

Centro de Ciências Agroveterinárias – CAV
Fitotecnia/Setor Fruticultura

Lages, 15 de janeiro de 2026

DECLARAÇÃO

Declaro para os devidos fins que Tainara Gris, inscrita no CPF nº 03417474086, portador do RG nº 2102237068, atuou no período de 04/2025 a 01/2026, desenvolvendo atividades técnico-científicas na área de produção vegetal, biotecnologia e inovação, com ênfase na cultura do morangueiro (*Fragaria* × *ananassa*), conforme descrito a seguir:

A profissional atuou diretamente na produção de mudas de morangueiro *in vitro*, realizando atividades de micropropagação vegetal, incluindo preparo e esterilização de meios de cultura, estabelecimento, multiplicação, alongamento, enraizamento, manutenção e aclimatização de plantas, seguindo protocolos técnicos e boas práticas de laboratório, com foco em qualidade fitossanitária e uniformidade das mudas.

Atuou na gestão de tarefas relacionadas à cultura do morango em ambiente de biofábrica, incluindo planejamento e organização da rotina produtiva, controle de etapas do processo de propagação, monitoramento de insumos e materiais, organização de cronogramas de produção, apoio à gestão da qualidade, rastreabilidade do material vegetal e inovação associadas à cultura.

Participou de atividades técnicas relacionadas à propagação de morangueiro em casa de vegetação, envolvendo a manutenção de plantas matrizes, multiplicação vegetal e monitoramento dos processos produtivos, oferecendo suporte às ações de pesquisa, desenvolvimento e inovação, com foco na qualidade, rastreabilidade e padronização do material propagativo. Paralelamente, apoiou no planejamento, execução e avaliação de ensaios experimentais com morangueiro, incluindo delineamento experimental, definição de tratamentos, coleta de dados morfofisiológicos e acompanhamento do desempenho das plantas em casa de vegetação, bem como a análise e interpretação dos resultados.



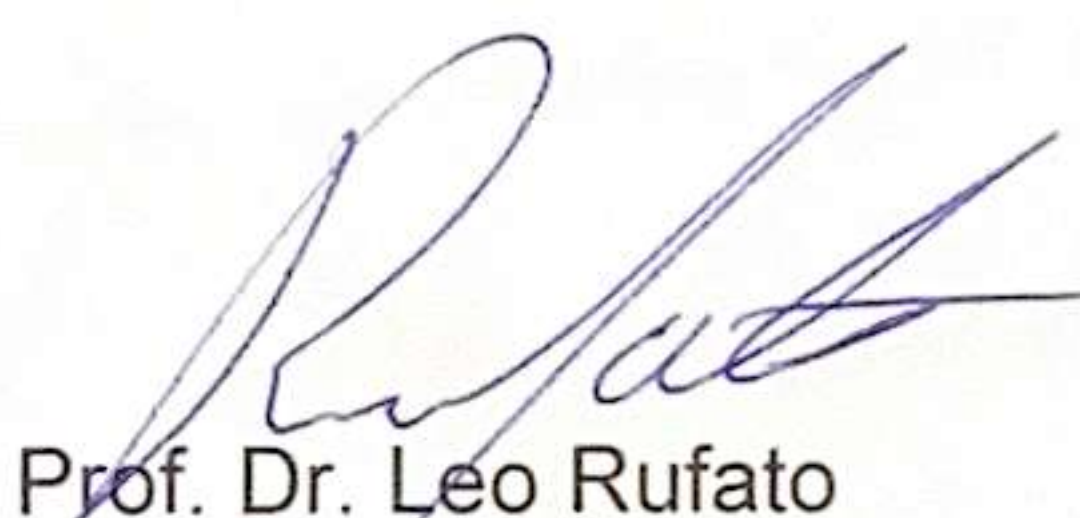
Professor Dr. Leo Rufato
Coordenador – Fruticultura
CAV/UDESC

UNIVERSIDADE DO ESTADO DE SANTA CATARINA - UDESC
CENTRO DE CIÊNCIAS AGROVETERINÁRIAS - CAV

ATESTADO

Atesto, para os devidos fins, que a Dra. Tainara Gris atuou na gestão das atividades e no treinamento da equipe de bolsistas de Iniciação Científica, voluntários e estagiários vinculados ao setor de Fruticultura do CAV/UDESC, bem como na execução e coordenação de projetos científicos, tecnológicos e de inovação envolvendo culturas como maçã, pera e morango, no período de abril de 2025 até a presente data.

Lages, 08 de julho de 2025.



Prof. Dr. Leo Rufato
Dr. em Fruticultura
Coordenador da Fruticultura
CAV/UDESC



**UNIVERSIDADE FEDERAL
DE SANTA CATARINA**
Centro de Ciências Agrárias

CCA UFSC
centro de
ciências agrárias

Rodovia Admar Gonzaga, 1346 - Itacorubi - Caixa Postal 476
CEP: 88040-900 - Florianópolis - SC – CNPJ: 83.899.526/0001-82

Declaro para os devidos fins que a Doutoranda TAINARA GRIS – inscrita sob RG nº2102237068 e CPF nº 034.174.740-86, atuou no Laboratório do Núcleo de Pesquisas em Biotecnologia Vegetal (NPBV) de outubro de 2020 até o momento atual realizando atividades na área acadêmica, dentre as quais as análises laboratoriais:

- Preparação de reagentes para meio de cultivo *in vitro* (macro e micronutrientes, vitaminas, reguladores de crescimento).
- Produção de meio de cultura.
- Análises de viabilidade de sementes (germinação, tetrazólio).
- Processamento de amostras para análise em microscopias (óptica, eletrônica de transmissão, varredura e Confocal).
- Análises histoquímicas.
- Análises fisiológicas (Clorofila *a*, *b* carotenóides e antocianicas – espectrofotômetro).
- Desenvolvimento e execução de protocolos necessários para análises bioquímicas.
- Análises estatísticas de dados (Software R Studio).

Florianópolis 19/01/2024.



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ROSETE PESCADOR

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Dra. Rosete Pescador

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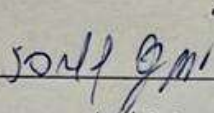
Orientadora

Diretora do Centro de Ciências Agrárias/UFSC

DECLARAÇÃO SERVIÇOS PRESTADOS

Declaro para os devidos fins que a Eng. Agrônoma TAINARA GRIS – inscrita sob RG n.º 2102237068 e CPF n.º 034.174.740-86, atuou na propriedade rural familiar inscrita sob inscrição estadual n.º 3401003927, cpf/cnpj n.º 447111239049 em nome de Joel Gris, localizada em Linha Santa Lucia, município de Barra Funda – RS, desde o ano de 2018 até o momento atual em atividades de gestão e assistência técnica, como fonte de apoio aos proprietários, desenvolvendo tarefas orientação para como poda de frutíferas em época correta, escolha de cultivares de soja e milho para plantio, auxílio na regulagem de maquinários agrícolas, nutrição e manejo de gado de corte em semi confinamento, plantio de mudas nativas e frutíferas, desenvolvimento e implementação de técnicas sustentáveis para conservação de solo, controle de pragas e técnicas para maximizar a produtividade das culturas.

Para fins de comprovação, segue Registro de Inscrição no CAR: RS-4301958-9F5F.1171.4B8E.4AC3.9864.AB5A.EE7E.8C31



Joel Gris

CPF n.º: 447111239049

Inscrição Estadual n.º: 3401003927

Produtor Rural



CROP SCIENCE

Light quality and sealing type affect *in vitro* growth and development of *Capsicum frutescens* cultivars

TAINARA GRIS, MARCOS V.M. PINHEIRO, LEONARDO A. THIESEN, ANDERSON R. WEBLER, DIÉSSICA L. JUNGES, EVANDRO HOLZ, IURI NAIBO, DIEGO S. BATISTA, WAGNER C. OTONI & DENISE SCHMIDT

Abstract: The aim of this work was to evaluate the effect of five light qualities [fluorescent lamps (FL); white (WL), red (RL), blue (BL), or red/blue LEDs (RBL)] and two types of flask sealing (with or without porous membranes) in the *in vitro* germination and growth of two *Capsicum frutescens* cultivars (Espagueteinho and Cayenne). For this, two seeds were inoculated per flask (350 mL) containing 50 mL of MS medium with 100 mg L⁻¹ myo-inositol, 30 g L⁻¹ sucrose, 6.0 g L⁻¹ agar, and pH 5.8 ± 0.1. The plants were kept under culture room conditions (16-h photoperiod, 25 ± 2°C and irradiance of 40 μmol m⁻² s⁻¹). The experiment was arranged in CRD, 2x5x2 factorial scheme (Cultivar X Light qualities X Sealing type). At 42 days, the following traits were evaluated: percentage of germination; root and shoot length; number of green leaves, senescent leaves and nodal segments; and fresh and dry weight. Plants grown under RL and BRL, showed greater number of green leaves, and longer shoots and roots. The use of porous membranes remarkably reduced the number of senescent leaves. Thus, the use of porous membranes, RL and BRL are recommended since they improve growth and development of pepper *in vitro*.

Key words: Pepper, Light-emitting diodes (LEDs), porous membranes, gas exchange.

INTRODUCTION

Pepper (*Capsicum* sp.) is a horticultural crop cultivated in tropical and temperate regions. Besides its high ornamental and medicinal value, its fruits are used in jellies, in the manufacture of preserved foods, sauces, spices or powdered for seasoning (Sanatombi & Sharma 2007, Valnir Júnior et al. 2015, Swamy et al. 2017). Among the uses of these plants, the medicinal application due to the high contents of capsaicin alkaloid in the fruits, which confers the pepper pungency of dihydrocapsaicin, homodihydrocapsaicin and homocapsaicin, all known as capsaicinoids (Davis et al. 2007, Mueller-Seitz et al. 2008). The capsaicinoids are synthesized in the fruits

placenta and some factors such as temperature, nutrient availability, nitrate fertilization and carbon availability may affect the accumulation of these substances (Garruña-Hernandez et al. 2013, Aguilar 2016).

Usually, the propagation of *Capsicum* plants is performed sexually. However, this seed-based propagation method can be limited by several pathogens, such as fungi, nematodes and viruses. So, *in vitro* propagation stands out as an alternative to allow a rapid production and multiplication of this genus, generating uniform, large-scale and disease-free plant material (Sanatombi & Sharma 2007, Chandra et al. 2010). Considering the susceptibility of peppers to diseases and pests, the improvement of tissue

culture techniques is very important. However, some authors report recalcitrance of the genus *Capsicum* for *in vitro* regeneration, which may hinder the applicability of genetic improvement techniques and molecular biology (Kothari et al. 2010, Mohamed & Alsadon 2011, Batista et al. 2017, Gammoudi et al. 2018). In addition, some authors report that this recalcitrance has a positive correlation to ethylene levels produced during *in vitro* growth and development, making it a limiting factor for species such as pepper (Santana-Buzzy et al. 2006, Batista et al. 2013, Gammoudi et al. 2018). Also, among the factors required for the success of *in vitro* regeneration, are the genotype, the light regime and the effect of gas exchange (Dabauza & Peña 2001, Ochoa-Alejo & Ramirez-Malagon 2001, Mohamed & Alsadon 2011, Batista et al. 2017). Especially in peppers of the genus *Capsicum*, the physiological responses are extremely genotype-dependent, which makes necessary studies directed to the cultivars of interest (Dabauza & Peña 2001, Steinitz et al. 2003).

In customary *in vitro* plant cultivation tight sealed flasks have been widely used. Remarkably, there is a restricted gas exchange leading to accumulation of ethylene and other gases, reduced gas exchange, low CO₂ concentration, high carbohydrate, low photosynthetic and transpiratory rates of the plants, lessening their rate of multiplication and survival during acclimatization (Aragón et al. 2010, Kozai 2010, Xiao et al. 2011, Nguyen et al. 2016, Batista et al. 2018). Notably, to overcome such constraints and improve the *in vitro* environment, porous membranes have been used. They promote gas exchanges resulting in increased inner CO₂ concentrations, reduced humidity and ethylene concentrations, stimulating photosynthesis and benefiting explants growth and allowing the photoautotrophic propagation (Kozai & Kubota 2001, Saldanha et al. 2012). Ultimately,

it favors to rustify *in vitro* grown plants during acclimatization, which is a delicate step for tissue culture.

The development and biological processes of the plants are influenced by light spectrum stimuli, interfering in the size and number of organs, number of shoots, seed germination, determination of growth and flowering habits, fruiting, among others (Morelli & Ruberti 2000, Carvalho et al. 2011). Under *in vitro* conditions, light stands out as an important factor, supporting plant growth and development (Muleo et al. 2001, Pawłowska et al. 2018). Although these plants depend on the sugars present in the culture medium as energy source, light is still an important regulator of plants development (Pawłowska et al. 2018). Advances in light technology led the researchers to explore light-emitting diodes (LEDs) in tissue culture, demonstrating great potential for their use in *in vitro* cultivation due to long lifespan, low power consumption, small mass and volume, low radiant heat emission, high wavelength specificity and capacity of emitting specific spectral qualities (Hung et al. 2016, Batista et al. 2018, Pawłowska et al. 2018).

The wavelengths of red and blue light are the focus of current research due to their regulatory effects on plant development, since they promote photosynthesis (Bantis et al. 2016). The red light (660 nm) is efficiently absorbed by photosynthetic pigments (chlorophyll and carotenoids) and stimulates the phytochrome fotoreceptor. The blue light (400-500 nm), by its turn, performs a variety of important photomorphogenic roles in plants, including stomatal opening, stem elongation and phototropism (Pawłowska et al. 2018).

Therefore, this study hypothesis that different light qualities and sealing types modify the *in vitro* germination and growth of *Capsicum frutescens* cultivars.

MATERIALS AND METHODS

Plant material and growing conditions

The experiment was carried out at the Tissue Culture and Aromatic Extracts Laboratory of the Federal University of Santa Maria, Frederico Westphalen, RS, Brazil.

Seeds from two cultivars of *Capsicum frutescens* namely 'Espaguetinho' and 'Cayenne' (ISLA®) were disinfested in 70% alcohol for 1 min, followed by sodium hypochlorite (NaClO) at 0.8% active chlorine for 15 min, and four rinses in autoclaved distilled water. After disinfestation, two seeds were inoculated into each glass flask (350 mL capacity) containing 50 mL of macronutrients, micronutrients and vitamins of the MS culture medium (Murashige & Skoog 1962), with 100 mg L⁻¹ myo-inositol, 30 g L⁻¹ sucrose, and 6.0 g L⁻¹ granulated agar. The pH was adjusted to 5.8 ± 0.1, prior to autoclaving at 120 °C, 108 kPa, for 15 min. The cultures were kept under culture room conditions with a 16-h photoperiod, temperature of 25 ± 2 °C and irradiance of 72 µmol m⁻² s⁻¹ from five different light qualities: four fluorescent lamps (FL, Luz do Dia Especial, 40 W, Osram, Brazil); two white LEDs (WL), red LEDs (RL), blue LEDs (BL) or red/blue LEDs (RBL, 60 and 40%, respectively), TEC LAMP®. In addition, two types of sealing were used: rigid metal lids without orifice and rigid metal lids with two 10 mm-diameter holes covered by porous membranes, which were prepared following the methodology proposed by Saldanha et al. (2012).

Analyzed characters

After 42 days of *in vitro* cultivation the following characters were evaluated: percentage of germination, root and shoot length, number of green leaves, number of nodes, fresh and dry weight, number of senescent leaves and

photosynthetic pigments (chlorophyll *a*, *b* and carotenoids).

Quantification of photosynthetic pigments

Three 3 mm-diameter leaf discs were removed from the second and third leaf of the apex towards the base and incubated in 3 mL of saturated dimethylsulfoxide (DMSO) with CaCO₃, following the modified methodology proposed by Santos et al. (2008). The discs remained in glass tubes covered with aluminum and kept in the dark for 48 hours at room temperature. After this, the absorbance of the samples was determined using a 10 mm quartz cuvette of optical path in Bel Photonics® SP 1105 spectrophotometer. The wavelengths and the equations to calculate chlorophylls *a*, *b*, and carotenoids concentrations were based on the methodology described by Wellburn (1994).

Experimental design and statistical analysis

The experiment was arranged in a completely randomized design (CRD), in a 2x5x2 factorial scheme (two cultivars, five light qualities and two types of sealing), totaling 20 treatments, with 10 replicates each. The experimental unit consisted of two plants per flask.

For the photosynthetic pigments analyzes three replicates were used, each one composed of a test tube containing three leaf discs. The data was submitted to Shapiro-Wilk's test and the growth parameters (root length, shoot length, number of green leaves, number of nodal segments, fresh weight, dry weight and number of senescent leaves) were transformed to $y = \text{square root of } x + 0.5$, to meet the normality assumptions (data is presented with non-transformed means). Data were submitted to analysis of variance by F-test and regression analysis for the quantitative data (days after inoculation). For qualitative data, the means were compared by the Tukey's test at 5%

significance level. All statistical analyzes were performed using the statistical program SISVAR (Ferreira 2011).

RESULTS

By the results of analysis of variance, root length, fresh weight and dry weight differed for the triple interaction among cultivars x light qualities x types of sealings. For the number of green leaves and number of nodal segments, there was a significant difference for cultivars x types of sealings and for light qualities. For number of senescent leaves, there was a significant difference for light qualities and types of sealing. For shoot length, there was a significant difference only for the light qualities. For percentage of germination, there was difference only for light qualities x types of sealing and for days after inoculation for both cultivars ('Espaguetinho' and 'Cayenne') ($p < 0.05$, data not shown).

Growth characters

For percentage of germination in the 'Espaguetinho', it was possible to infer that the red LED with membrane was significantly higher than other light qualities, and no difference was observed in the type of sealing without porous membranes (Figure 1h; Figure 2a). For the 'Cayenne', there was a significant difference only for red/blue LEDs without porous membranes, where the highest percentage of germination was observed (Figure 2b; Figure 3e).

The red and red/blue LEDs were showed more senescent leaves compared to the blue LED (Figure 4a), and plants produced under these blue light conditions generated reduced amount of green leaves (Figure 4c). Also, plants grown without membrane have more senescent leaves than those cultivated in flasks with

membranes (Figure 4b). The number of green leaves formed under red LEDs and red/blue LEDs was significantly higher as compared to white and blue LEDs and fluorescent lamps (Figure 4c). For cultivar x types of sealing, the 'Espaguetinho' without membrane showed more leaves than with membrane, while the 'Cayenne'

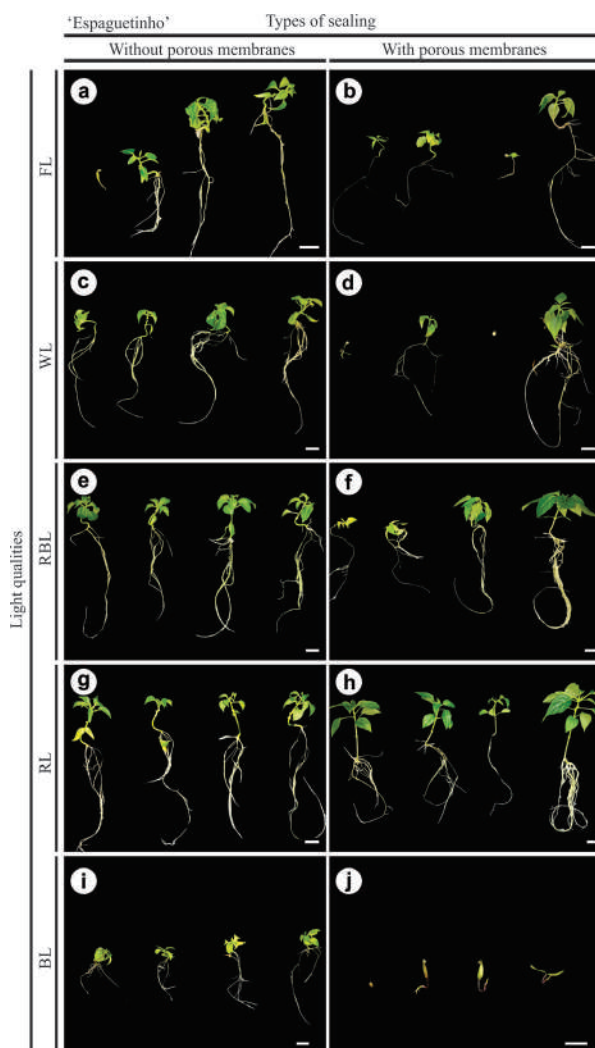


Figure 1. Plants of *Capsicum frutescens* cv. 'Espaguetinho' cultivated *in vitro* under different light qualities and types of sealing: Fluorescent (FL) without (a) and with porous membranes (b); White LED (WL) without (c) and with porous membranes (d); Red/blue LED (RBL) without (e) and with porous membranes (f); Blue LED (BL) without (g) and with porous membranes (h); Red LED (RL) without (i) and with porous membranes (j). Bars: 1 cm.

did not differ between the types of sealing. (Figure 4d).

The plants cultured in red/blue LEDs showed greater number of nodal segments, despite did not differ statistically from white and red LEDs (Figure 5a). For cultivar x types of sealing, plants grown in flasks without membrane had more nodal segments than those with membrane for 'Espagueteinho' and for 'Cayenne', the types of sealing were similar for this feature. 'Cayenne' had more nodal segments than 'Espagueteinho' in the treatments with membrane while without membrane there was no difference between the cultivars (Figure 5b).

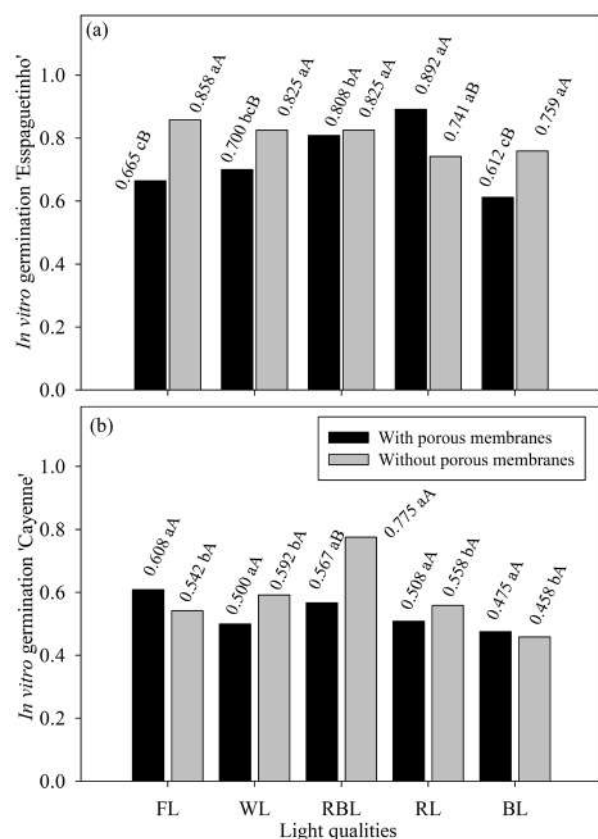


Figure 2. *In vitro* germination of *Capsicum frutescens* cv. Espagueteinho (a) and Cayenne (b), evaluated after 42 days of culture under different light qualities and types of sealing. *Lowercase letters in type of sealing (with or without membrane), and uppercase letters in the same light quality do not differ by the Tukey's test at 5% level.

Plants cultured in red LEDs developed longer shoots, followed by those grown under red/blue LEDs (Figures 1; 3; 5c). For root length, there was a triple interaction among the factors. Considering cultivar x light qualities x types of sealing between the 'Espagueteinho' and 'Cayenne' in the white LED, the former without membrane differed statistically from the one with membrane, with greater root length, whereas the latter did not differ. 'Espagueteinho' under blue LEDs and without membrane was superior from the one with membrane, while to 'Cayenne' they did not differ (Table I).

'Espagueteinho' plants grown under red LEDs in with membranes developed longer roots than those cultured in other light qualities. For the treatments without membrane, there was no significant difference between the light qualities instead. For 'Cayenne' with membrane, the lights fluorescent, and white, red/blue and red LEDs had longer roots than those grown under blue LEDs, the same occurred for the treatment without membrane in this cultivar. The comparisons among the lights red/blue, red and blue LEDs did not varied in root length between the cultivars, just as for the types of sealing in red/blue, red and blue LEDs (Table I; Figures 1e, 1f, 1g, 1h, 1i, 1j and 3e, 3f, 3g, 3h, 3i, 3j).

For fresh weight there was also a triple interaction among the treatments and both cultivars did not differ when analyzed in the fluorescent lamp and blue LED. However, 'Espagueteinho' without membrane differed from the one with membrane with greater fresh weight, while 'Cayenne' did not differ. For both cultivars, the treatment without membrane was superior from the one with membrane in the red/blue LED. In the red LED, 'Espagueteinho' did not present any significant difference. Unlike, for 'Cayenne' the treatment without membrane produced plants with greater fresh weight (Table II).

For light qualities x cultivar x types of sealing, the ‘Espaguetinho’ under the red LED was superior only from the white and blue LED in the type of sealing with membrane, while in the treatment without membrane, the red/blue LED was superior only from the fluorescent lamp and blue LED. Within ‘Cayenne’ with membrane, the light qualities did not show statistical

difference among the treatments; and for the treatment without membrane, the red/blue LED produced plants with greater fresh weight than all the other light qualities (Table II). When compared to membrane treatment between the two cultivars, there was no significant difference among the treatments in the light qualities. For the treatment without membrane, ‘Cayenne’ was superior from ‘Espaguetinho’ in the red/blue LED and red LED, while the other treatments did not differ among themselves (Table II).

For dry weight there was also a triple interaction. Thus, considering cultivar x light qualities x types of sealing, ‘Espaguetinho’ did not differ statistically, and the ‘Cayenne’ without membrane was superior when compared to the one with membrane with red/blue and red LEDs, while the other treatments did not differ for this cultivar. For light qualities x cultivar x types of sealing in the ‘Espaguetinho’ there was no difference among the light qualities; the ‘Cayenne’ in the treatment without membrane and red/blue LED produced plant with dry weight greater than all the other light qualities; while in the treatment with membrane for this cultivar there was no difference among the light qualities (Table III).

Considering the types of sealing x cultivar x light qualities, only the treatment with membrane and red LEDs differed statistically between the cultivars, showing higher values for dry weight, while in the treatment without membrane in the white LED, and ‘Espaguetinho’ was superior; in red/blue LED for ‘Cayenne’ the treatment without membrane was higher. For the other treatments in the cultivar Cayenne, the types of sealing did not differ statistically (Table III).

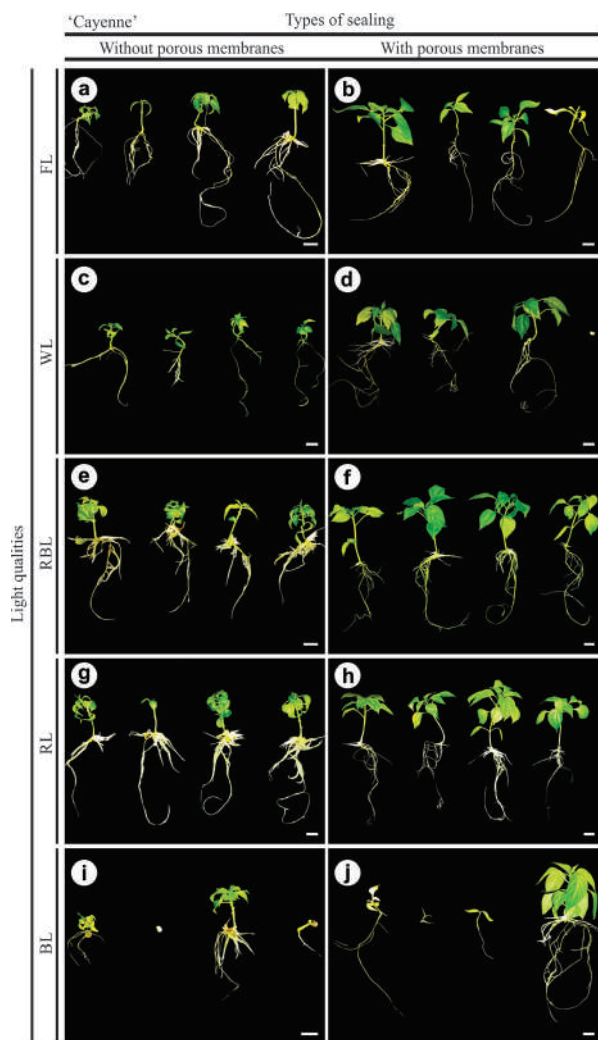


Figure 3. Plants of *Capsicum frutescens* cv. ‘Cayenne’ cultivated *in vitro* under different light qualities and types of sealing: Fluorescent (FL) without (a) and with porous membranes (b); White LED (WL) without (c) and with porous membranes (d); Red/blue LED (RBL) without (e) and with porous membranes (f); Blue LED (BL) without (g) and with porous membranes (h); Red LED (RL) without (i) and with porous membranes (j). Bars: 1 cm.

Photosynthetic pigments

By the analysis of variance, the chlorophyll *b* differed for the triple interaction between cultivars x light qualities x types of sealing. For the chlorophyll *a*, there was a significant difference for cultivar x light qualities and types

of sealing x light qualities. For carotenoids a significant difference was evidenced between cultivar x light qualities.

For chlorophyll *a* only 'Cayenne' in the blue LED was significantly higher compared to 'Espaguetinho' ($p < 0.05$). Light qualities within the cultivar, for 'Espaguetinho', the blue LED showed inferior results compared to the other light qualities, without differences for 'Cayenne' ($p < 0.05$) (Figure 6a). Still, for chlorophyll *a*, considering types of sealing within the light qualities, the treatment with membrane was superior compared to the treatment without membrane, only in the red/blue LED. For light qualities x types of sealing, the blue LED treatment was inferior to the other light qualities within the membrane treatment, while within the treatment without membrane, the

light qualities fluorescent and white LED were superior to the others (Figure 6b).

For 'Espaguetinho', cultivar x light qualities factorial was superior to 'Cayenne' for carotenoids only in red/blue and red LEDs. And for light qualities within the cultivar, plants grown under blue LEDs had less carotenoids than the other treatments in the 'Espaguetinho', while in the 'Cayenne' cultivar there was no significant difference among the light qualities (Figure 6c).

For the variable chlorophyll *b*, considering cultivar x light quality x types of sealing, the cultivar 'Espaguetinho', only the white LED treatment without membrane differed from the one with membrane; for 'Cayenne' there was no significant difference between types of sealing. In the types of sealing x cultivar x light qualities

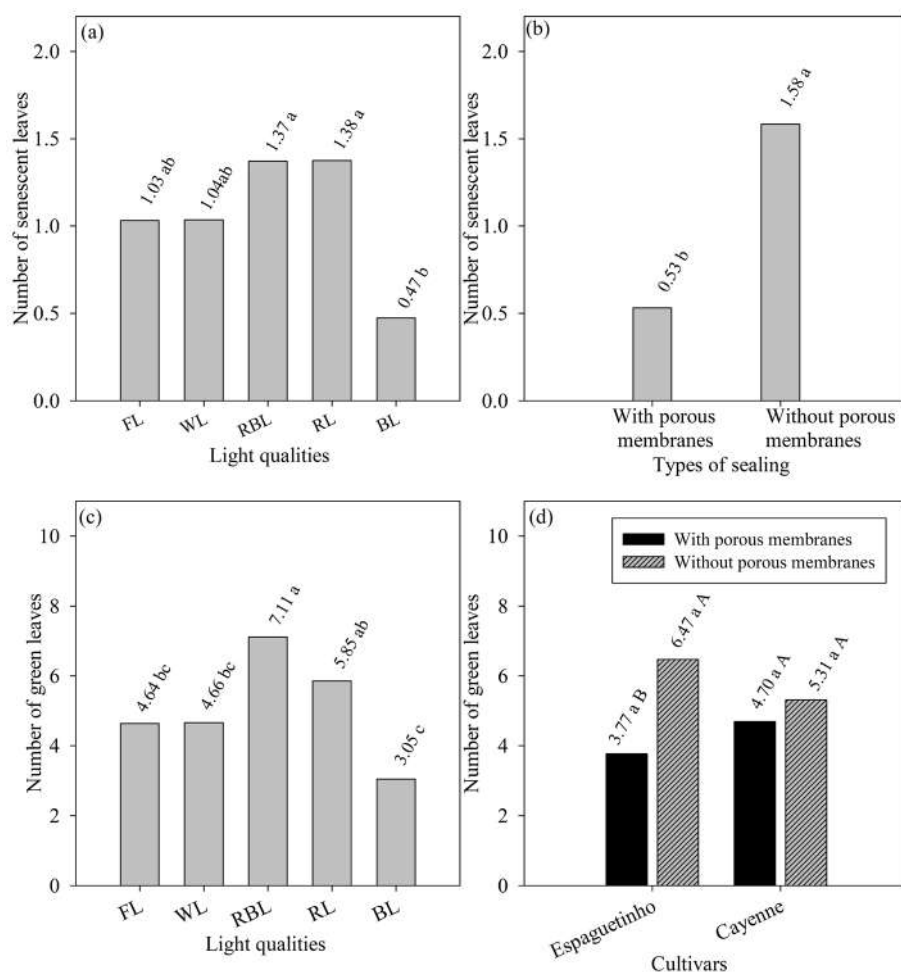


Figure 4. Growth variables of *Capsicum frutescens* cv. Cayenne and Espaguetinho, cultivated under different light qualities and types of sealing. Number of senescent leaves for the factor light qualities (a) and for the factor types of sealing (b); Number of green leaves for the factor light qualities (c) and for the interaction types of sealing and cultivars (d).^{*} Equal letters (figures a-c), do not differ by Tukey's test, 5% level; and lowercase letters equal in the same type of sealing (with or without membrane) and uppercase letters for the same cultivar ('Espaguetinho' or 'Cayenne') (figure d) do not differ from each other by the Tukey's test at 5% level.

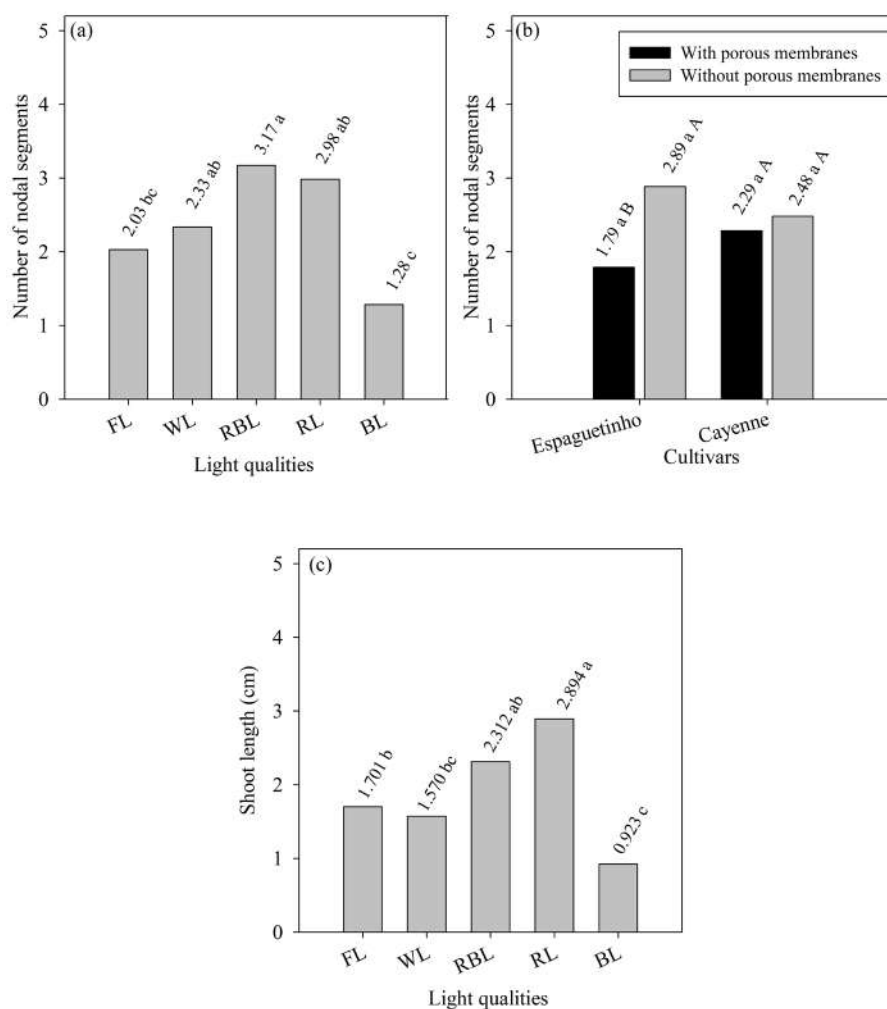


Figure 5. Growth variables of *Capsicum frutescens* cv. Cayenne and Espaguetinho cultivated under different light qualities and types of sealing. Number of nodal segments for the factor light qualities (a) and for the interaction types of sealing and cultivars (b); and shoot length for the light qualities factor (c). * Lowercase letters for light quality do not differ by Tukey's test, 5% level (a-c); Lowercase letters in the same type of sealing (with or without membranes) do not differ the cultivars between them, and uppercase letters in each cultivar do not differ for the type of sealing, by Tukey's test, 5% level (b).

Table I. Root length of *Capsicum frutescens* cultivars ('Espaguetinho' and 'Cayenne') cultivated under different light qualities and types of sealing.

	cv. Espaguetinho			cv. Cayenne	
	With porous membranes	Without porous membranes		With porous membranes	Without porous membranes
Light qualities	Root length (cm)				
Fluorescent lamp	2.98 aBβ	4.16 aAα		5.94 aAα	4,30 aABα
White LED	1.33 bBβ	5.35 aAα		5.24 aABα	3.69 aABα
Red/blue LED	4.34 aBα	5.50 aAα		6.92 aAα	4.88 aABα
Red LED	9.55 aAα	4.38 bAα		8.08 aAα	6.73 aAα
Blue LED	0.49 bBα	3.93aAα		1.71 aBα	2.01 aBα
CV (%)			37.41		

*Lowercase letters are equal in cultivars within each level of light qualities and types of sealing; uppercase letters are equal in light qualities within each level of cultivars and types of sealing; and Greek letters are equal in types of sealing within each level of cultivars and light qualities by Tukey's test, at 5% level.

Table II. Fresh weight of *Capsicum frutescens* cultivars ('Espaguetinho' and 'Cayenne') cultivated under different light qualities and types of sealing.

	cv. Espaguetinho			cv. Cayenne	
	With porous membranes	Without porous membranes		With porous membranes	Without porous membranes
Light qualities	Fresh weight (g)				
Fluorescent lamp	0.036 aBα	0.106 aBα		0.134 aAα	0.092 aBα
White LED	0.021 bBα	0.189 aBα		0.109 aAα	0.107 aBα
Red/blue LED	0.126 bABα	0.284 aAβ		0.180 bAα	0.436 aAα
Red LED	0.198 aAα	0.111 aABβ		0.114 bAα	0.254 aBα
Blue LED	0.093 aBα	0.099 aBα		0.037 aAα	0.099 aBα
CV (%)			10.18		

*Lowercase letters are equal in cultivars within each level of light qualities and types of sealing; uppercase letters are equal in light qualities within each level of cultivars and types of sealing; and Greek letters are equal in types of sealing within each level of cultivars and light qualities by Tukey's test, at 5% level.

Table III. Dry weight of *Capsicum frutescens* cultivars ('Espaguetinho' and 'Cayenne') cultivated under different light qualities and types of sealing.

	cv. Espaguetinho			cv. Cayenne	
	With porous membranes	Without porous membranes		With porous membranes	Without porous membranes
Light qualities	Dry weight (g)				
Fluorescent lamp	0.010 aAα	0.010 aAα		0.011 aAα	0.014 aBα
white LED	0.010 aAα	0.018 aAα		0.011 aAα	0.010 aBβ
Red/blue LED	0.014 aAα	0.018 aAβ		0.012 bAα	0.029 aAα
Red LED	0.016 aAα	0.013 aAα		0.004 bAβ	0.016 aBα
Blue LED	0.006 aAα	0.001 aAα		0.005 aAα	0.012 aBα
CV (%)			0.89		

*Lowercase letters are equal in cultivars within each level of light qualities and types of sealing; uppercase letters are equal in light qualities within each level of cultivars and types of sealing; and Greek letters are equal in types of sealing within each level of cultivars and light qualities by Tukey's test, at 5% level.

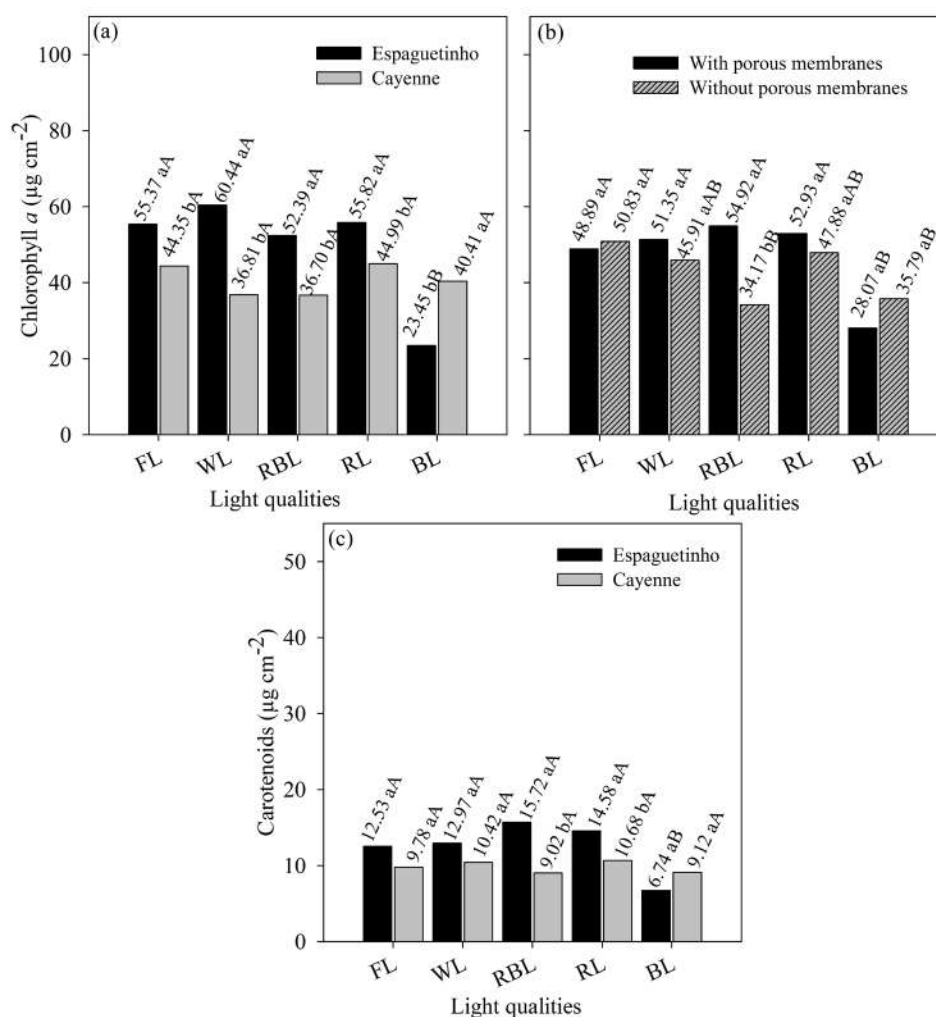


Figure 6. Photosynthetic pigments of *Capsicum frutescens* cv. Espaguetinho and Cayenne, cultivated under different light qualities and types of sealing. Chlorophyll a for the two cultivars in different light qualities (a); chlorophyll a for both types of sealing in different light qualities (b); Carotenoids for two cultivars in different light qualities (c). *Lowercase letters for the same cultivar and uppercase letters in the same light quality do not differ the cultivars from each other, by Tukey's test at 5% level (a and c). Lowercase letters for the same type of sealing and uppercase letters in the same light quality do not differ for the types of sealing, by Tukey's test, 5% level (b).

Table IV. Chlorophyll b contents of *Capsicum frutescens* cultivars ('Espaguetinho' and 'Cayenne') cultivated under different light qualities and types of sealing.

	cv. ‘Espaguetinho’			cv. ‘Cayenne’	
	With porous membranes	Without porous membranes		With porous membranes	Without porous membranes
Light qualities	Chlorophyll b (µg cm ⁻²)				
Fluorescent lamps	18.2585 aAα	18.6498 aBα		13.8718 aAα	9.5292 aAα
White LED	6.8423 bAα	36.7971 aAα		10.0560 aAα	6.0149 aAβ
Red/blue LED	11.0967 aAα	9.5425 aBα		8.2965 aAα	3.7168 aAα
Red LED	10.1240 aAα	7.8317 aBα		7.1692 aAα	4.7372 aAα
Blue LED	4.2678 aAα	8.5907 aBα		8.4236 aAα	8.3783 aAα
CV (%)			20.83		

*Lowercase letters are equal in cultivars within each level of light qualities and types of sealing; uppercase letters are equal in light qualities within each level of cultivars and types of sealing; and Greek letters are equal in types of sealing within each level of cultivars and light qualities by Tukey's test, at 5% level.

among the cultivars in the treatment with membrane, there was no significant difference between the light qualities; in the treatment without membrane only the white LED was superior in 'Espagueteinho', differing significantly from 'Cayenne' (Table IV).

DISCUSSION

This work describes *in vitro* germination, growth and development of *Capsicum frutescens* using different light qualities and gas permeable membranes. The use of gas-permeable membranes associated with red and red/blue LEDs, resulted in plants with significant differences in growth and morphophysiological parameters (Figures 1f, 1h, 3f, 3h, 4, 5 and 6). The germination and development of different species are affected by intrinsic characteristics of seeds or environmental factors such as light quality (Victório & Lage 2009); and, in this case, the red-light spectrum stimulates seed germination of several species (Figure 3g and 3h). Similar results were observed in the present work, in which the red LED with porous membrane presented greater percentage of germination for the cultivar 'Espagueteinho', and the red/blue LED without membrane for the 'Cayenne' cultivar (Figures 1h and 3h).

In this study, the use of porous membranes remarkably reduced the number of senescent leaves, a constraint in tissue culture systems due to either ethylene accumulation or the low nutrients absorption from the medium due low transpiration rates. Leaf abscission is a challenge for *in vitro* cultivation due to the accumulation of ethylene inside the culture environment and low gas exchange, which can generate physiological anomalies in the plants. Gas-permeable membranes have been used to provide the maintenance of CO₂ concentration, stimulate photosynthesis, lessen or inhibit the

negative effects of this ethylene, reduce the relative humidity, increase the transpiration and absorption of water and nutrients, stimulating the photoautotrophic development of plants *in vitro* (Rodrigues et al. 2011, Xiao et al. 2011). These gas exchanges allow ethylene releasing, which reduce the effect of leaf senescence (Rodrigues et al. 2011). This was also observed in this study when porous membranes were used (Figure 4a and 4b).

The progress of leaf senescence is influenced by physical and/or chemical factors in the growth conditions (e.g. temperature, precipitation and radiation). There are reports claiming that the plant regulates internal factors such as oxidative status and sugar levels to control senescence (Eldeen & Elgimabi 2017). Causin et al. (2006) observed that light quality affected oxidative metabolism in wheat leaves and senescence was delayed under blue light. In our work the blue light quality reduced leaf senescence in both cultivars (Figure 4a) however, plants produced under these conditions generated a reduced amount of green leaves (Figure 1i, 1j, 3i, 3j and 4c).

Plants are dependent on processes that involve the action of photoreceptors, which control plant development phases and are highly responsive to changes in light quality (Jensen et al. 2018, Braga et al. 2009). Wavelengths between 400 and 700 nm are required for the photosynthesis. These spectra were found in blue and red LED lamps, causing an increase in chlorophyll and carotenoids (Yeh & Chung 2009). In studies with *Lilium* sp., cultivar Pesarounder, red/blue LEDs promoted greater fresh and dry weight compared to fluorescent lamps (Lian et al. 2002). Rocha et al. (2010) also reported promising results on the use of red LEDs in photosynthetic pigment contents and a higher number of shoots in *Fragaria* x *Ananassa* plants cultured *in vitro*. These results corroborate with

the present work, demonstrating the superiority and efficiency of red/blue and blue LEDs for fresh and dry weight and photosynthetic pigments for both cultivars analyzed.

Regarding the photosynthetic pigments, Saldanha et al. (2012) observed an increase when plants of *Pfaffia glomerata* were cultivated in flasks with porous membranes. Likewise, in the present work, the use of porous membranes associated with red/blue LEDs favored the increase of total chlorophyll content (Figure 6a and 6b). Red LED also promoted a greater increase in chlorophyll content in *Ocimum basilicum* (Ahlman et al. 2017). Chlorophyll molecules absorb blue and red wavelengths more efficiently since they correspond to the light absorption spectra of chlorophyll and carotenoids, which improves the photosynthetic metabolism with characteristics associated to autotrophic growth in plants (Yeh & Chung 2009).

In this study, the red LED provided an increase in root length (Table I, Figures 1g, 1h, 3g, and 3h). Hung et al. (2016) also observed that red light was better for *in vitro* rooting of *Vaccinium corymbosum*. The recognition of light qualities by plants occurs by the phytochrome. The different light spectra increase active forms of phytochrome, inducing rooting (Godoi & Takaki 2005, Victório & Lage 2009). In fact, Pawłowska et al. (2018) observed that the red LED resulted in the formation of numerous adventitious roots with short lengths, which is beneficial during the transfer to *ex vitro* conditions.

As in the present work (Figure 5c), also observed a reduction in the growth of tomato seedlings cultivated under blue LED light compared to those cultivated under other light qualities. Pawłowska et al. (2018) also observed that the blue light strongly suppressed the growth of *Gerbera jamesonii*, causing a significant length reduction and shortening of petioles. This characteristic is related to the

inhibition of hypocotyl elongation, caused by cryptochrome signaling, due to the increased of blue light absorption by the phototropin in hypocotyl cells (Folta & Edgar 2001).

This work is the first report on the influence of light quality and sealing type in the *in vitro* germination, growth and development of two *Capsicum frutescens* cultivars. The use of porous membranes in the culture flasks is important to face frequent problems in conventional tissue culture such as leaf senescence. In general, the light quality provided by red and red/blue LEDs substantially improved the growth and development parameters of produced *in vitro* plants, which are superior to those cultured in fluorescent lamps commonly used in conventional cultivation, demonstrating that LEDs may be advantageous substituent in the cultivation of plants *in vitro*. Despite the cultivar 'Espagueteinho' showed higher chlorophyll a content than 'Cayenne', in general there were no differences in morphogenic responses between these cultivars, showing that the recommendations of *in vitro* culture conditions can be standardized for the two genotypes. Furthermore, the present study provides a basis for future researches and applications to anticipate the productive cycle of *Capsicum frutescens* under *ex vitro* conditions.

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Abbreviations

LED Light-emitting diodes
 FL Fluorescent lamps
 WL White LEDs

RL Red LEDs
 BL Blue LEDs
 RBL Red/blue LEDs
 CRD Completely randomized design

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TAINARA GRIS¹

<https://orcid.org/0000-0001-7229-9230>

MARCOS V.M. PINHEIRO²

<https://orcid.org/0000-0002-5028-7818>

LEONARDO A. THIESEN³

<https://orcid.org/0000-0002-3439-842X>

ANDERSON R. WEBLER⁴

<https://orcid.org/0000-0003-0744-4694>

DIÉSSICA L. JUNGES²

<https://orcid.org/0000-0002-4866-4178>

EVANDRO HOLZ⁴

<https://orcid.org/0000-0002-8018-6743>

IURI NAIBO⁴

<https://orcid.org/0000-0003-2281-0015>

DIEGO S. BATISTA⁵

<http://orcid.org/0000-0002-5798-7761>

WAGNER C. OTONI⁶

<https://orcid.org/0000-0002-9614-9373>

DENISE SCHMIDT⁴

<http://orcid.org/0000-0002-9963-4956>

¹Núcleo de Pesquisas em Biotecnologia e Desenvolvimento Vegetal, Universidade Federal de Santa Catarina/UFSC, Centro de Ciências Agrárias, Rod. Admar Gonzaga, 1346, Itacorubi, 88034-000 Florianópolis, SC, Brazil

²Programa de Pós-Graduação em Agricultura e Ambiente, Universidade Estadual do Maranhão/UEMA, Centro de Ciências Agrárias, Cidade Universitária Paulo VI, Tirirical, 65055-970 São Luís, MA, Brazil

³Programa de Pós-Graduação em Agronomia, Universidade Federal de Santa Maria/UFSM, Av. Roraima, 1000, Cidade Universitária, Camobi, 97105-900 Santa Maria, RS, Brazil

⁴Programa de Pós-Graduação em Agronomia Agricultura e Ambiente, Universidade Federal de Santa Maria/UFSM, Campus Frederico Westphalen, Linha Sete de Setembro, s/n, 98400-000 Frederico Westphalen, RS, Brazil

⁵Universidade Federal da Paraíba, Departamento de Agricultura, Campus Universitário III, Rua João Pessoa, s/n, 58220-000 Bananeiras, PB, Brazil

⁶Universidade Federal de Viçosa, Laboratório de Cultura de Tecidos LCTII/BIOAGRO, Departamento de Biologia Vegetal, Av. Peter Henry Rolfs, s/n, Campus Universitário, 36570900 Viçosa, MG, Brazil

Correspondence to: **Marcos V. M. Pinheiro**

E-mail: macvini@gmail.com

Author contributions

Tainara Gris: Contribution to the conception and design of the study, data collection, data analysis and interpretation, scientific writing. Marcos Vinícius Marques Pinheiro: Contribution to the conception and design of the study, data collection, analysis and interpretation of data, scientific writing, and contribution to critical review. Leonardo Antonio Thiesen and Anderson Rafael Webler: Contribution to data collection, contribution to data analysis and interpretation. Diéssica Letícia Junges, Evandro Holz and Iuri Naibo: Contribution to data collection. Diego Silva Batista, Wagner Campos Otoni and Denise Schmidt: Contribution to the preparation of the manuscript, contribution to the critical review, adding intellectual content.





Light sources indoor benefit the growth and development of pepper cultivars

Marcos Vinícius Marques Pinheiro¹ , Maria Inês Diel^{2*}, Oscar Valeriano Sánchez Valera³, Leonardo Antonio Thiesen⁴, Anderson Rafael Webler⁵, Guilherme Masarro-Araujo⁵, Diéssica Leticia Junges⁵, Tainara Gris⁶, Denise Schmidt⁵

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ABSTRACT

Light is a determining factor in plant morphophysiology, as it influences the growth and development of agricultural crops. Thus, the objective was to investigate the effects of light sources on the growth and development of “biquinho” pepper cultivars. The experiment was performed in two stages (Exp1 and Exp2), evaluating two cultivars (BRS Moema; Airetama biquinho) in five light sources (white LEDs, red LEDs, blue LEDs, red/blue LEDs, and fluorescent lamps). In Exp1 the plants were kept in a controlled condition, with a completely randomized design, in a 2x5 factorial scheme (cultivars x light sources) until 76 days after emergence (DAE), in which growth variables and photosynthetic pigments were evaluated. In Exp2, the plants were removed from the above conditions and transplanted in pots, being kept in greenhouse for more 76 DAE. At 152 DAE, the same variables as Exp1 were evaluated, as well as gain of shoot fresh and dry mass, and gain of root fresh and dry mass. In both experiments, growth variables were affected by cultivar and the light sources, however, the behavior did not follow the same trend for all variables, indicating that the light quality influences the growth of the crops, and impacting during greenhouse conditions.

Keywords: *Capsicum chinense*; light quality; light-emitting diodes (LEDs); photosynthetic pigments.

INTRODUCTION

The study of the physiology of plants and their behavior in different environments allowed humans to both select plants and modify their environment to obtain greater productivity and other desired characteristics. However, environmental factors, ie water availability, nutrients and the quality and quantity of light are important for plant growth and development (Guo *et al.*, 2016; Zhang *et al.*, 2019).

Among these environmental factors, light stands out as an important regulator of plant development, morpho-

genesis and physiology, and the quality provided may be able to influence plant productivity. The visible light range, between 400 and 700 nm, is known as photosynthetically active radiation, with the bands of red (600 to 700 nm) and blue (400 to 500 nm) being the ones that most affect photosynthesis, because the molecules of chlorophyll absorb wavelengths in these bands, while the others are usually reflected or transmitted.

Recent innovations in plant growth lighting, particularly through light-emitting diode (LED) technology, allow

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¹ Universidade Estadual do Maranhão, São Luís, Maranhão, Brazil. macvini@gmail.com

² Universidade Federal do Pampa, Itaqui, Rio Grande do Sul, Brazil. mariaines.diel@hotmail.com

³ Instituto Nacional do México, Instituto Tecnológico Superior de Zongolica, Veracruz, Mexico. oscarvalera@itszongolica.edu.mx

⁴ Universidade Federal de Santa Maria, Santa Maria, Rio Grande do Sul, Brazil. thiesen07@hotmail.com

⁵ Universidade Federal de Santa Maria, Frederico Westphalen, Rio Grande do Sul, Brazil. anderson.webler@gmail.com; guilhermemasarroaraujo@gmail.com; diessicajunges@gmail.com; denise@ufsm.br

⁶ Universidade Federal de Santa Catarina, Florianópolis, Santa Catarina, Brazil. tainaragris95@gmail.com

*Corresponding author: mariaines.diel@hotmail.com

for the creation of customized light spectra, bringing spectra into the decision-making process when a grower or researcher is selecting agricultural lighting (Claypool & Lieth, 2020). LEDs have the flexibility to provide specific wavelengths with the possibility of selecting the emission peak that most closely matches the absorption of photo-receptors, and thus faster and more favorable results for researchers and plant producers (Gupta & Jatothu, 2013; Miler *et al.*, 2019). Using light sources based on LEDs it is possible to regulate and control the physiological aspects of plant growth, such as photosynthesis and/or photomorphogenesis (Gupta & Jatothu, 2013).

In addition, the light emitted from the LEDs is an abiotic elicitor capable of being used in plant morphogenesis, as it has high specificity in wavelengths, allowing researchers to eliminate other wavelengths found in white light, and thus study the stimulating them in the architecture of the plant and in the productive responses. The use of light wavelengths promotes different morphogenetic and photosynthetic responses that may vary among plant species (De Hsie *et al.*, 2019), and in terms of plant production, there are only a few applications where a spectrum of pure monochrome light produces good growth results, such as keeping plants compact or retarding plant growth (Miler *et al.*, 2019).

LED lighting technologies for plant cultivation are rapidly evolving, and lamps for indoor cultivation are often designed to optimize their light emissions in the photosynthetically active spectrum (i.e. red and blue), to reduce energetic requirements for satisfactory yield (Pennisi *et al.*, 2020). This technology has been widely used in horticultural facilities in recent years, however, the influence of light quality should be further explored (Yang *et al.*, 2018). Red and blue lights are currently two types of light spectra that have been most studied on plant photobiology (Zhang *et al.*, 2020).

Plants respond differently to each photosynthetic pigment, the quality of light has varying influences on plant growth and development. The red light (660 nm) and the distant red light (730 nm) affect phytochrome, which affects from seed germination to flowering, fruiting and aging (Oren *et al.*, 2021). The blue-violet light (400-490 nm) regulates plant growth through cryptochromes and phototropins, affecting the growth and development of the root system, and plant stem growth (Pedmale *et al.*,

2016). The yellowish-green light (490-550 nm) is also photosynthetically active radiation (Lin *et al.*, 2020). In *Dendranthema grandiflorum* (chrysanthemum) under red LEDs, increased in height and larger internodes, under blue/red LEDs there was largest fresh weight and greater plant growth, and reduced plant growth kept under blue LEDs (Kim *et al.*, 2004). In *Vaccinium corymbosum* the red light promoted greater rooting and elongation of the stem, and the combinations of blue/red LEDs benefited the accumulation of plant biomass *in vitro* (Hung *et al.*, 2016).

The use of far red inside the canopy of tomato plants resulted in stem elongation, difference in leaf morphology, greater length/width ratio of the leaves, largest leaf area and increase of 7 to 12% in the production of ripe fruits (Zhang *et al.*, 2019). In peppers, the effects of LED lights on growth, yield and fruit quality were tested, with an increase in fruit production, in the dry matter content of the fruits and in the content of fruit-promoting compounds in the fruits (i.e. total phenolic content, carotenoid content and antioxidant activities) (Guo *et al.*, 2016).

In *Capsicum annuum*, plant biomass was reduced when the plants remained under red LEDs in the absence of the blue wavelength, producing characteristics such as greater height and greater mass of the stem, suggesting that the plants require supplementary radiation especially in the blue region for the normal growth and development (Brown *et al.*, 1995). Even with these results, the same authors confirm the physiological and morphological effects of the quality of light, and they can vary according to the species. For cultivars of biquinho pepper (*Capsicum chinense*), light spectra were studied during the seed germination process, concluding that the luminous environment in green, red and far red colors positively influence the germination and the amount of abnormal plants was increased in the dark (Diel *et al.*, 2019). For this species, this is the only report, and it is crucial to study the influence of light source on the morphogenesis and physiology of this culture.

Several studies have revealed the effects of light on the biomass of different species, using LEDs of specific wavelengths. For this, the question remains: which band of the light spectrum can influence the morphogenesis of *Capsicum chinense*? The aim of the study was to evaluate the effects of light sources indoor on the morphogenesis (growth and development) of two cultivars of pepper.

MATERIALS AND METHODS

2.1 Study area and growth conditions

The experiment was carried out at the Federal University of Santa Maria UFSM campus Frederico Westphalen - Rio Grande do Sul, Brazil. The geographical location of this region is 27°22'S, 53°25'O at 480 m of altitude. According to the Köppen classification, the region's climate is Cfa, humid subtropical (Alvares *et al.*, 2013).

For the conduct of the experiment, two steps were performed (Experiment I and II), the first was conducted in a growth room with controlled temperature, humidity and light intensity conditions and the second in a greenhouse.

2.2 Experiment I - Does the light source indoor benefit the vegetative process of biquinho pepper cultivars?

2.2.1 Plant material and propagation

Seeds of two cultivars of "biquinho" pepper, *Capsicum chinense*, (BRS Moema and Aretama Biquinho) were used, characterized by red and yellow fruits when ripe, respectively. The seeds were pre-germinated on Gemitex® paper in transparent plastic Gerbox® and kept in a growth chamber (BOD type) at a constant temperature of 25 °C, 12 hours of light and 12 hours of photoperiod with 36 $\mu\text{mol m}^{-2} \text{s}^{-1}$ irradiance from two fluorescent lamps ("Luz do Dia Especial", 40 W, Osram®, Brazil). To break the seed dormancy, KNO_3 solution (2%) was added, following the standards of MAPA (2009), and after about 15 days after emergence (DAE), when 50% of the seeds showed root protrusion, they were transplanted into transparent plastic cups (300 mL) filled with Carolina® commercial substrate.

From the transplant to plastic cups, the seedlings were kept in a growth room, with a temperature of 25 ± 2 °C, a photoperiod of 16 hours of light and eight hours of darkness, with a luminous intensity of 72 $\mu\text{mol m}^{-2} \text{s}^{-1}$ from different light sources: four fluorescent lamps ("Luz do Dia Especial", 40 W, Osram®, Brazil); two tube lamps (TECNAL TECLAMP®, Piracicaba, Brazil) of different colors [white LEDs, red LEDs (660 nm), blue LEDs (450 nm), red/blue LEDs (660 and 450 nm, with a ratio of 60 and 40%, respectively).

The plants were irrigated manually keeping the humidity constant (to avoid water stress), and the plant nutrition was carried out via fertigation, with nutrient solution (200 g 1000 L⁻¹ of HidrogoodFert®, 250 g 1000 L⁻¹ of calcium

nitrate and 15 g 1000 L⁻¹ of iron EDDHA, Yara®), and electrical conductivity of the solution maintained at 600 μS . The plants remained in growth room conditions until the beginning of flowering, which was determined when 50% of the plants in the plot emitted flowers, that is, with 76 DAE.

2.2.2 Experimental design and variables analyzed

The experimental design used was entirely random in a 2 x 5 factorial scheme, with two cultivars of pepper (BRS Moema and Aretama Biquinho) and five light sources (fluorescent lamps, white LEDs, red LEDs, blue LEDs, and red/blue LEDs), totaling ten treatments with four repetitions per treatment, the experimental unit being composed of four plants, totaling 16 plants per treatment.

At 76 DAE and before transplantation (Experiment II) were evaluated: plant height (PH, cm), number of leaves (NL), shoot fresh mass (SFM, g), shoot dry mass (SDM, g), root fresh mass (RFM, g), root dry mass (RDM, g), root volume (RV, mL), root length (RL, cm), leaf area (LA, m²) and photosynthetic pigments [chlorophyll *a* (Chl*a*), chlorophyll *b* (Chl*b*), total chlorophylls (ChlT), carotenoids (Car) and total chlorophyll/carotenoid ratio (ChlT/Car)].

Before transplanting the plants to the pots, half of them were separated for destructive evaluations of Experiment I and the other half for Experiment II, being evaluated at the end of 152 DAE.

The number of leaves and plant height were evaluated from the emission of the first expanded leaf to the first fork in the main stem of the plant. The root volume was calculated immediately after calculating the fresh mass, from the displacement of water in a graduated cylinder after submersion of the root system. The root length was evaluated by measuring the length of the main root (pivoting root).

The leaf area (LA, cm²) was determined using an LA integrator [model Licor LI- 3100 (LI-COR®, Lincoln, Ne, USA)]. For this, all the leaves were separated from the stem of the plants, being passed one by one in the analyzer.

2.3 Experiment II - Mass gains and quality of plants subjected to light source during the vegetative process of cultivars of biquinho pepper

2.3.1 Plant material

At 76 DAE the plants were removed from the growth room conditions and transplanted in black pots (5 L) filled with typical dystrophic Red Latosol soil, and kept in a

greenhouse with a metallic structure in the shape of an arch, 3.5 m high, 10 and 20 m wide and long, covered with plastic film 150 microns thick, remaining for another 76 days, with a total of 152 DAE (fruit ripening; 50% of plants with ripe fruit).

The plants were irrigated manually, always maintaining constant humidity to avoid water stress. For this purpose, the same fertigation solution mentioned above was used, remaining until 152 DAE.

2.3.2 Experimental design and variables analyzed

This experiment was conducted in a randomized block design in a 2 x 5 factorial scheme, with two cultivars of biquinho pepper (BRS Moema and Airetama Biquinho) and plants from five light sources (cited in Experiment I), totaling ten treatments with ten repetitions per treatment, and each repetition composed of a plant.

At 152 DAE, were evaluated: plant height (PH, cm), number of leaves (NL), shoot fresh mass (SFM, g), shoot dry mass (SDM, g), root fresh mass (RFM, g), root dry mass (RDM, g), root volume (RV, mL), root length (RL, cm), photosynthetic pigments [chlorophyll *a* (Chl*a*), chlorophyll *b* (Chl*b*), total chlorophylls (ChlT), carotenoids (Car) and total chlorophyll/carotenoid ratio (ChlT/Car)] and fresh fruit mass (FFM, g) and dry fruit mass (DFM, g). The mass gain was calculated as a percentage for SFM, SDM, RFM, SDM shoot fresh mass (SFM, g), shoot dry mass (SDM, g), root fresh mass (RFM, g) and shoot dry mass (SDM, g), at 76 DAE and 152 DAE (Experiment I and II). That is, during the period between and greenhouse conditions (76 DAE and 152 DAE, respectively), the masses were related, being calculated as a percentage: gain of shoot fresh mass (%), GSFM), gain of shoot dry mass (%), GSDM), gain of root fresh mass (%), GRFM), gain of root dry mass (%), GRDM).

2.3.3 Photosynthetic pigments

To determine photosynthetic pigments (Experiment I and II), chlorophyll *a*, chlorophyll *b*, total chlorophyll and carotenoids, five disks of 5 mm diameter each were obtained from the second green leaf (from the apex to the base) and incubated in glass test tubes containing 5 mL of dimethylsulfoxide (DMSO) saturated with calcium carbonate (CaCO₃), kept in the dark at room temperature for 48 hours, following the modified methodology of Santos *et al.* (2008), totaling four repetitions per treatment. After 48 hours of darkness, absorbance was determined using

the SPERCORD 50/Plus[®] spectrophotometer (Analytik-jena, Germany) using a 10 mm quartz cuvette. Wellburn (1994) methodology was used to establish wavelength and equations to calculate the concentrations of chlorophylls [*a*, *b*, total (*a* + *b*)] and carotenoids and the unit used was in µg cm⁻².

2.4 Statistical analysis

The variables of both experiments (I and II) were subjected to analysis of variance and the treatment means, when significant, were separated by the Tukey test at 5% probability of error. In addition, based on the desired values of the variables studied, the MGIDI index was used to select the best treatments (Olivoto & Nardino, 2020) and were calculated as follows: $MGIDI_i = [\sum_{j=1}^f (\gamma_{ij} - \gamma_j)^2]^{0.5}$, where MGIDI_{*i*} is the multi-trait genotype-ideotype distance index for the *i*th treatment; γ_{ij} is the score of the *i*th treatment in the *j*th factor (*i* = 1; 2; ...; *t*; *j* = 1; 2; ...; *f*), being *t* and *f* the number of treatments and factors, respectively; and γ_j is the *j*th score. Treatments that have the lowest calculated indices are the best. Statistical analyzes were performed with the aid of packages metan (Olivoto & Lúcio, 2020), ggplot2 (Wickham, 2016), ExpDes (Ferreira *et al.*, 2021) available in the R program (R Development Core Team, 2021).

RESULTS

3.1 Experiment I - Light source indoor benefit the vegetative process of biquinho pepper cultivars

From the analysis of variance, there was a significant interaction between cultivars x light sources for the variables PH, NL, SFM, RFM, SDM, RDM and LA. The variables RL and RV were significant only for the cultivars factor, and CR only for light sources. For photosynthetic pigments, there was significant interaction between cultivars x light sources for Chl*a*, Chl*b*, ChlT, Car, ChlT/Car.

The growth variables were affected by both the cultivar and the light sources, in the first stage of the experiment (Figure 1). For the PH variable, the cultivar BRS Moema was superior under blue (15.5 cm) and red LEDs (11.37 cm) but obtained lower averages than Airetama in the fluorescent light source (8.21 cm) (Figure 1A). The same pattern occurred for the variables SFM and SDM (Figure 1C, 1D, respectively). BRS Moema, when kept under LEDs, also obtained higher NL values except for the fluorescent

light source, where NL was higher for the cultivar Airetama (Figure 1B). Differently, RDM presented another behavior when compared to the other variables, with higher averages in the cv. Airetama when grown under Blue LEDs (Figure 1F). For the RFM variable, the inferior performance was observed for the BRS Moema cultivar grown under white

LEDs (Figure 1E).

For the variable RL, the cultivar Airetama had a longer root length when grown under white LEDs (Figure 2A), and shorter when the plants remained under fluorescent and red LEDs (Figure 2C), the same being observed for the variable RV (Figure 2B).

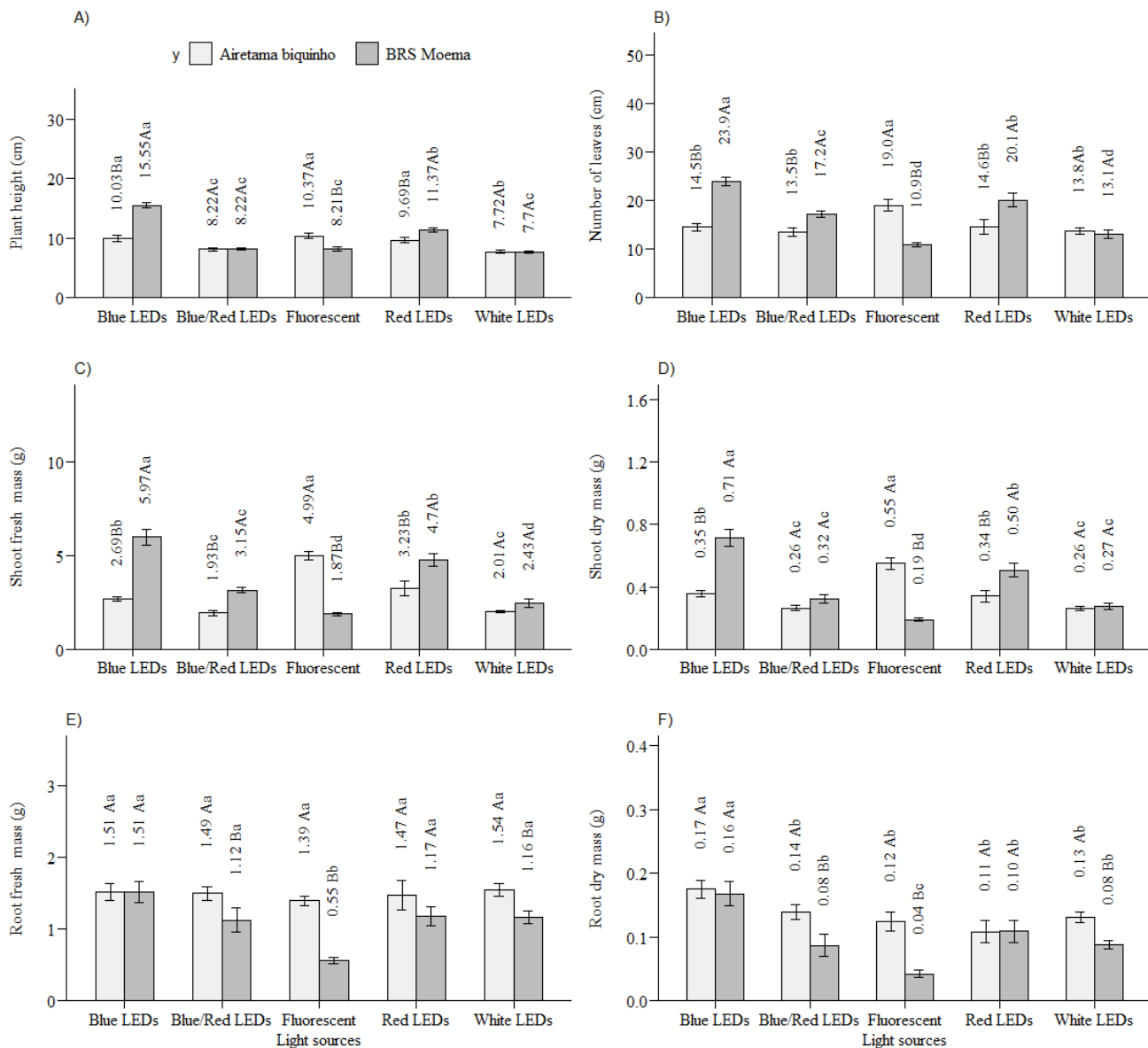


Figure 1: Means of growth variables of biquinho pepper cultivars under different light sources in experiment I: A) plant height (PH, cm), B) number of leaves (NL), C) shoot fresh mass (SFM, g), D) shoot dry mass (RDM, g), E) root fresh mass (SDM, g), F) root dry mass (RDM, g). Lower case letters differ in light sources and upper-case letters differ in cultivars by Tukey's test, at 5% significance.

The cultivar BRS Moema showed superior results of LA when cultivated under blue LEDs and red LEDs. The cultivar Airetama performed better under fluorescent light, while both cultivars showed low performance under the

light sources blue/red LEDs and white LEDs (Figure 3A). For chlorophyll *a* (Chla), the cultivar BRS Moema obtained superior results when cultivated under blue LEDs and blue/red LEDs, and inferior performance under fluorescent light,

in which the cultivar Aretama obtained superior results (Figure 3B). BRS Moema presented superior results of chlorophyll *b* (Chl*b*) under blue LEDs when compared to Aretama, in the other light sources studied, the two cultivars did not present significant differences. The cultivar Aretama did not differ in any of the light sources, while the cultivar BRS Moema obtained a higher Chl*b* content in the blue light source (Figure 3C). Carotenoids showed significant differences between cultivars in the blue/red LED light source, in which BRS Moema was superior to Aretama, and when kept under fluorescent light, the Aretama cultivar was superior to BRS Moema. It was also observed in the light sources in each cultivar, with BRS Moema being superior under blue/red LEDs and Aretama under fluorescent (Figure 3D).

For the variable ChlT, among the cultivars, BRS Moema was significantly superior to Aretama in the blue and blue/red LED light sources, while the cultivar Aretama was superior to BRS Moema in the fluorescent light source, in which it had superior performance when

comparing with all the other light sources studied. BRS Moema had a similar performance when grown under blue, red and blue/red LEDs (Figure 3E). The ChlT/Car ratio showed significant differences between cultivars only under blue LEDs, while within each BRS Moema cultivar it presented a higher ChlT/Car ratio under blue LEDs, and Aretama did not show significant differences between light sources (Figure 3F).

By using the multi-trait index (MGIDI), we selected the 2 best treatments (20%) being T3 (Aretama biquinho and fluorescent light) and T6 (BRS Moema and Blue LEDs), showing the difference in the response of the cultivars in relation to the type of light to which it was submitted (Figure 7A). The two treatments were selected with 90% of the variables with desired values, and only the RV variable did not have the desired selection (SD = -2,35%). Thus, we can say that treatments T3 (Aretama biquinho and fluorescent light) and T6 (BRS Moema and blue LEDs) had a good performance in all analyzed variables, except for RV.

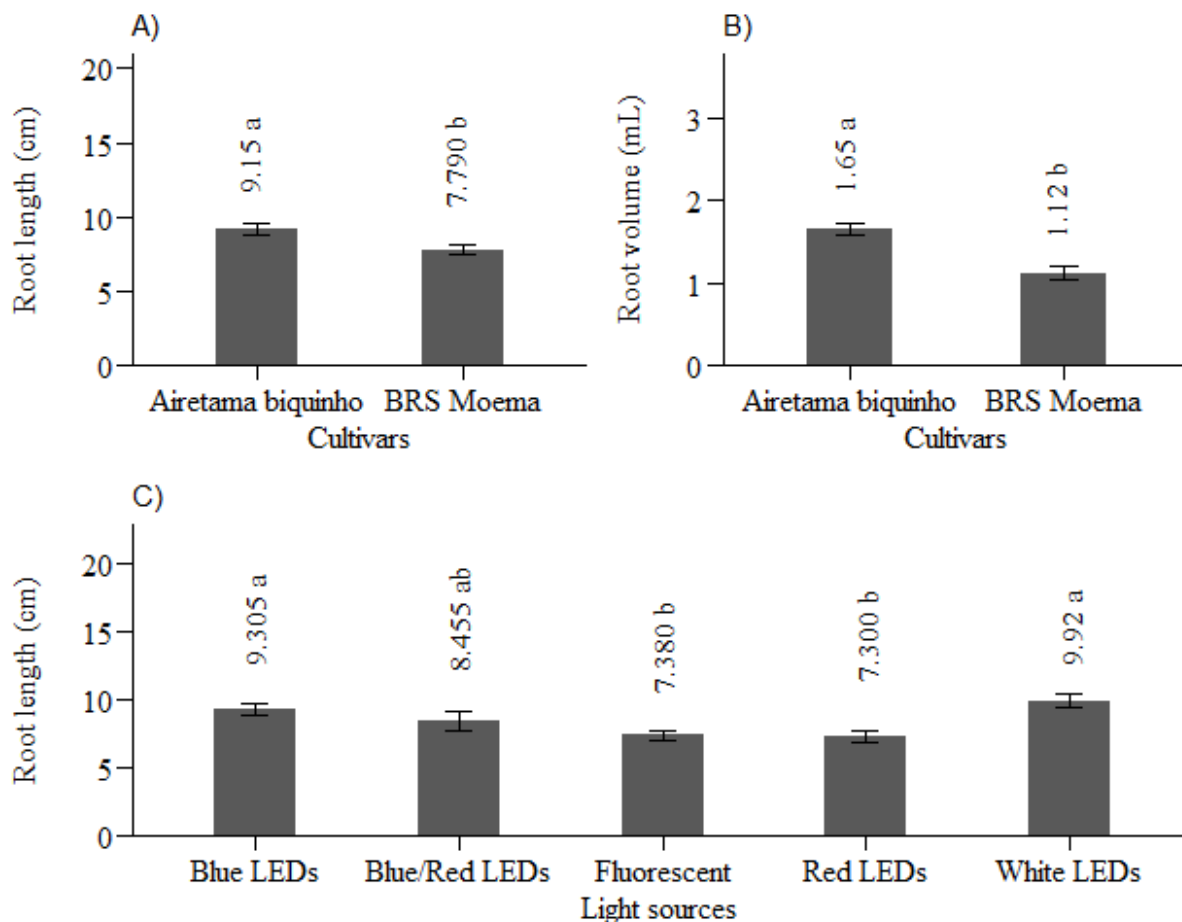


Figure 2: Growth variables (A, C) root length (RL, cm) and (B) root volume (RV, mL) as a function of biquinho pepper cultivars under different light sources in growing room. Lower case letters differ by Tukey's test, at 5% significance.

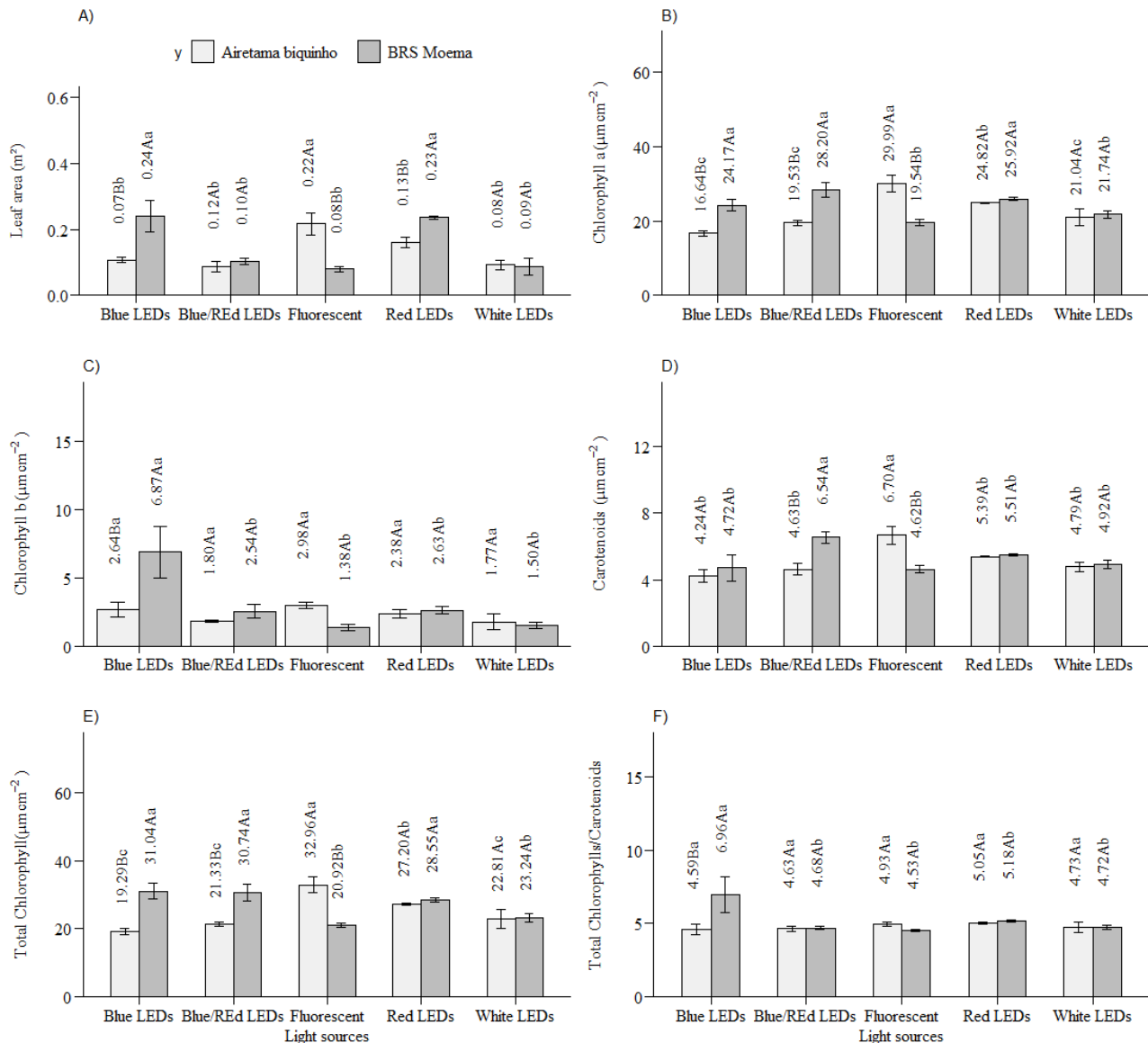


Figure 3: (A) leaf area (LA, m²), (B) chlorophyll *a* (Chl*a*, µm cm⁻²), (C) chlorophyll *b* (Chl*b*, µm cm⁻²), (D) carotenoids (CAR, µm cm⁻²), (E) total chlorophyll content (ChlT, µm cm⁻²), and (F) total chlorophyll/carotenoid ratio (ChlT/Car) of biquinho pepper cultivars grown under different light sources in growing room. Lower case letters differ in light sources and upper-case letters differ in cultivars according to the Tukey's test, at 5% significance.

3.2 Experiment II - Mass gains and quality of plants subjected to light sources during the vegetative process of cultivars of biquinho pepper

From the analysis of variance, it was possible to observe that there was interaction between cultivars x light sources for the growth variables RV, SFM, RSM, RDM. For PH, NL, SDM and RL there was no significant difference. For photosynthetic pigments, there was interaction between cultivars x light sources for the variables Chl*a*, ChlT and Car, whereas for Chl*b* and ChlT/Car ratio there was no

significant effect. For the variables of mass gain (GSFM, GSDM, GRFM, GRDM) there was a significant interaction between cultivar x light sources.

The variable RV, after transplanting the seedlings to pots kept inside the greenhouse, the behavior of the cultivar Aretama was superior to BRS Moema when grown under blue LEDs and red LEDs. In the other light sources, the cultivars did not differ significantly. For each cultivar, Aretama showed superior results when kept under blue LEDs and red LEDs, and the BRS Moema cultivar showed no significant differences for light sources (Figure 4A).

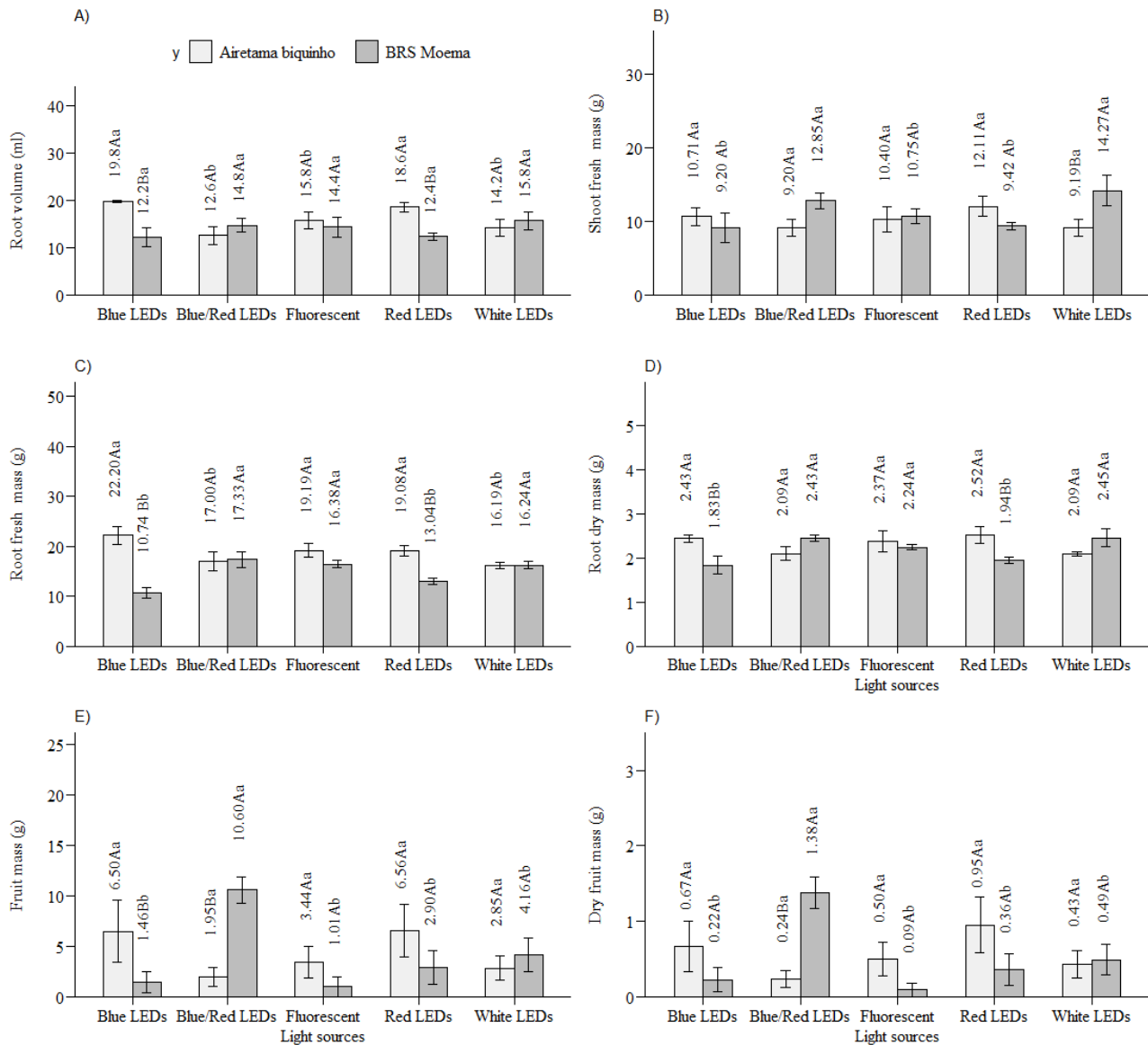


Figure 4: (A) root volume (RV, ml), (B) shoot fresh mass (SFM, g), (C) root fresh mass (g), (RFM, D) root dry mass (RDM, g), (E) fresh fruit mass (FFM, g) and (F) dry fruit mass (DFM, g) of piquet pepper cultivars at 152 DAE in greenhouse. Lower case letters differ in light sources and upper-case letters differ in cultivars according to the Tukey test, at 5% significance.

As for photosynthetic pigments, contrary to what was observed in Experiment I, lower levels of Chl a were observed for the BRS Moema cultivar when comparing Aretama under blue LEDs, however the fluorescent light continued to be the one with the lowest Chl a values of the BRS Moema cultivar (Figure 5A). For Chl T , among cultivars, different from experiment I, Aretama was significantly superior to BRS Moema in blue LEDs and under fluorescent lamps, while the cultivar BRS Moema was significantly superior to Aretama when kept under

red LEDs. Within each cultivar, BRS Moema showed higher Chl T content when the plants were under red and blue/red LEDs. Under blue LEDs, Aretama showed superior performance (Figure 5B). There were significant differences between cultivars for carotenoids, that is, the cultivar Aretama when grown under blue LEDs and fluorescent lamps was superior to BRS Moema, while the latter was significantly superior under red LEDs. Within each cultivar, this variable followed the same trend found for the Chl T variable (Figure 5C). Analyzing the results

obtained, we can infer that each cultivar has different characteristics regarding the production of photosynthetic pigments and in relation to each light source.

The mass gain was significant for all treatments (light sources x cultivar), for 76 days passed from the initial to the final evaluation. For GSFM, the lowest mass gain of the cultivar Airetama was observed in the fluorescent light source (101.4%), while for the cultivar BRS Moema the lowest mass gains were observed under blue LEDs (57.3%) (Figure 6A). For GSFM, the cultivar Airetama had no differences between the light sources, while for the cultivar BRS Moema higher values were observed when they were under fluorescent and white LEDs (1338.3 and 1240.1% respectively). Another important factor was observed for the fluorescent source, which showed low GSDM for the cultivar Airetama (332.6%), while for BRS Moema it was superior (Figure 6B).

For GRFM, the cultivar Airetama did not differ between the light sources evaluated, while for the cultivar BRS Moema, when they were subjected to fluorescent sources, it presented the greatest gains compared to LEDs (2578.3%). In comparison to cultivars within each light source, the differences were also related to gains in cultivation under fluorescent (Figure 6C). The same trend was observed for the GRDM variable, in which the greatest gains were achieved under fluorescent lamps for the cultivar BRS Moema (5213.6%) (Figure 6D).

Regarding the multi-trait index (MGIDI), as in experiment I, the 2 best treatments were also selected (20%) being T1 (Airetama biquinho and blue LEDs) and T3 (Airetama biquinho and fluorescent light), showing the difference in the response of the light used (Figure 7B). The two treatments were selected with 60% of the variables with desired values, and the variables RL, NL, SFM and SDM did not have the desired selection ($SD = -5.3\%$, -9.57% , -2.37% , and -0.56% , respectively). Thus, we can say that treatments T1 (Airetama biquinho and blue LEDs) and T3 (Airetama biquinho and fluorescent light) had a good performance in most of the variables analyzed.

DISCUSSION

This is the first report on the use of light source in the cultivation of *Capsicum chinense* cultivars kept under con-

trolled conditions (Experiment I) and the impact of these on the growth and development of plants in greenhouse cultivation (Experiment II) to infer about the increment and gain of the plants in those conditions.

For most of the variables analyzed, there was an interaction between cultivars x light sources evaluated in the study. It is known that pepper genotypes can respond differently to environmental stimuli, and depending on the environment, they can produce, for example, different amounts of capsaicinoids and have differences in development (Jeeatid *et al.*, 2018).

The cultivars showed different responses to the light sources in which they were submitted. For example, the plant height (PH) of the cultivar BRS Moema was higher when they were associated with blue LEDs and red LEDs. The spectrum of blue and red light also impacted the height of petunia flowers, due to the elongation of the stem, due to the blue light stimulating the production of gibberellins, and thus causing changes in height (Fukuda *et al.*, 2016). However, the wavelengths in blue and red can positively or negatively affect the growth and development of the species, and this is because these wavelengths are responsible for the activation of different genetic expressions in plants (Jeeatid *et al.*, 2018).

For growth variables, plants from cultivar BRS Moema showed superior results when grown under monochromatics blue or red LEDs. In contrast, the cultivar Airetama showed greater growth when cultivated under a source of fluorescent light and white LEDs; this reveals that the responses between genotypes of the same species may be different (Jeeatid *et al.*, 2018), and also demonstrated by MGIDI in Experiment I. Fluorescent lamps commonly applied, generally lack a wavelength in red, which is very important for the development of plants, for example in stem elongation and phytochrome activity, while these lamps emit a lot in the green and yellow light spectra, which are less efficient for plants (Miler *et al.*, 2019). In *Capsicum annuum*, a broad spectrum including red, green, and blue wavelengths resulted in the highest shoot dry weight and plant compactness, and under monochromatic blue LEDs, these authors observed a reduced leaf area under blue LEDs (Claypool & Lieth, 2020); differently from the present work, suggesting that this may be a species-specific response.

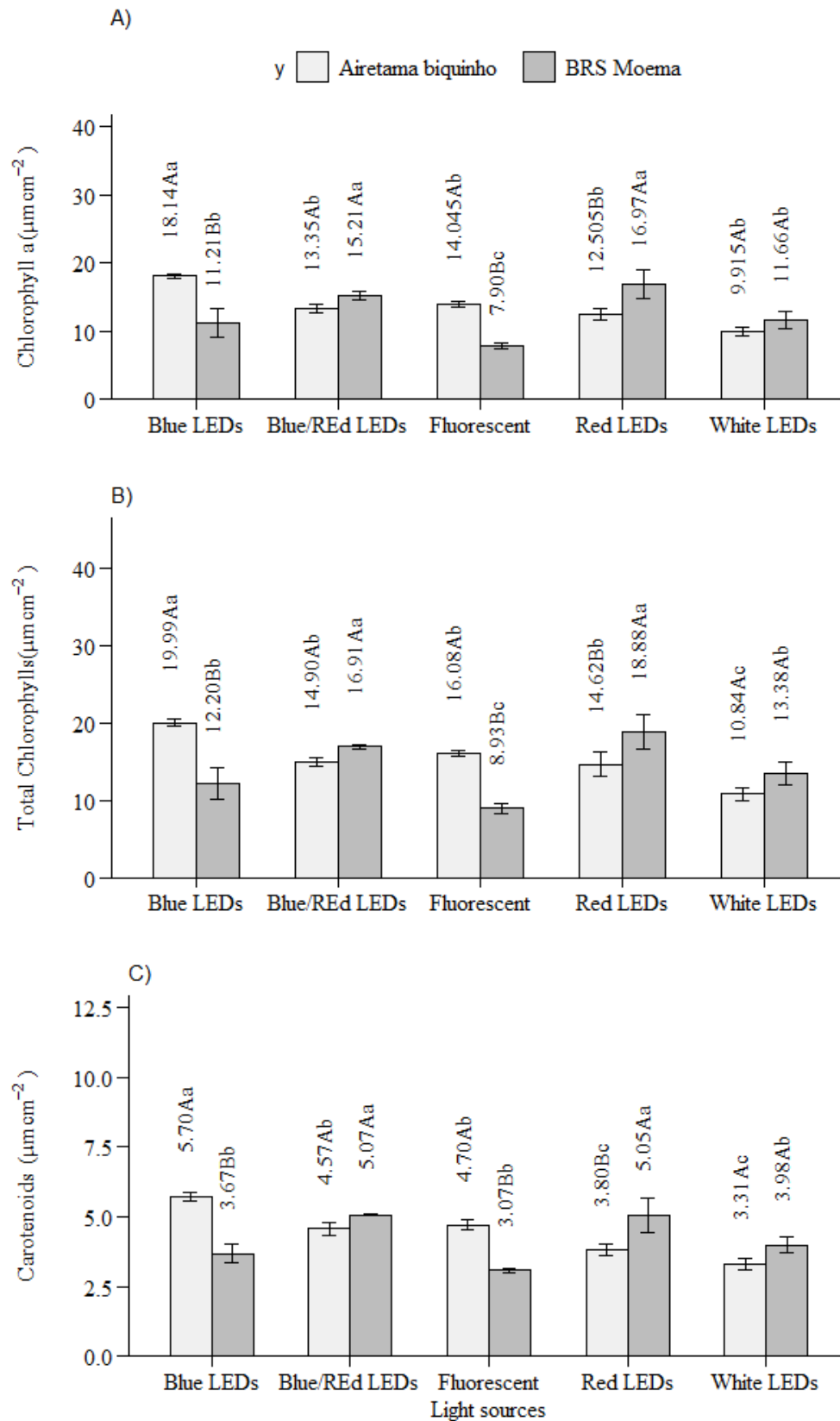


Figure 5: (A) chlorophyll *a* (Chl*a*, $\mu\text{m cm}^{-2}$), B) total chlorophyll (ChlT, $\mu\text{m cm}^{-2}$), C) carotenoids (Car, $\mu\text{m cm}^{-2}$) from biquinho pepper cultivars grown at 152 DAE in greenhouse. Lower case letters differ in light sources and upper-case letters differ in cultivars according to the Tukey's test, at 5% significance.

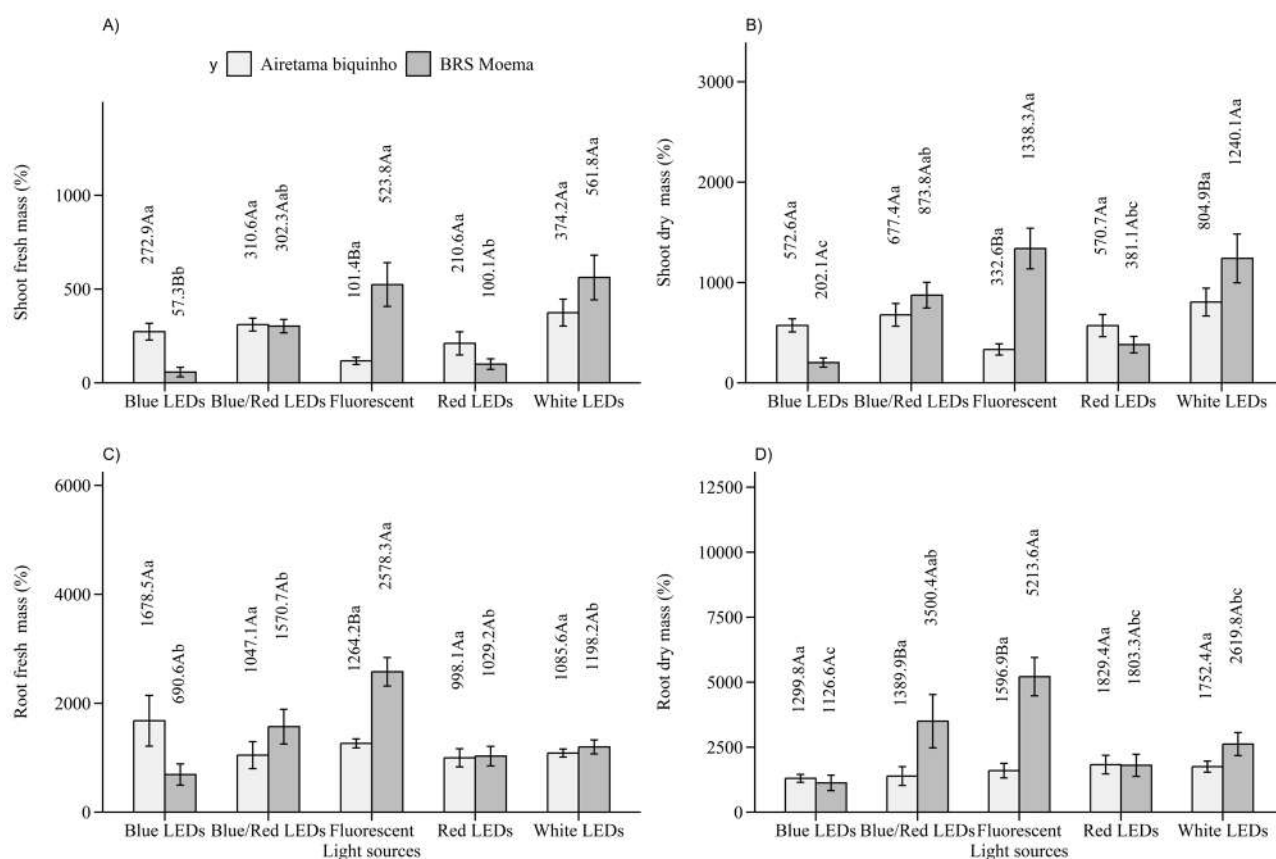


Figure 6: Mass gain as a percentage of 76 DAE to 152 DAE for (A) gain of shoot fresh mass (GSFM, %), (B) gain of shoot dry mass (GSDM, %), (C) gain of root fresh mass (GRFM, %) and (D) gain of root dry mass (GRDM, %) for Airtama and BRS Moema cultivars at 152 DAE in greenhouse. Lower case letters differ in light sources and upper-case letters differ in cultivars according to the Tukey's test, at 5% significance.

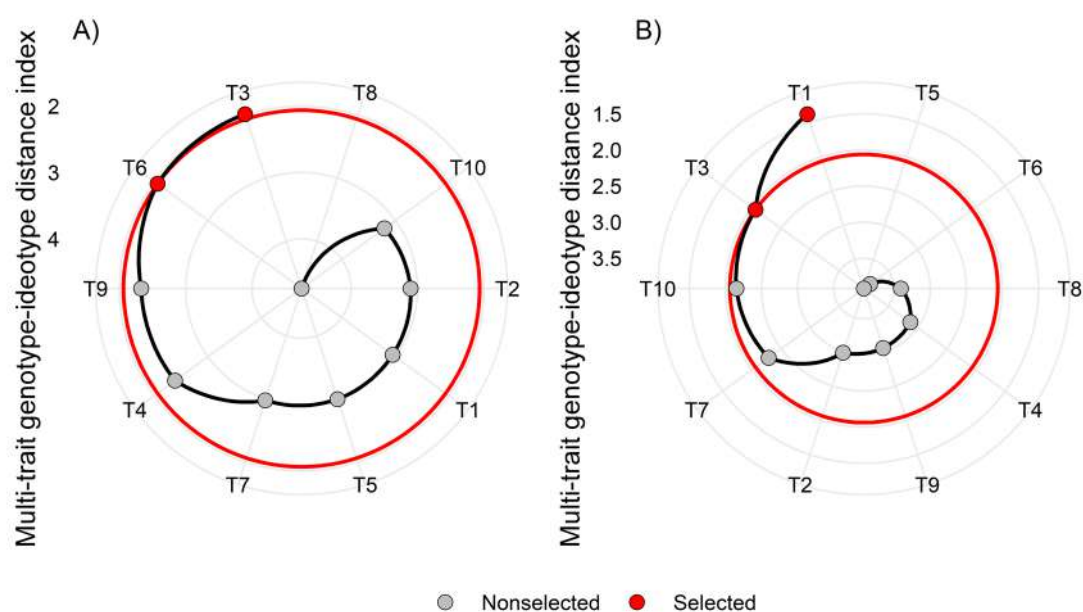


Figure 7: Treatments ranking in ascending order for the MGIDI index. The selected treatments are shown in red color and the red circle represents the cutpoint according to the selection pressure. T1: Airtama biquinho and Blue LEDs, T3: Airtama biquinho and fluorescent light and T6: BRS Moema and Blue LEDs.

Chlorophylls are photosynthetic pigments that absorb light to provide photosynthetic energy to plants (Fang *et al.*, 2022) and contribute to plant vigor due to photosynthetic efficiency (Huang *et al.*, 2013), mainly comprise chlorophyll a (Chl a), chlorophyll b (Chl b) and carotenoids (Car). Chlorophyll (Chl) absorb energy from sunlight and convert the light into chemical energy (Björn, 2015), while carotenoids have the function of collecting light in the range of 450-570 nm and protecting plants against photooxidative damage (Frank & Cogdell, 1996). For photosynthetic pigments, the cultivars showed different responses, while the contents of Chla, Chlb and carotenoids in the cultivar BRS Moema were higher results for the blue, red LEDs and their combination. Shin *et al.* (2008), also observed that pigment biosynthesis was increased in *Doritaenopsis* plants grown with the plus of red and blue LEDs. These same authors report that the use of this mixed red and blue radiation can benefit the quality production of plants. The cultivar Airetama showed higher values of Chla and Chlb for the fluorescent light, in contrast on lettuce (Chen *et al.*, 2014) and *Doritaenopsis* (Shin *et al.*, 2008) both under fluorescent lamps. It is therefore difficult to indicate a single spectrum of light suitable for the propagation of all plant species (Miler *et al.*, 2019), and in the present work, this response was species-specific in many of the analyzed variables.

There was a change in the behavior of BRS Moema plants at 76 DAE, when they were compared to 152 DAE for the variables SFM, RFM e SDM. At 76 DAE, these plants showed superiority when grown under blue LEDs, however, at 152 DAE, this result changed, with those grown under fluorescent and white LEDs with greater increment; suggesting that plant growth responses to light quality may not only be associated with species or cultivars, but also the plant growth stages (Chen *et al.*, 2014).

The use of artificial lighting has a positive effect on the growth and development of the biquinho pepper cultivars, proven by the gain of differential biomass between them. The greatest gains of SFM and SDM for BRS Moema cultivar were under fluorescent and white LEDs, for the variables RFM and RDM the greatest gains were observed in the fluorescent. The cultivar Airetama showed no differences ($p > 0.05$) for mass gain in different light sources.

The increase gains attributed to the fluorescent and white LEDs in the period; may be related to the phase in which the plant is at the moment (Chen *et al.*, 2014). In contrast, Ajdanian *et al.* (2019), observed superiority with the application of blue and red light, as there was an increase in fresh and dry masses of cress (*Lepidium sativum*), as well as their biomass compared to plants grown under natural sunlight conditions.

Due to the large number of treatments tested (2 cultivars and 5 light sources = 10 treatments) it can be difficult to select the treatments that present the greatest selection differential, that is, desired characteristics. Using MGIDI we have the possibility to find the best treatments in a simple way and based on a multitrait framework (Olivoto & Nardino, 2020).

Light is an important signal element that regulates plant morphology, physiology and development during the plant growth cycle (Chen *et al.*, 2014), and the application of different light sources and their effects on plants is positive, as they result in the improvement of the biochemical characteristics and stimulates the use of these light sources in an effort to increase the quality of the plant and understand biochemically what happens with this application, and how it influences plant morphology. And this is only possible due to advances in technology, in which they must be constantly updated, and simultaneously stimulates the use of these in new studies and applications by researchers worldwide, and can also be used as allies in future plant production.

CONCLUSIONS

The results of the present study indicate that the light sources emitted in part of the growth of the plants becomes crucial during greenhouse conditions when these plants were transferred to soil. The treatments selected under greenhouse conditions are T3 (Airetama biquinho and fluorescent light) and T6 (BRS Moema and Blue LEDs) and in field conditions T1(Airetama biquinho and Blue LEDs) and T3 (Airetama biquinho and fluorescent light). Our discovery achieved the proposed objective, demonstrating that the use of LEDs is effective in the development and more vigorous growth of *Capsicum chinense*, and that this response is dependent cultivar.

ACKNOWLEDGMENTS FINANCIAL SUPPORT AND FULL DISCLOSURE

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CONFLICT OF INTERESTS

There is no conflict of interests in carrying this research and publishing this manuscript.

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**Tipos e concentrações de auxinas no enraizamento *ex vitro* de mirtilheiro
'Woodard'****Types and concentrations of auxins in the *ex vitro* rooting of 'Woodard'
mirtiller**

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Bruna Andressa dos Santos OliveiraDoutoranda em Sistemas de Produção Agrícola Familiar pela Faculdade de Agronomia
Eliseu Maciel

Instituição: Universidade Federal de Pelotas

Endereço: Universidade Federal de Pelotas, Faculdade de Agronomia Eliseu Maciel.
Campus da Universidade Federal de Pelotas - Centro - 96010900 - Pelotas, RS - Brasil -
Caixa-postal: 354

E-mail: brunah.andressa@gmail.com

Patricia Maciejewski

Doutoranda em Agronomia pela Faculdade de Agronomia Eliseu Maciel

Instituição: Universidade Federal de Pelotas

Endereço: Universidade Federal de Pelotas, Faculdade de Agronomia Eliseu Maciel.
Campus da Universidade Federal de Pelotas – Centro - 96010900 - Pelotas, RS - Brasil -
Caixa-postal: 354

E-mail: pmaciejewski0111@gmail.com

Aline Ramm

Doutoranda em Agronomia pela Faculdade de Agronomia Eliseu Maciel

Instituição: Universidade Federal de Pelotas

Endereço: Universidade Federal de Pelotas, Faculdade de Agronomia Eliseu Maciel.
Campus da Universidade Federal de Pelotas – Centro - 96010900 - Pelotas, RS - Brasil -
Caixa-postal: 354

E-mail: alineramm@yahoo.com.br

Dianini Brüm Frölech

Doutorando em Agronomia pela Faculdade de Agronomia Eliseu Maciel

Instituição: Universidade Federal de Pelotas

Endereço: Universidade Federal de Pelotas, Faculdade de Agronomia Eliseu Maciel.
Campus da Universidade Federal de Pelotas – Centro - 96010900 - Pelotas, RS - Brasil -
Caixa-postal: 354

E-mail: dianinifrolech.enologia@gmail.com

Marilaine Garcia de Mattos

Mestre em Agronomia pela Faculdade de Agronomia Eliseu Maciel

Instituição: Universidade Federal de Pelotas

Endereço: Universidade Federal de Pelotas, Faculdade de Agronomia Eliseu Maciel.
Campus da Universidade Federal de Pelotas – Centro - 96010900 - Pelotas, RS - Brasil -
Caixa-postal: 354
E-mail: marimattos1@outlook.com

Tainara Gris

Mestre em Agronomia pela Faculdade de Agronomia Eliseu Maciel
Instituição: Universidade Federal de Pelotas
Endereço: Universidade Federal de Pelotas, Faculdade de Agronomia Eliseu Maciel.
Campus da Universidade Federal de Pelotas – Centro - 96010900 - Pelotas, RS - Brasil -
Caixa-postal: 354
E-mail: tainaragris95@gmail.com

Adriane Marinho de Assis

Doutora em Agronomia pela Universidade Estadual de Londrina.
Instituição: Universidade Federal de Pelotas
Endereço: Universidade Federal de Pelotas, Faculdade de Agronomia Eliseu Maciel.
Campus da Universidade Federal de Pelotas – Centro - 96010900 - Pelotas, RS - Brasil -
Caixa-postal: 354
E-mail: agroadri17@gmail.com

Márcia Wulff Schuch

Doutorado em Agronomia pela Faculdade de Agronomia Eliseu Maciel
Instituição: Universidade Federal de Pelotas
Endereço: Universidade Federal de Pelotas, Faculdade de Agronomia Eliseu Maciel.
Campus da Universidade Federal de Pelotas – Centro - 96010900 - Pelotas, RS - Brasil -
Caixa-postal: 354
E-mail: marciaws@hotmail.com

RESUMO

Na micropropagação do mirtilheiro (*Vaccinium* sp.) a realização da etapa de enraizamento *ex vitro* (ao invés de *in vitro*) poderá representar uma alternativa para a redução dos custos de produção das mudas. Diante disso, o objetivo deste trabalho foi avaliar o efeito de concentrações das auxinas ácido indolbutírico (AIB) e ácido naftaleno-acético (ANA) no enraizamento *ex vitro* de mirtilheiro 'Woodard'. O delineamento experimental foi o inteiramente casualizado, em esquema bifatorial (dois tipos (AIB; ANA) e quatro concentrações (0; 0,2; 0,4 e 0,6 mg L⁻¹) **de auxina**), totalizando oito tratamentos e quatro repetições, sendo cada repetição constituída de uma bandeja Sanpack® com 15 microestacas. Aos 60 dias avaliou-se: sobrevivência, porcentagem de enraizamento, número de raízes, comprimento da maior raiz e massa de matéria seca das raízes. Para a sobrevivência, não houve influência da aplicação das auxinas, verificando-se alta eficiência (100%). Da mesma forma foi verificado para a porcentagem de enraizamento das microestacas. Para o número de raízes, a maior média foi observada no tratamento com o uso de AIB, quando utilizado a concentração 0,2 mg L⁻¹; não diferindo da concentração 0,6 mg L⁻¹. O comprimento da maior raiz, apresentou as maiores médias quanto utilizado AIB. Para a massa de matéria seca das raízes, o tratamento sem a utilização das auxinas apresentou a maior massa; entretanto, não diferiu dos tratamentos com a utilização de AIB. Assim, o enraizamento *ex vitro* de mirtilheiro 'Woodard' pode ser realizado sem o uso das auxinas ácido indolbutírico e ácido naftaleno-acético.

Palavras chaves: *Vaccinium* sp. Micropropagação. Regulador de Crescimento. Pequenas frutas.

ABSTRACT

In the blueberry (*Vaccinium* sp.) Micropropagation, the *ex vitro* rooting step (instead of *in vitro*) may represent an alternative to reduce seedling production costs. Therefore, the objective of this work was to evaluate the effect of concentrations of auxins indolbutyric acid (AIB) and naphthalene-acetic acid (ANA) on the *ex vitro* rooting of blueberry 'Woodard'. The experimental design was completely randomized, in a bifactorial scheme (two types (AIB; ANA) and four concentrations (0; 0.2; 0.4 and 0.6 mg L⁻¹) of auxin), totaling eight treatments and four repetitions, each repetition consisting of a Sanpack® tray with 15 micropiles. At 60 days it was evaluated: survival, percentage of rooting, number of roots, length of the largest root and root dry matter. For survival, there was no influence of the application of auxins, with high efficiency (100%). Likewise it was verified for the percentage of rooting of the microcuttings. For the number of roots, the highest average was observed in the treatment with the use of IBA, when using the concentration 0.2 mg L⁻¹; not differing from the 0.6 mg L⁻¹ concentration. The length of the largest root showed the highest averages when using IBA. For the dry matter mass of the roots, the treatment without the use of auxins showed the highest mass; however, it did not differ from treatments with the use of IBA. Thus, the *ex vitro* rooting of blueberry 'Woodard' can be performed without the use of auxins indolbutyric acid and naphthalene-acetic acid.

Keywords: *Vaccinium* sp. Micropropagation. Growth Regulator. Small fruits.

1 INTRODUÇÃO

Dentre as pequenas frutas o mirtilheiro (*Vaccinium* spp.) é uma das culturas mais promissoras para o cultivo na região sul do Brasil, devido às condições edafoclimáticas favoráveis à adaptação de várias cultivares, além de ser muito apreciado pelo sabor exótico e valor econômico, além da ampla divulgação dos frutos como fonte da longevidade (SHARPE, 1980; RUFATO; ANTUNES, 2016).

No Brasil essa cultura encontra-se em fase de desenvolvimento, ocasião em que se busca um sistema de produção eficiente e competitivo para inserir o país no rol dos grandes produtores mundiais (RUFATO; ANTUNES, 2016). Assim, um dos fatores primordiais para o sucesso no cultivo é a utilização de mudas de qualidade (OLIVEIRA, 2020).

Uma opção para aumentar a disponibilidade de mudas dessa frutífera é a micropropagação (DAMIANI; SCHUCH, 2009). Essa técnica possibilita, além da produção de grande quantidade de plantas em curto período de tempo, a obtenção de plantas livres de doenças e a propagação de espécies difíceis de serem multiplicadas por outros métodos (GRATTAPAGLIA; MACHADO, 1998). Por outro lado, implica em elevados custos na produção comercial de mudas (KODYM; ZAPATA-ARIAS, 1998).

Visando a redução nos custos da muda micropropagada, o enraizamento *ex vitro* das plântulas apresenta-se como alternativa, pois de acordo com Pedrotti e Voltolini (2001), propicia a diminuição de 50% do preço final da muda, comparativamente ao uso do enraizamento *in vitro*.

No enraizamento *ex vitro* as partes aéreas dos explantes são manipulados como microestacas e todo o processo de enraizamento é feito em substrato. Segundo Grattapaglia e Machado (1998), a regeneração de raízes diretamente no substrato produz um sistema radicular funcional e com maior número de raízes secundárias.

Para promover o enraizamento em estacas de espécies frutíferas auxinas como ácido indolbutírico e ácido naftaleno-acético em aplicação exógena mostram-se bastante eficientes (FACHINELLO et al., 2005). Porém, a resposta da planta à auxina varia tanto com a natureza do tecido, época do ano e condições fisiológicas da planta e da estaca, quanto com a concentração (XAVIER et al., 2009).

Alguns estudos com enraizamento *ex vitro* e uso de reguladores de crescimento foram realizados com amoreira-preta (*Rubus* sp.) 'Xavante' (PELIZZA et al., 2013); amoreira-preta 'Brazos' (AUGUSTO et al., 2006); porta-enxerto de macieira (*Malus pumilla*) M.9 (PEDROTTI; VOLTOLINI, 2001); abacaxizeiro (*Ananas comosus*) (DIAS et al., 2010); erva-mate (*Ilex paraguariensis* A. St Hil.) (TRONCO et al., 2015). Entretanto, são escassas as informações a respeito do uso desta técnica em mirtilheiro, o que ressalta a necessidade de estudos, que poderão contribuir com avanços na micropropagação dessa frutífera.

Nesse sentido, o presente trabalho teve como objetivo avaliar o efeito de diferentes concentrações das auxinas ácido indolbutírico e ácido naftaleno-acético no enraizamento *ex vitro* de mirtilheiro 'Woodard'.

2 METODOLOGIA

O experimento foi realizado no período de setembro a novembro de 2018, no Laboratório de Propagação de Plantas Frutíferas, pertencente ao do Departamento de Fitotecnia, da Faculdade de Agronomia Eliseu Maciel, da Universidade Federal de Pelotas (UFPel/RS), localizada no município Capão do Leão-RS.

O delineamento experimental foi o inteiramente casualizado, em esquema bifatorial, sendo os fatores: tipos de auxina (ácido indolbutírico (AIB) e ácido naftaleno-acético (ANA)) e concentrações (0; 0,2; 0,4 e 0,6 mg L⁻¹), totalizando oito tratamentos, com quatro repetições,

sendo cada repetição constituída de uma embalagem plástica transparente e articulada Sampack® (22x14x10 cm) com 15 microestacas cada.

Foram utilizadas microestacas provenientes do cultivo *in vitro* de mudas de mirtilheiro ‘Woodard’, medindo 2,5 de comprimento com sete gemas, sete folhas e ápice caulinar, mantidas em meio de cultura WPM (Wood Plant Media - LOYD; McCOWN, 1980). Aos 60 dias após a multiplicação *in vitro* as plantas foram retiradas dos frascos, lavadas em água corrente para a limpeza do meio de cultivo e, em seguida, o sistema radicular foi imerso nos reguladores de crescimento e concentrações, conforme o tratamento.

Em seguida, as microestacas foram acondicionadas nas embalagens transparentes e articuladas Sanpack®, contendo um litro vermiculita média expandida, sendo previamente hidratadas com 500 mL de água destilada. Após, foram mantidas em casa de vegetação com temperatura controlada a $25\pm 2^{\circ}\text{C}$ e luminosidade natural. Durante o enraizamento, sempre que necessário, procedeu-se a rega com 25 mL de água destilada, com o auxílio de um pulverizador manual Tramontina®, mantendo-se as embalagens fechadas para evitar a desidratação.

Após 60 dias as variáveis avaliadas foram: sobrevivência (%), enraizamento, número de raízes, comprimento da maior raiz (cm) e massa de matéria seca das raízes (g). Para o comprimento médio das raízes utilizou-se régua graduada. Quanto a obtenção da massa de matéria seca, o material foi mantido em estufa com ventilação forçada a 50°C até a obtenção de peso constante e, após, pesado em uma balança digital analítica.

Os dados foram submetidos à análise de variância e as médias comparadas pelo teste de Tukey a 5% de probabilidade.

3 RESULTADOS E DISCUSSÃO

Em relação a variável sobrevivência foi constatada 100%, ou seja, todos os explantes sobreviveram, independente do tratamento. Em trabalho realizado sobre o enraizamento *ex vitro* de mirtilheiro, Pelizza (2009) verificou resultados semelhantes a este trabalho, em que ‘Bluebelle’ e ‘Woodard’ apresentaram 99,4 e 100% de sobrevivência, respectivamente. Para Oliveira (2020), a porcentagem de sobrevivência pode interferir na rentabilidade do produtor, visto que está relacionada com a quantidade de mudas a ser comercializada.

Avaliando o enraizamento, não houve significância estatística entre os tipos de auxina e suas concentrações, verificando-se 100 %, ou seja, alta eficiência no enraizamento das microestacas de mirtilheiro ‘Woodard’ (Tabela 1).

Tabela 1 – Porcentagem de enraizamento (%), comprimento médio de raiz (cm) e massa seca das raízes (g), de plantas de mirtilheiro 'Woodard' aos 60 dias após o transplante, em função dos tipos e concentrações de auxina.

Pelotas-RS, 2019.

Tipo de auxina	Concentrações (mg.L ⁻¹)			
	0	0,2	0,4	0,6
	Sobrevivência (%)			
AIB	100 ^{NS}	100	100	100
ANA	100	100	100	100
C.V. (%)	0			
	Porcentagem de enraizamento (%)			
AIB	100 ^{NS}	100	100	100
ANA	100	100	100	100
C.V. (%)	0			
	Número de raízes			
AIB	3,52 abA	4,35 aA	3,87 abA	4,10 aA
ANA	3,05 bB	3,47 abB	3,42 abB	3,65 abB
C.V. (%)	10,84			
	Comprimento da maior raiz (cm)			
AIB	4,58 ^{NS} A	4,39 A	4,01 A	4,06 A
ANA	3,90 B	3,83 B	3,54 B	3,57 B
C.V. (%)	20,01			
	Massa de matéria seca da raiz (g)			
AIB	0,18 aA	0,11 abA	0,10 bA	0,10 bA
ANA	0,09 bB	0,09 bB	0,08 bB	0,10 bA
C.V. (%)	30,87			

^{1/} Médias seguidas pela mesma letra minúscula na linha e maiúscula na coluna não diferem entre si pelo teste Tukey ($p \geq 0,05$). C.V: coeficiente de variação. ^{NS}: não significativo.

Pelizza (2009), verificou resultados semelhantes no enraizamento *ex vitro* de mirtilheiro 'Bluebelle' com a utilização de AIB na concentração de 250 mg L⁻¹, obtendo porcentagem de enraizamento de 98,7%.

Segundo Damiani e Schuch (2009), o desenvolvimento de um sistema de enraizamento mais eficiente resulta em mudas com maior qualidade fisiológica e diminuição de perdas durante a fase de aclimatização. Entretanto, pode sofrer interferência de vários fatores, entre eles destacam-se: estado nutricional das plantas, época do ano, taxa de respiração e fotossíntese, bem como a relação carbono/nitrogênio (KRAMER; KOZLOWSKI, 1972).

Para as variáveis número de raízes, comprimento da maior raiz e massa de matéria seca da maior raiz observou-se interação entre os fatores de estudo (Tabela 1).

Quanto ao número de raízes, comparando os tipos de auxina em relação as concentrações, a maior média foi observada no tratamento com o uso de AIB, quando utilizado a concentração $0,2 \text{ mg L}^{-1}$, não diferindo da concentração $0,6 \text{ mg L}^{-1}$.

Os resultados obtidos no presente estudo foram superiores aos observados por Pelizza (2009), que avaliando o enraizamento *ex vitro* de mirtilheiro 'Bluebelle' observou o maior número de raízes (2,97) quando utilizou 250 mg L^{-1} de AIB e substrato vermiculita. De acordo com Sorace et al. (2007), a quantidade de raízes interfere na absorção de água e nutrientes; e consequentemente, pode promover maior desenvolvimento vegetativo.

Em relação ao comprimento da maior raiz, os tratamentos com o uso do AIB propiciaram as maiores médias em relação a ANA. Entre as concentrações, não houve significância estatística para ambas as auxinas (Tabela 1). Segundo Hartman et al. (2002), o uso do AIB estimula as plantas a produzirem raízes maiores e mais fibrosas. Aliado ao uso de auxina, o substrato utilizado no presente trabalho pode ter contribuído para tal resultado.

Martins et al. (2009), descreveram que a vermiculita apresenta vantagens como: fácil obtenção, baixa densidade, uniformidade na composição química e granulométrica, porosidade e capacidade de retenção de água. Em trabalho realizado por Pelizza (2009), avaliando diferentes cultivares de mirtilo, este substrato proporcionou melhores resultados quanto ao comprimento da maior raiz.

Quanto a massa de matéria seca das raízes, ao compararmos os tipos de auxina para cada concentração, o tratamento sem a utilização dos reguladores de crescimento apresentou a maior massa; entretanto, não diferiu dos tratamentos com a utilização de AIB (Tabela 1). Quando comparadas as concentrações, a maior média foi obtida sem o uso do regulador; porém, não diferiu da concentração $0,2 \text{ mg L}^{-1}$ de AIB.

Pelizza (2009), em experimento sobre o enraizamento *ex vitro* de mirtilheiro observou a maior massa quando utilizado 250 mg L^{-1} de AIB e substrato vermiculita para as cultivares Bluebelle e Woodard. De acordo com Tavares et al. (1995), o maior número, comprimento e massa de matéria seca de raízes favorecem o desenvolvimento das plantas e, consequentemente, a qualidade das mudas formadas.

Diante do exposto, o enraizamento *ex vitro* de mirtilheiro 'Woodard' pode ser realizado sem a utilização das auxinas AIB e ANA nas concentrações testadas. Tal fato poderá contribuir na redução no custo de produção das mudas, principalmente em escala comercial, pois além do enraizamento *ex vitro* reduzir o tempo de permanência das mesmas no

laboratório, não será necessário adquirir esses reguladores de crescimento e não haverá demanda de mão de obra para o preparo dos mesmos.

4 CONCLUSÃO

O enraizamento *ex vitro* de mirtileiro 'Woodard' pode ser realizado sem o uso das auxinas ácido indolbutírico e ácido naftaleno-acético.

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Utilização de ácidos húmicos na multiplicação *in vitro* de framboeseira 'Schönemann'

Tainara Gris^{1*}, Eliane Lima de Aquino¹, Mariana Salbego de Franco¹, Zeni Fonseca Pinto Tomaz², Adriane Marinho de Assis³, Marcia Wulf Schuch³

¹UFPEL – Universidade Federal de Pelotas, acadêmico de Pós-graduação (PPGA/FAEM/UFPE), tainaragris95@gmail.com, ²bolsista (PNPD/PPGA/FAEM), ³Professor Universitário/Pesquisador (PQ/FAEM/UFPE). Caixa Postal 354, CEP 96010-900 Pelotas, Rio Grande do Sul/Brasil

Palavras Chave: bioestimulante, pequenas frutas, micropropagação

Introdução

A crescente demanda por frutas e a expansão do cultivo da framboesa requer a obtenção de plantas com maior qualidade para implantação e renovação dos pomares, logo, a formação de mudas pela técnica de micropropagação *in vitro* é viável e permite a produção e multiplicação rápida de espécies, gerando material vegetal uniforme, em larga escala e livre de doenças (Maro et al., 2014).

Entre os vários tipos de matéria orgânica do solo, as substâncias húmicas desempenham papéis importantes na fixação e transporte de nitrogênio, fósforo e minerais, e geralmente exercem um efeito positivo sobre o crescimento das plantas com atividade bioestimulante (Tan et al., 2014).

Com isso o objetivo do presente trabalho foi avaliar o comportamento da framboeseira 'Schönemann' na etapa de multiplicação *in vitro* com adição de doses de ácidos húmicos ao meio de cultura.

Material e Métodos

O experimento foi conduzido no Laboratório de Propagação de Plantas Frutíferas da Universidade Federal de Pelotas. O delineamento utilizado foi o inteiramente casualizado (DIC). Os tratamentos consistiram em quatro níveis de concentração de ácidos húmicos (AH) – SoloHúmics® no meio de cultura sendo elas (0 mg L⁻¹ AH + 0,8 mg L⁻¹ BAP; 1 mg L⁻¹ AH + 0,8 mg L⁻¹ BAP; 2 mg L⁻¹ AH + 0,8 mg L⁻¹ BAP; 3 mg L⁻¹ AH + 0,8 mg L⁻¹ BAP). Em condições de câmara de fluxo laminar cinco explantes de framboeseira 'Schönemann' foram inoculados em frascos de vidro contendo 50 mL de meio de cultura MS (Murashige & Skoog, 1962) acrescido de 100 mg L⁻¹ de mio-inositol, 30 g L⁻¹ de sacarose, geleificado com 6,0 g L⁻¹ de ágar e pH ajustado para 5,7 ± 0,1 anteriormente à autoclavagem a 120°C, 108 kPa, durante 15 minutos. Os explantes foram mantidos durante 60 dias em condições de sala de crescimento com fotoperíodo de 16 horas, temperatura de 25 ± 2°C. Foram avaliados dados de matéria fresca (MF) e matéria seca (MS). Os dados foram submetidos à análise de variância e à análise de médias pelo teste tukey a 5% de probabilidade de erro.

Resultados e Discussão

As doses apresentaram diferentes potenciais na variável matéria fresca com diferença significativa para o tratamento de 2mgL⁻¹AH+0,8mgL⁻¹BAP.

Os efeitos mais relatados dos ácidos húmicos, nas plantas, estão relacionados com o sistema radicular e envolvem a formação de raízes, aumentando a sua massa e área de superfície, o que contribui para a maior absorção de água e de nutrientes (Eyheraguibel et al., 2008), o que pode explicar o resultado do presente onde a variável matéria seca não teve diferença estatística entre os tratamentos, com grande perda de água durante a secagem em estufa.

Tabela 1. Matéria fresca e seca de framboeseira 'Schönemann' submetida a diferentes doses de ácidos húmicos na etapa de multiplicação *in vitro*.

Tratamentos	Matéria fresca	Matéria seca
0mgL ⁻¹ AH+0,8mgL ⁻¹ BAP	1.47 b*	0.37a ^{ns}
1mgL ⁻¹ AH+0,8mgL ⁻¹ BAP	1.80ab	0.26a
2mgL ⁻¹ AH+0,8mgL ⁻¹ BAP	2.83a	0.37a
3mgL ⁻¹ AH+0,8mgL ⁻¹ BAP	1.46 b	0.24a
CV(%)	22,67	25,49

*Significativo a 5% de probabilidade pelo teste de F. Médias seguidas por letras diferentes na coluna diferem entre si, pelo teste de Tukey, a 5% de probabilidade. ^{ns} não significativo.

Conclusões

A utilização de ácidos húmicos aliado ao regulador de crescimento proporcionou aumento da matéria fresca de plantas de framboeseira 'Schönemann' na dose de 2mgL⁻¹AH.

Agradecimentos

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Qualidade de luz e 2iP na multiplicação *in vitro* de mirtilheiro 'Bluecrop'

Eliane L. de Aquino¹, Tainara Gris², Márcia W. Schuch³, Adriane M. de Assis⁴

¹UFPel/PPGA (PG). Faculdade de Agronomia Eliseu Maciel, Campus Capão do Leão, 96010-900, Pelotas –RS. eliane.laquino@gmail.com; ²UFPel/PPGA (PG). Faculdade de Agronomia Eliseu Maciel, Campus Capão do Leão, 96010-900, Pelotas –RS; ³UFPel (PQ). Faculdade de Agronomia Eliseu Maciel, Campus Capão do Leão, 96010-900, Pelotas –RS; ⁴UFPel (PQ). Faculdade de Agronomia Eliseu Maciel, Campus Capão do Leão, 96010-900, Pelotas –RS.

Palavras Chave: Micropropagação, *Vaccinium* sp., qualidade espectral, cultivo *in vitro*.

Introdução

Dentre os fatores que interferem no sucesso da micropropagação de espécies frutíferas está a qualidade da luz que incide sobre as plântulas e a presença de fitorreguladores no meio de cultura. Assim, o objetivo deste trabalho foi avaliar o efeito da utilização de filtros de luz com presença e ausência de 2-Isopenteniladenina (2iP) na multiplicação *in vitro* de mirtilheiro 'Bluecrop'.

Material e Métodos

O experimento foi conduzido no Laboratório de Micropropagação de Plantas Frutíferas da UFPel, Pelotas – RS. Foram utilizados segmentos nodais de mirtilheiro 'Bluecrop' contendo duas gemas, cultivados previamente *in vitro*. O delineamento experimental foi o inteiramente casualizado, em esquema fatorial 4 x 2 (quatro tipos de qualidade de luz - filtros de acetato celulose nas cores azul, vermelha, laranja, além da luz branca) e presença ou ausência de 2-Isopenteniladenina (100 mg/L⁻¹), em meio de cultura WPM (*Wood Plant Media* – Lloyd; McCown, 1980), sendo: T1= (azul + 2iP); T2= (azul s/ 2iP); T3= (laranja + 2iP); T4= (laranja s/ 2iP); T5= (branca + 2iP); T6= (branca s/ 2iP); T7= (vermelho + 2iP); T8= (vermelho s/ 2iP). Cada tratamento foi constituído por cinco repetições, sendo utilizado um frasco com quatro explantes por repetição. Após 90 dias avaliou-se: porcentagem de sobrevivência, número de gemas, número de brotações e matéria fresca (g). Os resultados foram submetidos à análise de variância e as médias comparadas pelo teste Tukey a 5% de significância.

Resultados e Discussão

Não foram observadas diferenças quanto à porcentagem de sobrevivência, exceto para o tratamento T2 (Figura 1). Para a variável número de brotações e matéria fresca, o tratamento T5 obteve as maiores médias dentre os tratamentos. Para número de gemas, maiores médias foram observadas nos tratamentos T3 e T5 (Tabela 1).

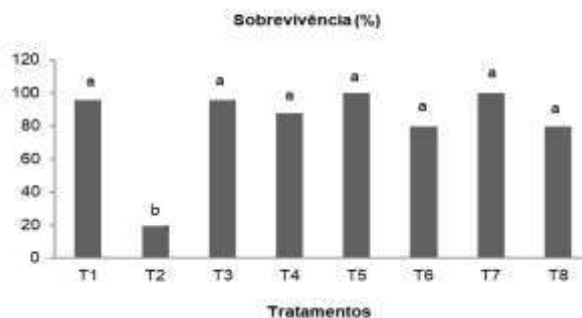


Figura 1. Porcentagem de sobrevivência de plântulas de mirtilheiro 'Bluecrop'. Colunas com mesma letra não diferem entre si pelo teste Tukey a 5% de significância.

Tabela 1. Valores médios de nº de brotações, nº de gemas e matéria fresca em plântulas de mirtilheiro 'Bluecrop' submetidas a diferentes qualidades de luz e presença/ausência de 2iP.

Tratamento	Nº brotações	Nº gemas	Matéria Fresca (g)
T1	2,72 bc	24,66 b	0,350 bc
T2	0,20 d	0,84 c	0,020 c
T3	4,80 b	42,28 a	0,778 ab
T4	0,52 cd	4,04 c	0,122 c
T5	8,24 a	46,88 a	0,967 a
T6	0,80 cd	5,36 c	0,124 c
T7	3,80 b	39,84 ab	0,649 ab
T8	0,80 cd	4,16 c	0,097 c
CV(%)	41,39	39,58	60,82

Médias seguidas de mesma letra não diferem entre si pelo teste Tukey a 5% de significância.

Conclusão

O cultivo *in vitro* sob luz branca com utilização de 2-Isopenteniladenina é o mais indicado para a multiplicação do mirtilheiro 'Bluecrop'.

Agradecimentos

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Germinação de sementes de *Litchi chinensis* sobre efeito da pré-embebição

Mariana Salbego de Franco¹, Josiane Otalacoski¹, Jacqueline Barcelos¹, Tainara Gris¹, Andreia da Silva Almeida²

¹UFPEL – Universidade Federal de Pelotas, acadêmico de Pós-graduação (PPCTS/FAEM/UFPe), marianasalbego@gmail.com ²bolsista (PNPD/PPCTS/FAEM), Avenida Eliseu Maciel, s/n, Bairro Jardim América, Capão do Leão-RS.

Palavras Chave: pré-condicionamento de sementes, lichia, Sapindaceae.

Introdução

Pertencente à família Sapindaceae, lichia (*Litchi chinensis* Sonn.) é uma árvore de bom crescimento, com altura variável de 10 a 15m. É típica do clima subtropical e amplamente distribuída na Ásia, África e Américas. O principal atrativo tem sido atribuído aos seus frutos, que são utilizados tanto como fonte de alimento como pela indústria de cosméticos (LIMA et al., 2010). A propagação da lichia de forma sexuada é utilizada em melhoramento genético, contudo, essa propagação é dificultada pela curta longevidade das sementes que, quando arbitrariamente armazenadas, perdem a viabilidade em 24 horas após a extração do fruto (YAMANISHI et al., 2005). O objetivo deste trabalho foi avaliar a eficiência da pré-embebição em sementes de lichia.

Material e Métodos

O estudo foi realizado no Laboratório de Análise de Sementes, da Universidade Federal de Pelotas. As sementes foram coletadas a partir de duas matrizes; beneficiadas manualmente e colocadas para secar a sombra sob temperatura ambiente. Em seguida, as sementes foram acondicionadas em sacos transparentes onde permaneceram em geladeira durante 15 dias, conforme recomendado por Yamanishi et al. (2005). Os tratamentos corresponderam aos períodos de pré-embebição das sementes em água, utilizando-se para cada tratamento oito repetições de 25 sementes. As sementes foram imersas em recipiente contendo 100 ml de água e mantidas em germinador a 25°C por 0, 24, 48, 72 e 96 horas. Logo após cada período, as sementes foram colocadas para germinar em recipientes gerbox contendo substrato tipo vermiculita. Os dados obtidos foram submetidos ao teste de normalidade (Lilliefors) e logo, atendendo as pressuposições do modelo estes foram submetidos à análise de variância (ANOVA), para verificar o nível de significância dos tratamentos analisados F (P>0,05), sendo em seguida realizada análise de regressão, obtendo-se o ponto de máxima eficiência técnica (PMET) dos tratamentos.

Resultados e Discussão

O teor de água das sementes correspondeu a 47,33%, que de acordo com Martins et al., (2001) trata-se de uma espécie com comportamento de recalcitrância. O peso de mil sementes correspondeu a aproximadamente 2.734 gramas. A emergência das sementes de lichia teve início ao 1º dia e se estendeu até o 14º dia.

Sementes matricionadas pelo período de 72 horas apresentaram melhor percentual de emergência (60%) quando comparadas aos demais

períodos avaliados. As sementes submetidas ao matricionamento tiveram uma maior taxa de germinação em comparação com o tratamento controle. O tratamento controle, onde não ocorreu matricionamento, houve apenas 15% de emergência (Gráfico 1). Esse efeito deve-se ao fato de que tratamentos pré-germinativos, que envolvem a hidratação controlada de sementes, propiciam o início do metabolismo e podem possibilitar que a emergência ocorra de forma mais rápida (PERTEL, 2000).

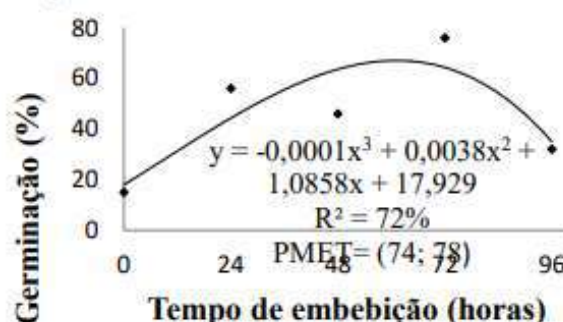


Gráfico 1: Porcentagem de emergência de lichia em função do período de pré-embebição.

Nota-se que o PMET que corresponde ao período de 74 horas de pré-embebição, pode alcançar 78% de emergência. De acordo com Marcos Filho (2015), para a técnica de condicionamento fisiológico é importante conhecer o padrão de embebição das sementes em vários potenciais hídricos para estabelecer o momento em que as sementes devem ser retiradas do condicionamento.

Conclusões

A pré-embebição melhora o desempenho de emergência das sementes de lichia, principalmente no que tange ao aumento da velocidade de germinação das sementes.

Agradecimentos

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Rio Grande, 30 de Setembro de 2019.

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Título: Influência da qualidade espectral no desenvolvimento de mudas e produtividade de pimenta biquinho (*Capsicum annuum* L.)

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Alunos matriculados: Não se aplica

Alunos concluintes: Não se aplica

Palavras-chave: LEDs, pimenta biquinho, produção de mudas, desenvolvimento

201760898 - ANDERSON RAFAEL WEBLER	Estudante de Pós-graduação	PG Agronomia - Agricultura e Ambiente - Mestrado - CAMPUS UFSM-FW	Colaborador	Não	2	0	06/03/2017	30/11/2017
201611751 - AXEL BRUNO MARIOTTO	Estudante de Graduação	Agronomia/CESNORS/FW	Estagiário	Não	2	0	03/10/2016	30/11/2017
1413652 - BRAULIO OTOMAR CARON	Docente	DEPARTAMENTO DE CIÊNCIAS AGRONÔMICAS E AMBIENTAIS - UFSM-FW	Colaborador	Não	1	0	03/10/2016	30/11/2017
201670409 - DANIELE CRISTINA FONTANA	Estudante de Pós-graduação	PG Agronomia - Agricultura e Ambiente - Mestrado /CESNORS/FW	Colaborador	Não	2	0	03/10/2016	30/11/2017
1412802 - DENISE SCHMIDT	Docente	DEPARTAMENTO DE CIÊNCIAS AGRONÔMICAS E AMBIENTAIS - UFSM-FW	Colaborador	Não	1	0	03/10/2016	30/11/2017
201611171 - DIÉSSICA LETÍCIA JUNGES	Estudante de Graduação	Agronomia/CESNORS/FW	Estagiário	Não	2	0	03/10/2016	30/11/2017
201510582 - EVANDRO HOLZ	Estudante de Graduação	Agronomia/CESNORS/FW	Estagiário	Não	2	0	03/10/2016	30/11/2017
201660726 - JULLIE DOS SANTOS	Estudante de Pós-graduação	PG Agronomia - Agricultura e Ambiente - Mestrado - CAMPUS UFSM-FW	Colaborador	Não	2	0	03/10/2016	30/11/2017
201760900 - LEONARDO ANTONIO THIESEN	Estudante de Pós-graduação	PG Agronomia - Agricultura e Ambiente - Mestrado - CAMPUS UFSM-FW	Colaborador	Não	2	0	06/03/2017	30/11/2017
18461 - MARCOS VINÍCIUS MARQUES PINHEIRO	Voluntário	DEPTO. DE CIÊNCIAS AGRONÔMICAS E AMBIENTAIS-FW-CESNORS	Coordenador	Não	10	0	03/10/2016	30/11/2017
201511707 - MATHEUS MILANI PRETTO	Estudante de Graduação	Agronomia/CESNORS/FW	Estagiário	Não	2	0	03/10/2016	29/07/2017
201511707 - MATHEUS MILANI PRETTO	Estudante de Graduação	Agronomia/CESNORS/FW	Estagiário	Não	1	0	30/07/2017	30/11/2017
201561253 - OSCAR VALERIANO SÁNCHEZ VALERA	Estudante de Pós-graduação	PG Agronomia - Agricultura e Ambiente - Mestrado /CESNORS/FW	Colaborador	Não	2	0	03/10/2016	30/10/2017
201611765 - RONIBERTO DA SILVA FARIAS	Estudante de Graduação	Agronomia/CESNORS/FW	Estagiário	Não	2	0	03/10/2016	30/11/2017
201310576 - TAINARA GRIS	Estudante de Graduação	Agronomia - CAMPUS UFSM-FW	Estagiário	Não	2	0	01/08/2017	30/11/2017

* carga horária semanal

UNIDADES VINCULADAS

UNIDADE	FUNÇÃO	VALOR	INÍCIO	TÉRMINO
33.21.00.00.0.0 - DEPARTAMENTO DE CIÊNCIAS AGRONÔMICAS E AMBIENTAIS - UFSM-FW	Responsável		03/10/2016	30/11/2017

CLASSIFICAÇÕES

TIPO DE CLASSIFICAÇÃO	CLASSIFICAÇÃO
Classificação CNPq	5.01.03.04-0 - PRODUÇÃO DE MUDAS
Grupo do CNPq	378 - PESQUISA EM PRODUÇÃO VEGETAL
Linha de pesquisa	04.00.00 - CIENCIAS AGRARIAS
Quanto ao tipo de projeto de pesquisa	2.01 - Projeto de Pesquisa
Objetivos de desenvolvimento sustentável da ONU	15 - Vida Terrestre

INOVAÇÃO

PROJETO POSSUI POTENCIAL DE INOVAÇÃO DE PRODUTOS, PROCESSOS OU SERVIÇOS

Não

POTENCIAL DE INOVAÇÃO DO PROJETO

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REGIÕES DE ATUAÇÃO

CIDADE	UF	PAÍS	INÍCIO	TÉRMINO
Frederico Westphalen	Rio Grande do Sul	Brasil	03/10/2016	30/11/2017