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DOES THE ULTRAVIOLET RADIATION AFFECT THE GERMINATION OF *FAGOPYRUM ESCULENTUM* MOENCH SEEDS?

A RADIAÇÃO ULTRAVIOLETA AFETA A GERMINAÇÃO DAS SEMENTES DE FAGOPYRUM ESCULENTUM MOENCH?

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ABSTRACT

Light is essential to growth and development throughout the life cycle of plants. Plants modify their morphological traits in response to a varying intensity and quality of light signals. Observations regarding the parameters that impact seed germination are critical for understanding the germination process. Thus, this research analyzed the effect of ultraviolet radiation (UV-B and UV-C) on buckwheat seed germination. Initially, the seeds were exposed to UV radiation for various amounts of time (doses) (0, 1h, 2h, 4h, and 8h). They were sown on germitest paper and stored in a Biochemical Oxygen Demand chamber set at 20 °C and a 12-hour photoperiod. Tests were conducted for germination, first count, length, and dry mass of seedlings. The exposure of buckwheat seeds to UV-B and UV-C radiation did not significantly affect germination and seedling root length. However, a decrease in shoot length was observed with higher doses of UV radiation. These findings suggest that buckwheat seeds exhibit relative tolerance to UV-C radiation, while showing some sensitivity to UV-B radiation.

Keywords: buckwheat, light, process of germination.

RESUMO

A luz é essencial para o crescimento e desenvolvimento ao longo do ciclo de vida das plantas. As plantas modificam suas características morfológicas em resposta a uma intensidade e qualidade variáveis de sinais luminosos. Observações sobre os parâmetros que afetam a germinação das sementes são fundamentais para a compreensão do processo de germinação. Assim, esta pesquisa analisou o efeito da radiação ultravioleta (UV-B e UV-C) na germinação de sementes de trigo mourisco. Inicialmente, as sementes foram submetidas a diferentes tempos (doses) de exposição à luz UV (0, 1h, 2h, 4h e 8h). Em seguida, foram semeadas em papel germitest e armazenadas em câmara de germinação (Biochemical Oxygen Demand), a 20 ºC e fotoperíodo de 12 horas. Foram realizados testes de germinação, primeira contagem, comprimento e massa seca de plântulas. A exposição das sementes de trigo mourisco à radiação UV-B e UV-C não afetou significativamente a germinação e o comprimento da raiz das plântulas. No entanto, uma diminuição no comprimento da parte aérea foi observada com maiores doses de radiação UV. Esses achados sugerem que as sementes de trigo mourisco exibem tolerância relativa à radiação UV-C, enquanto mostram alguma sensibilidade à radiação UV-B.

***Palavras-chave**: trigo mourisco, luz, processo germinativo.*

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INTRODUCTION

Buckwheat (*Fagopyrum esculentum* Moench) is in the family Polygonaceae and originally from China and Central Asia (ZHANG *et al*., 2012). It is an herbaceous, rustic plant, with an uncertain growth pattern and a short life cycle, and can grow in a variety of soils and temperature conditions. Japan, Italy, Ukraine, China, Canada, India, and Brazil are among the major producers and consumers of buckwheat.

Nutritionally, it is distinguished from other cereals by the superior quality of its protein and the greater number of vitamins and minerals it contains (ŠKROBOT *et al*., 2019). In addition, its seeds do not contain gluten (GIMÉNEZ-BASTIDA; PISKUŁA; ZIELIŃSKI, 2015) and their starch content may exceed 70 percent of the total dry weight (ZHU, 2016). Other research has proved the nutritional potential of its use as an ingredient in animal feed and as an alternative forage (GÖRGEN *et al*., 2016).

One of humanity's challenges is to increase the amount and quality of the food supply for the population. In order to achieve this goal, research has concentrated on alternative physical approaches in response to the demands of the modern world (RIFNA *et al*., 2019), which may reduce soil degradative processes, help preserve the environment, safeguard food production and, as a result, make the population healthier and increase quality of life (HERNANDEZ-AGUILAR *et al*., 2016). The use of ultraviolet (UV) radiation is one of these ways. Several studies have shown that UV-B and UV-C light have a beneficial or harmful effect on seed germination and seedling growth of various cultivated plants, as well as physiological and biochemical processes in seeds and plants, depending on the amount of radiation (SHAUKAT *et al*., 2013; NEELAMEGAM; SUTHA, 2015; RUPIASIH; VIDYASAGAR, 2016; LAZIM; NASUR, 2017; POURNAVAB *et al*., 2019; SADEGHIANFAR *et al*., 2019; TRIPATHI *et al*., 2019; LAZIM; RAMADHAN, 2020; VANHAELEWYN *et al*., 2020; HERNANDEZ-AGUILAR *et al*., 2021; OZEL *et al*., 2021; SEMENOV *et al*., 2021).

Ultraviolet light is electromagnetic radiation with wavelengths classified as UV-A (320-390 nm), UV-B (280-320 nm), and UV-C (200-280 nm). UV-C radiation has high photochemical activity and is biologically lethal, although some authors claim it has been used to stimulate seed germination (NEELAMEGAM; SUTHA, 2015; RUPIASIH; VIDYASAGAR, 2016; SADEGHIANFAR *et al*., 2019). UV-A light is neutral or even beneficial to microorganisms, including plant colonization by phytopathogens, DNA repair, and infection-related processes. In contrast, exposure to UV-B and UV-C light causes adverse effects that frequently result in the death of microorganisms. Therefore, they are suitable for agricultural use if the plant or beneficial organisms are damaged less by the UV light than the pathogen (VANHAELEWYN *et al*., 2020). UV-induced effects vary according to the ultraviolet intensity and developmental stage (MOREIRA-RODRIGUEZ *et al*., 2017).

In this context, UV radiation at low doses for seed treatment is an environmentally sound option for increasing plant production, quality and yield, as well as inducing resistance to various biotic and abiotic stresses (FORGES *et al*., 2018; DHANYA THOMAS; PUTHUR, 2017). Considering the above, the purpose of this research was to evaluate the effect of ultraviolet radiation (UV-B and UV-C) on the germination of buckwheat seeds.

MATERIAL AND METHODS

The research was conducted at the Laboratory of Plant Genetics, Department of Biology, at the Federal University of Santa Maria (UFSM), Rio Grande do Sul (RS), Brazil. The seeds of buckwheat (*Fagopyrum esculentum* Moench), cultivar IPR 92 Altar were acquired from a traditional company involved in the commercialization of seeds (Agroindustrial e Comercial Pozza Eireli).

Before every procedure, the lamps were on for five minutes. Then, the seeds were placed in Petri dishes and inserted into an irradiation chamber with a lamp emitting UV-B radiation (Ushio G15T8E) at a distance of 25.5 cm from the lamp, for different intervals of exposure to the light (0, 1h, 2h, 4h, and 8h), according to Table 1. At a distance of 34 cm, the identical operation was carried out using a UV-C radiation lamp (Philips TUV 15WG15T8). The UV-B radiation intensity was calibrated using a UV Monitor MS-211-1 from EKO Instruments Co., Ltd., and the UV-C intensity was calibrated with a UV-C 254 radiometer from Lutron. It was essential to adapt the distance between the base and the UV-B and UV-C lamps to ensure that the seeds got the same amount of radiation intensity (2.5 W m^{-2}).

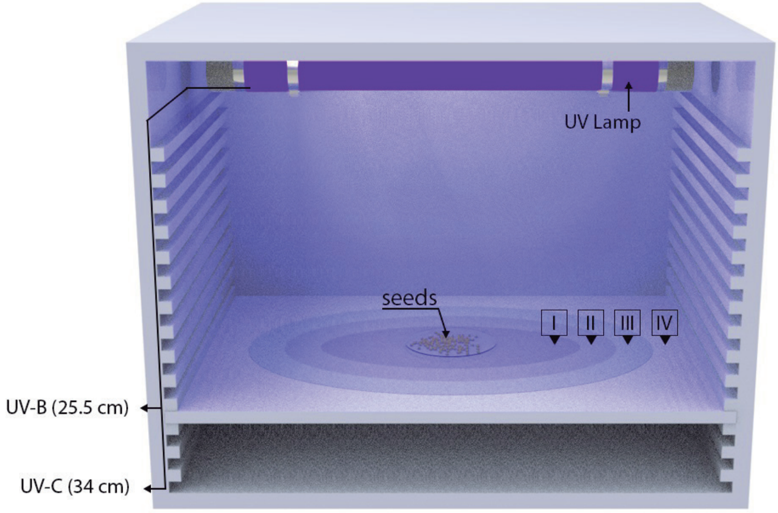
Table 1 - UV-B and UV-C doses and exposure times for buckwheat seed in a constant irradiance chamber.

Exposure time	Dose (J m^{-2})	Dose (mJ cm^{-2})
0 (control)	0	0
1 h	9000	900
2 h	18000	1800
4 h	36000	3600
8 h	72000	7200

Source: Authors.

The seeds were placed inside a glass Petri dish as spread out as possible to avoid overlapping each other and ensure that they were reached by the same intensity of radiation. The intensity of UV radiation was measured in different regions of the irradiation chamber using radiometers (models described above). The constant and highest intensity value was observed in the central region. The Petri dish with the seeds was placed in the central part of the chamber during the exposure times (treatments), ensuring that they were reached by the same intensity of UV light (Figure 1).

Figure 1 - A representative scheme irradiation chamber shows seeds at the bottom and a UV lamp at the top. The indicators UV-B (25.5 cm) and UV-C (34 cm) on the left side show the level position where the seeds are left before installing the UV lamp (B or C). The intensity gradually decreases away from the center in the four areas (I, II, III, and IV) on the bottom center (I = 2.5 W m^{-2}, II = 2.1 W m^{-2}, III = 1.8 W m^{-2}, and IV = 0.7 W m^{-2}).



Source: Authors.

The physiological potential of the seeds was assessed by subjecting the seeds to different amounts of UV light. Buckwheat seeds were distributed on paper rolls and moistened with distilled water (at a rate of 2.5 times the paper weight). The paper rolls (four replications of 50 seeds) were stored in a Biochemical Oxygen Demand chamber after sowing, at a temperature of 20 °C, for 12 hours of light, and the counts were done on the 5th and 7th days, according to the Brasil (2009). To assess the seedling length (cm), four replications of 20 seeds were sown in two rows in the upper third of the germitest paper and maintained under the same condition as the germination test. On the 5th day after sowing, the lengths (shoots and root) of 10 normal seedlings of each replication were measured. Following the procedure, ten normal seedlings were chosen from each replicate of the seedling length test to determine seedling dry mass (mg). The seedlings were weighed on a precision balance (of 0.001 g), after drying the material in a forced ventilation oven at 60 ± 5 °C for 48 h.

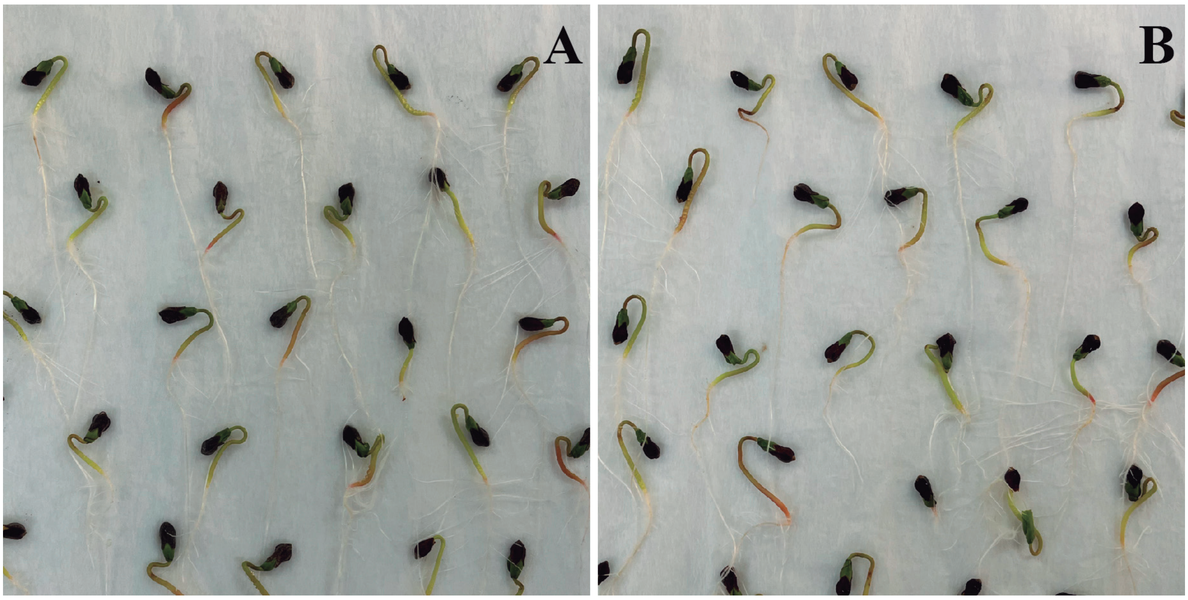
The experimental design was totally randomized, with the treatments consisting of various times (doses) of UV-B and UV-C light exposure. The data were analyzed by the Sisvar program.

RESULTS AND DISCUSSION

GERMINATION UNDER UV-B RADIATION EXPOSURE

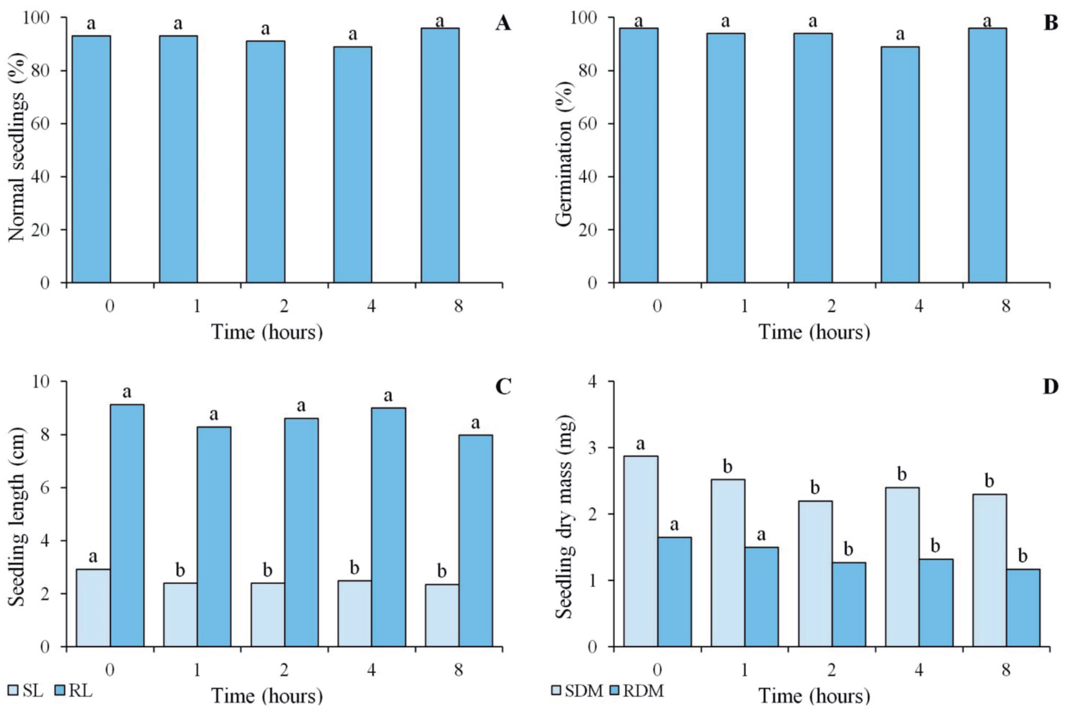
The variables germination, first count, and root length for buckwheat showed no significant difference ($p > 0.05$) in the data analysis (Figures 2 and 3).

Figure 2 - Germination of buckwheat seeds exposed to UV radiation. Absence of radiation (A) and 72000 J m^{-2} (B).



In contrast, when examining the data for shoot length and shoot and root dry mass as a function of the treatments (exposure periods to UV-B radiation), differences were identified (Table 2). Exposure to UV-B radiation for one hour (9000 J m^{-2}) reduced the length of seedlings from 2.92 to 2.39 cm. Furthermore, after 1 hour (9000 J m^{-2}) and 2 h (18000 J m^{-2}) of exposure, there were significant differences in the dry mass of shoots (from 2.87 to 2.52 mg) and dry mass of roots (from 1.65 to 1.27 mg) (Figure 3).

Figure 3 - First count (A) and germination (B), shoot length (SL) and root length (RL) (C), shoot dry mass (SDM), and root dry mass (RDM) (D) of buckwheat seedlings exposed to UV-B radiation



Source: Authors

According to our results, buckwheat seeds are tolerant to radiation. These tolerance responses may be attributed to the structure of the seeds, which have a relatively thick integument and high starch content. UV irradiation has different impacts on different species and cultivars (SARGHEIN *et al.*, 2011), which might be attributed to different quantities of oils, proteins, and other substances in seed structures. According to Tripathi *et al.* (2019), under combined UV-B and ozone (O_3) exposure, oil content and seed quality parameters (total sugar, protein, amino acids, and oil) were more affected in sunflower seeds. Furthermore, Pournavab *et al.* (2019) report that due to the high content of lipids in their seeds, both sunflower and pine demonstrated great sensitivity to UV dosages, which would accelerate oxidation and degeneration of the plasma membrane.

In other studies, Pournavab *et al.* (2019) observed that the effects of UV-B irradiation on soybean seeds were manifested in the hypocotyl, with necrotic damage, curvature, and intertwining of the cotyledons that limited epicotyl emergence, as well as cracks or splits in the radicle. In *Arabidopsis*, the response to the UV-B wavelength (280 nm and 300 nm) inhibited seedling hypocotyl elongation and curvature (LIZANA *et al.*, 2009).

Despite that UV-B photons can potentially cause damage; it is becoming evident that UV damage is more likely to be the exception rather than the norm. As a result, the harmful effects of UV-B radiation are considered rare. The susceptibility of plant tissue to irradiation varies significantly by variety, physiological stage, composition, and thickness of the plant's epidermis (RIVERA-PASTRANA *et al.*, 2007). UV-B radiation, on the other hand, is often only effective when it lasts for an extended period, typically many hours or days (SEMENOV *et al.*, 2020).

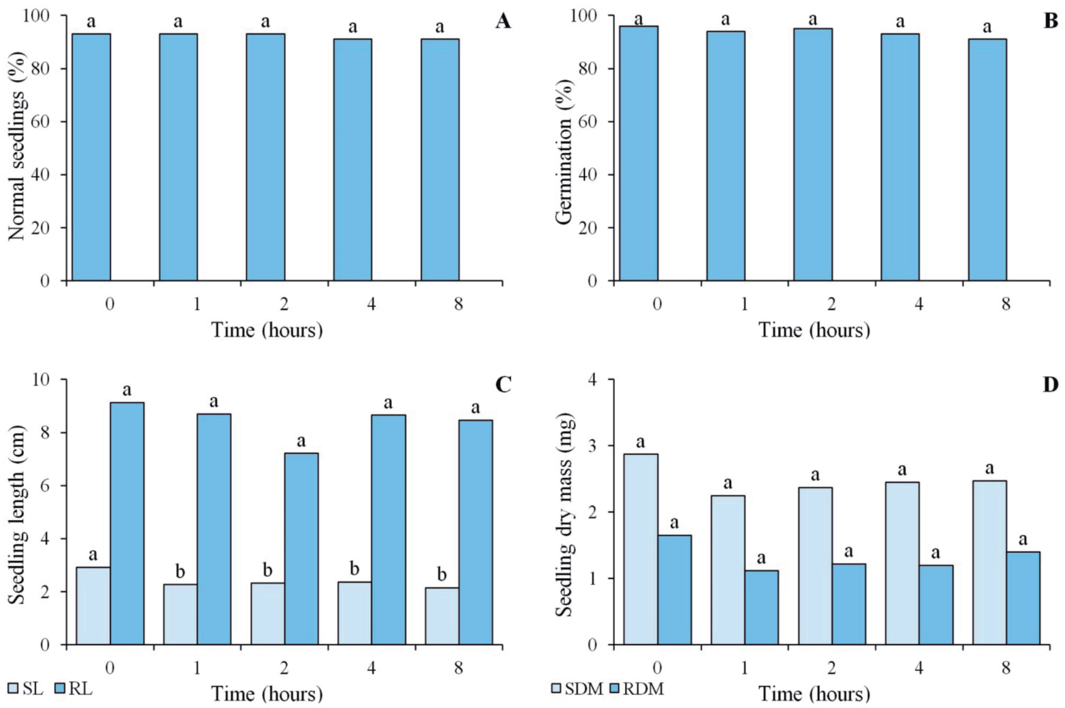
Since plants are food sources, research about all elements that influence plant health and growth is valuable. Therefore, the effects of UV-B radiation on plants must be explored from a variety of perspectives. Despite that this radiation is a stress-inducing component, it may also have positive effects on plants. UV-B radiation, for instance, damages plant tissues, but it may also increase the buildup of antioxidant and UV-protective compounds in certain plants that are used as food (HE *et al.*, 2019). In addition, the effects of UV-B should be studied in relation to the following: production of genotypes that are less susceptible to the effects of global climate change; the development of antioxidants, antimicrobials, and antifungals in plants; and the development of individuals that are resistant to other stress factors (OZEL *et al.*, 2021).

GERMINATION UNDER UV-C RADIATION EXPOSURE

The variables germination, first count, root length, seedling dry mass, and root dry mass for buckwheat showed no significant difference ($p > 0.05$) in the data analysis. However, after examining the data, differences in shoot length were observed (Figure 4) depending on the treatments (UV-C radiation exposure times). UV-C radiation at exposure times of up to 8 hours (doses of up to 72000 J m^{-2})

had little effect on the buckwheat seeds, indicating that this species is relatively tolerant to UV-C radiation. A decrease in shoot growth (from 2.92 to 2.27 cm) was observed at UV radiation doses over 9000 J m^{-2} (1 hour).

Figure 4 - First count (A) and germination (B), shoot length (SL) and root length (RL) (C), shoot dry mass (SDM), and root dry mass (RDM) (D) of buckwheat seedlings exposed to UV-C radiation.



Source: Authors.

Similar to our results, Sadeghianfar *et al.* (2019) observed that treatments with UV-C radiation (254 nm - intensity 54 mW cm^{-2}) for 0 minutes, 30 minutes, 2 hours, 4 hours, 8 hours, and 12 hours had no significant effect on the germination percentage of maize and beet seeds. After exposing maize, sorghum, and peanut seeds to UV-C radiation for up to 1 hour, Sadeghianfar *et al.* (2019) and Neelamegam and Sutha (2015) observed no significant difference in the germination percentage. In addition, Hernandez-Aguilar *et al.* (2021) observed no significant differences for the variables germination, dry weight, and length of bean seedlings (*Phaseolus vulgaris* L.) for different exposure times to UV-C radiation (0, 2, 5, 10, and 15 min - 700 W cm^{-2}). However, Siddiqui *et al.* (2011) noticed a considerable increase in mung bean (*Vigna radiata* L.) germination when the seeds were exposed to UV-C radiation for 30 minutes.

In other studies, Rupiasih and Vidyasagar (2016) found that wheat seeds exposed to UV-C radiation (30, 60, 90, 120, and 180 min) reduced the growth rate of seedlings (shoot and root) for all periods of radiation exposure compared to the control group. The decrease in shoot growth was gradual with the increase in the exposure time to UV-C radiation, while the decrease in root growth varied with the exposure time. Furthermore, when sorghum seedlings (*Sorghum bicolor* L.) were irradiated with UV-C for 30 minutes and 1 hour, Lazim and Nasur (2017) reported no significant effects on germination percentage and root length.

However, Semenov *et al.* (2021), using UV-C radiation doses ranging from 50 to 30000 J m^{-2}, discovered that the most effective dosage of ultraviolet irradiation applied to vetch (*Vicia villosa*) seeds was 1000 J m^{-2}, which increased germination by 15%. In the case of barley seeds (*Hordeum vulgare* L.), Lazim and Ramadhan (2020) found that exposing the seeds to UV radiation for 2 hours resulted in 88 % germination.

In circumstances when microorganisms are inside tissues or stuck to injured areas, the germicidal effect of UV-C radiation may be inhibited. Since ultraviolet light cannot access their cells, the radiation has no effect on the microorganisms (GÓMEZ *et al.*, 2015). In this regard, the surface properties of vegetables have a significant impact on the efficacy of UV-C sterilization. The existence of cracks, cavities, and other surface irregularities, as well as the surface's roughness, might reduce the incident energy.

According to Hernandez-Aguilar *et al.* (2021), it is crucial to explore the optimum radiation parameters, such as exposure time, radiation intensity, light source power, radiation regimes, the conditions and placement of the seeds, and the container in which they are stored. It is crucial to apply the proper treatment and conditions in order to achieve the desired beneficial result. Therefore, further research is required to comprehend the effect of UV radiation on seed germination and plant development.

CONCLUSIONS

The exposure of buckwheat seeds to UV-B and UV-C radiation did not significantly affect germination and seedling root length. However, a decrease in shoot length was observed with higher doses of UV radiation. These findings suggest that buckwheat seeds exhibit relative tolerance to UV-C radiation, while showing some sensitivity to UV-B radiation. The results contribute to the understanding of how buckwheat responds to UV radiation exposure.

However, the long-term effects of UV-B radiation on plants are still incompletely understood. Further study with more prolonged exposure periods or different dosages is required to understand the physiological mechanisms involved and the effects of the interaction of UV radiation with other stress factors. These studies may lead to a better understanding of plant survival in ecosystems, the maintenance and propagation of species, and how to provide high-quality food to the population.

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