horticultura brasileira

Research

GOMES, RF; ARRUDA, RS; ROSÁRIO, ICB; ANDRADE, FLN; MELLO, MN; SANTOS, LS. Amazon chicory: growing at full sunlight or under shade? *Horticultura Brasileira*, v.41, 2023, elocation e2554. DOI: http://dx.doi.org/10.1590/s0102-0536-2023-e2554

Amazon chicory: growing at full sunlight or under shade?

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ABSTRACT

Climatic factors can decisively influence the growth and productivity of agricultural crops. For unconventional vegetables, such as the Amazon chicory, the influence of sunlight on growing cycle is unknown. The aim of this study was to evaluate the influence of shading levels on the productive performance of Amazon chicory. The authors used a randomized block design, with four treatments and five replicates. The treatments were black polypropylene screens, 30, 50 and 70% shading, and cultivation at full sunlight. Vegetative development and production traits were evaluated. Correlation and principal components analysis (PCA) were performed with the aid of the computer program R. No significant difference between the shading levels for the evaluated traits was noticed. Nevertheless, the cultivation at full sunlight allowed an increase in production, compared to the 70% shading screen. A strong positive correlation between productivity, leaf fresh mass and amount of water in the shoot area was verified, with a coefficient equal to 1. Only the leaf area characteristic was poorly correlated with other traits (angle >90º). Therefore, we suggest growing the Amazon chicory both at full sunlight and under 70% shading.

Keywords: *Eryngium foetidum*, shading screen, unconventional vegetables.

RESUMO

Chicória da Amazônia: cultivo a pleno sol ou sombreado?

Fatores climáticos podem influenciar de modo decisivo no crescimento e produtividade de culturas agrícolas. Para hortaliças não convencionais, como a chicória da Amazônia, é desconhecido a influência da luz solar em seu ciclo de cultivo. O objetivo deste trabalho foi avaliar a influência de níveis de sombreamento no desempenho produtivo de chicória da Amazônia. Para isso, adotou-se o delineamento em blocos ao acaso, com quatro tratamentos e cinco repetições. Os tratamentos foram telas de polipropileno preta, com 30, 50 e 70% de sombreamento e cultivo a pleno sol. Avaliou-se características de desenvolvimento vegetativo e de produção. Realizou-se a análise de correlação e de componentes principais (PCA), no programa computacional R. Não houve diferença significativa entre os níveis de sombreamento para as características avaliadas. Apesar disso, o cultivo a pleno sol possibilitou incremento na produção, em comparação à tela de 70% de sombreamento. Houve forte correlação positiva entre a produtividade, massa fresca das folhas e quantidade de água da parte aérea, com coeficiente igual a 1. Apenas as características de área foliar foram pouco correlacionadas com as demais (ângulo >90º). Logo, pode ser indicado que a chicória da Amazônia seja cultivada tanto a pleno sol como em 70% de sombreamento.

Palavras-chave: *Eryngium foetidum*, tela de sombreamento, hortaliça não convencional.

Received on August 25, 2022; accepted on January 20, 2023

In horticulture, certain conditions can considerably affect plant development and production parameters, especially those related to climate (Filgueira, 2008). Temperature and luminosity are factors which most influence vegetables, mainly the short-cycled ones, as they depend on specific climatic windows (Hirata & Hirata, 2015).

Amazon chicory (*Eryngium foetidum*, Apiaceae) is a perennial unconventional leafy vegetable, commonly grown annually, in the tropical countries (Paul *et al.*, 2011). It shows small or medium size, with glabrous and simple leaves, characterized as oblong-lanceolate or lanceolate, with serrated margins; the upper leaves are sessile, whereas the lower leaves show a short petiole, with a light or dark green color (Singh *et al.*, 2014; Callejas *et al.*, 2016).

In Brazil, the Northern Region stands out when it comes to growing this vegetable for food or medicinal purposes. Due to its outstanding aroma and the presence of essential oils, this vegetable has been studied by the cosmetics and perfume industries, as well as by the pharmaceutical industry for drug formulation (Singh *et al.*, 2014; Nataraj *et al.*, 2020).

Amazon chicory has generally been grown in Brazil by small producers, at full sunlight. However, according to Singh *et al.* (2014) this crop shows a higher vegetative development when growing in shaded areas, because when it is grown under direct sunlight it tends to shows smaller, less tender leaves, with unsatisfactory nutritional quality and reduced aroma.

Although being responsible for

the process of photosynthesis, the high incidence of sunlight can have a negative role on the growing of certain vegetables, especially on those with C3 photosynthetic metabolism, such as Amazon chicory (Taiz *et al.*, 2017). For plants which present limitations regarding its growth at full sunlight, one of the possible technologies to be applied is the use of shading screens. In literature, many authors reported positive effects of shading in productive traits of vegetables (Hirata & Hirata, 2015; Guerra *et al.*, 2017; Mozumder *et al.*, 2020).

According to Queiroga *et al.* (2001), shading screens reduce the quantity of light reaching the plants, favoring the growth and production of horticultural species more sensitive to high solar radiation. For Amazon chicory, Nataraj *et al.* (2020) suggested the use of 50-70% shading screens, which would be the most suitable environments to increase productivity. According to Abade *et al.* (2019), no significant difference between the treatments for productivity was noticed (kg/m^2) for rocket, which is also a leafy vegetable, when grown at full sunlight or under shading (30 and 50% shading).

Thus, due to few studies in literature on responses of chicory to shading, and intending to increase this crop's production capacity, this study aimed to evaluate the influence of shading levels on productive performance of Amazon chicory.

MATERIAL AND METHODS

The experiment was carried out at Setor de Olericultura of Universidade Federal Rural da Amazônia, Campus Capanema, Pará (1º11'45"S; 47º10'50"W; 25 m altitude), from June to August, 2019. According to Köppen-Geiger's classification, the local climate is "Ami", wet megathermal, with average annual temperature, relative humidity and rainfall corresponding to 26ºC, 85% and 2500 mm, respectively (Alvares *et al.*, 2013).

The experimental design was of randomized blocks, with four treatments and five replicates. The treatments consisted of growing Amazon chicory under black polypropylene screens (30, 50 and 70% shading) and at full sunlight (control).

In order to produce the chicory seedlings, seeds were sown in polystyrene trays with 128 cells, filled with commercial substrate Tropstrato®, two seeds were sown per cell. After sowing, the trays were kept in open air, being manually irrigated once a day, in the afternoon (5 p.m.). The emergence began six days after sowing (DAS).

For cultivation, seedbeds (5.0 m long x 1.0 m wide, 20 cm high) were built. The seedlings were transplanted to the field at 86 DAS, when four well-developed definitive leaves were noticed. The spacing was 20 cm between lines and 20 cm between plants, totalizing twelve pants per plot, being only the four central plants evaluated (Figure 1).

The shading screens were installed in the plots according to its treatments (corresponding to 1 m^2) at seven days after transplanting (DAT), following the seedling adaptation to the field. The screens were placed individually in low tunnels in the experimental plots, 60 cm from the surface of the seedbeds. The arch was structured using bamboo attached to the ground and supported by wooden stilts. Afterwards, the screens were placed (stretched) and sewn on the arches.

The experiment was conducted in Dystrophic Yellow Latosol, and the chemical analysis was carried out in arable layer (0-20 cm), showing the following characteristics: pH_{CaCl2} = 4.70; P = 7.0 mg/dm^3; K^+ = 0.5 mmolc/dm^3; Ca^{+2} = 12.0 mmolc/dm^3; Mg^{+2} = 3.0 mmolc/dm^3; Al^+ = 2.0 mmolc/dm^3; H+Al = 43.0 mmolc/dm^3; SB = 15.5 mmolc/dm^3; CTC = 58.5 mmolc/dm^3; V = 26.0%; M.O. = 21 g/dm^3.

Planting and topdressing fertilizations, as well as liming were performed according to the soil chemical analysis and followed the recommendation for growing leafy vegetables in Pará, according to Brasil *et al.* (2020). For planting fertilization, we used only the simple superphosphate as phosphorus source (111 g/m^2). For top dressing fertilization, urea was used as nitrogen source (22.5 g/m^2) and potassium chloride (19.98 g/m^2) as potassium source, split every 10 days after transplanting. Plants were irrigated manually twice a day, in the morning (7:30 a.m.) and in the afternoon (5 p.m.), until reaching the field capacity.

Due to the indeterminate flowering pattern, emerging floral tassel, on all chicory plants, was weekly pruned. Also, during the experiment, invasive plants were manually controlled. No application of phytosanitary products was carried out, since no significant occurrence of pests or pathogens was verified.

The following vegetative development traits were evaluated at the end of the experiment, at 65 DAT: number of leaves; leaf area (cm²/plant), using the leaf disk method, adapted by Souza *et al.* (2012); leaf area index (cm²/m²), estimated using ratio of the leaf area to the area occupied by each plant in soil; specific leaf area (cm²/g), obtained by the ratio of the leaf area to leaf dry mass; and number of tillers per plant.

For productive performance, we evaluated leaf fresh mass (g), leaf dry mass (g), by drying in an oven with forced air circulation at 65°C; amount of water in shoot area (g/plant), obtained by the difference between fresh and dry mass of leaves; productivity (kg/m^2), estimated based on the fresh mass per plant in relation to area of one square meter, yield (bunches/m^2), obtained using the number of plants/m^2, based on the commercial bunch mass (100 g).

Data were submitted to variance analysis (ANOVA), and the assumptions were evaluated. In order to compare the averages, the authors used Tukey test at 5% significance, using the AGROESTAT software (Barbosa & Maldonado, 2015). Correlation analysis and principal component analyses (PCA) were also performed. We used the R software, packages ggcorrplot (Kassambara, 2019), FactoMineR (Husson *et al.*, 2020) and Factoextra (Kassambara & Mundt, 2020).

RESULTS AND DISCUSSION

Considering the vegetative development traits evaluated for shade levels (environments) no significant difference was noticed (Table 1). For number of leaves (NL), we observed 21 leaves per Amazon chicory plant, corresponding to an average leaf area (LA) of 1.92 cm^2/plant. The average leaf area index (LAI) of the plant in shade environments and at full sunlight was 4.81, whereas the average of specific leaf area (SLA) was 0.91 cm^2/g (Table 1).

We expect significant differences when it comes to analyzing the leaf development in relation to shading (Llic & Fallik, 2017), nevertheless some vegetables presented different behaviors. Some studies, which were carried out by Ferreira *et al.* (2021), on shading on jambu plants (*Acmella oleracea*), which is also an unconventional vegetable, showed that the shading screens had not provided significant differences for leaf area considering the evaluated varieties. The same was observed in this study. Thus, this fact can indicate that the Amazon chicory, like jambu, shows a wide adaptation ability in leaf morphology, in relation to luminosity in the growing environment.

Another factor that could have contributed to non-verified significant differences in vegetative development traits was the kind of shading screen used, since according to Shahak (2008), the black screens can only reduce the light intensity, without changing its quality. When the quality of light is changed, positive responses for the crop yield can be verified.

The authors observed an average of three tillers per plant in the full sunlight treatment. On the other hand, in the treatments using shading screens, this number was reduced (two per plant), totalizing a general average of 2.4 tillers (Table 1). Gomes *et al*. (2012), studying *E. foetidum* and fertilization sources, observed three and two tillers per plant. This result may show that *E. foetidum* is more demanding concerning solar radiation for a better productive development, considering that the number of tillers can influence on an increase of the crop total yield.

According to Llic & Fallik (2017), plants with C3 photosynthetic metabolism normally saturate CO_2 at radiation levels between 600-900 μmol m^2/s in the environment, which corresponds to rates ranging from 30 to 40% of total radiation. However, little is known about unconventional food plants, as they are semi-domesticated crops with many characteristics of rusticity, which can allow wide adaptation to high solar radiation environments.

Table 1. Average values of number of leaves (NL), leaf area (LA), leaf area index (LAI), specific leaf area (SLA) and number of tillers per plant (NTP) in relation to shading levels for Amazon chicory cultivation. Capanema, UFRA, 2019.

Shading levels	NL	LA (cm²/plant)	LAI (m²/plant)	SLA (cm²/g)	NTP
No screen	23.80	2.03	5.08	0.90	3.00
30% shading screen	19.65	1.68	4.21	0.93	2.00
50% shading screen	20.38	1.95	4.87	0.97	2.00
70% shading screen	21.65	2.03	5.07	0.83	2.00
F Test	0.88 ns	0.59 ns	0.59 ns	0.12 ns	0.82 ns
General average	21.00	1.92	4.81	0.91	2.40
CV (%)	20.32	24.94	24.91	42.77	26.32

ns = non significant by F test (p>0.05); CV (%) = variation coefficient.

Table 2. Average values of leaf fresh mass (LFM), leaf dry mass (LDM), amount of water in the shoot area (AWSA), productivity (PROD) and yield (YLD) in relation to shading levels for the Amazon chicory cultivation. Capanema, UFRA, 2019.

Shading levels	LFM (g)	LDM (g)	AWSA (g/plant)	PROD (kg/m²)	YLD (bunches/m²)
No screen	53.91	3.29	50.63	1.35	12.87
30% shading screen	39.16	2.18	36.72	0.98	8.61
50% shading screen	49.33	3.35	45.63	1.23	9.64
70% shading screen	47.08	3.33	43.84	1.18	11.77
F Test	0.72 ns	2.07 ns	0.69 ns	0.71 ns	1.18 ns
General average	47.37	3.04	44.29	1.19	10.72
CV (%)	34.48	29.38	35.18	34.39	37.33

ns = non significant by F test (p>0.05); CV (%): variation coefficient.

In relation to leaf fresh mass (LFM), the treatments showed general average corresponding to 47.37 g, whereas for leaf dry mass (LDM) and amount of water in shoot area (AWSA) showed average values of 3.0 g and 44.29 g/plant, respectively (Table 2). Thus, when productivity was evaluated, we observed an average of 1.19 kg/m^2, considering 10 bunches/m^2 of seedbed.

Productivity and yield of the crop showed the same behavior we observed for fresh mass (Table 2). We highlight that the chicory plants grown at full sunlight showed an increase of 14.41% in productivity and 9.35% in yield in relation to the environment with 70% shading screen, which reinforces a wide adaptation to light levels of the Amazon chicory. This trait can be considered as high phenotypic plasticity or wide acclimatization and further research to understand how this modulation occurs is quite important.

Analyzing linear correlation between traits measured in the growing environments of the Amazon chicory, in relation to shading levels, the authors observed strong correlation (values above 0.80) between yield and productivity traits, leaf fresh mass and amount of water of shoot area, showing coefficients of 0.97, 0.97 and 0.96, respectively (Figure 2). We highlight that the correlations between

Figure 1. Seedling production (A and B), transplanting (C) and reproductive phase (D) with emission of floral tassel of *Eryngium foetidum*. Capanema, UFRA, 2019.

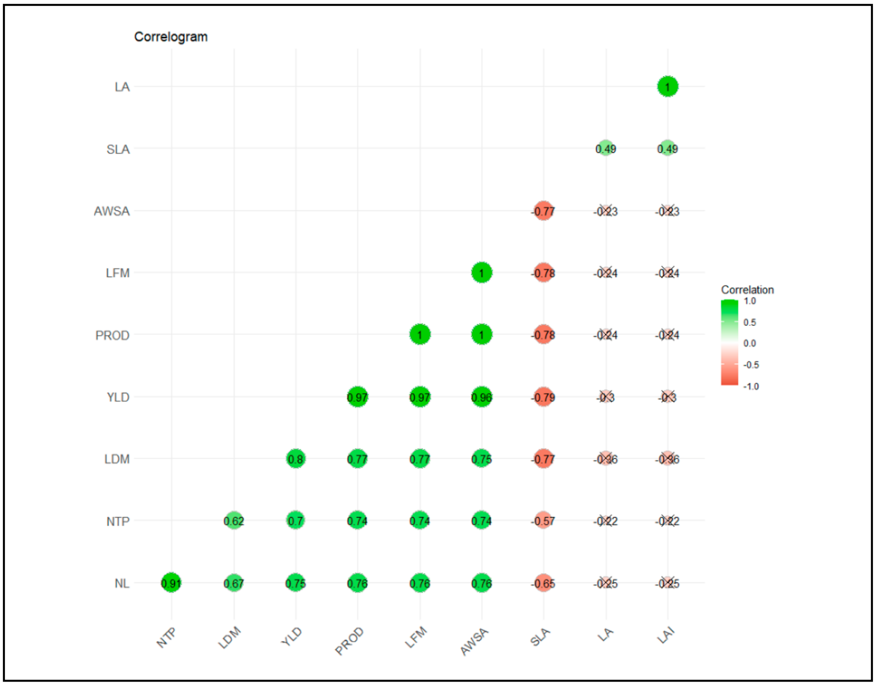

Figure 2. Pearson's correlation coefficient for number of leaves (NL), number of tillers per plant (NTP), leaf fresh mass (LFM), leaf dry mass (LDM), leaf area (LA), leaf area index (LAI), specific leaf area (SLA), amount of water of the shoot area (AWSA), productivity (PROD) and yield (YLD), in relation to shading levels for the Amazon chicory cultivation (*Eryngium foetidum*). *x = no significant effect. Capanema, UFRA, 2019.

productivity, leaf fresh mass and amount of water of shoot area was equal to 1, showing a strong interdependence. We still noticed positive correlation between productivity and leaf dry mass, corresponding to 0.80 (Figure 2).

Leaf area and leaf area index showed strong positive correlation, with coefficient equal to 1 (Figure 2). The interdependence between these traits is observed in leafy vegetable cultivation, since as higher the leaf area index is, higher is the capacity of the plant to explore the ground, that means, we noticed an increase in the leaf area.

The correlation coefficient was positive and equal to 1 (Figure 2) for LFM and AWSA, showing that in chicory the higher fresh mass of the leaves, the greater amount of water, which possibly improves the sensorial traits of the leaves, especially concerning to softness. The same behavior is noticed: NL and NTP showed positive correlation, 0.91 (Figure 2). These results showed that for the Amazon chicory, traits like leaf fresh mass, amount of water in leaves and number of tillers directly influence productivity and crop yield, generating greater income gains for the growers.

For SLA, we verified negative correlation with LDM, PROD, YLD, LFM and AWSA, showing coefficient values superior to -0.70 (Figure 2). According to Martins *et al.* (2015), studies using ratio of leaf dry mass to leaf area to estimate SLA do not show the difference of other leaf morphological components, such as the petiole and the main vein, which may generate inconsistencies, from a practical point of view, estimating SLA, increasing the measurement error. Therefore, further studies are needed to understand the dynamics of SLA of the Amazon chicory and consequently its adaptative capacity to variation in light intensity.

In order to understand the total variation observed in the data of this research, the authors performed the principal components analysis (PCA) presented in the Biplot (Figure 3). In this analysis, the authors presented the linear combination between the traits (variables) represented by vectors

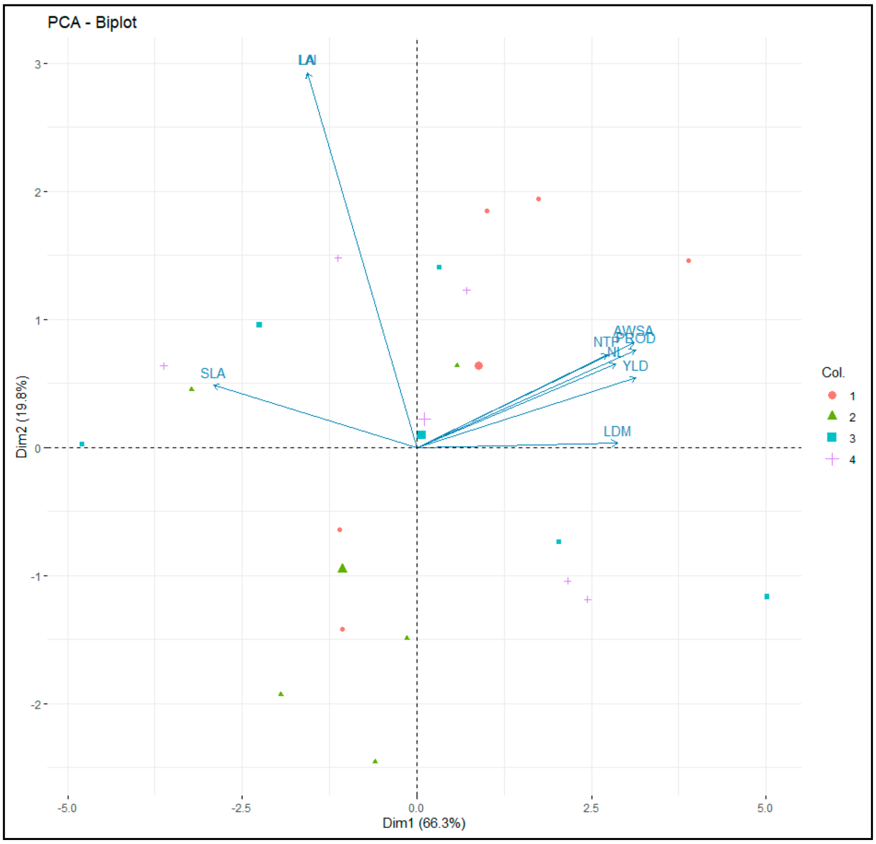

Figure 3. Principal component analysis (PCA) biplot for leaf fresh mass (LFM), leaf dry mass (LDM), number of leaves (NL), amount of water of the shoot area (AWSA), leaf area (LA), specific leaf area (AFE), leaf area index (LAI), productivity (PROD) and yield (YLD), in relation to shading levels for the Amazon chicory cultivation (*Eryngium foetidum*). PC1 = principal component 1. PC2 = principal component 2; 1 = At full sunlight; 2 = 30% shading; 3 = 50% shading; 4 = 70 % shading. Capanema, UFRA, 2019.

and shading levels (environments) represented by the points (1, 2, 3 and 4). We verified that the two first components (CP1 and CP2) obtained 86% of the total variation of the data set, which shows that the generated estimates are reliable, according to Cruz *et al.* (2012).

LFM, NL, AWSA, NTP, PROD and YLD, which showed angles less than 90° are positively correlated. This result shows that this morphological trait set was influenced both by the full sunlight environment and shade environments (50 and 70% shading). LA, LAI and SLA showed angle greater than 90°, being negatively correlated in relation to other traits (Figure 3), corroborating the behavior observed in Figure 2. The 30% shading environment showed low values for the traits in the first quadrant, that means, low influence of these traits.

We highlight that further studies on understanding influence of the shading level on leaf morphological traits of Amazon chicory (LA, LAI and SLA) and its impact on productivity and production are quite important. Mozumder *et al.* (2020), evaluating the shading effect on chicory production in Bangladesh observed statistical differences of the plants grown in shade environment in relation to the control. Moreover, Nataraj *et al.* (2020) also suggested that 50-70% shading screens would be the most appropriate environments to increase productivity.

In Amazon, the cultivation of this unconventional vegetable is often associated with shade environments in yards close to homes. However, this study makes clear the low influence of shading on production and productivity, which can be a high adaptative capacity to light levels (phenotypic plasticity). So, this trait, when well managed, may provide a diversified exploration of cultivation systems, contributing to the profitability and income of family producers at different times of the year.

Thus, the shading levels tested in this study showed no significant differences concerning the productive performance of the Amazon chicory. However, the cultivation at full sunlight provided an increase of 14.41% in productivity and 9.35% in the crop yield, comparing with 70% shading. Thus, we conclude that the Amazon chicory can be grown both at full sunlight and in 70% shade environments.

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