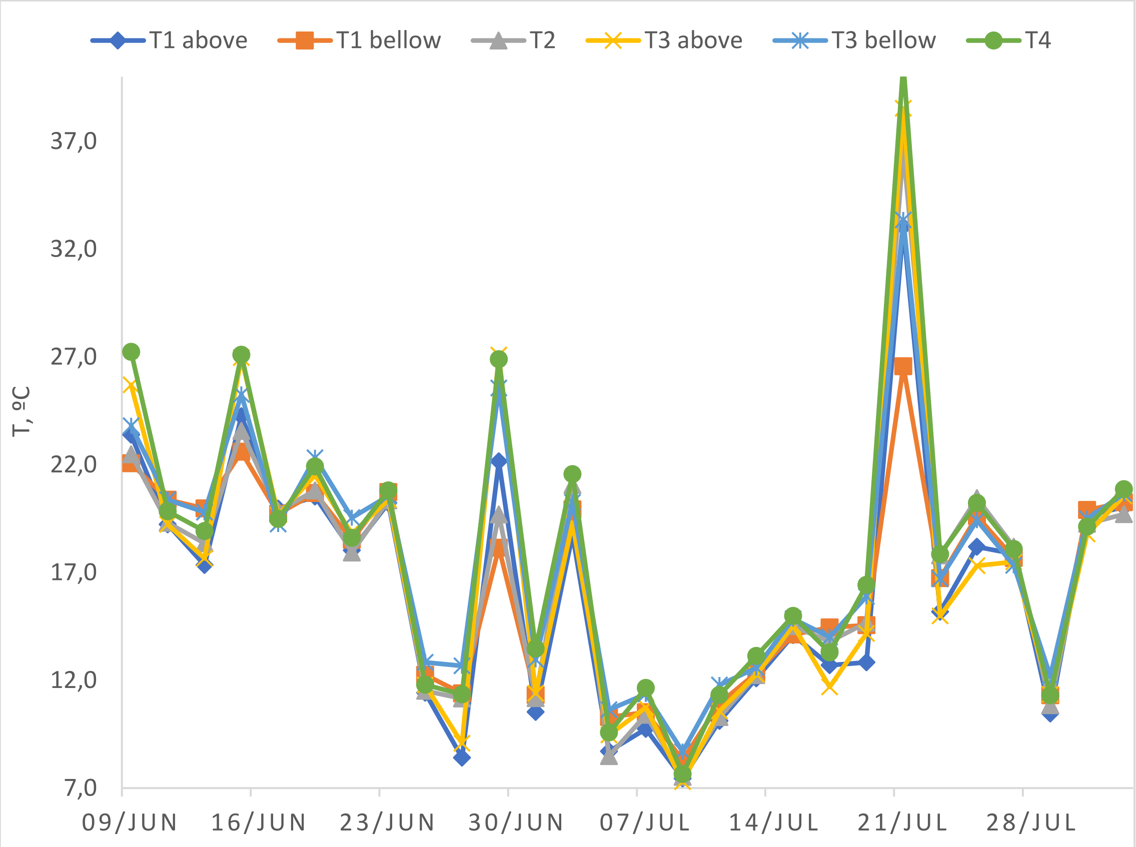

Figure 1. Variation of soil temperature in bare soil and in mulched soil (above and below the mulch layer).

According to the data presented above, greater temperature variation was observed, in general, in the treatments without mulch (T2, T4), both on days with higher temperatures and on days with lower temperatures, when compared with the mulched treatments (T1, T3). In the treatments without mulch, a thermal amplitude of 33.1 °C was recorded, considering the maximum temperature obtained in treatment T4 (40.6 °C) and the minimum observed in treatment T2 (7.5 °C).

In their study on soil temperature with and without mulch, Coelho et al. (2013) also reported lower thermal amplitude variation in mulched soil compared with bare soil, particularly under higher temperatures, with bare soil showing higher maximum values.

Extreme temperatures, whether high or low, directly affect plant metabolism, triggering physiological changes that compromise growth and development. When exposed to thermal peaks, plants reduce or even interrupt vegetative growth as a self-protection strategy, redirecting metabolic resources to defense mechanisms. This process includes the synthesis of heat shock proteins (HSPs), which stabilize cellular structures and repair damage caused by reactive oxygen species (ROS), commonly produced under severe heat stress (LIU et al., 2020).

In addition, photosynthesis inhibition, impaired enzymatic activity, and thylakoid damage in chloroplasts occur, compromising energy production and biomass accumulation (RAJ et al., 2021). These responses result from the modulation of gene expression, prioritizing the maintenance of cellular homeostasis overgrowth, especially during periods of higher solar radiation.

According to Trevisan et al. (2002), soil mulching reduces the amount of radiation reaching the surface and the energy absorbed for evaporation, forming a layer of air with low thermal conductivity, which prevents the soil from heating rapidly. Table 1 presents the results of the evaluation of plant diameter in two lettuce cultivars grown in bare soil and in mulched soil under no-tillage conditions.

When analyzing the variable “plant diameter,” a significant interaction was observed between the factors *cultivar* and *mulching*. This finding suggests that the effect of mulching on lettuce diameter varies according to the cultivar. In the loose-leaf cultivar, mulching resulted in significantly larger plant diameters.

Table 1. Plant diameter of two lettuce cultivars grown under no-tillage, in bare soil and in mulched soil.

Cultivar	**Soil cover**		
	With mulch	**Without mulch**	**Mean**
Loose-leaf	25.75 Aa*	23.75 Ab	24.75
Crisphead	22.25 Ba	23.62 Aa	22.93
Mean	24.00	23.68	

***Means followed by the same lowercase letter in the row and uppercase letter in the column do not differ from each other by Tukey’s test at 5% probability.**

These results differ from those reported by Rodrigues et al. (2009), who, in a study on the effect of different soil covers on the diameter of loose-leaf lettuce, did not observe significant differences for this parameter. Pinto et al. (2016), however, reported that loose-leaf lettuce presented larger diameters compared with crisphead lettuce, which corroborates the results obtained in this study.

For the crisphead cultivar, mulching had no significant effect, as average diameters with and without mulch were statistically similar (Table 1). This result is consistent with the findings of Câmara et al. (2024), who, when analyzing the effect of different soil covers on the diameter of crisphead lettuce, also found no statistical difference for this parameter.

When comparing cultivars within treatments, loose-leaf lettuce presented a significantly larger diameter than crisphead lettuce under mulched conditions. On the other hand, in bare soil, both cultivars exhibited similar average diameters.

Regarding fresh mass in different lettuce cultivars (loose-leaf and crisphead) and between treatments with and without mulching, no significant differences were observed. This suggests that the use of mulch did not directly affect lettuce fresh mass (Table 2).

Mógor et al. (2007) evaluated different lettuce cultivars grown under various soil covers in a no-tillage system, in comparison with bare soil. The authors found statistical differences in several factors, including yield and fresh mass, among the cultivars evaluated, with lower weights recorded in treatments without soil cover.

Table 2. Fresh mass (g) of two lettuce cultivars grown under no-tillage, in bare soil and in mulched soil.

Cultivar	**Soil cover**		
	With mulch	**Without mulch**	**Mean**
Loose-leaf	101.63 ns*	87.18 ns	94.44 ns
Crisphead	111.56 ns	110.83 ns	111.20 ns
Mean	106.63 ns	99.01 ns	

***ns = not significant. Means followed by different uppercase letters in the column (cultivar) and lowercase letters in the row (mulching) differ by Tukey's test ($p < 0.05$).**

Some factors that may explain the differences compared with the results of the present study include the cultivation period, since the experiment by Mógor et al. (2007) was conducted during the summer season, whereas the present study was carried out in winter. Another factor is the type of mulch, as Mógor et al. (2007) tested different mulch materials, which consequently led to distinct interactions in the soil and with the cultivars, as reflected in their results.

Regarding the analysis of shoot dry mass, no significant effects were observed from the interaction between the factors *mulching* and *cultivar*. However, when analyzing the mulching factor in isolation, results showed that the overall mean dry mass in mulched treatments was significantly lower than the overall mean in treatments without mulch (Table 3).

This result can be explained by several interconnected factors. First, mulching influences soil moisture retention by reducing water evaporation and maintaining higher moisture levels in the root zone (COELHO et al., 2013). This may lead to greater water retention in plant tissues, increasing fresh mass but reducing the proportion of dry matter.

Moreover, the lower thermal amplitude of mulched soils (GASPARIM et al., 2005) may favor vegetative growth, leading to greater total biomass accumulation but with a lower relative concentration of dry matter due to the dilution effect. In contrast, in bare soils, plants may experience water stress more rapidly, promoting greater tissue lignification (MÓGOR; CÂMARA, 2007), which increases relative dry mass.

Table 3. Shoot dry mass (g) of two lettuce cultivars grown under no-tillage, in bare soil and in mulched soil.

Cultivar	**Soil cover**		
	With mulch	**Without mulch**	**Mean**
Loose-leaf	7.55 ns*	11.01 ns	8.08 ns
Crisphead	6.58 ns	9.59 ns	9.28 ns
Mean	7.06 b	10.30 a	

***ns = not significant. Means followed by different uppercase letters in the column (cultivar) and lowercase letters in the row (mulching) differ by Tukey's test ($p < 0.05$).**

Mulching may also reduce the need for physiological adaptation of plants to adverse environmental conditions, thereby influencing final biomass composition. As previously observed, mulch acts as a thermal insulator, preventing abrupt temperature variations and creating a more stable microclimate for crop development (TREVISAN et al., 2002; PANTANO et al., 2015).

Another factor that may explain the lower concentration of dry matter in plants grown in mulched soil is the reduced rate of lignification observed under these conditions. According to Ziech et al. (2014), mulching reduces abiotic stress and favors moisture retention, which can result in more succulent plants that are less prone to dry matter accumulation.

Thus, the results suggest that although mulching contributes to a more favorable environment for lettuce growth, promoting greater biomass development, this effect may be associated with a lower concentration of dry matter due to increased water retention in plant tissues.

Mulching plays an essential role in conserving and improving soil quality, especially in no-tillage systems for vegetable production. Several studies have shown that this practice significantly reduces erosion by acting as a physical barrier that protects the soil surface from the direct impact of raindrops and runoff, potentially reducing erosion losses by up to 90% (CID INC., 2023). In addition, the presence of plant cover favors increased soil biodiversity, creating a suitable environment for the development of beneficial microorganisms responsible for nutrient cycling and pathogen suppression (LIU et al., 2020). These biological effects are fundamental for agroecosystem resilience and productivity enhancement.

Another relevant benefit is the gradual release of nutrients through the decomposition of organic matter derived from mulch, which contributes to increased levels of carbon, nitrogen, and phosphorus, improving soil structure and water retention capacity (RAJ et al., 2021). Therefore, mulching not only mitigates environmental impacts but also sustains soil fertility and health in the medium and long term in no-tillage vegetable systems.

CONCLUSION

This study demonstrated that the use of mulching in the No-Tillage System for Vegetables (NTSV) reduced soil thermal amplitude, creating more stable conditions for lettuce growth. Despite this positive effect on the soil microclimate, plants grown under mulch showed lower dry matter accumulation, possibly due to higher moisture retention and reduced need for tissue lignification.

From an agronomic perspective, mulching represents a sustainable and low-cost strategy for smallholder farmers, particularly in regions such as Rio Grande do Sul, as it reduces irrigation demand and contributes to soil conservation.

Although some evaluated parameters did not show statistically significant differences, it is important to emphasize that the effects of NTSV tend to become more evident in the medium and long term. Therefore, further long-term studies are recommended, along with the evaluation of different types of mulching and their interactions with crop nutrition, in order to expand the understanding of the cumulative benefits of this system for vegetable production.

REFERENCES

ATLAS SOCIOECONÔMICO DO RIO GRANDE DO SUL. 7. ed. Atualizado em setembro de 2022. Disponível em: https://atlassocioeconomico.rs.gov.br/clima-temperatura-e-precipitacao#:~:text=como%20Mesot%C3%%A3o%20de%20K%C3%B6ppen). Accessed on: March 11, 2025.

BRITO, L. M. et al. *Effects of soil, root mycorrhization, organic and phosphate fertilization in organic lettuce production*. In: RAHMANN, G.; AKSOY, U. (Eds.). *Building Organic Bridges*. Proceedings of the 4th ISOFAR Scientific Conference, at the Organic World Congress 2014, Istanbul, Turkey. v. 2, p. 925-928, 2014. Disponível em: https://orgprints.org/23031/1/23031%20Brito_MM.pdf. Accessed on: May 9, 2025.

COELHO, M. E. H.; FREITAS, F. C. L.; CUNHA, J. L. X. L.; SILVA, K. S.; GRANGEIRO, L. C.; OLIVEIRA, J. B. Coberturas do solo sobre a amplitude térmica e a produtividade de pimentão. Revista Planta Daninha, Viçosa, MG, v. 31, p. 369-378, 2013. Disponível em: https://www.scielo.br/j/pd/a/SCD39B9cXvjD6NNRnXG4Dqm/?format=html&lang=pt. Accessed on: March 11, 2025.

CID INC. *Mulch and soil erosion control*. Available at: https://cid-inc.com/mulch-and-soil-erosion-control/. Accessed: May 9, 2025.

SANTOS, H. G. et al. Sistema Brasileiro de Classificação de Solos. 5. ed. rev. e ampl. Brasília, DF: Embrapa, 2018.

FAVARATO, L. F. et al. Influência de diferentes sistemas de cultivo de alface de outono/inverno sobre variação térmica e temperatura do solo e planta. 2017. Disponível em: https://biblioteca.incaper.es.gov.br/digital/handle/123456789/2859. Accessed on: September 19, 2025.

FRODELLA, W.; LAZZERI, G.; MORETTI, S.; KEIZER, J.; VERHEIJEN, F. G. A. Applying Infrared Thermography to Soil Surface Temperature Monitoring: Case Study of a High-Resolution 48 h Survey in a Vineyard (Anadia, Portugal). *Sensors*, v. 20, n. 9, p. 2444, 2020. Disponível em: https://www.mdpi.com/1424-8220/20/9/2444. Accessed: May 9, 2025.

GLOBE. *Soil Temperature Protocol*. The GLOBE Program, 2014. Disponível em: https://www.globe.gov/documents/352961/353769/Soil%2BTemperature%2Bprotocol/87a3491a-25af-4123-9e0c-08f341bfc004. Accessed: 9 May 2025.

INSTITUTO AGRONÔMICO DE CAMPINAS. Hortaliças. Disponível em: https://www.iac.sp.gov.br/imagem_informacoestecnologicas/7.pdf. Accessed on: 11 March 2025.

GASPARIM, E.; RICIERI, R. P.; DALLACORT, R. Temperatura no perfil do solo utilizando duas densidades de cobertura e solo nu. Acta Scientiarum. Agronomy, Maringá, v. 27, p. 107-115, 2005. Disponível em: https://periodicos.uem.br/ojs/index.php/ActaSciAgron/article/view/2127. Accessed on: 11 March, 2025.

HIRATA, A. C. S.; HIRATA, E. K.; CAMARA, J. A. R. Adaptabilidade de cultivares de alface ao plantio direto sobre palha de *Urochloa ruziziensis*. Revista Horticultural Science, publicado em julho de 2018. Disponível em: https://doi.org/10.1590/S0100-204X2018000700006. Accessed on: 11 March, 2025.

LIMA, N. S. Uso da manipueira como biofertilizante na cultura do alface. 2010. 34 f. Monografia (Trabalho de Conclusão de Curso) - Universidade Federal de Alagoas, Rio Largo-AL. Disponível em: <https://ceca.ufal.br//pt-br/graduacao/agronomia/documentos/tcc/tcc2010/Nadielan%20da%20Silva%20 Lima.pdf>. Accessed on: 11 March, 2025.

LIMA, G. S.; SILVA, Ê. F. F.; CORRÊA, M. M.; FILHO, J. A. C. A.; COIMBRA, O. W.; YAMASHITA, L. M. R. Necessidade hídrica da alface submetida a doses de potássio aplicadas via fertirrigação na região metropolitana do Recife. XVIII Simpósio Brasileiro de Recursos Hídricos. Disponível em: https://abrh.s3sa-east1.amazonaws.com/Sumarios/110/c1b4e0c1c8281f662955294056c86602_023f5c89bf7cc21a2b3db8942c51122f.pdf. Accessed on: 11 March, 2025.

LIU, Han et al. *Soil microbiome diversity under different cropping systems and mulching treatments*. *Frontiers in Microbiology*, Lausanne, v. 11, 2020. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7143828/. Accessed: 9 May 2025.

MAGGI, C. F.; POLEZE, T. Variedades de alface cultivadas sobre diferentes coberturas de solo. V Congresso Latinoamericano de Agroecologia - SOCLA, 7 a 9 de outubro de 2015, La Plata, 2015.

MASCARENHAS, N. M. H. Microclima na produção de alface em ambiente protegido com diferentes telas de sombreamento: uma revisão. Revista Ambientale, Revista da Universidade Estadual de Alagoas/UNEAL, Ano 14, Vol. 14 (3), julho-outubro, 2022. Disponível em: https://doi.org/10.48180/ambientale.v14i4.384. Accessed on: March 05, 2025.

MÓGOR, Á. F.; CÂMARA, F. L. A. Produção de alface no sistema orgânico em sucessão a aveia preta, sobre a palha, e diferentes coberturas do solo. Scientia Agraria, v. 8, n. 3, p. 239-245, 2007.

NETO, F. B. et al. Sombreamento para produção de mudas de alface em alta temperatura e ampla luminosidade. Horticultura Brasileira, 23 mar. 2005. Disponível em: https://doi.org/10.1590/S0102-05362005000100028. Accessed on: March 05, 2025.

PANTANO, A. P.; NOVO, M. C. S. S.; TRANI, P. E. Desempenho de cultivares de alface na região de Americana, SP. Irriga, v. 20, n. 1, p. 92-104, 2015. DOI: 10.15809/irriga.2015v20n1p92. Disponível em: https://revistas.fca.unesp.br/index.php/irriga/article/view/926. Accessed on: March 05, 2025.

PINTO, L. E. V. et al. Influência da casca de amendoim como cobertura vegetal para a produção de alface. Colloquium Agrariae, vol. 12, n. Especial, jul-dez, 2016, p. 55-60. DOI: 10.5747/ca.2016.v12.nesp.000171. Disponível em: https://d1wqtxts1xzle7.cloudfront.net/68192138/9a1f20536dc920d151ee9cec73e537b06760-libre.pdf. Accessed on: April 04, 2025.

RAJ, Ankit et al. *Long-term effects of organic mulching on soil nutrient dynamics and vegetable yield under conservation agriculture*. *Soil & Tillage Research*, Amsterdam, v. 213, p. 105136,

2021. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0167198720304992. Accessed: May 9, 2025.

SAMINÊZ, C. E. et al. *Cultivo de alface em sistema orgânico de produção*. Brasília, DF: Embrapa Hortaliças, 2007. (Circular Técnica, 56). Disponível em: https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/780841/1/alface-organico-CT56-2007.pdf. Accessed: May 9, 2025.

TREVISAN, R. et al. Variação da amplitude térmica do solo em pomar de pessegueiro cultivado com aveia preta (Avena sp.) e em sistema convencional. R. Bras. Agroci., v. 8, n. 2, p. 155-157, 2002. Disponível em: https://periodicos.ufpel.edu.br/index.php/CAST/article/view/442. Accessed: May 9, 2025.

ZIECH, A. R. D. et al. Cultivo de alface em diferentes manejos de cobertura do solo e fontes de adubação. Revista Brasileira de Engenharia Agrícola e Ambiental, Campina Grande, PB, UAEA/UFCG, v. 18, n. 9, p. 948–954, 2014. Disponível em: http://www.agriambi.com.br. Accessed: April 04, 2025.