

## Performance of lettuce cultivars in different growing environments in the spring season in the semiarid region of Minas Gerais

Desempenho de cultivares de alface em diferentes ambientes de cultivo na estação primavera no semiárido mineiro

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### Abstract

The cultivation of lettuce (*Lactuca sativa* L.) plays a significant role in the Brazilian economy as it is the most consumed leafy vegetable in the country. Temperatures above the ideal range (7 to 24°C) cause a phenomenon known as photoinhibition, which favors early bolting, leading the farmer to harvest plants at a reduced size and with a bitter taste, depreciating the commercial value of the vegetable. The objective of this study was to evaluate the morphological behavior and



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productivity of loose-leaf and curly lettuce cultivars under different cultivation environments in the conventional system during the spring season in the semi-arid region of Minas Gerais, Brazil. The experiment was conducted at the Olericulture Unit of the Federal Institute of Education, Science and Technology of Northern Minas (*Instituto Federal de Educação, Ciência e Tecnologia do Norte de Minas*) - Januária campus, from October to December 2022, in a conventional cultivation system, consisting of 8 treatments, conducted in a split-plot scheme, in a randomized block design, with three replications. The cultivation environments were allocated to the plots: Full sun, black shade net/50% mesh; ChromatiNet Diffuser®/50% mesh; and Aluminet®/50% mesh; the subplots were the cultivars Vanda and BRS Mediterrânea. After the harvest, the following variables were evaluated: Number of leaves, fresh leaf mass, dry leaf mass, leaf area, stem length, stem diameter, fresh stem mass, dry stem mass, head diameter, fresh head mass, dry head mass, specific leaf area, and productivity. The BRS Mediterrânea cultivar subjected to the Pleno Sol environment allowed for greater vegetative development and higher productivity during the study period.

**Keywords:** *Lactuca sativa* L., temperature, irradiance

### Resumo

A cultura da alface (*Lactuca sativa* L.) desempenha um papel expressivo na economia brasileira por ser a hortaliça folhosa mais consumida no país. Temperaturas superiores à faixa ideal (7 a 24°C) provocam um fenômeno conhecido como fotoinibição, que favorece o pendoamento precoce, fazendo com que o agricultor antecipe a colheita de plantas de tamanho reduzido, gosto amargo, depreciando o valor comercial da olerícola. Objetivou-se com este trabalho avaliar o comportamento morfológico e de produtividade de cultivares de alface de folhas soltas e crespas em condições de diferentes ambientes de cultivo no sistema convencional, na estação da primavera no semiárido mineiro. O experimento foi realizado na Unidade de Olericultura do Instituto Federal de Educação, Ciência e Tecnologia do Norte de Minas – campus Januária, no período de outubro a dezembro de 2022, em sistema convencional de cultivo, constituído de 08 tratamentos, conduzidos no esquema de parcelas subdivididas, em delineamento de blocos ao acaso, com três repetições. Nas parcelas foram alocados os ambientes de cultivo: pleno sol, sombrite preto/malha 50%; ChromatiNet Difusor®/malha 50% e Aluminet®/malha/50%); subparcelas as cultivares Vanda e BRS Mediterrânea. Após a colheita foram avaliadas as variáveis: número de folhas, massa fresca de folhas, massa seca de folhas, área foliar, comprimento do caule, diâmetro do caule, massa fresca do caule, massa seca do caule, diâmetro da cabeça, massa fresca da cabeça, massa seca da cabeça, área foliar específica e produtividade. A cultivar BRS Mediterrânea submetida ao ambiente Pleno Sol, possibilitou maior desenvolvimento vegetativo e maior produtividade durante o período de estudo.

**Palavras-chave:** *Lactuca sativa* L., temperatura, irradiância

### INTRODUCTION

The lettuce (*Lactuca sativa* L.) belongs to the Asteraceae family, is an annual vegetable, which thrives in moderate climatic conditions, showing better growth and vegetative development when grown in mild temperature conditions (Henz and Suinaga, 2009). The types of lettuce most sold in the Brazilian market are respectively: Curly, American, smooth, and romaine, being the leafy vegetable most consumed in the country, with an estimated production of 671,509 tons per year (IBGE, 2017).

The optimal temperature range for production varies from 7 to 24 °C, although some cultivars can withstand light frosts and others higher temperatures. Optimal temperatures for growth and production are around 18 °C; however, high temperatures above 25 °C and long days facilitate flowering with the formation of fewer leaves per plant (Sediyama *et al.*, 2019).

It is observed that when environmental conditions exceed this limit, the plants tend to flower prematurely, resulting in stem elongation, reduction in the number of leaves, compromising commercial quality due to the bitter taste caused by the increased production of latex (Silva *et al.*, 2000; Yuri *et al.*, 2005). This leads to the early harvesting of plants with small leaves and lower quality (Souza *et al.*, 2008).

In the semi-arid region of Minas Gerais, the cultivation of this vegetable crop goes through an unfavorable period during the spring/summer seasons, when the temperature reaches (above 24°C) and the intensity of solar radiation is high (Queiroz *et al.*, 2014). To mitigate the negative effects in regions where climatic and edaphic conditions hinder the development of the crop, the use of protected environments and hydroponic cultivation has been adopted (Valcárcel *et al.*, 2016).

The adoption of these technologies enables a more efficient use of water, nutrient availability, and reduction of irradiance, which can minimize the temperature in the environment, enhancing net photosynthesis and thus increasing quality and productivity (Domingues *et al.*, 2012).

Research has found positive effects of shading on lettuce cultivation (Neves, 2016; Souza, 2021); however, studies are scarce in the semi-arid region of Minas Gerais, which could guide vegetable growers in decision-making regarding the choice of crisp and loose-leaf lettuce cultivars and types of environments to be cultivated during the spring season.

In view of this regional demand, the work was carried out with the objective of evaluating the effect of different cultivation environments, during the spring season, on the morphological and productivity behavior of the Vanda and BRS Mediterrânea cultivars, with the aim of identifying the cultivar that presents the best commercial and productivity characteristics for the climatic conditions of the semi-arid region of Minas Gerais.

## MATERIAL AND METHODS

The experiment was conducted at the Horticulture Unit of the Federal Institute of Education, Science and Technology of Northern Minas (*Instituto Federal de Educação, Ciência e Tecnologia do Norte de Minas - IFNMG*) - Januária Campus (MG), located in Northern Minas Gerais, at 15° 28' 55" S latitude and 44° 22' 41" W longitude, at an altitude of 474 meters. According to the Koppen-Geiger classification, the climate of Januária is classified as Aw (tropical humid climate with dry winter and rainy summer), with an average precipitation of 850 mm, average relative humidity of 60%, and an annual average temperature of 27 °C (CPTEC/INPE, 2024). The region has a rainy season between October and March. The experiment was carried out from November 1<sup>st</sup>, 2022, to December 21<sup>st</sup>, 2022, in a conventional cultivation system, under different shading environments.

During the experimental period, the climatic data (Table 1) extracted from the automatic station Januária (A559) of INMET - National Institute of Meteorology were recorded.

**Table 1.** Precipitation values (mm), sunshine (h), radiation (W/m<sup>2</sup>), maximum temperature, average temperature, minimum temperature in (°C), maximum relative air humidity, average relative air humidity, and minimum relative air humidity in (%), for the period between the transplanting of the seedlings and the harvest of the lettuce crop obtained by the INMET/ Januária (MG) automatic station.

Day	Precipitation (mm)	Sunstroke (h)	Radiation W/h/m <sup>2</sup>	Maximum Temperature	Average Temperature	Minimum Temperature	Maximum Air Humidity	Average Air Humidity	Minimum Air Humidity
1	6.2	0.6	383.5	22.9	22.4	22.0	98.4	96.5	94.6
2	17.0	2.2	219.5	24.3	23.9	23.4	95.1	92.7	90.2
3	0.6	2.9	343.8	24.5	24.0	23.5	93.6	95.7	97.8
4	1.1	4.1	331.4	24.7	24.0	23.3	96.6	93.0	89.3
5	12.1	5.0	335.4	24.4	24.0	23.6	90.3	87.2	84.0
6	3.4	5.7	439.3	25.4	24.8	24.2	90.7	86.9	83.2
7	2.3	2.2	449.1	22.9	22.3	21.8	98.8	96.3	93.7
8	9.8	5.0	267.0	24.1	23.3	22.5	96.0	92.3	88.6
9	1.2	3.0	396.8	24.9	24.3	23.8	92.3	89.7	87.0
10	23.0	5.2	324.4	25.0	24.5	24.0	88.1	84.9	81.7
11	0.0	4.4	459.8	24.6	24.3	24.0	84.6	82.8	81.0
12	0.7	11.1	458.4	24.7	24.2	23.7	87.9	85.4	82.9
13	0.0	9.7	544.2	25.6	25.0	24.4	81.4	77.6	73.8
14	0.0	8.1	530.3	26.2	25.4	24.7	84.3	79.9	75.5
15	7.1	5.0	494.2	25.9	25.2	24.6	92.2	88.2	84.3
16	0.0	7.0	371.5	25.5	24.8	24.2	90.1	87.0	84.0
17	0.0	4.9	451.4	24.4	23.8	23.2	95.9	93.2	90.5
18	12.8	8.8	308.3	25.3	24.5	23.8	92.0	88.8	85.5
19	23.6	3.1	474.0	25.1	24.4	23.7	93.2	89.5	85.8
20	1.4	3.6	370.9	24.4	23.9	23.4	96.5	94.2	92.0
21	15.1	1.0	349.8	23.6	23.1	22.6	98.9	97.8	96.7
22	16.5	3.7	209.2	25.3	24.7	24.0	92.2	88.5	84.8
23	27.0	1.5	340.7	23.5	23.0	22.4	97.6	94.6	91.6
24	3.9	1.7	295.6	23.5	23.1	22.6	98.2	96.2	94.2
25	52.8	0.9	271.7	23.1	22.8	22.4	99.6	98.3	97.0
26	57.2	1.4	232.1	23.5	23.1	22.7	97.2	95.4	93.6
27	0.4	3.0	304.5	23.7	23.1	22.5	92.6	89.8	86.9
28	21.0	0.2	257.7	24.5	24.0	23.4	92.8	89.9	87.0
Average	11.3	4.1	364.8	24.5	24.0	23.4	93.1	90.4	87.8

Source 1: Automatic station, Januária (A559) INMET, National Institute of Meteorology - 2022.

The data presented refer to the external atmosphere of the protected environments Aluminet I° 50%, Sombrinet° 50%, and ChromatiNet° Leno 50% and are relevant to the environment cultivated in full sun. The climatic elements used for analyzing plant growth were the 28-day averages between seedling transplant and commercial harvest of the plants. The climatological data obtained from INMET through the automatic station (JANUÁRIA A559) provide the radiation in the unit of KJ/m<sup>2</sup>; to convert to the unit W/m<sup>2</sup>, the following formula was used:

$$W/m^2 = (KJ/m^2 * 1.000) / (t/3.600)$$

Where:

W/m<sup>2</sup> = Radiation unit;

KJ/m<sup>2</sup> = Radiation unit obtained by INMET;  
 1.000 KJ to J conversion factor;  
 t = Radiation time in hours/day.  
 3.600 = Hour to seconds conversion factor.

The experimental units were oriented in the East-West direction, using the following equipment: pocket compass NATURAL SINES and GPS GARMIN GPSMASP 64s.

Soil samples and composted barn manure were collected for analysis in the soil and plant tissue laboratory of IFNMG - Januária Campus (MG). The soil collection was carried out at a depth of 0 to 20 to check the chemical and physical characteristics (Table 2).

**Table 2.** Values of the chemical and physical analyses of the soil sample. Januária MG, IFNMG, 2022.

Chemical Characteristics	Values
pH in water (1:2,5) <sup>1</sup>	7.31
P (mg dm <sup>-3</sup> ) <sup>2</sup>	344.97
P-rem (mg L <sup>-1</sup> )	50.35
K (mg dm <sup>-3</sup> ) <sup>3</sup>	139.20
Ca <sup>+2</sup> (cmolc dm <sup>-3</sup> ) <sup>4</sup>	4.17
Mg <sup>+2</sup> (cmolc dm <sup>-3</sup> ) <sup>4</sup>	0.29
Al <sup>+3</sup> (cmolc dm <sup>-3</sup> ) <sup>4</sup>	0.0
H + Al (cmolc dm <sup>-3</sup> ) <sup>5</sup>	0.81
SB (cmolc dm <sup>-3</sup> ) <sup>5</sup>	4.8
CTC (t) (cmolc dm <sup>-3</sup> ) <sup>6</sup>	4.8
CTC (T) (cmolc dm <sup>-3</sup> ) <sup>7</sup>	5.6
V (%) <sup>8</sup>	85.7
m (%) <sup>9</sup>	0.0
MO (dag Kg <sup>-1</sup> ) <sup>2</sup>	1.76
Zn (mg dm <sup>-3</sup> ) <sup>3</sup>	6.60
Fe (mg dm <sup>-3</sup> ) <sup>3</sup>	11.01
Mn (mg dm <sup>-3</sup> ) <sup>3</sup>	26.38
Cu (mg dm <sup>-3</sup> ) <sup>3</sup>	3.19
Physical Characteristics	Values
Clay (%)	14
Silt (%)	04
Sand (%)	82
Textural Classification	Sandy loam

<sup>1</sup>pH in water; <sup>2</sup>Colorimetry; <sup>3</sup>Extractor Mehlich-1x; <sup>4</sup>Extractor KCl 1 mol/L; <sup>5</sup>pH SMP; <sup>6</sup>Extractor BaCl<sub>2</sub>, 500 mg/L of P HOAc 2mol/L; <sup>8</sup>Balance solution of P; SB = sum of bases; t = effective CTC; T = CTC to pH 7; V = base saturation; m = aluminum saturation; <sup>8</sup>P-rem = remaining phosphorus; CE = electrical conductivity; dag/kg = %; mg/dm<sup>3</sup> = ppm; cmolc/dm<sup>3</sup> = meq/100 cm<sup>3</sup>. All methods apply solely to soil analysis for agronomic purposes. MO = organic matter, P = phosphorus; K = potassium; Na = sodium; Ca = calcium; Mg = magnesium; Al = aluminum; H = hydrogen; SB = sum of bases; t = effective CTC; T = CTC; V = base saturation; B = boron; Cu = copper; Fe = iron; Mn = manganese; Zn = zinc; S = sulfur; Prem = Remaining phosphorus; CE = electrical conductivity.  
 Source: LAST - IFNMG/ Water, soil, and plant tissue laboratory, IFNMG - Januária, 2022.

Based on the soil analysis, no need for liming was found, due to the methodology used in the state of Minas Gerais for neutralizing aluminum and increasing calcium and magnesium levels. The recommendation for fertilization of phosphorus and potassium doses for the crop cycle were (40 kg ha<sup>-1</sup>) and (60 kg ha<sup>-1</sup>) respectively, and for nitrogen (150 kg/ ha<sup>-1</sup>). At the time of planting fertilization, cured barn manure (Table 3) and single superphosphate were used (CFSEMG, 1999).

**Table 3.** Chemical and physical composition of cured bovine manure used in planting. Januária, MG, IFNMG, 2022.

Physico-Chemical Results	Values
Humidity (%)	-
pH in CaCl <sub>2</sub>	8.26
Conductivity	0.57
K <sub>2</sub> O (mg.Kg <sup>-1</sup> )	6.68
P <sub>2</sub> O <sub>5</sub> (mg.Kg <sup>-1</sup> )	5.60
Ca (mg.Kg <sup>-1</sup> )	7.42
Mg (mg.Kg <sup>-1</sup> )	9.20
Na (mg.Kg <sup>-1</sup> )	-
Saline index (%)	7.12
Cu (mg.Kg <sup>-1</sup> )	0.20
Fe (mg.Kg <sup>-1</sup> )	2.62
Zn (mg.Kg <sup>-1</sup> )	1.41
Mn (mg.Kg <sup>-1</sup> )	0.49
Na (mg.Kg <sup>-1</sup> )	104.0
M.O (%)	19.97
C.O (%)	11.09
N (%)	1.18
Rel. C/N	9.4

Source: LAST- IFNMG/ Water, soil and plant tissue laboratory, IFNMG - Januária, 2022.

The beds were built using the rotary bed former agricultural implement, and the finishing was done manually using a hoe. The planting fertilization (Table 4) was carried out ten days before transplanting, during which cured bovine manure and single superphosphate planting fertilizer (Table 4) were incorporated. In the complementary fertilizations, the fertilizers potassium chloride and ammonium sulfate (Table 5) were used, carried out at 7, 14, and 21 days after transplanting in accordance with the absorption curve of the nitrogen and potassium elements required by the plant.

**Table 4.** Chemical composition of the fertilizers used in planting fertilization. Januária, MG, IFNMG, 2022.

Fertilizers	Chemical composition
Single superphosphate	18% P <sub>2</sub> O <sub>5</sub> soluble in (CNA + H <sub>2</sub> O); 16% P <sub>2</sub> O <sub>5</sub> soluble in H <sub>2</sub> O; 18 to 20% of Ca and 10 to 12% of S.

Source: Soil Fertilizer Committee of the State of Minas Gerais - Recommendations for the use of liming materials and fertilizers in Minas Gerais: 5<sup>th</sup> approximation, Viçosa MG, 1999.

**Table 5.** Chemical composition of the fertilizers used in supplemental fertilization. Januária, MG, IFNMG, 2022.

Fertilizers	Chemical composition
Potassium Chloride	58% of K <sub>2</sub> O soluble in water and 45 to 48% of Cl.
Ammonium Sulfate	20% of N; Ammoniacal (NH <sub>4</sub> <sup>+</sup> ) and 22 to 24% of S.

Source: Soil Fertilizer Commission of the State of Minas Gerais - Recommendations for the use of lime and fertilizers in Minas Gerais: 5<sup>th</sup> edition, Viçosa, MG, 1999.

During the crop cycle, three applications of the foliar fertilizer commercial brand (Sett<sup>®</sup>) were carried out with the following guarantees: N = 5%, Ca = 10%, B = 1%, with the first application at a dose of 1L/ha, the second application at a dose of 1.5 L/ha, and the third application at a dose of 2L/ha.

The curly lettuce cultivars used in the experimental work were: Vanda and BRS Mediterrânea, which have the following characteristics:

- **Cultivar Vanda:** High resistance to LMV-II; high hardiness; high tolerance to Tip Burn, large plants, long leaves with bright light green color, moderate curliness, vigorous root system, total average cycle of 55 days, can be grown year-round, widely adaptable to planting in tropical climatic conditions, and recommended for field and hydroponic cultivation. The most marketed cultivar in the semi-arid region of northern Minas Gerais (SAKATA, 2024).
- **Cultivar BRS Mediterrânea:** Lettuce of the large-sized curly segment; more upright, vigorous, and productive. It shows variations in the cycle depending on climatic conditions, being around 35 days in hotter periods and 45 days in cooler periods. On average, 6 to 8 days early. It shows great tolerance to tip burn (calcium deficiency), early flowering caused by heat, and lower water requirements due to its earliness, being adapted to cultivation in tropical regions. Regarding phytosanitary aspects, it is tolerant to downy mildew races, lettuce mosaic virus (LMV), *Fusarium oxysporum f.sp. lactucae race 1*, *Thielaviopsis basicola* (root rot) and root-knot nematode. They do not become bitter after passing the harvesting point. It produces plants weighing between 700 to 800 g on average, within the spacings usually used. It can be recommended for cultivation in all producing regions, whether in open fields, in protected cultivation, or in hydroponic systems. (AGROCINCO, 2024).

The sowing was carried out manually on November 1<sup>st</sup>, 2022, in Styrofoam trays with 128 cells, where one seed was placed in the center of each cell at a depth of 5 mm. For the planting substrate, the following were used: Commercial substrate, sieved organic compost, Yoorim thermophosphate, and expanded vermiculite. After sowing, the trays were moistened and covered with a black tarp until the beginning of emergence, when the trays were uncovered and transferred to the protected seedling production environment of the Horticulture Unit at IFNMG Januária Campus (MG). When the seedlings reached three true leaves, 22 days after sowing, they were transplanted to the experimental beds.

Three types of shading screens with the following specifications were used:

- Aluminet I<sup>®</sup> 50%: Recommended for the cultivation of leafy vegetables, lettuce, arugula, bell peppers, flowers, seedlings, and hydroponics. It offers the following benefits: reduces the internal temperature of greenhouses and shade structures in the summer or on hot days; maintains a higher internal temperature in the winter or on cold nights; transmits diffuse light for greater gain in photosynthetic activity; reduces the incidence of direct radiation on plants; controls the microclimate in protected environments; increases productivity and quality; acts as a barrier to heat waves (infrared), both in summer and winter, and reduces thermal fluctuations (day/night) in the protected environment; controls air movement; conserves relative humidity (stability); and enhances the absorption and translocation of nutrients by plants (GINEGAR, 2024).
- Sombrinet<sup>®</sup> 50%: Shading screen made of monofilament that does not fray. It has high protection against ultraviolet radiation. High mechanical resistance to winds and heavy rains, in addition to reducing the passage of insects. Recommended for sides and external and internal shading of greenhouses and nets (GINEGAR, 2024).
- ChromatiNet<sup>®</sup> Leno 50%: Light photoconverting screen (increase of photosynthetically active radiation). It allows the vegetative development of the plant, favors leaf size, sprouting, height, weight, flowering, and maturation, through the transmission of specific light spectra resulting from the conversion promoted by special additives that increase the amount of PAR radiation transmitted to the plants. There is also a reduction in leaf and fruit burn, moderate temperature reduction, addition of diffuse light, reduction of direct radiation incidence, and a decrease in the incidence of some disease vector insects (GINEGAR, 2024).

The experiment was composed of eight (treatments), corresponding to two lettuce cultivars and four study environments. The dimensions of the beds were 1.20 m in width by 2.70 m in length and 0.3 m in height. The protected environments were built with a height of 2.20 m relative to the bed. The experiment was conducted using a split-plot design in a randomized block layout, with three repetitions. The cultivation environments were allocated to the plots: (Pleno Sol, Sombrinet® black/ mesh 50%; ChromatiNet Difusor®/ mesh 50% and Aluminet®/ mesh 50%) and in the subplots the cultivars Vanda and BRS Mediterrânea.

The use of different environments aimed to verify the effects of climatic conditions of sunlight, radiation, temperature, and relative air humidity acting on the environments and affecting the growth and development of plants.

When the plants reached the harvest point (28 days after transplanting), the following evaluations were carried out:

- Number of plant leaves<sup>-1</sup> (NFP): The NFP was obtained by counting all the leaves present on the head with a minimum length of 5 cm.
- Fresh plant leaf dough<sup>-1</sup> (MFFP) and dry mass of plant leaves<sup>-1</sup> (MSFP): The MFFP was obtained by weighing the mass of the head leaves without the stem, after harvesting, expressed in g per plant<sup>-1</sup>. The MSFP, the leaves, after drying in an oven with forced ventilation at 65 °C, until constant mass, expressed in g per plant<sup>-1</sup>.
- Plant leaf area<sup>-1</sup> (AFP): The leaf area of the plant was estimated using the Blackman and Wilson (1951) method, adapted to the experiment. Three leaves at different stages of development were removed. From these leaves, three discs of the leaf blade were taken, with the help of a metal disc.

These were dried in an oven, and the leaf area was determined by the following equation:

$$AFP = ND * AD * MSL / MSD$$

Where:

AFP = Leaf area of the plant in (cm<sup>2</sup>);

ND = Number of sampled disks;

AD = Disk area (cm<sup>2</sup>);

MSL = Dry matter mass of the leaf blade (g);

MSD = Dry matter mass of the discs (g).

- Plant stem length<sup>-1</sup> (CCP): The CCP was the corresponding measure of the portion of stem present in the commercial head, expressed in cm. Using a graduated ruler.
- Plant stem diameter<sup>-1</sup> (DCP): The DCP was carried out using a 150 mm/6" (0.05 mm) KINGTOOLS universal caliper, with the second third of the evaluated stems being quantified.
- Fresh plant stem mass<sup>-1</sup> (MFCP) and dry mass of the plant stem<sup>-1</sup> (MSCP): MFCP was obtained by weighing the mass of the stem present in the head, without the leaves, immediately after harvest; and MSCP, after drying in an oven with forced ventilation at 65 °C, until constant mass; both expressed in g per plant<sup>-1</sup>. Equipment used: Digital scale.
- Plantar head diameter<sup>-1</sup> (DCAP): The DCAP was obtained using a manual metal tape measure, where the commercial heads were placed on the bench and their diameter was measured.
- Fresh plant head dough<sup>-1</sup> (MFCAP): Was obtained by the sum of the MFFP and MFCP values, expressed in g per plant<sup>-1</sup>. Equipment used: Digital scale.

- Dry mass of the plant head<sup>-1</sup> (MSCAP): Was obtained by summing the values of MSFP plus MSCP, after drying in an oven with forced ventilation at 65°C, until constant weight, expressed in g per plant. Equipment used: Digital balance.
- Plant specific leaf area<sup>-1</sup> (AFEP): Specific leaf area (AFEP) relates the surface area to the dry mass of the leaf itself, determined according to the equation.

$$AFEP = AFP/MSFP$$

Where:

AFEP - Plant specific leaf area<sup>-1</sup>, in cm<sup>2</sup> g<sup>-1</sup>;

AFP - Leaf area, in cm<sup>2</sup>;

MSFP - Dry mass of the leaves, in g<sup>-1</sup>.

- Productivity (PROD): PROD was obtained by multiplying the average fresh mass of the head by the population of plants present in an area equivalent to 8,400 m<sup>2</sup> (usable area), expressed in Mg ha<sup>-1</sup>. Totaling 93,300 plants.

The obtained data were subjected to analysis of variance and the means were compared using the F-test at 5% probability. Regardless of the significance of the interaction, the unfolding of the means was performed for all characteristics. The means of the qualitative factors (cultivars and cultivation environments) were compared using the Tukey test, adopting a 5% probability level, through the SISVAR software (Ferreira, 2011).

## RESULTS AND DISCUSSION

The morphological results presented in the tables (tables 6, 7, and 8) express the interaction of the genotypes of the BRS Mediterrânea and Vanda cultivars with the climatic elements of the research site (table 1) during the spring season in the semi-arid region of Minas Gerais.

The daily averages during the study period were: precipitation 11.75 mm; sunshine 4.11 h; radiation 364.8 W/m<sup>2</sup>; air temperatures maximum 24.48 °C, average 23.93 °C, and minimum 23.37 °C; relative air humidity maximum 93.11%, average 90.44%, and minimum 87.76%. It is understood that for protected environments the radiation was lower than 364.8 (W/m<sup>2</sup>) (table 1), due to the meshes that were 50% and the colors aluminum (Aluminet I), black (Sombrinet<sup>®</sup>), and red (Chromatinet Leno), also interfering with the maxima, averages, and minima of air temperatures and humidity. The rainy weather with a low number of daylight hours and radiation reduced the photosynthetic activity of the cultivars researched.

The BRS Mediterrânea cultivar showed more vigorous growth compared to the Vanda cultivar in full sun conditions, presenting significantly higher values for the characteristics NFP (30.8 units), MFFP (296.3 g), MSFP (12.9 g), and AFP (8,456.7 cm<sup>2</sup>), expressing a percentage increase compared to cv. Vanda of 29.0; 33.01; 25.6; and 45.2%, respectively (Table 6). The Vanda cultivar, when analyzed across all growing environments for the variables NFP, MFFP, and MSFP, did not show a significant difference; in contrast, the BRS Mediterrânea cultivar in the full sun environment statistically differed with a higher mean compared to the other studied environments (Table 6).

**Table 6.** Average values of number of plant leaves<sup>-1</sup> (NFP), fresh plant leaf pulp<sup>-1</sup> (MFFP), dry leaf mass of a plant<sup>-1</sup> (MSFP) and plant leaf area<sup>-1</sup> (AFP) of lettuce, based on the Vanda and BRS Mediterrânea cultivars in full sun growing environments, and under Aluminet I® 50%, Sombrinet® 50% and ChromatiNet® Leno 50%. Januária - MG. IFNMG, 2022.

Characteristics	Cultivars	Environments				CV (%) <sup>1</sup>	CV (%) <sup>2</sup>
		Pleno Sol	Aluminet I 50%	Sombrinet 50%	Chromatinet Leno 50%		
NFP (und)	Vanda	21.8 bA	20.3 aA	21.0 aA	18.9 aA	10.21	5.31
	BRS Mediterrânea	30.8 aA	22.1 aB	24.1 aB	21.5 aB		
MFFP (g)	Vanda	198.3 bA	181.5 aA	198.8 aA	166.8 aA	16.27	7.08
	BRS Mediterrânea	296.3 aA	205.3 aB	203.5 aB	190.5 aB		
MSFP (g)	Vanda	9.6 bA	8.9 aA	8.2 aA	7.8 aA	8.15	14.21
	BRS Mediterrânea	12.9 aA	8.9 aB	9.2 aB	8.1 aB		
AFP (cm <sup>2</sup> )	Vanda	4.632,4 bB	4.519,9 bB	5.985,3 bA	4.166,1aB	11.69	6.03
	BRS Mediterrânea	8.456,7 aA	6.019,1 aBC	7.226,2 aAB	4.956,7 aC		

Means followed by different lowercase letters in the column comparing the cultivars with the characteristics evaluated in each environment and different uppercase letters in the row comparing the characteristics of each cultivar across the cultivated environments show significant differences according to the Tukey test, at 5% significance. <sup>1</sup>parcel and <sup>2</sup>subparcel.

The number of leaves in lettuce production is an essential characteristic, closely related to the temperature of the growing environment and the photoperiod (Costa and Leal, 2009). The cultivation sites and the genetic characteristics of each cultivar are largely responsible for the physiological and morphological changes of the plants (Nascimento *et al.*, 2021).

The fresh leaf mass is a fundamental attribute for accessible trade, as it reflects the appearance and weight of the plant. BRS Mediterrânea stands out in this regard, presenting a higher fresh mass due to its high water retention capacity in thicker leaves, especially under high temperatures. The Vanda cultivar, although it has a lower fresh mass, compensates with a dense texture and attractive coloration, which are highly valued in the consumer market (Assunção *et al.*, 2023).

The changes in metabolism induced by light intensity are the result of various physiological responses of the plant, among which the modifications in growth, transpiration, stomatal behavior, photosynthetic activity, and finally, dry matter accumulation stand out (Guerra *et al.*, 2017).

For the fresh and dry matter of the leaves, it was observed that the Vanda cultivar did not differ statistically when observed in the growing environments. In contrast, the BRS Mediterrânea lettuce plants submitted to full sun had MFFP (296.3 g) and MSFP (12.9 g) that differed statistically from the Vanda lettuce and the shaded environments (Table 6).

The dry mass of the leaves reflects the efficiency in converting light into biomass and in nutrient accumulation by the plant. Studies indicate that the Vanda cultivar has greater efficiency in this regard, especially in moderate climates, while the BRS Mediterrânea cultivar maintains good dry mass production even under conditions of higher thermal stress (Sousa *et al.*, 2018). During the experimental period, the BRS Mediterrânea cultivar exposed to full sun was more efficient than the Vanda cultivar and the shaded environments in nutrient accumulation and the increase of fresh and dry matter.

Leaf area per plant (AFP) is a growth variable that has a direct relationship with photosynthetic activity, which is decisive in plant productivity, since the photosynthesis carried out depends on the interception of light energy by the canopy and its conversion into chemical energy (Favarin *et al.*, 2002).

When analyzing the AFP characteristic (Table 6), the Vanda cultivar was significantly superior in the Sombrinet 50% environment (5,985.3 cm<sup>2</sup>); on the other hand, it was observed that the BRS Mediterrânea cultivar in the Full Sun and Sombrinet 50% environments obtained significantly higher averages for AFP, 8,456.7 cm<sup>2</sup> and 7,226.2 cm<sup>2</sup>, respectively. In the Chromatinet Leno 50% environment, the BRS Mediterrânea and Vanda cultivars did not show significant differences in their leaf areas, 4,956.7 cm<sup>2</sup> and 4,166.1 cm<sup>2</sup>, respectively.

The BRS Mediterrânea cultivar has a larger leaf area, which favors growth and productivity in protected systems or with lower solar radiation incidence. On the other hand, Vanda, despite having a smaller leaf area, stands out for the density and quality of its leaves, which increases its market accessibility, especially for fresh consumption (Filgueira, 2013).

Unlike Brzezinski's work (2017), protected environments affected the leaf area of lettuce cultivars. It is noteworthy that for the Vanda and BRS Mediterrânea cultivars, there was no significant difference when grown in the environment with Chromatinet Leno 50% mesh. The likely reduction in leaf area for the Vanda cultivar compared to BRS Mediterrânea is due to the average radiation and sunlight during the experimental period and the genetic characteristics of the study materials.

The characteristics plant stem length (CCP), plant stem diameter (DCP), fresh stem mass (MFCP), and dry stem mass (MSCP) of the Vanda cultivar showed no significant difference in all research environments. In contrast, the BRS Mediterrânea cultivar under full sun treatment was statistically superior to the Aluminet I<sup>o</sup> 50%, Sombrinet<sup>o</sup> 50%, and Chromatinet Leno 50% environments for (CCP), (DCP), (MFCP), and (MSCP), according to (Table 7).

**Table 7.** Average stem length values of the plant<sup>-1</sup> (CCP), plant stem diameter<sup>-1</sup> (DCP), fresh plant stem mass<sup>-1</sup> (MFCP) and dry stem plant mass<sup>-1</sup> (MSCP) of the lettuce cultivars Vanda and BRS Mediterrânea, depending on the cultivation environments pleno sol, Aluminet I<sup>o</sup> 50%, Sombrinet<sup>o</sup> 50% and ChromatiNet<sup>o</sup> Leno 50%. Januária - MG, IFNMG, 2022.

Characteristics	Cultivars	Environments					CV (%) <sup>1</sup>	CV (%) <sup>2</sup>
		Pleno sol	Aluminet I 50%	Sombrinet 50%	Cromatinet Leno 50%			
CCP (cm)	Vanda	5.12 bA	5.01 aA	4.99 aA	4.81 aA	12.14	6.29	
	BRS Mediterrânea	7.09 aA	5.84 aB	5.66 aB	5.18 aB			
DCP (cm)	Vanda	2.29 bA	2.29 bA	2.28 bA	2.13 bA			
	BRS Mediterrânea	2.99 aA	2.56 aB	2.57 aB	2.42 aB	4.63	3.01	
MFCP (g)	Vanda	21.02 bA	20.25 bA	19.42 bA	17.32 aA	17.22	9.28	
	BRS Mediterrânea	39.88 aA	29.45 aB	27.87 aB	22.30 aB			
MSCP (g)	Vanda	0.91 bA	0.81 bA	0.80 bA	0.72 aA	15.55	10.38	
	BRS Mediterrânea	1.56 aA	1.14 aB	1.10 aB	0.86 aB			

Means followed by different lowercase letters in the column comparing the cultivars with the characteristics evaluated in each environment and different uppercase letters in the row comparing the characteristics of each cultivar between the cultivated environments show significant differences according to the Tukey test, at 5% significance. <sup>1</sup>parcel and <sup>2</sup>subparcel.

When compared in each environment, the BRS Mediterrânea cultivar under full sun treatment was significantly superior to the Vanda cultivar for the variable plant stem length CCP (7.09 cm), stem diameter DCP (2.99 cm), fresh stem mass MFCP (39.88 g), and dry plant stem mass MSFP (1.56 g) with increases of 27.8; 23.4; 47.29 and 41.67%, respectively (Table 7).

The reduced stem length is a positive characteristic in lettuce cultivation, as it reflects on the quality of the plant. However, underdeveloped and small plants that have been subjected to

some severe stress condition, nutritional deficiency, limited light, solar radiation, or water stress may exhibit these characteristics.

The stem length is a characteristic that affects the commercial quality of lettuce. In a physiological response caused by low light or when lettuce is grown in dense spacing, the plants increase stem length to seek more light (Assunção *et al.*, 2023). In this study, the BRS Mediterrânea cultivar in full sun presented a greater stem length (7.09 cm), as the plants were larger, with higher accumulation of fresh matter, dry matter, more leaves, and higher productivity. The ideal amount of sunlight for lettuce depends on the cultivation system, environmental conditions, and the genotypes of the cultivars, but in general, lettuce requires 10 to 12 hours of light per day for good development (Taiz, 2017). During the experimental period, the overall average sunlight under open field conditions was 4.11 hours; in contrast, in the shaded treatments, this sunlight was even lower, causing a light deficit for the cultivars and environments under study.

The ideal stem size for the commercialization of iceberg lettuce ranges between 6.0 and 9.0 cm in length, but there is no defined standard for stem size for loose-leaf curly lettuce (Sousa *et al.*, 2018). In shaded environments, stem sizes were below 5.84 cm, meaning that we can say the plants were small.

For the stem diameter characteristic DCP (Table 7), the BRS Mediterrânea cultivar differed statistically from the Vanda cultivar in the environments full sun, Aluminet 50%, Chromatinet Leno 50%, and Sombrinet 50%. The Vanda lettuce genotype did not differ statistically in any study environment for the DCP characteristic. When analyzing BRS Mediterrânea in the cultivation environments, there was a statistical difference in the Full Sun environment compared to the shaded treatments.

The smaller stem diameter of the Vanda cultivar indicates its inferiority when compared to the BRS Mediterranean cultivar during the spring.

The MFCP and MSCP characteristics of the BRS Mediterrânea cultivar were significantly superior in the full sun, Aluminet I° 50%, and Sombrinet° 50% cultivation environments, but there was no difference between the BRS Mediterrânea and Vanda cultivars in the Chromatinet Leno 50% environment. Analyzing the BRS Mediterrânea cultivar separately in the environments, there was a statistical difference for the full sun (*pleno sol*) environment, whereas the Vanda cultivar did not differ statistically from the treatments (table 7).

Solar radiation is one of the most important factors for the development of lettuce, as it regulates photosynthesis and, consequently, stem growth. The ideal radiation range for the BRS Mediterrânea and Vanda cultivars is between 200 and 400 W/m<sup>2</sup> (Silva *et al.*, 2021).

Exposure in this interval promotes the increase in the length and diameter of the stem, while very intense or insufficient radiation can reduce morphological quality.

The optimal temperatures for lettuce depend on the stage of crop development: During germination 15 to 20 °C and, during development 14 to 18 °C, with day temperatures of 5 to 20 °C and night temperatures of 15 to 20 °C, with a maximum not exceeding 30 °C and a minimum of 6 °C (Lima Junior, 2008). Extreme temperatures can reduce the fresh mass of the stem and promote an increase in dry biomass due to thermal stress (Ferreira *et al.*, 2019).

For the DCAP characteristic, the Vanda cultivar did not show a significant difference across growing environments; however, the BRS Mediterrânea cultivar was significantly superior in full sun (*pleno sol*), Sombrinet 50%, and Cromatinet Leno 50% environments (Table 8). Analyzing the cultivars within the environments, there was a statistical difference for the Sombrinet 50% and full sun (*pleno sol*) environments, in which the BRS Mediterrânea cultivar achieved higher average values of 33.88 and 33.75 cm, respectively. The commercial size of the plants is a consequence of the diameter.

**Table 8.** Valores médios de diâmetro de cabeça planta<sup>-1</sup> (DCAP), massa fresca de cabeça planta<sup>-1</sup> (MFCA), massa seca de cabeça planta<sup>-1</sup> (MSCA), área foliar específica planta<sup>-1</sup> (AFEP) e produtividade (PROD) das cultivares de alface Vanda e BRS Mediterrânea em função dos ambientes de cultivo pleno sol, Aluminet 50%, Sombrinet 50% e Chromatinet 50%. Januária – MG, IFNMG, 2022.

Characteristics	Cultivars	Environments				CV (%) <sup>1</sup>	CV (%) <sup>2</sup>
		Pleno Sol	Aluminet I 50%	Sombrinet 50%	Cromatinet Leno 50%		
DCAP (cm)	Vanda	31.31 aA	30.94 aA	30.13 bA	31.06 aA	5.51	2.43
	BRS Mediterrânea	33.75 aA	30.13 aB	33.88 aA	31.50 aAB		
MFCAP (g)	Vanda	222.25 bA	203.50 aA	221.25 aA	186.25 aA	16.34	7.06
	BRS Mediterrânea	338.00 aA	236.50 aB	233.00 aB	214.25 aB		
MSCAP (g)	Vanda	10.53 bA	9.69 aA	8.97 aA	8.52 aA	8.43	13.79
	BRS Mediterrânea	14.44 aA	10.00 aB	10.33 aB	8.93 aB		
AFEP (cm <sup>2</sup> g <sup>-1</sup> )	Vanda	483.38 aA	515.99 aA	727.11 aA	531.48 aA	20.68	14.40
	BRS Mediterrânea	663.64 aA	672.24 aA	785.72 aA	611.68 aA		
PROD (Mg ha <sup>-1</sup> ) <sup>1</sup>	Vanda	18.52 bA	16.95 aA	18.43 aA	15.52 aA	16.34	7.06
	BRS Mediterrânea	28.16 aA	19.70 aB	19.41 aB	17.85 aB		

Means followed by different lowercase letters in the column comparing the cultivars with the characteristics evaluated in each environment and different uppercase letters in the row comparing the characteristics of each cultivar across the cultivated environments show significant differences according to the Tukey test, at 5% significance. <sup>1</sup>parcel and <sup>2</sup>subparcel.

For the variables fresh head weight and dry head weight, there was no statistical difference when observing the Vanda cultivar in the experimental environments. When analyzing the BRS Mediterrânea cultivar, it was observed that the full sun (*pleno sol*) environment differed statistically from the other environments. When analyzing the two cultivars in the environments, the BRS Mediterrânea cultivar was significantly superior to the Vanda cultivar in the full sun (*pleno sol*) environment with an average fresh weight of 338 g per plant<sup>-1</sup> and dry mass with a value of 14.44 g per plant<sup>-1</sup>, showing a percentage increase of 34.24 and 27.08%, respectively (Table 8).

AFEP expresses in (cm<sup>2</sup> g<sup>-1</sup>) the cultivars Vanda and BRS Mediterrânea did not show significant differences when analyzed across all cultivation environments and also between cultivars within the environments (Table 8). The specific leaf area, which is the result of the leaf area divided by its respective weight, indicated that the cultivation environments did not influence the performance of the cultivars for this characteristic.

Lettuce production is largely influenced by environmental conditions, with solar radiation, temperature, and humidity being the most critical factors for plant development. The BRS Mediterrânea and Vanda cultivars have specific characteristics that require management tailored to their needs to maximize yield and production quality (Costa, 2020).

For the study of productivity (Table 8), it was found that the Vanda cultivar did not show a significant difference between the cultivation environments, and the BRS Mediterrânea cultivar was significantly superior when grown in the full sun environment, presenting the average value of 28,16 Mg ha<sup>-1</sup> with an increase of 34.23% compared to the Vanda cultivar.

In this research, due to the climatic elements, it was observed that the cultivation of loose curly lettuce BRS Mediterrânea in the Full Sun growing environment was significantly superior to the Vanda cultivar for the characteristics: NFP, MFFP, MSFP, AFP, CCP, DCP MFCP, MSCP, MFCAP, MSCAP and PROD, contrary to studies that used shading screens.

The BRS Mediterrânea cultivar under full sun cultivation conditions performed better compared to Vanda under the same condition and in cultivations in environments under Aluminet<sup>®</sup> 50%, Sombrinet<sup>®</sup> 50%, and ChromatiNet Leno<sup>®</sup> 50% shading screens.

The weather conditions during the research period, temperature, precipitation, radiation, cloudiness, and sunshine 4.1 h of light/day, associated with the genotype of the cultivars under study and the use of screens, reduced the incidence of solar radiation on the plants, resulting in lower net photosynthesis and reduced growth for the cultivar Vanda.

The lack of a positive response in shaded environments during the study period can be attributed to the excessive cloudiness that occurred during the conduct of the experiment, causing a restriction of light for the loose curly lettuce plants.

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