The Effect of UV-B Exposure on the Seedling Vigor of *Vigna radiata*

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Abstract
The effect of UV-B exposure on the seedling vigor of mung beans (*Vigna radiata*) was studied. Seeds were exposed to UV-B light for times of 0, 1, 2, 4, 8, 12, and 16 hours, and were then left to germinate for a total of 48 hours, including exposure time. The length of the seedling radicle and the percentage of seeds that germinated were measured. It was found that seedling vigor increased at two hours of UV-B exposure, with a gradual decrease in seedling vigor after two hours. There was no significant difference in the seedling vigor for the durations of 1, 4, and 8 hours of UV-B light exposure.

***Keywords*:** Mung beans (*Vigna radiata*), UV-B light, Seedling Vigor, Germination

I. INTRODUCTION

Mung beans (*Vigna radiata*) are widely cultivated in Asia and are a staple ingredient in many dishes. The destruction of the ozone layer may threaten the cultivation of these beans and many other crops. The ozone layer of the atmosphere shields the earth from harmful UV-B radiation transmitted from the sun, and approximately 95 percent of the sun's UV-B radiation is absorbed by this layer.[1] However, gaseous CFCs and other gases have been degrading this protective layer, allowing harmful wavelengths of ultraviolet light through, potentially impacting the ecosystem.

Research has shown that the regulation of photomorphogenesis can be managed through the manipulation of UV-B light radiation, leading to increased seed germination and growth; however, excessive radiation of UV-B light may damage the seeds' DNA, which can cause wilting and even cell death.[2] Past studies have shown that positive seed responses were significantly reduced when exposed to long periods of UV-B light by subjecting *Vigna mungo* seeds to a range of 280 – 320 nm of UV-B light for 40 minutes a day for 1, 4, and 8 days, measuring photosynthetic activity.[3] Photomorphogenic activity increased in all UV-B exposures compared to no UV-B exposure, but decreased by 30% when subjected to UV-B light for eight days rather than one day. These outcomes demonstrate a positive correlation between seeds' initial UV-B light exposure and plant success, whereas prolonged UV-B light is shown to have a negative correlation with seed growth.

The germination and growth of mung beans is harmed by prolonged exposure to UV-B, as this causes overproduction of reactive oxygen species which cause mutations in the DNA bases.[4] Previous studies have shown that exposure to UV-B radiation causes a decrease of globulins, an essential protein for mung bean seeds, which is detrimental to the nutritional quality of seedling growth.[5] Other proteins are also indirectly inactivated, halting the growth of seedlings, providing a further understanding as to why longer exposure to UV-B light inhibits the growth of mung bean radicles.[6]

With an increased amount of UV-B radiation penetrating the atmosphere, this paper aims to investigate the effect of exposure to UV-B light on mung bean seeds for the first 48 hours of growth. The effect of UV-B light on mung bean seeds is measured by the seedling vigor, which consists of germination percentage and seedling length. The seed's growth is measured by the length of the radicle that appears after germinating for 48 hours, including any time of UV-B radiation exposure. The seedling vigor index,

used to calculate the success of germination and early growth,[7] is calculated by multiplying the product of seedling length (in cm) and the germination percentage of these seeds, with the resulting units expressed as %cm. There are various ways to measure seedlings' germination and growth, including plant height, root length, and leaf surface area,[8] however, for this investigation, the measurement of the length of the radicle allows for observation of the UV-B light effect on the embryo and pre-existing food supply, rather than the effect on photosynthesis. By measuring this after 48 hours, the radicle length is equivalent to the seedling length; therefore, the standard seedling vigor index is applicable. The radicle will be measured in centimeters using digital analysis, as shown in Figure 1, while the percentage germination will be assessed by recording the number of sprouted seeds.

II. METHODS

Preliminary UV-B Irradiation Testing

The mung bean seeds were all soaked for 1 hour in distilled water. A total of 25 seeds were then placed in 5 Petri dishes, 2 trials each for 0, 2, and 8 hours. These time intervals were selected to determine if there would be a difference in the germination percentage and growth. It was discovered that 8 hours of UV-B light exposure did not show clear inhibition of radicle length. Furthermore, optimal growth for the seeds was observed at 2 hours of UV-B light exposure, prompting an adjustment to shorter intervals of 0 to 4 hours to determine the most effective duration under UV-B light for optimal growth. The hours under UV-B light were also extended to 12 hours and 16 hours to determine if this would inhibit the growth of the beans, since research has shown that prolonged exposure to UV-B light can damage the seeds.[2]

Preparation of UV-B Irradiation Apparatus

As seen in Figure 2, a 4-watt UV-B light bulb was taped to the inside top of a container that was 24.5 cm wide, 34.5 cm long, and 14.0 cm high. Petri dishes with the seeds were placed on the bottom of the container so that the germinating seeds were 10-12 cm away from the bulb, with measured UV-B intensity ranging from 0.024 to 0.028 W/m^2, for an average value of 0.026 W/m^2 for the UV-B intensity that the seeds were exposed to. To calculate the energy density in J/m^{2}hr, the UV-B intensity of 0.026 W/m^2 was multiplied by 3600 seconds. For post-exposure germination, a fully sealed box was used to ensure total darkness for the remaining germination process.

Seed Preparation and UV-B Exposure

In total, 230 *Vigna radiata* seeds from a single bag of "Raitip" brand mung beans were soaked in distilled water for one hour. Cotton wool was soaked in 40 ml of water and spread across the bottom of each of five petri dishes. Twenty-five seeds were placed in each petri dish, covered with the plastic lids, and then placed in the light-sealed container for exposure to UV-B radiation. This was done for times of 0, 1, 2, 4, 8, 12, and 16 hours.

Post-Exposure Germination and Radicle Length Measurement

After the set duration of time, the UV-B light was turned off, the petri dishes were removed from the

Figure 1. An Example of a Tracing on the Digital Analysis Program Used to Measure the Radicle Length

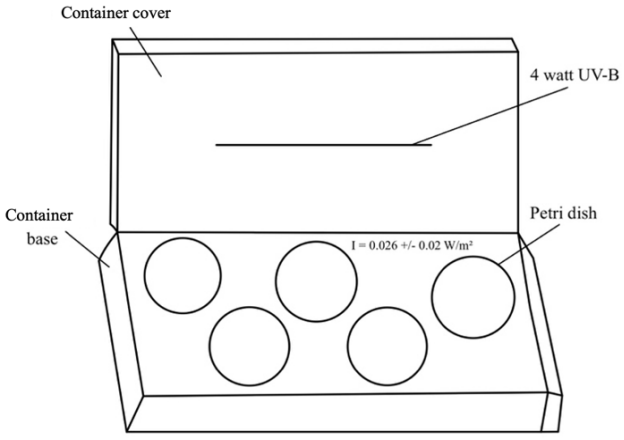

Figure 2. Setup of the irradiation environment, with the intensity of the UV-B light exposure indicated.

Exposure time (hours) (± 20 sec)	Energy density (J/m^2)	Uncertainty (J/m^2)
0	0	± 0
1	94	± 7
2	187	± 14
4	374	± 29
8	749	± 58
12	1123	± 86
16	1498	± 115

Table 1. UV-B exposure time and the total energy density delivered to the seeds.

box, and transferred to a sealed box, allowing the seeds to germinate for the remainder of the 48 hours without exposure to light. Once the germination period was over, the seeds from each petri dish were laid out and photographed (Figure 1). These steps were repeated twice for each of the different levels of UV-B exposure, with the initial growth of the seeds measured by the ImageJ program.

III. RESULTS AND DISCUSSION

Table 1 shows the durations of exposure and the resulting total energy density to which each seed was exposed. Figure 5 shows how the duration of UV-B exposure affected both the germination rate and radicle length after 48 hours.

It is observed in Figure 5 that both germination rate and seedling length show the same pattern when exposed to various durations of UV-B light, meaning that breaking dormancy and growth are both affected. Seedling length and germination percentage are both observed to increase in their values up to two hours as the duration of exposure to UV-B light increases. This suggests that exposure to increasing durations of UV-B light is associated with higher germination percentages and also supports greater seedling growth. It was also observed that the increase in the seedling length was greater than the increase in germination percentages. When comparing the longest time tested, 16 hours of exposure, to 2 hours of exposure, the seedling length is seen to decrease to less than half, whereas the germination rate is about ¾ of what it is at 2 hours.

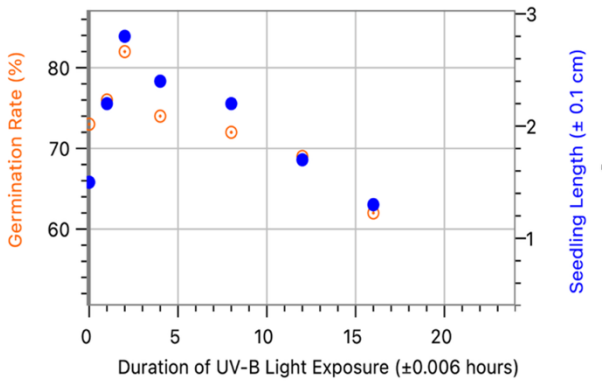

Figure 5. Durations of UV-B light exposure vs. germination rate (%) and seedling length (± 0.1 cm).

Figure 6 effectively confirms that post-optimal UV-B exposure, the longer a seed is exposed to UV-B light, the more the seedling vigor will be inhibited and decrease. As seen in Figure 6, the optimal UV-B exposure for a seed is 2 hours. As the UV-B exposure increases above two hours, the mean seedling vigor gradually decreases at a slower rate compared to the initial drop observed immediately after two hours. After 12 hours, the seedling vigor drops below 1.1 %cm (the vigor that corresponds to 0 hours of exposure), meaning that growth is being hindered rather than stimulated by the UV-B light after 12 hours of exposure.

Statistical Test

An analysis using the ANOVA and Tukey-Kramer post hoc was conducted. Two hours (187 J/m^2) of UV exposure produced significantly higher seedling vigor than one hour ($p < 0.00001$) or four hours ($p < 0.0001$). Seedling vigor was also significantly lower at 16 hours of UV exposure than at 0 hours ($p = 0.033$). These results signify that 2 hours of exposure

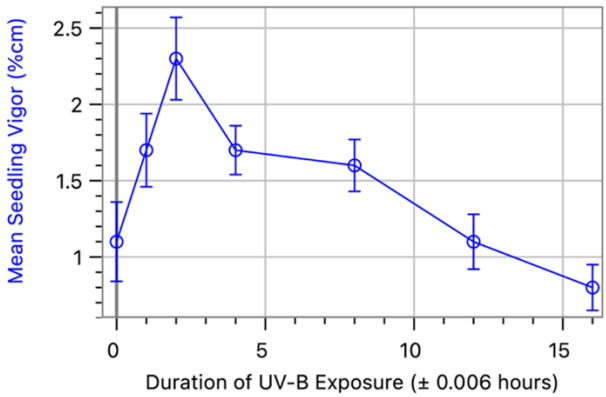

Figure 6. Durations of UV-B light exposure (± 0.006 hours vs. the mean seedling vigor (% cm)

is a particular duration of significance for seedling vigor, which is reaffirmed by the graph as it peaks at the 2-hour interval, indicating that it is the optimal duration of exposure. Additionally, from 12-16 hours of exposure to UV-B light, the p-values are smaller when compared to other values (except 12 and 0 hours). This is due to the significantly worse seedling vigor with 12-16 hours of exposure than with 0 hours of exposure.

Further research is suggested to test whether different frequencies of UV-B light may affect mung bean growth differently, as well as testing different types of crops to help provide a broader understanding of the true effects of UV-B exposure on farming plants. The effect of UV-B exposure over a longer period of time – past 48 hours – could also be investigated to see whether this effect lasts until the complete maturity of a plant. Moreover, the presence of soil may have an effect on the results of UV-B exposure; therefore, continuing research should be done for seeds germinating under soil with exposure to UV-B from above.

Studies could also address the current limitations of this investigation. As the distribution of mung bean seeds could have potentially been uneven, leading to uneven growth, it is important to ensure an even distribution of the seeds in the petri dish to avoid overlapping. Furthermore, not accounting for the 3-dimensional shape of the bean radicles could have distorted the true length of the beans when recording the size. Future research may address this issue by combining both mass and radicle length for a more standardized value, reducing this limitation.

IV. CONCLUSION

The results of this study suggest that UV-B exposure can have both positive and negative effects on the seedling vigor of mung beans. While limited amounts of UV-B light exposure were shown to enhance the seedling vigor of mung beans, extended periods of irradiation led to a decrease in overall seedling vigor. It was also noted that there was a significant drop in seedling vigor after 12 hours, suggesting that UV-B light exposure becomes harmful to mung beans in factors such as germination success and early seedling growth, reflected through a decline in both germination percentages and reduced radicle length.

V. REFERENCES

1. “Ultraviolet Waves.” *Nasa.gov*, 10 Aug. 2016, https://science.nasa.gov/ems/10_ultravioletwaves/. Accessed 21 Mar. 2024.
2. Shi, Chen, and Hongtao Liu. “How Plants Protect Themselves from Ultraviolet-B Radiation Stress.” *Plant Physiology*, vol. 187, no. 3, 26 May 2021, pp. 1096–1103, https://doi.org/10.1093/plphys/kiab245.
3. Shahid, Syed, et al. “Effect of Enhanced UV-B Radiation on Germination, Seedling Growth and Biochemical Responses of Vigna Mongo (L.) Hepper.” *Pak. J. Bot*, vol. 45, no. 3, 2013, pp. 779–785.
4. Subramanian, Supriya. “The Mechanism of DNA Damage by UV Radiation.” *News-Medical*, 10 Apr. 2018, www.news-medical.net/life-sciences/The-Mechanism-of-DNA-Damage-by-UV-Radiation.aspx#:~:text=UVA%20(and%20also%20UVB)%20radiation,the%20DNA%20bases%20causing%20mutations. Accessed 12 Apr. 2024.
5. Wang, Junqi, et al. “Protein Mobilization in Germinating Mung Bean Seeds Involves Vacuolar Sorting Receptors and Multivesicular Bodies.” *Plant Physiology*, vol. 143, no. 4, 23 Feb. 2007, pp. 1628–1639.
6. Moss, Anthony, and Jimmy Kim. *The Effect of Uv Irradiation on Vigna Radiata Seeds’ (Mung Beans) Germination and Growth*. 2019.
7. Tekrony, D M. “Precision Is an Essential Component in Seed Vigour Testing.” *Seed Science and Technology*, vol. 31, no. 2, 1 July 2003, pp. 435–447, https://doi.org/10.15258/sst.2003.31.2.20.
8. BYJU'S. “How Do You Measure Plant Growth - BYJU-S NEET.” *Byjus.com*, BYJU’S, 4 July 2022, byjus.com/question-answer/how-do-you-measure-plant-growth/. Accessed 29 Mar. 2024.