Prado *et al.*
*Cerrado: Agricultural and Biological Research*, 3(1), 1-6, 2026
https://doi.org/10.14295/cerrado.v3i1.817

**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*

*Article history*
Received: October 02, 2025
Revised: November 24, 2025
Accepted: November 27, 2025

*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 ($\lambda$ = 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).

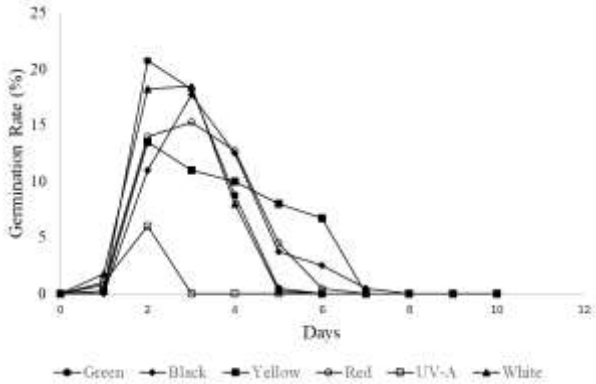


Figure 1. Germination graph under different light spectra and UV-A radiation for tomato cv. Cherry. Source: Authors, 2025.

*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.

## 6. Acknowledgement

We thank the UniBRAS Rio Verde University Center for providing the laboratory facilities.

## 7. References

Alves, C. F. G., Daibes, L. F., Barbosa, F. S., Moura, F. B. P., & Silva, J. V. Physiological and biochemical alterations driven by light quality during germination and initial growth of the mandacaru cactus (*Cereus jamacaru* DC.). *Brazilian Journal of Botany*, 47, 55-

65, 2024. https://doi.org/10.1007/s40415-023-00972-y

Coelho, A. M., França, G. E., Bahia Filho, A. F. C., & Guedes, G. A. A. Doses e métodos de aplicação de fertilizantes nitrogenados na cultura do milho sob irrigação. *Revista Brasileira de Ciência do Solo*, 16, 61-67, 1992.

Costa, E., Santo, T. L. E., Silva, A. P., Silva, L. E., Oliveira, L. C., Benett, C. G. S., & Benett, K. S. S. Ambientes e substratos na Formação de mudas e produção de frutos de cultivares de tomate cereja. *Horticultura Brasileira*, 33, 110-118, 2015. http://dx.doi.org/10.1590/S0102-053620150000100018

Demétrio, C. A., Jacob, J. F. O., Ambrosano, G. B., & Rodrigues, P. H. V. In vitro germination of Abricó-de-Macaco (*Couroupita guianensis* aubl.) zygotic enbryos in different culture media and light spectra. *Ciência Rural*, 52(1), e20190906, 2022. http://doi.org/10.1590/0103-8478cr20190906

Falcinelli, B., Bulgari, R., Nicola, S., & Benincasa, P. The effect of blue: Red light proportion on germination parameters, growth attributes, and quality of borage sprouts. *Scientia Horticulturae*, 336, 113399, 2024. https://doi.org/10.1016/j.scienta.2024.113399

Guilherme, D. O., Pinho, L., Cavalcanti, T. F. M., Costa, C. A., & Almeida, A. C. Análise sensorial e físico-química de frutos tomate cereja orgânicos. *Revista Caatinga*, 27(1), 181-186, 2024.

Gómez, C., & Mitchell, C. A. Growth responses of tomato seedlings to different spectra of supplemental lighting. *HortScience*, 50(1), 112-118, 2025. https://doi.org/10.21273/HORTSCI.50.1.112

He, W., Wang, Y., Dai, Z., Liu, C., Xiao, Y., Wei, Q., Song, J., & Li, D. Effect of UV-B radiation and a supplement of $CaCl_2$ on carotenoid biosynthesis in germinated corn kernels. *Food Chemistry*, 278, 509-514, 2019. https://doi.org/10.1016/j.foodchem.2018.11.089

Hernandez-Aguilar, C., Dominguez-Pacheco, A., Tenango, M. P., Valderrama-Bravo, C., Hernández, M. S., Cruz-Orea, A., & Ordonez-Miranda, J. Characterization of bean seeds, germination, and phenolic compounds of seedlings by UV-C radiation. *Journal of Plant Growth Regulation*, 40, 642-655, 2021. https://doi.org/10.1007/s00344-020-10125-0

Kerbauy, G. B. Fisiologia Vegetal. 2. Ed., Rio de Janeiro, Guanabara Koogan S. A., 431 p, 2008.

Loconsole, D., & Santamaria, P. UV Lighting in horticulture: A sustainable tool for improving production quality and food safety. *Horticulturae*, 7, 1-13, 2021. https://doi.org/10.3390/horticulturae7010009

Ma, M., Wang, P., Yang, R., & Gu, Z. Effects of UV-B radiation on the isoflavone accumulation and physiological-biochemical changes of soybean during germination: Physiological-biochemical change of germinated soybean induced by UV-B. *Food Chemistry*, 250, 259-267, 2018. https://doi.org/10.1016/j.foodchem.2018.01.051

Mariz-Ponte, N., Mendes, R. J., Sario, S., Correira, C. V., Correia, C. M., Moutinho-Pereira, J., Melo, P., Dias, M. C., & Santos, C. Physiological, biochemical and molecular assessment of UV-A and UV-B supplementation in *Solanum lycopersicum*. *Plants*, 10(5), 918, 2021. https://doi.org/10.3390/plants10050918

Moreira-Rodriguez, M., Nair, V., Benavides, J., Cisneros-Zevallos, L., & Jacobo-Elazquez, D. A. UVA, UVB light, and methyl jasmonate, alone or combined, redirect the biosynthesis of glucosinolates, phenolics, carotenoids, and chlorophylls in Broccoli sprouts. *International Journal of Molecular Sciences*, 18, 2330, 2017. https://doi.org/10.3390/ijms18112330

Pieraccini, R., Whatley, L., Koedam, N., Vanreusel, A., Dolch, T., Dierick, J., & der Stocken, T. V. Gibberellic acid and light effects on seed germination in the seagrass *Zostera marina*. *Physiologia Plantarum*, 177(2), e70137. https://doi.org/10.1111/ppl.70137

Puntel, R. T., Stefanello, R., Silva, A. C. F., Garcia, W. J. S., & Dorneles, L. S. Radiação ultravioleta (UV-B) na germinação de sementes de aveia-branca. *In*: Sementes: Foco em pesquisa sobre qualidade fisiológica e sanitária, Vol. 2, 107-116, 2024. https://doi.org/10.46420/9786585756280cap9

Schalka, S., & Correa, M. P. The silent UVA. *Journal of Photochemistry and Photobiology B: Biology*, 257, 112942, 2024. https://doi.org/10.1016/j.jphotobiol.2024.112942

Silva, P. A., Rabelo, J. S., Guimarães, M. A., Silva, J. C. V., Oliveira, L. S. C. Sistemas de condução na produção comercial de tomate "cereja". *Nativa*, 5(5), 316-319, 2017. https://doi.org/10.31413/nativa.v5i5.4723

Silva, A. C. B., Lameira, O. A., Oliveira, H. S., Souza, J. M. M., Miranda, S. R., Ferreira, T. A. A., Guedes, A. S., & Costa, M. S. M. Efeito da intensidade de luz no desenvolvimento de espécies medicinais e aromáticas em condições in vitro. *Revista Contribuciones a Las Ciencias Sociales*, 16(5), 2632-2649, 2023.

Souza, S. S., Silva, M. O. Effects of light spectrum and UV-A radiation on *in vitro* seed germination and

seedlings of Massa grass (*Panicum maximum* cv. Massai). *Brazilian Journal of Science*, 4(11), 1-7, 2025. https://doi.org/10.14295/bjs.v4i11.808

Stefanello, R., Puntel, R. T., Garcia, W. J. S., & Dorneles, L. S. Corn seed conditioning with ultraviolet light to mitigate salt stress. *Ciência e Natura*, 47, e89295, 2025. https://doi.org/10.5902/2179460X89295

Stefanello, R., Barreto, R. A. M., Müller, G. L., Rodrigues, A. H. S., Garcia, W. J. S., & Dorneles, L. S. UV-B and UV-C radiation on the germination of soybean seeds. *Revista Brasileira de Ciências Agrárias*, 18(2), e2964, 2023.

Sullivan, J. A., & Deng, X. W. From seed to seed: the role of photoreceptors in *Arabidopsis* development. *Developmental Biology*, 260, 289-297, 2003.

Thongtip, A., Mosalleyanon, K., Korinsak, S., Toojinda, T., Darwell, C. T., Chutimanukul, P., & Chutimanukul, P. Promotion of seed germination and early plant growth by $KNO_3$ and light spectra in *Ocimum tenuiflorum* using a plant factory. *Scientific Report*, 12. https://doi.org/10.1038/s41598-022-11001-5

Trento, D. A., Antunes, D. T., Júnior, F. F., Zanuzo, M. R., Dallacort, R., Júnior, S. S. Desempenho de cultivares de tomate italiano de crescimento determinado em cultivo protegido sob altas temperaturas. *Nativa*, 9(4), 359-356, 2021. https://doi.org/10.31413/nativa.v9i4.10945

Vatistas, C., Avgoustaki, D. D., Monedas, G., & Bartzanas, T. The effect of different light wavelengths on the germination of lettuce, cabbage, spinach and arugula seeds in a controlled environment chamber. *Scientia Horticulturae*, 331, 113118, 2024. https://doi.org/10.1016/j.scienta.2024.113118

Victório, C. P., Silva, N. C. B., & Sato, M. A. E. The influence of light spectra, UV-A, and growth regulators on the *in vitro* seed germination of *Senecio cineraria* DC. *Revista Ceres*, 57(5), 576-580, 2010.

Victório, C. P., & Lage, C. L. S. Efeitos da qualidade de luz na germinação e desenvolvimento inicial in vitro de *Plyllanthus tenellus*. *Revista Ciência Agronômica*, 40(3), 400-405, 2009.

Yousef, A. F., Ali, M. M., Rizwan, H. M., Ahmed, M. A. A., Ali, W. M., Kalaji, H. M., Elsheery, N., Wróbel, J., Xu, Y., & Chen, F. Effects of light spectrum on morphophysiological traits of grafted tomato seedlings. *Plos ONE*, 16(5), e0250210, 2021. https://doi.org/10.1371/journal.pone.0250210

Zhong, Z., Wang, X., Yin, X., Tian, J., & Komatsu, S. Morphophysiological and proteomic responses on plants of irradiation with electromagnetic waves. *International Journal of Molecular Sciences*, 22(22), 12239, 2021. https://doi.org/10.3390/ijms222212239

## Funding Information

Private research fund.

## Author's Contributions

This section should state the contributions made by each author in the preparation, development, and publication of this manuscript.

## Ethics

The authors state that there is no ethical conflict in this study.