Bioagro 36(1): 105-112. 2024 doi: http://www.doi.org/10.51372/bioagro361.10

Technical Note

PRODUCTION OF AMERICAN LETTUCE CULTIVARS UNDER DIFFERENT COLORED SHADE NETS

Cipriano R. Enciso-Garay[1], Noelia I. Godoy Medina[1], Victoria R. Santacruz Oviedo[1], Romina Burgos Rotela[1], Fanni P. Ruiz Samudio[1] and Nadia C. Sanabria Verón[1]

ABSTRACT

Shading nets are used to reduce the amount of radiant energy reaching crops. The objective of the work was to compare the influence of black and red shading nets on the production of nine American lettuce cultivars in the Autumn period under the conditions of the Central Department of Paraguay. The experiment was carried out in the Experimental Field of the Departmental Agronomic Center (CAD) in the Municipality of Julián Augusto Saldívar. The treatments consisted of the combination of two types of shading netting (red with 35% shade and black with 35% shade) and nine cultivars of American lettuce (Julia, Dora, Angelina, Tainá, Sun Valley, Betty, Lucy Brown, Mara, and Serena) totaling 18 treatments. The experiment consisted in a complete randomized block design, arranged in split blocks 2×9 (the color of shading netting was considered the main plot, and the lettuce cultivars as the secondary plot) with four repetitions. Each experimental unit consisted of four crop rows with seven plants. Plant diameter, plant height, head diameter and height, commercial number of leaves per plant, fresh mass, and commercial productivity were evaluated. The data were subjected to analysis of variance, and when differences were found, the means were compared by the Scott-Knott test at 5% probability. The results indicate that using the red netting with the Serena and Dora cultivars provides greater fresh mass and commercial production.
Additional Keywords: Competition, fresh mass, *Lactuca sativa*, protected yield

RESUMEN

Producción de cultivares de lechuga americana bajo mallas de sombreo de diferentes colores

Las mallas de sombra se utilizan para reducir la cantidad de energía radiante que llega a los cultivos. El objetivo de este trabajo fue comparar la influencia de las mallas sombreadoras negras y rojas en la producción de nueve cultivares de lechuga americana en el período otoñal en las condiciones del Departamento Central del Paraguay. El experimento se realizó en el Campo Experimental del Centro Agronómico Departamental (CAD), en el municipio de Julián Augusto Saldívar. Los tratamientos consistieron en una combinación de dos tipos de malla sombra (roja con 35% de sombra y negra con 35% de sombra) y nueve cultivares de lechuga americana (Julia, Dora, Angelina, Tainá, Sun Valley, Betty, Lucy Brown, Mara y Serena) totalizando 18 tratamientos. El diseño experimental fue en franjas en bloques completos al azar de 2×9 (las mallas de color fueron consideradas la parcela principal y los cultivares la parcela secundaria) y cuatro repeticiones. Cada unidad experimental constó de cuatro hileras de cultivo, con siete plantas. Se evaluó diámetro de planta, altura de planta, diámetro y altura de cabeza, número comercializable de hojas por planta, masa fresca y rendimiento comercializable. Los resultados fueron sometidos a análisis de varianza y, cuando se encontraron diferencias significativas, se usó la prueba de Scott-Knott al 5% de probabilidad para la comparación de medias. Los resultados indican que el uso de la red roja con los cultivares Serena y Dora proporciona mayor producción de masa fresca y comercializable.
Palabras clave adicionales: Ambiente protegido, competencia, *Lactuca sativa*, masa fresca, rendimiento

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is the most cultivated and consumed leafy vegetable in Paraguay, mainly fresh in salads. The American or head lettuce, also known as "iceberg" and "crisphead" (var. capitata), was recently introduced to the country. It has a growing demand and great acceptance by consumers due to its longer postharvest life and the possibility of using it to prepare salads and fast foods.

In Paraguay, lettuce is cultivated throughout the year, mainly in the horticultural belts of the urban centers of the Central Department, by family farmers. It is characterized by low yields and the use of cultivars poorly adapted to local climatic conditions because the country does not produce seeds of this species. The cultivars available in the national market present limitations

Received: Mayo 12, 2023 Accepted: Noviembre 30, 2023
[1]Facultad de Ciencias Agrarias, Universidad Nacional de Asunción. San Lorenzo Km 11, Departamento Central. Paraguay. Email: cenciso@agr.una.py (autor de correspondencia), noelia.godoy@agr.una.py, vrossmary@agr.una.py, romina.burgos@agr.una.py, fruiz@agr.una.py, nsanabria@agr.una.py

for their cultivation at certain times of the year; therefore, selecting the cultivar best adapted to the climate and soil conditions for each season is extremely important for be successful. In the country, lettuce is traditionally cultivated in open fields; however, the climatic conditions, mainly temperature, and precipitation, do not allow for obtaining quality products, so it is necessary to resort to protection systems that allow adequate development of the crop and thereby improving the quality of the harvest. The use of shading nettinges is a technique used to control the microclimate in the production of vegetables to reduce the intensity of radiation through the use of different percentages of shading and thus avoiding the detrimental effect of high temperatures during the development of the crop, and protecting the plants from the adverse effect of high rainfall (Shahak et al., 2004; Ilić et al., 2017).

Shaders are structures built to reduce radiation, the temperature at the leaf level, and evapotranspiration, and to increase the relative humidity of the environment and regulate moisture at ground level (Ferratto et al., 2010). The shading nettinges of different colors aim to modify the radiation spectrum available to plants by providing metabolic adjustments in the photosynthetic system (Sabino et al., 2016).

In the local market, shading nets of different colors and light retention percentages are offered, but there is little information about the most suitable shading net color to produce American lettuce cultivars in the autumn period. Using shading nets and suitable cultivars in conditions of elevated temperature and light can increase the yield and production of American-type lettuce.

The objective of this work was to compare the influence of black and red shading nets on the production of American lettuce cultivars in the autumn-winter period under the edaphoclimatic conditions of the Central Department of Paraguay.

MATERIALS AND METHODS

The experiment was carried out in the Experimental Field of the Departmental Agronomic Center (CAD) of the Faculty of Agricultural Sciences of the National University of Asunción, located at the geographic coordinates 25°25'11" South and 57°26'11" West, in the municipality of Julián Augusto Saldívar, Central Department, Paraguay, between April and July of the year 2019. Table 1 shows the monthly averages of precipitation, maximum, minimum, and average temperature recorded during the experiment.

Table 1. Monthly means of maximum, minimum, average temperature, precipitation, and relative humidity during the experiment (DINAC, 2019).

Months	Temperature (ºC)			Precipitation (mm)	Mean relative humidity (%)
	Maximum	Minimum	Mean		
April	27.9	19.9	23.5	194.4	82.5
May	25.0	18.0	21.0	166.4	83.7
June	25.6	16.6	20.5	0.6	72.9
July	22.5	12.7	16.7	29.9	69.7

The soil in the experimental area belongs to the Ultisol order with a sandy loam texture (López et al., 1995). The soil at the 30-cm top layer has a pH = 6.64, organic matter = 0.45 %, P = 123.1 mg kg^{-1}, Ca^{+2} = 1.89 cmolc kg^{-1}, Mg^{+2} = 0.47 cmolc kg^{-1}, K^{+} = 0.09 cmolc kg^{-1}, Al^{3++}.

The treatments consisted of using two different types of shade netting: red (35% shade) and shade netting black (35% shade), combined with nine cultivars of American lettuce (Julia, Dora, Angelina, Tainá, Sun Valley, Betty, Lucy Brown, Mara, and Serena) totaling 18 treatments. The experimental design was a complete randomized block 2×9 in strips (the color of shading netting was considered the main plot and the lettuce cultivars as the secondary plot) and four

repetitions. Each experimental unit consisted of 28 plants, distributed in four crop rows, with seven plants each.

Seedlings were produced in polystyrene trays with 160 cells loaded with commercial Kekkila, a substrate for horticultural seedbeds. Sowing was carried out on April 15, 2019, depositing one seed per cell. Then, the trays were placed on countertops at 1 m height inside a greenhouse, where irrigation was applied through micro-sprinkling.

Soil preparation in the experimental area was done by plow and harrow. Fertilization was applied according to the results of the soil analysis, and consisted in a basic fertilization with 10 Mg ha^{-1} poultry manure, 100 kg ha^{-1} nitrogen and 80 kg ha^{-1} K_2O. Subsequently, eight soil beds of 1.40 m wide and 27 m long were made. Two drip tapes were installed on each board with emitters spaced every 0.30 m, and then covered with two-color (black and white) mulching.

Four 27 m long beds represented each environment. In each environment, 2.20 m high poles were placed, separated every 2.5 m, and joined by wires at the top to form flat roof structures. Red shading netting with 35% light retention was placed on these structures and black shading netting with 35% light retention on the other four beds. The black netting was used as a control because it is the most widespread among national producers.

Twenty-four-old-day seedlings were transferred to the ground beds at 0.35 m between rows and 0.35 between plants. The top dress fertilization consisted of 44 kg ha^{-1} urea (45% N) at 15, 30, and 45 days after transplanting. Irrigation was applied for one hour per day, distributed in times of 30 minutes in the morning and 30 minutes in the afternoon.

The harvest was carried out on July 8, 2019, when the lettuce plants presented a compact head, and the harvest was performed 84 days after sowing for American lettuce. Six plants were selected from the central row in each experimental unit for the evaluations. The following evaluations were carried out: plant diameter, plant height, head diameter, head length, number of commercial leaves per plant, commercial fresh mass, and commercial productivity per hectare.

The data obtained were subjected to the analysis of variance, and when a significant statistical difference was found, the means were compared by the Scott and Knott test at a 5% probability using the InfoStat statistical software (Di Rienzo et al., 2020).

RESULTS AND DISCUSSION

The shading nets and the American lettuce cultivars did not present significant interaction for the following variables: plant diameter, plant height, head length, head diameter, and number of commercial leaves per plant, demonstrating that the cultivars had similar behavior in both environments. Differences were observed for the netting color factor for plant diameter, head diameter, and number of commercial leaves per plant and between cultivars for plant diameter and height (Table 2).

The Dora and Serena cultivars presented greater plant diameter and height, differing from the other evaluated cultivars. These results agree with those mentioned by Queiroga et al. (2001), who, in their research with different colors of shading nettinges (white, green, and black), also found differences between cultivars for said variable; however, they did not obtain differences based on the color of the nettinges. On the other hand, they differ from Neves et al. (2016), who found no differences between cultivars in plant diameter nor between the environments when evaluating four cultivars of American lettuce in five cultivation environments under shading nets.

Plant height can be an indicator of the susceptibility of a cultivar to early flowering. However, at the harvest time in this experiment, none of the cultivars showed signs of floral scape emission, which may indicate that they had adapted to the climatic conditions during the investigation. The average temperatures after the transplant (Table 1) were 21 °C (May), 20.5 °C (June), and 16.7 °C (July), which can be considered favorable for the growth and development of the plants of lettuce, taking into account that the ideal temperature is between 15.5 and 18.3 °C. According to Sanders (2019) the plants can tolerate temperatures between 26.6 and 29.4 °C for a few days. Among cultivars, mean head heights were between 10.76 cm (Serena) and 13.39 cm (Lucy Brown). These results coincide with those of Enciso et al. (2019), who compared eight cultivars of American lettuce in the period from July to October under black shading netting

and did not find differences for this variable either.

Regarding head diameter, the means were between 15.01 cm (Betty) and 13.67 cm (Mara), without significant differences between cultivars. Comparable results were found by Ferreira et al. (2021) when evaluating six American lettuce cultivars under protected environment conditions. The values found in this investigation are higher than those reported by Brzezinski et al. (2017), who, when evaluating four cultivars of American lettuce in two cultivation systems (low tunnel and open field), reported that the Taina cultivar presented an average of 12.72 cm, lower than that obtained in this investigation, which was 14.09 cm. This variable indicates the size of the product to be marketed, which is a particularly important characteristic for American lettuce marketing, considering that those with a larger diameter are the most preferred by national consumers.

The number of commercial leaves per plant is an important factor because it represents the number of usable leaves for consumption; it varied between 14.96 (Mara) and 17.15 (Julia) without significant statistical differences. According to Ilić et al. (2018), for lettuce to form heads correctly, the individual leaves must be large enough, the petioles short, the stem elongation rate slow, and the production of the leaves, for which they need colored shade.

Table 2. Plant diameter (PD), plant height (PH), head length (HL), head diameter (HD), and number of commercial leaves per plant (NCL) of American lettuce cultivars under different color shade netting in the autumn-winter period. J. Augusto Saldívar, Central Department, Paraguay, 2019

Shade color	PD (cm)	PH (cm)	HL (cm)	HD (cm)	NCL
Red	44.79 a	22.56 a	12.58 a	48.04 a	17.38 a
Black	38.80 b	21.69 b	11.83 a	42.96 b	14.69 b
Cultivar					
Julia	38.92 ns	21.69 b	13.25 ns	46.96 ns	17.15 ns
Dora	49.37	26.15 a	11.08	46.48	16.63
Angelina	43.94	21.33 b	12.95	45.48	15.94
Tainá	39.98	20.06 b	11.70	44.27	16.21
Sun Valley	41.30	21.04 b	11.82	46.10	15.88
Betty	38.15	20.69 b	12.42	47.17	15.77
Lucy Brown	39.51	22.23 b	13.39	45.83	15.92
Mara	37.83	21.46 b	12.44	42.96	14.96
Serena	47.11	24.49 a	10.76	44.25	15.92
Mean	41.79	22.13	12.20	45.50	16.03
CV (%)	14.61	16.23	13.39	10.07	20.49

Means followed in each column with the same letter do not differ statistically by the Scott-Knott test at 5% probability of error. ns= not significant. CV: coefficient of variation

It was verified that the netting color and lettuce cultivar factors showed a slight interaction in some cultivars (Betty and Serena) for fresh mass and commercial productivity (Table 3). All cultivars with red netting, except for Betty, presented higher means in both variables.

The observed superiority of the Dora, Angelina, Taíná and Serena cultivars compared to the others (Table 3) may be due to their better adaptation to the prevailing environmental conditions during the conductions of the research.

Table 3. Commercial fresh mass and productivity of American lettuce cultivars with different colors shade netting. Julián Augusto Saldívar, Central Department, Paraguay, 2019

Cultivars	Commercial Fresh Mass (g·plant^{-1})		Commercial productivity (t·ha^{-1})	
	Shade netting Red	Shade netting Black	Shade netting Red	Shade netting Black
Julia	323.67 Ad	219.96 Bb	21.70 Ad	14.75 Bb
Dora	588.17 Aa	293.63 Ba	39.44 Aa	19.69 Ba
Angelina	386.71 Ac	272.03 Ba	25.93 Ac	18.24 Ba
Tainá	376.54 Ac	270.29 Ba	25.25 Ac	18.12 Ba
Sun Valley	379.58 Ac	215.13 Bb	25.45 Ac	14.43 Bb
Betty	252.38 Ad	212.54 Ab	16.92 Ad	14.25 Ab
Lucy Brown	308.16 Ad	195.87 Bb	20.66 Ad	13.13 Bb
Mara	283.63 Ad	158.25 Bb	19.02 Ad	10.61 Bb
Serena	467.50 Ab	366.98 Ba	31.35 Ab	24.61 Ba
Mean	374.04 A	244.96 B	25.08 A	16.43 B
CV (%)	20.89		20.89	

Means followed by uppercase letters in each line (main plot) and the same lowercase letters in each column (secondary plot) do not differ by the Scott-Knott test at a 5% probability of error. CV: coefficient of variation

These results agree with those of Shahak et al. (2004), who reported increases in the yield of lettuce, basil, and pepper with red shading netting compared to blue and black nettinges. In the same way, Beraud and Morales (2015), when evaluating four types of shading netting (red with 40 and 18% shading, aluminized netting with 40% shading, and black netting with 35% shading) in the production and quality of fruits of blueberry, obtained higher yield and fruit size with red nettinges with 40 % shade. Similar results were also reported by De Andrade et al. (2021) who, comparing different colors of shading nets (without cover, blue, white, yellow, and red) in the fresh mass production of the Salad Bowl variety lettuce, obtained the best results with the red nets, which did not differ of the yellow netting, but it was superior to the other netting colors. However, they do not agree with Rech et al. (2019), who evaluated the influence of different shading netting colors (black, green, silver, and red) on the commercial production of Lucy Brown head lettuce in the period from June to July in the State of Paraná, Brazil, and did not find differences based on netting colors, with an average of 286.50 g head^{-1} for the red netting and 250.19 g head^{-1}, with the black netting, respectively, lower than those obtained for the same cultivar in this research, with the same netting colors.

Black shade nets differ from nets with other colors in that they only reduce the intensity without affecting light quality (Ilić and Fallik, 2017). The photosynthetic activity of the leaves is higher under red shade netting (Shahak et al., 2004) because they transfer lighter from the red, far-red spectrum and diffuse the light that passes through the netting, being more efficient in plant development (Li, 2006).

The highest commercial fresh mass was obtained with the cultivars Dora (588.17 g plant^{-1}) and Serena (467.50 g plant^{-1}). These values are higher than those reported by Ferreira et al. (2021), who obtained mean commercial fresh mass of 222.71 and 250.70 g plant^{-1}, with the most productive cultivars when evaluating six cultivars of American lettuce. Likewise, the mean obtained with Dora is higher than that reported by Carini et al. (2020), who, evaluating American lettuce cultivars in the autumn-winter period in Santa María, Rio Grande do Sul, Brazil, mention that the Gloriosa cultivar with fresh mass between 530.76 and 547.81 g plant^{-1} was the most productive. An experiment carried out by Yuri et al. (2017) in Petrolina, Pernambuco, Brazil, reported that in the same period in which this research was carried out

(April to July), the most productive cultivar produced a fresh mass of 500 g plant^{-1}, lower than that obtained with Dora, but higher than Serena's.

The superiority of the Dora and Serena cultivars compared to the other cultivars evaluated in this research may be due to the better adaptation to the climate and soil conditions during this research.

The Mara, Betty, and Lucy Brown cultivars presented the lowest means of fresh mass and commercial productivity, evidencing their lower adaptation to the conditions in which the research was conducted.

The differences between cultivars in fresh mass and commercial productivity may be because lettuce is a crop that presents an interaction between genotype and environment (Silva et al., 2019); therefore, to improve productivity and quality, it is important to identify the best-adapted cultivars for the different times of the year due to the great diversity of cultivars in the market (Resende et al., 2017).

CONCLUSION

The use of red shading netting allows for increased commercial fresh mass, commercial yield, and quality of the American lettuce cultivars.

The Dora, Angelina, Tainá and Serena cultivars performed better under red colored nets due to the higher fresh mass and commercial yield.

ACKNOWLEDGMENT

We appreciate the support of the National Council of Science and Technology (Conacyt) and the Faculty of Agricultural Sciences of the National University of Asunción to finance Project PINV 15-152.

LITERATURE CITED

1. Beraud, M.M. and D.M. Morales-Ulloa. 2015. Efecto de mallas sombreadoras sobre la producción y calidad de frutos de arándano (*Vaccinium corymbosum* L.) cv. Brigitta. Scientia Agropecuaria 6(1): 41-50.
2. Brzezinski, C.R., J. Abati, A. Geller, F. Werner, and C. Zucareli. 2017. Produção de cultivares de alface Americana sob dois sistemas de cultivo. Revista Ceres 64: 83-89.
3. Carini, F., A. Cargnelutti-Filho, J.A. Kleinpaul, I.M. Márcio-Neu, D. Lixinski Silveira, M. Pacheco and J. Luiz-Andriolo. 2020. Rendimiento agronómico de cultivares de lechuga en diferentes estaciones y condiciones de sombra. Idesia (Arica) 38(1): 47-58.
4. De Andrade, A.R., B.M. De Souza, E.G. Da Silva, R.G. Pereira, E.T. Da Silva, M.G. Dos Santos Silva and J.F. Da Silva. 2021. Influência dos tipos de tela de sombreamento (TNTs) no desenvolvimento da alface nas condições climática de Garanhuns–PE. Brazilian Journal of Development 7(1): 4833-4853.
5. Di Rienzo, J.A., F. Casanoves, M.G. Balzarini, L. Gonzalez, M. Tablada and C.W. Robledo. 2020. InfoStat Ver. 2020. Centro de Transferencia InfoStat, FCA, Universidad Nacional de Córdoba, Argentina.
6. DINAC (Dirección Nacional de Aeronáutica Civil). Dirección de Meteorología e Hidrología, Paraguay. 2019. Anuario climatológico. 76.
7. Enciso-Garay, C.R., V.R. Santacruz, N.I. Godoy and C.A. Caballero. 2019. Agronomic behavior of American lettuce cultivars in the central department of Paraguay. Horticultura Argentina 38(97): 13-22.
8. Ferratto, J.A., M.C. Mondino, R.O. Grasso, M.P. Ortiz-Mackinson, P. Mauricio, A. Longo et al. 2010. Buenas prácticas agrícolas para la agricultura familiar: cadena de las principales hortalizas de hojas en Argentina. FAO–Conicet, Buenos Aires. https://ri.conicet.gov.ar/handle/11336/193678#ds-main
9. Ferreira, R.L., S.E. de Araújo-Neto, L.G. de Souza, G. Marino, A. de Albuquerque Pinheiro, M.I. Rezende and G.P. Pinto. 2021. Desempenho agronômico de cultivares de alface Americana sob cultivo orgânico em Rio Branco, Acre. Scientia Naturalis 3(1).
10. López, O., E. González, P.A. Llamas, A. Molinas, E. Franco, S. García and E. Ríos. 1995. Estudio de reconocimiento de suelos,

capacidad de uso de la tierra y propuesta de ordenamiento territorial preliminar de la Región Oriental del Paraguay. Asunción, PY: MAG. 1: 197.

11. Li, J.C. 2006. Uso de mallas en invernaderos. Horticultura Internacional 1: 86-91.
12. Ilić, S.Z., L. Milenković, A. Dimitrijević, L. Stanojević, D. Cvetković, Z. Kevrešan and J. Mastilović. 2017. Light modification by color nets improves quality of lettuce from summer production. Scientia Horticulturae 226: 389-397.
13. Ilić, Z.S and E. Fallik. 2017. Light quality manipulation improves vegetable quality at harvest and postharvest: A review. Environmental and Experimental Botany 139: 79-90.
14. Ilić, Z.S., L. Milenković, L. Šunić and M. Manojlović. 2018. Color shade nets improve vegetables quality at harvest and maintain quality during storage. Contemporary Agriculture, 67(1): 9-19.
15. Neves, J.F., I.D. Nodari, S.S. Júnior, L.D. Dias, L.B. da Silva and R. Dallacort. 2016. Produção de cultivares de alface Americana sob diferentes ambientes em condições tropicais. Revista Agro@mbiente on-line 10(2): 130-136.
16. Queiroga, R.C., F. Bezerra-Neto, M.Z. Negreiros, A.P. Oliveira and C.M. Azevedo. 2001. Produção de alface em função de cultivares e tipos de tela de sombreamento nas condições de Mossoró. Horticultura Brasileira 19: 324-328.
17. Rech, L.L., A.R. Lopes, M. Dotto, C.M. Giarola and K. Pirola. 2019. Influência de telas de sombreamento de diferentes colorações no desenvolvimento da alface Americana. Revista Brasileira de Engenharia de Biossistemas 13(4): 324-329.
18. Resende, G.M., J.E. Yuri, N.D. Costa, A.G. Silva and J.H. Mota. 2017. Desempenho produtivo de genótipos de alface crespa no Submédio do Vale do São Francisco. Scientia Plena 13(11).
19. Sanders, D. 2019. Lettuce Horticulture Information Leaflets. N.C. State University. https://content.ces.ncsu.edu/lettuce
20. Sabino, M., C. Korpan, B.G. Ferneda and A.C. Silva. 2016. Crescimento de mudas de ipês em diferentes telas de sombreamento. Nativa 4(2): 61-65.
21. Shahak, Y., E. Gussakovsky and R. Gal Ganelevin. 2004. ColorNets: Crop protection and light-quality manipulation in one technology. Acta Horticulturae 659: 143-159.
22. Silva, O., W.D. Lopes, G.H. Nunes, M.Z.D. Negreiros and J.O. Espínola-Sobrinho. 2019. Adaptability and phenotypic stability of lettuce cultivars in a semiarid region. Revista Caatinga 32: 552-558.
23. Yuri, J.E., G.M. Resende, N.D. Costa and A.S. Gomes. 2017. Desempenho agronômico de genótipos de alface Americana no Submédio do Vale do São Francisco. Horticultura Brasileira 35: 292-297.