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ORIGINAL RESEARCH PAPER

Effects of light spectrum and UV-A radiation on *in vitro* germination and morphophysiological parameters of *Solanum pimpinellifolium* seeds

Guilherme Rafael do Prado[1*], Douglas Augusto Gaspio[1], Matheus Vinícius Abadia Ventura[1,2] & Antonio Carlos Pereira de Menezes Filho[1,3]

[1] *UniBRAS University Center Rio Verde, Rio Verde, Goiás, Brazil*
[2] *Goiano Federal Institute, Rio Verde, Goiás, Brazil*
[3] *Jataí Federal University, Jataí, Goiás, Brazil*

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*Corresponding Author: Prado, G. R., UniBRAS University Center Rio Verde, Rio Verde, Brazil.
Email: guilhermerafael.14rv@gmail.com

Abstract: Different light spectra, such as red, yellow, green, and blue, can exert distinct effects on germination rates and on the morphophysiological traits of seedlings and plants at various developmental stages. In contrast, energy sources such as UV-A radiation often produce adverse and potentially harmful effects. In this study, we evaluated the influence of different light spectra and UV-A radiation on the *in vitro* germination and early development of tomato cv. Cherry seedlings (*Solanum pimpinellifolium*), including shoot length, root length, and fresh and dry biomass. Our results showed that germination rates did not differ among the evaluated light spectra or darkness; however, UV-A radiation proved to be extremely detrimental. Darkness promoted the greatest shoot elongation, while red and green spectra yielded the highest root lengths. The green spectrum resulted in the greatest fresh biomass accumulation, whereas the yellow, green, and dark treatments produced the highest dry biomass. Consistently, UV-A radiation was the most harmful factor across all evaluated parameters. Overall, the appropriate selection of light spectra can enhance germination and morphophysiological performance in tomato cv. Cherry seedlings grown *in vitro*, whereas exposure to UV-A radiation should be strictly avoided during germination and early development.
Keywords: *Solanum* genus; UV-A radiation; seedling mass; seedling root.

1. Introduction

Tomato (*Solanum pimpinellifolium*) is a species widely adapted to different climatic conditions as a result of extensive domestication and hybrid selection processes, which have contributed to its status as one of the most cultivated and consumed fruits worldwide. In addition to its nutritional value, it is highly appreciated for its culinary versatility, being commonly used in sauces, pasta dishes, salads, and various preparations (Guilherme et al., 2014; Silva et al., 2017; Trento et al., 2021). Each year, large agricultural areas are dedicated to tomato cultivation, and among its varieties, the Cherry tomato cultivar stands out due to its ability to grow in limited spaces, making it suitable even for domestic environments such as balconies and pots (Costa et al., 2015).

The use of different light spectra—such as blue, red, green, and yellow—as well as darkness or exposure to energetic ultraviolet radiation (UV-A), has been increasingly incorporated into cultivation systems of agriculturally important species, particularly under *in vitro* and indoor conditions (Stefanello et al., 2023; Hernandez-Aguilar et al., 2024). These light stimuli can enhance physiological processes such as accelerating and increasing germination rates, as well as improving morphophysiological traits of seedlings (Victório; Lage, 2009; Alves et al., 2024). Light intensity, quality, direction, and duration are key factors influencing plant development and can directly affect essential processes, especially germination (Victório et al., 2010; Souza; Silva, 2025).

Seedlings possess a variety of phytochemical groups, including photoreceptor proteins such as phytochromes and cryptochromes, which are responsible for light perception and absorption. Numerous studies have demonstrated that red and blue light spectra effectively stimulate germination and early growth (Sullivan; Deng, 2003; Kerbauy, 2008; Falcinelli et al., 2024). However, the effects of other energetic radiation sources, particularly ultraviolet (UV-A), remain poorly understood, and studies examining their influence on plant tissues and physiological responses are still limited (Mariz-Ponte et al., 2021).

Although the ozone layer protects terrestrial organisms by absorbing most ultraviolet radiation from the sun, a portion of this energy reaches the Earth's surface and can be absorbed by plants, generating variable effects (Schalka; Correa, 2024). Classical studies indicate that UV-A radiation may be involved in DNA repair processes, increased photosynthesis, and the biosynthesis of specialized metabolites such as flavonoids, as well as promoting anatomical modifications in leaves, including changes in epidermal and parenchymal tissue thickness (Zhong et al., 2021; Thongtip et al., 2022; Demétrio et al., 2022; Vatistas et al., 2024). Pieraccini et al. (2025) and Ge et al. (2007) also reported that different gibberellins may be affected depending on the extent of tissue damage caused by UV-A radiation.

Thus, understanding how different light spectra, the absence of light, and UV-A radiation influence germination and early seedling development is essential for species of commercial interest, such as tomato.

In this context, the objective of this study was to evaluate the effects of different light spectra, darkness, and UV-A radiation on germination and on morphophysiological parameters of in vitro–grown Cherry tomato seedlings in a germination chamber.

2. Material and Methods

2.1. Plant material

In this experiment, tomato seeds of the Cherry cultivar (*S. pimpinellifolium*) (Isla, Brazil) were used, characterized as annual, with a 90-day cycle, round shape, red skin color, red pulp color, indeterminate growth type, 3–4 cm diameter, weight between 18–23 g, and a germination rate of 98%. The seeds were treated with Metalaxyl-M (fungicide).

2.2 Light spectra and UV-A treatments

The experiment was conducted in germination boxes (Gerbox, clear acrylic) using germination paper moistened with sterile distilled water at twice its dry weight. In each germination box, two sheets of germination paper were placed as a base layer, on which the seeds were distributed, and then covered with an additional sheet. Fifty seeds were used per replicate, totaling four replicates per treatment.

The treatments consisted of illumination with Sylvania fluorescent lamps (F20 W T-12, Brazil) of different colors: white (control, 20 µmol m^{-2} s^{-1}), green (12 µmol m^{-2} s^{-1}), blue (17 µmol m^{-2} s^{-1}), red (14 µmol m^{-2} s^{-1}), and UV-A (16 µmol m^{-2} s^{-1}) within the wavelength range of 330–380 nm, including a portion of blue light (λ = 380 nm). The dark condition was obtained by enclosing the germination boxes in black plastic bags.

2.3 Experimental design

The experimental design was completely randomized, with four replications of 50 seeds, totaling 200 seeds per treatment, in a 6 × 4 factorial scheme. Germination was considered to begin with radicle protrusion. Germination was evaluated daily for ten days. Seedling analysis lasted for 17 days under controlled climatic conditions in a growth chamber maintained at 25 ± 2 °C with a 16-hour photoperiod (SolidSteel, Mod. SSBOD342-110, Brazil). Irradiance levels were measured using a quantum sensor (Bio Spherical Instruments Inc., Model QSL100, China).

2.4 Experiment and analyses

After 17 days of germination, seedlings maintained under the same light spectrum and UV-A conditions were evaluated for initial development. The parameters analyzed included the number of leaves, seedling height, and root length (measured with a digital caliper) (Mitutoyo 150 mm, Mod. 500, Japan), expressed in millimeters (mm), as well as fresh and dry mass per seedling (measured with a digital analytical balance) (Bel, Mod. M5 M214AiH, Brazil), expressed in grams (g). A total of 25 seedlings were evaluated per light and UV-A treatment.

2.5 Statistical analysis

The mean data were subjected to analysis of variance (ANOVA), and statistical comparisons among treatments were performed using *Tukey's* test at a 5% significance level, with the aid of the Sisvar software (Ferreira, 2019).

3. Results

3.1. Germination rate

It can be observed that the highest number of germinated seeds occurred on the second day, except under UV-A radiation. Germination rates were higher under red, white, yellow, and green light spectra, as well as in darkness, all of which showed statistically significant differences when compared with the UV-A treatment, which resulted in only 14% germination (Figure 1).

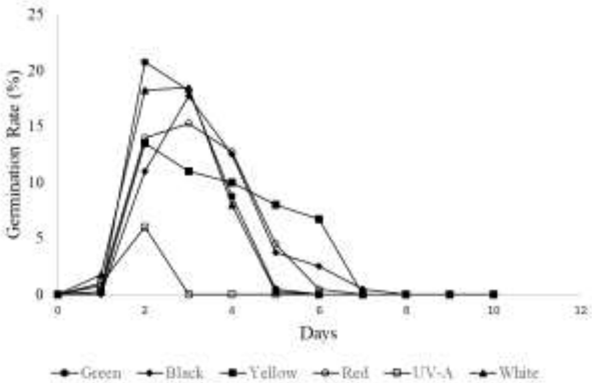

Figure 1. Germination graph under different light spectra and UV-A radiation for tomato cv. Cherry. Source: Authors, 2025.

3.2 Morphophysiological parameters

Regarding the germination parameter, our results show that there was no difference among the treatments, except when compared with the UV-A radiation source. For seedling length, treatment effects were observed under the absence of light, where seedlings reached 36 mm in length. In contrast, the UV-A treatment showed the poorest results, with seedlings measuring only 12 mm in length.

For root length, the red and green spectra did not differ from each other, although both exhibited higher values compared to the other spectra and UV-A. With respect to seedling fresh mass, the green light treatment resulted in the highest mass (0.053 g). For seedling dry mass, the yellow, green, and dark treatments showed the best results, although no statistical differences were observed among them (Table 1).

Table 1. Morphological parameters of in vitro seedlings of tomato cv. Cherry was evaluated under different light spectra and UV-A radiation.

Spectra	Germination (%)	Shoot length (mm)	Root length (mm)	Seedling fresh mass (g)	Seedling dry mass (g)
UV-A	14.00 b	13.97 d	18.16 c	0.036 ab	0.0012 b
Red	95.50 a	26.91 bc	75.98 a	0.041 ab	0.0016 ab
White	93.50 a	22.15 cd	43.48 b	0.029 b	0.0012 b
Yellow	99.00 a	27.99 bc	56.16 ab	0.036 ab	0.0019 a
Green	96.50 a	30.60 ab	75.86 a	0.053 a	0.0018 a
Black	96.00 a	36.98 a	44.82 b	0.038 ab	0.0017 a
CV (%)	4.09	24.03	29.39	34.75	19.70

Note: Means followed by the same letter in the column do not differ significantly from each other according to *Tukey's* test at the 5% significance level. Source: Authors, 2025.

4. Discussion

Different spectra of blue, green, yellow, and red light, their absence (darkness), and some sources of ultraviolet radiation show potential in seed germination, increasing the germination rate and various morphophysiological parameters in several groups of tested plants. In our research, we observed that the light spectra and the absence of light did not differ in the number of germinated tomato seeds cv. Cherry. However, when compared to the UV-A light source, UV-A was stressful and inhibited germination, possibly due to embryo destruction or the induction of a dormancy state. UV-A sources are commonly used for sterilization and can cause deleterious effects on living tissues, especially in plants.

Semenov et al. (2020) and Moreira-Rodriguez et al. (2017) discuss that UV sources present diverse results regarding their effects, in which the type of source, dose, and exposure time lead to different outcomes. Deleterious effects are less frequently observed under UV-B sources. These authors also highlight that these factors are interconnected with the thickness of the layers surrounding the seed embryo, and thinner seeds may suffer more damage than thicker ones. This may explain our findings.

In a study developed by Puntel et al. (2024), the researchers showed that UV-B radiation at different exposure times did not affect the number of germinated seeds, first count, seedling length, or dry mass in white oat (*Avena sativa* L.). The germination rate among treatments and the control remained equal at 93%, with seedlings measuring between 14.25 and 15.16 cm in length. In the study by Stefanello et al. (2025), the use of UV-C proved to be effective in the germination rate of maize seeds and in mitigating the harmful effects in seeds exposed to a 100 mM NaCl (*w/v*) solution.

UV-A and UV-B sources may promote the accumulation of antioxidant and UV-protective molecules in some groups of food-relevant plants (He et al., 2019). Other groups of phytomolecules involved include isoflavones, vitamin C, phenolics, carotenoids, chlorophylls, anthocyanins, and flavonoids (Ma et al., 2019; Loconsole; Santamaria, 2021).

Regarding the morphophysiological parameters of tomato cv. Cherry seedlings, the light spectra did not influence shoot length, although the absence of light showed a positive effect and resulted in greater shoot length compared to the spectra and UV-A. In contrast, Souza & Silva (2025) observed in Massai grass (*Panicum maximum* cv. Massai) seedlings that the yellow light spectrum produced seedlings with the greatest shoot length, whereas UV-A resulted in the poorest outcomes, with grass seedlings measuring 23.74 mm. In medicinally relevant plants, Silva et al. (2023) reported that different intensities of white light spectra (35, 45, and 75 µmol m^{-2} s^{-1}) showed positive effects on sprouting, shoot length, and the content of photosynthetic pigments such as chlorophyll in *Aeollanthus suaveolens*, *Hypericum cavernicola*, and *Hypericum teretiusculum*. Yousef et al. (2021) obtained similar results for tomato cv. Gangmu nº 1 (*Solanum lycopersicum* L.) plants using LED light spectrum sources, where red and blue lights significantly increased total leaf area, dry mass (total, shoot, and root), total chlorophyll/carotenoid ratio, soluble protein, and sugar content. Encouraging results were also obtained by Gómez & Mitchell (2015) when evaluating tomato seedlings under supplemental red and blue lighting at a ratio of 80:20%, respectively. They reported values superior to the control for hypocotyl diameter, hypocotyl length, leaf number, and leaf expansion.

Root length was higher under the red and green light spectra for the tomato cv. Cherry seedlings. These results vary among plant groups, which can be observed in forage species such as Massai grass in the study by Souza & Silva (2025), where the best root length results were obtained under white and yellow light spectra, with lengths of 54.63 and 65.32 mm, respectively.

Fresh and dry mass parameters in our findings for the tomato cv. Cherry was noteworthy. The green light spectrum resulted in higher fresh mass content in seedlings, with values exceeding 0.050 g. For dry mass, seedlings exposed to yellow and green spectra, as well as those grown in the absence of light, showed values above 0.016 g. For Massai grass seedlings, Souza & Silva (2025) reported that fresh mass was higher under the yellow light spectrum, while the green spectrum produced seedlings with dry mass values exceeding 0.050 g. Gómez & Mitchell (2015) obtained results that diverged from ours regarding the fresh and dry mass of tomato plants cv. (*S. lycopersicum x S. habrochaites*). The researchers supplemented light with red and blue spectra and found that this supplementation was beneficial, inducing tomato plants to exhibit greater fresh and dry shoot mass.

5. Conclusion

The effects of different light spectra, UV-A radiation, and the absence of a light source significantly influence germination rate and morphophysiological parameters such as shoot and root length, as well as seedling fresh and dry mass. The yellow, red, and green spectra, as well as darkness, showed satisfactory results for the in vitro development of tomato cv. Cherry seedlings.

Furthermore, it was observed that UV-A radiation is extremely harmful at all stages evaluated in this study. Therefore, exposure to ultraviolet radiation with wavelengths between 330–380 nm must be avoided during the germination period and seedling development.

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Ethics

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