Performance of Lettuce Cultivars under Different Production Environments

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Authors’ contributions

This work was carried out in collaboration among all authors. Author PHMSC prepared the study, performed the statistical analysis, wrote the protocol and wrote the first version of the manuscript. Authors GMO and RCR managed the analysis of the study. Authors JEP, TSC and ALLVP managed the literature searches. All authors read and approved the final manuscript.

ABSTRACT

Lettuce is a crop with high commercial and social importance, reaching from the macro to the Brazilian micro producer. The objective of this study was to evaluate the agronomic performance of Elba and Rouge lettuce cultivars in terms of development and production, under different environments, for the edaphoclimatic conditions of Juazeiro, Bahia. The experimental design adopted was completely randomized, in a split plot scheme, with two production environments (shaded environment and full sun) in the plots, and two lettuce cultivars (Crespa, CV. 1 Elba and Roxa, CV. 2 Rouge) in the subplots. The variables analyzed were: plant height, plant diameter, average fresh weight, average dry weight, total productivity and water use efficiency. The cultivation system in a protected environment showed better development and high productivity for the two lettuce cultivars, when compared to the system in full sun. Cultivar 1 showed superior performance to cultivar 2, in all variables analyzed, in both cultivation systems.

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1. INTRODUCTION

Lettuce is a crop with high commercial and social importance, reaching from the macro to the Brazilian micro producer [1]. It is among the main vegetables with the highest production volume, second only to watermelon and tomatoes, with an average annual turnover of R $ 8 billion in retail alone, with production of more than 1.5 million tons per year [2].

Thus, the largest volume of lettuce production, for many years, was attributed to the curly and smooth cultivars, which led to the advancement of the genetic improvement of such plants. With that, plants emerged for summer cultivation or adapted for tropical regions, with high temperatures and rainfall [3]. The genetic advancement of these cultures has made them more resistant to processing, in addition to having higher productivity [4].

The cultivation of lettuce, among other vegetables, in many places is impaired due to weather conditions, which can decrease the supply of the product [5]. In order to maintain the regularity of product supply throughout the year, cultivation in a protected environment can ensure product supply when climatic variations do not favor conventional cultivation [6].

According to [7] and [8], the alternative use of the protected environment tends to reduce the photic excess along with the temperature, when compared to the open field production system, which it can avoid physiological damage such as photorespiration, photoinhibition, accelerated evapotranspiration, in addition to conditions with a higher incidence of pests and diseases, reflected in the drop in production and quality of tomato fruits.

[4] reports that the cultivation of lettuce in a protected environment, presents better conditions for the growth, development and yield of the culture when compared to the system of cultivation in the open field. However, in order to be successful with the adopted cultivation system, one of the factors to be considered is the choice of the appropriate cultivar, since the manifestation of the productive potential of lettuce depends on the genotype x environment interaction [3].

Given the above, the aim of this study was to evaluate the agronomic performance of Elba and Rouge lettuce cultivars in terms of development and production, under different environments, for the edaphoclimatic conditions of Juazeiro, Bahia.

2. MATERIALS AND METHODS

The study was carried out from October to November 2018, in the experimental field of the State University of Bahia, municipality of Juazeiro (Lat. 9° 24’ 50” S; Long. 40° 30’ 10” W; Alt. 368 m), in two environments: one in the open field and the other covered with gray canvas, with a shading percentage of 35%, dimensions 12 mx 18 m, ceiling height 4.0 m, “sombrero” type structure.

The region where the study was conducted is characterized by a high evaporation rate, due, among other factors, to high air temperature values, with an average annual value around 27ºC. In Juazeiro and neighboring cities, the mildest temperatures occur in the month of July and oscillate around 22° C; the annual average of precipitation is around 600 mm, with great spatial and temporal variability, dry period from June to August, and rainy, from November to April.

The soil of the experimental area classified as Neossolo Flúvico, Was collected at a depth of 0 - 20 cm and later analyzed in the water, soil and limestone laboratory - LASAC of the University of the State of Bahia (Table 1).

<table>
<thead>
<tr>
<th>pH</th>
<th>C.E</th>
<th>Ca(^{2+})</th>
<th>Mg(^{2+})</th>
<th>K(^{+})</th>
<th>Na(^{+})</th>
<th>SB</th>
<th>Al(^{3+})</th>
<th>H+Al(^{3+})</th>
<th>T</th>
<th>V</th>
<th>PST</th>
<th>P</th>
<th>Org. Mat</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.7</td>
<td>0.02</td>
<td>2.62</td>
<td>1.81</td>
<td>0.16</td>
<td>0.04</td>
<td>4.63</td>
<td>0</td>
<td>0.15</td>
<td>4.78</td>
<td>96.9</td>
<td>0.83</td>
<td>58</td>
<td>5.82</td>
</tr>
</tbody>
</table>

C.E - electrical conductivity; T - cation exchange capacity; V - percentage of base saturation; PST - percentage of exchangeable sodium; Org. Mat - Organic matter
The soil preparation consisted of ploughing, harrowing, as well as preparing 0.50 m wide and 0.10 m high beds. Drip irrigation was performed, using two drip hoses per site, with 0.50 m x 0.25 m spacing and 2 L h\(^{-1}\) flow, under kgf cm\(^{-2}\) pressure.

The supply of nutrients occurred through fertigation, using the Venturi system, according to the phonological phase of the culture, as proposed by [9].

To obtain the lettuce seedlings, sowing was carried out in polystyrene trays with substrate for growth, remaining until 10 days after sowing (DAS), and, later, they were transplanted to the experimental area, where the spacing of was adopted. 25 mx 0.25 m.

A completely randomized design was used, in a split plot scheme, with two production environments (shaded environment and full sun) in the plots, and two lettuce cultivars (Crespa, CV. Elba - henceforth named CV. 1 and Roxa, CV. Rouge - henceforth denominated CV. 2) in the subplots, repeating five times. The cultivars studied are Brazilian.

For the management of irrigation, two class A tanks were used, one for each type of environment. The determination of the daily replacement blade was determined using the following equations:

\[ ETo = ECA \times kp \]  
(eq 1)

\[ ETC = ETo \times Kc \]  
(eq 2)

On what:
ETo - Reference evapotranspiration estimated by the Class A tank method (mm day\(^{-1}\));
ECA - Evaporation of the Class A tank (mm d\(^{-1}\));
Kp - Class A tank coefficient (0.75, dimensionless).
ETC - Crop evapotranspiration (mm day\(^{-1}\))
Kc - Culture coefficient, according to [10]

In each environment, microclimates were monitored by means of installed meteorological sensors and coupled to automatic data collection systems, programmed to take readings every five seconds and hourly averages.

The meteorological elements monitored on a daily scale were: precipitation, temperature (maximum and minimum), relative humidity and global solar radiation.

The variables analyzed were: total productivity (P.T); water use efficiency (W.U.E); plant height (P.H); plant diameter (P.D); average fresh weight (A.F.W.); dry average mass (D.A.M.). For the evaluations, the total harvest of the area was carried out at 50 days after transplanting (DAT).

To the results obtained, analyzes of variance and average comparison test were applied, adopting Tukey at 5% probability, using the statistical program ASSISTAT 7.6.

3. RESULTS AND DISCUSSION

Throughout the experimental period, the global solar radiation, in the shaded environment, varied from 5.4 to 20.1 MJ m\(^{-2}\) day\(^{-1}\), with an average value of 12.7 MJ m\(^{-2}\) day\(^{-1}\), while in the field open was 6.4 to 23.4 MJ m\(^{-2}\) day\(^{-1}\), with an average value of 14.9 MJ m\(^{-2}\) day\(^{-1}\) (Fig. 1). That is, the shading screen reduced approximately 15% of the radiation verified in the open field. According to [8] this effect is due, of course, to the fact that the shading screen acts as a barrier, promoting reflection and absorption of part of the solar radiation that reaches the roof.

According to [11] the average intensity of solar radiation for the plant to have its full growth, is 8.4 MJ m\(^{-2}\) day\(^{-1}\). Although the shade screen promoted a 15% reduction in solar radiation monitored at full soil, the level of light radiation during the growing period was approximately 1.5 times the minimum necessary for the full growth of lettuce plants. In full sun, the global radiation averaged 1.7 times the threshold established by the FAO.

During the conduct of the experiment, precipitations occurred, which added up to 26.7 mm and 40.2 mm in the shaded environment and in full sun, respectively. (Fig. 1).

The maximum and minimum temperatures inside the protected environment were 0.6% higher than the temperature in full sun. The relative humidity of the air was 4.2% lower in the shaded environment, than in full sun (Fig. 2). Fact justified by [12], who reports that the physical barrier interposed between the canopy of the culture and the atmosphere, by the coverage, causes alteration of the microclimate of the protected environments. As an example, [13], states that the rise in air temperature, in protected environments covered with thermal reflective screens, conditions an accumulation of thermal load in the environment, through reflection of part of the incident solar radiation.
[8] found that, on the daily scale, the temperature of the air inside the shaded environment by an external thermo effective screen, was very close to that found in the external environment, in agreement with [13], however, [14] found temperatures in protected environments higher than those recorded in the external environment. With the daily evaporation data, quantified with the aid of the Class A Tank, the water demand in the studied environments was determined (Table 2). In the production system in a shaded environment, water demand was 15% lower than in full sun. According to [15], cultivation in a protected environment reduces water demand in...
relation to the system in full sun, as it decreases wind speed and the incidence of solar radiation, which is the basic source of water evaporation.

Regarding the variables analyzed after the harvest, it was found in the two cultivars studied, a higher performance when cultivated in the shaded environment. Fact attributed to the physiological discomfort caused by the intensity of solar radiation in the cultivation system under full sun (Fig. 1). [4] and [16] report that the factors: temperature and solar radiation affect the performance of lettuce plants in full sun, as cultivars are generally sensitive to extreme temperatures.

Regarding total productivity, there was a significant interaction, in which, the relationship between the genotype (CV 1) x environment (Shaded) resulted in greater productive potential, revolving around 29.76 t ha\(^{-1}\) (Table 3).

With the exception of the treatment that relates CV 2 - shaded environment, the others showed total productivity within the range of the national agricultural reality, which and above 19.6 t ha\(^{-1}\) for protected environments and 11 t ha\(^{-1}\) for full production sun, as described by [17].

Similar conditions found by [18], who observed increased productivity of lettuce with the use of shading, noting that the crop is highly influenced by environmental conditions.

Table 3 shows the water use efficiency values, showing that the use of the shaded environment in the cultivation of lettuce results in greater production with a reduction in water consumption. As for the lettuce cultivars analyzed, CV 1 (209 kg ha\(^{-1}\) mm\(^{-1}\)) showed greater efficiency in the use of water, being this variable represented by the amount of fresh mass produced, per volume of water applied.

With the exception of the treatment that relates the CV 1 - shaded environment, the other treatments obtained results similar to those observed by [19] and [20].

The high value of efficiency in the use of water presented in the CV treatment 1 - shaded environment, can be attributed to the best climatic condition for the development of the cultivar.

Plants produced in a shaded environment had a higher height, at a significance level of \(p < 0.01\), than those in full sun (Table 4). This difference between the cultivation systems may be associated with the favorable microclimate, provided by the shaded environment. Similar results to those found by [18], who, when evaluating the effect of shade screen on the production of lettuce (Cultivar Great Lakes), observed the variation of the height of the plants between 260 mm and 240 mm for environment shaded and in full sun, respectively. [6], when evaluating the agronomic performance of curly lettuce plants in a protected environment and subjected to irrigation with different water qualities, obtained plant heights of 290 mm in treatments irrigated with water supply.

According to [21] plants kept in shade tend to be taller and have a larger leaf area compared to those that grow in full sunlight, because when plants grow in full sunlight, intense light favors development long palisade cells, often arranged in two or three rows, while shading favors the production of a greater amount of lacunous parenchyma.

For the variables D.P, A.F.W and D.A.M, the CV 1 performed better. Being the D.A.M. the only variable that did not have a significant interaction between the factors; however, there was a significant difference in the protected environment factor.

Differing from the data obtained by [22] and [23], who, when evaluating different lettuce cultivars in regions with high solar intensity, observed greater performance of the fresh and dry mass of plants in the cultivation a full sun.

As well as the variables productivity and efficiency in the use of water, the plant diameter and the fresh average mass showed a higher performance in the interaction CV 1 - shaded environment (Table 5). Analyzing the fresh mass of cultivars produced in a shaded environment, CV 1 obtained an increase in mass of 50% and CV 2 of 19% over those produced in full sun. Fact attributed to the cultivation conditions in which the plants were submitted. According to [24], when a crop is being conducted within an optimal variation of light, with other favorable factors, photosynthesis and the amount of carbohydrates used for plant growth and development are high.
Table 2. Water demand quantifies with the aid of the class A tank in the shaded environment and at full soil

<table>
<thead>
<tr>
<th>Environments</th>
<th>mm⁻¹ plant⁻¹ cycle⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaded</td>
<td>142</td>
</tr>
<tr>
<td>Full Sun</td>
<td>168</td>
</tr>
</tbody>
</table>

Table 3. Breakdown of the interaction between the types of environment vs. factors. Cultivars for the variables total productivity (P.T) and water use efficiency (W.U.E.)

<table>
<thead>
<tr>
<th>Production environments</th>
<th>P.T t ha⁻¹</th>
<th>W.U.E kg ha⁻¹ mm⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CV. 1</td>
<td>CV. 2</td>
</tr>
<tr>
<td>Full Sun</td>
<td>15,03 bA</td>
<td>11,71 bA</td>
</tr>
<tr>
<td>Shaded</td>
<td>29.76 aA</td>
<td>14,33 aB</td>
</tr>
<tr>
<td>CV %</td>
<td>16.02</td>
<td>15.57</td>
</tr>
</tbody>
</table>

Averages followed by the same lowercase letter in the column and uppercase letters in the row do not differ statistically, using the Tukey test at the 5% level of significance.

Table 4. Summary of analysis of variance and test of means of the studied variables

<table>
<thead>
<tr>
<th>Variation Source</th>
<th>A.P</th>
<th>D.P</th>
<th>A.F.W.</th>
<th>D.A.M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environments</td>
<td>48.92 **</td>
<td>31.73 **</td>
<td>32.92 **</td>
<td>25.34 **</td>
</tr>
<tr>
<td>Cultivars</td>
<td>1.25 ns</td>
<td>119.95 **</td>
<td>38.45 **</td>
<td>19.95 **</td>
</tr>
<tr>
<td>Int. Environment X Cultivars</td>
<td>2.06 ns</td>
<td>9.49 **</td>
<td>16.02 **</td>
<td>2.65 ns</td>
</tr>
<tr>
<td>CV (%)</td>
<td>9.31</td>
<td>12.85</td>
<td>9.87</td>
<td>14.24</td>
</tr>
</tbody>
</table>

Table 5. Breakdown of the interaction between the types of environment vs. factors. cultivars for the variables plant diameter (D.P) and average fresh weight (A.F.W)

<table>
<thead>
<tr>
<th>Production environments</th>
<th>D.P</th>
<th>A.F.W.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>grams</td>
</tr>
<tr>
<td>Full Sun</td>
<td>CV. 1</td>
<td>CV. 2</td>
</tr>
<tr>
<td></td>
<td>11.83 bA</td>
<td>9.19 aB</td>
</tr>
<tr>
<td>Shaded</td>
<td>14.77 aA</td>
<td>10.05 aB</td>
</tr>
<tr>
<td>CV %</td>
<td>12.85</td>
<td>9.87</td>
</tr>
</tbody>
</table>

Averages followed by the same lowercase letter in the column and uppercase letters in the row do not differ statistically, using the Tukey test at the 5% level of significance.

The data for the plant diameter variable were lower than those found by [4], who, when studying lettuce cultivars, observed an average diameter of 31 cm; however, the results found for the fresh medium mass variable are similar to those found by the authors, for the cultivars Angelina (175 g) and Tainá (188 g). The data of fresh average mass found in treatment CV 1 - Shaded Environment, were higher than those found by [25].

4. CONCLUSION

The cultivation system in a protected environment showed better development and high productivity for the two lettuce cultivars, when compared to the system in full sun.
Cultivar 1 showed superior performance to cultivar 2, in all variables analyzed, in both cultivation systems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES


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