Effects of light spectrum and UV-A radiation on *in vitro* seed germination and seedlings of Massai grass (*Panicum maximum* cv. Massai)

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Abstract

The objective of this study was to evaluate the effects of different visible light spectra and UV-A radiation on the germination and morphology of Massai grass (*Panicum maximum* cv. Massai) seedlings in vitro. Seeds of cv. Massai from the 2024/2025 harvest were used. The experiment was conducted in germination boxes maintained at 25 ºC for 17 days under different light sources: white, red, green, yellow, absence of light (black), and UV-A radiation. Germination was monitored daily by counting the number of germinated seeds, with a 16-hour photoperiod. At the end of the experiment, seedlings were collected and evaluated for shoot length, root length, and fresh and dry mass. Results showed that the highest germination rates occurred between days 2 and 4 under green, red, and white light spectra. The lowest germination rate was observed under UV-A, reaching a maximum of 42%. Regarding seedling morphology, yellow light provided the best results, enhancing shoot length, root length, and fresh mass. In conclusion, visible light spectra such as green, red, and white promote rapid germination in a shorter time, while the yellow spectrum (570–590 nm) optimizes seedling morphological development in Massai grass. UV-A radiation, however, exerts deleterious effects from germination through early seedling growth.

Keywords: Massai cultivar, seedling development, grass germination, effects of light spectra.

Efeitos do espectro de luz e UV-A na germinação e nas plântulas *in vitro* de sementes de capim-Massai (*Panicum maximum* cv. Massai)

Resumo

O objetivo deste estudo foi avaliar os efeitos de diferentes espectros de luz visível e radiação UV-A sobre a germinação e a morfologia de plântulas de capim-Massai (*Panicum maximum* cv. Massai) in vitro. Foram utilizadas sementes da cultivar Massai da safra 2024/2025. O experimento foi conduzido em caixas de germinação mantidas em câmara climatizada a 25 °C por 17 dias, sob diferentes fontes luminosas: espectros branco, vermelho, verde, amarelo, ausência de luz (preto) e radiação UV-A. A germinação foi avaliada diariamente pelo registro do número de sementes germinadas. O fotoperíodo foi de 16 h de luz. Ao final do experimento, as plântulas foram coletadas e avaliadas quanto ao comprimento da parte aérea, comprimento radicular, massa fresca e seca. Os resultados mostraram que os maiores índices de germinação ocorreram entre os dias 2 e 4 para os espectros verde, vermelho e branco. A menor taxa de germinação foi observada no tratamento com UV-A, com um máximo de 42%. Em relação aos parâmetros morfológicos, o espectro amarelo apresentou os melhores resultados, favorecendo o comprimento da parte aérea, comprimento da raiz e massa fresca das plântulas. Conclui-se que o uso de espectros de luz visível, como verde, vermelho e branco, estimula a germinação rápida em menor tempo, enquanto o espectro amarelo (570–590 nm) promove maior eficiência no desenvolvimento morfológico das plântulas de capim-Massai. A radiação UV-A, por sua vez, apresenta efeito deletério desde a germinação até o desenvolvimento inicial das plântulas dessa forrageira.

Palavras-chave: cultivar Massai, desenvolvimento de plântulas, germinação de capim, efeitos de espectros de luz.

1. Introduction

Light is an essential energy source that directly influences the regulation of germination, growth, development, and the overall metabolism of higher plants (Raffo et al., 2020). Planet Earth is continuously exposed to a wide range of light spectra, including red, blue, green, yellow, and white light, as well as ultraviolet (UV) radiation, which comprises three ionizing types: UV-A (315–400 nm), UV-B (280–315 nm), and UV-C (200–280 nm). According to Victório & Lage (2009), light acts as a physical environmental factor capable of triggering internal signaling pathways that activate or deactivate various metabolic routes in seeds and plants.

As described by Morelli & Ruberti (2000), light exerts a strong regulatory role on plant physiology. Its absorption by photoreceptors—such as those belonging to the phytochrome and cryptochrome families—photomodulates a series of morphogenic and developmental responses. Phytochromes are chromoproteins that reversibly interconvert between active and inactive forms. In their inactive state, they absorb red or blue light, leading to a conformational change in their chromophore and conversion to the active form. When they absorb far-red light, they revert to the inactive state.

Seeds of different species exhibit distinct responses depending on the quality and intensity of the light spectrum. In the embryo, the transition from a heterotrophic stage, dependent on nutrient reserves, to an autotrophic stage in seedlings is regulated by light spectra (Kerbauy, 2008). Various wavelengths have been extensively investigated to elucidate seed and seedling behavior across agricultural, wild, and exotic species. Consequently, the influence of green, blue, yellow, red, and white light sources has been assessed in relation to morphological and physiological parameters, optimization of primary and secondary metabolite production, and acceleration of early growth to obtain vigorous and healthy seedlings in a shorter time (Victório; Lage, 2009; Islam et al., 1999).

Regarding ultraviolet radiation, it is well established that certain UV wavelengths can alter the physiology, growth, and productivity of terrestrial plants (Puntel et al., 2024; Loconsole; Santamaria, 2021). Among them, UV-A is considered a neutral or even beneficial form of radiation for microorganisms and plants, as it is associated with processes such as plant–pathogen interactions, DNA and RNA repair, and infection responses.

According to Mariz-Ponte et al. (2018), UV-A radiation acts as a natural stressor, inducing the synthesis of bioactive compounds associated with the plant's secondary metabolism, such as carotenoids and anthocyanins. These metabolites are not only beneficial to the plant but also contribute to biomass accumulation and the synthesis of several stress-related compounds. However, excessive UV exposure can negatively impact plant quality, productivity, germination, and seedling development. Although the current understanding of UV radiation effects on seed biology and germination remains limited, further studies are necessary to elucidate the physiological mechanisms underlying the responses of seeds to this ionizing energy source (Rupiasih; Vidyasagar, 2016). What is currently known is that seeds can perceive and respond to UV-A radiation according to its wavelength characteristics.

The successful establishment and maintenance of pastures depend on the appropriate management of forage species and on the genetic characteristics of the selected cultivar used as a nutritional source for livestock (Capistrano et al., 2025; Ferreira et al., 2024; Cunha et al., 2022). Therefore, characterizing the influence of different light spectra and UV-A radiation on the germination rate and early development of forage grass seedlings is crucial for ensuring rapid and high-quality feed availability for beef, dairy, and rearing systems. Such efforts align with the principles of modern livestock production, which integrate research, plant breeding, and sustainable food production.

The present study aimed to evaluate the effects of different light spectra and UV-A radiation on the germination and early development of Massai grass (*Panicum maximum* cv. Massai) seedlings under controlled *in vitro* conditions.

2. Materials and Methods

2.1 Plant material and seed sterilization

Commercial seeds of Massai grass (*Panicum maximum* cv. Massai) (Terra do Agro, Ribeirão Preto, São Paulo, Brazil) were surface-sterilized by immersion in 30% commercial sodium hypochlorite (1.5% active chlorine) and rinsed with sterile distilled water between treatments with different light spectra and UV-A radiation. The seed lot viability was approximately 98%, according to the commercial supplier.

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 of germination paper. 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 (Biospherical 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 centimeters (cm), as well as fresh and dry mass per seedling (measured with a digital analytical balance) (Bel, Mod. M5 M214AiH, Brazil), expressed in milligrams (mg). 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

Figure 1 shows the daily germination rate of Massai grass seeds under different light spectra and UV-A. The highest germination rates were observed between the second and fourth days for seeds exposed to green, red, and white light spectra. In contrast, seeds subjected to yellow and black light spectra exhibited lower germination rates, with the germination period extending until the sixth day. Exposure to UV-A radiation resulted in the lowest germination rate among all treatments.

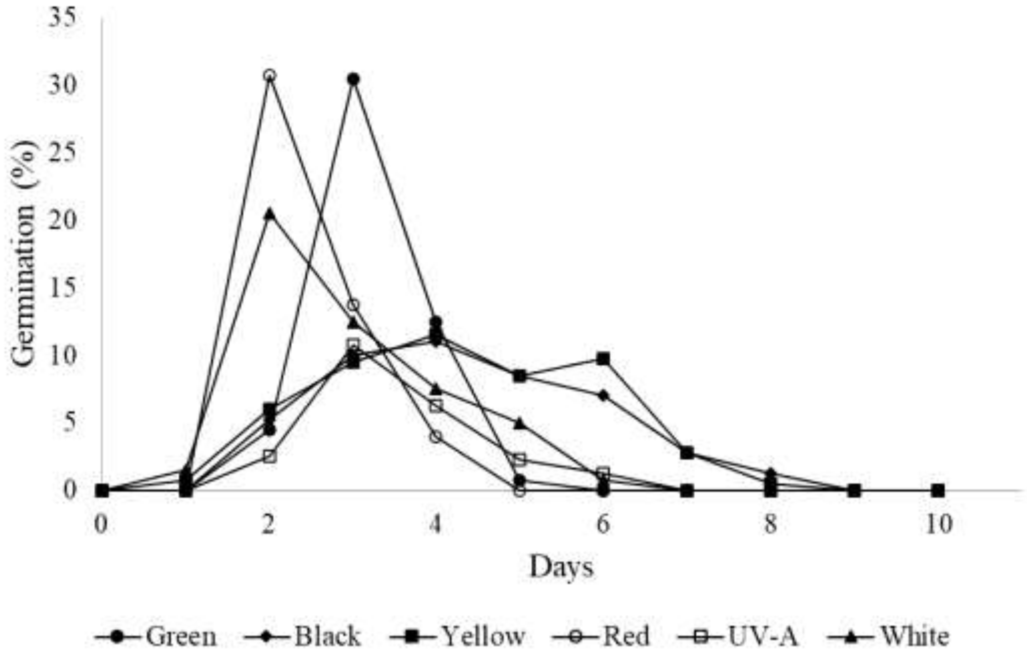

Figure 1. *In vitro* germination rate (%) of Massai grass seeds under different light spectra and UV-A exposure. Source: Authors, 2025.

3.2 Germination and morphological parameters

Table 1 describes the results for germination rate and morphological parameters, including shoot length, root length, and fresh and dry mass of Massai grass seedlings grown in vitro under different light spectra and UV-A. No significant statistical differences were observed in the germination rate (%) among treatments exposed to different light spectra. However, when compared to UV-A radiation, a marked reduction was observed, with germination rates below 50%. Regarding seedling length, the treatment under the yellow light spectrum showed the best performance, with seedlings reaching lengths greater than 40 mm. For root length, the white and yellow light spectra did not differ significantly, both presenting roots longer than 50 mm. In terms of fresh mass, seedlings exposed to yellow light exhibited higher mean values, with masses exceeding 0.040 g. For dry matter (straw), the highest yield was observed under the green light spectrum, with dry mass values above 0.0050 g.

Table 1. Germination and morphological parameters of Massai grass seedlings under different light spectra and UV-A radiation *in vitro*.

Luzes	Germination (%)	Shoot length (mm)	Root length (mm)	Seedling fresh weight (g)	Seedling dry weight (g)
UV-A	42.00 b	23.74 c	18.91 c	0.031 ab	0.0013 b
Red	96.50 a	31.04 bc	32.91 b	0.023 b	0.0018 b
White	93.50 a	22.76 c	54.63 a	0.022 b	0.0013 b
Yellow	98.50 a	44.13 a	65.32 a	0.045 a	0.0021 b
Green	96.50 a	34.26 b	18.99 c	0.037 ab	0.0055 a
Black	91.50 a	27.33 bc	23.06 bc	0.024 b	0.0018 b
CV (%)	5.45	20.65	28.66	42.16	35.10

Note: Equal letters in the same column do not differ statistically by Tukey's test with a 5% probability. CV = Coefficient of variation. Source: Authors, 2025.

4. Discussion

Our results demonstrated that Massai grass exhibited a germination rate exceeding 90% under a 16-hour photoperiod, compared to other species, such as *Paspalum virgatum* (20%) and *Sporobolus indicus* (79.6%) (Fernandes et al., 2021). It was also observed that S. indicus seeds require light for germination, whereas light was not an essential requirement for *P. virgatum*. Massai grass performed well under different visible light spectra and even in the absence of light, maintaining germination rates above 90%. Similar findings were reported by Bastiani et al. (2015) for barnyardgrass (*Echinochloa crusgalli*) under varying light and temperature conditions.

However, exposure to UV radiation, particularly UV-A, had a strongly negative effect, resulting in germination rates below 50%. Our findings contrast with those reported by Puntel et al. (2024), who observed germination above 93% in white oat (Avena sativa) seeds exposed to different periods of UV-B radiation, a grass species also used in forage production.

Regarding morphological parameters, yellow light promoted greater aerial growth of seedlings. Similar results were reported by Ferrari et al. (2016) in *Curcuma longa*, where yellow and white light spectra enhanced seedling development, affecting fresh and dry mass of both shoots and roots. Hypocotyl length was not significantly influenced by the absence of light, unlike the results reported by Bastiani et al. (2015) in barnyardgrass, where darkness led to increased hypocotyl elongation.

A temperature of 25 °C was not a decisive factor for germination or germination rate index (GRI) in our study. However, Fernandes et al. (2021) reported that this temperature is optimal for achieving higher germination and GRI in *P. virgatum* and *S. indicus*. Seedlings exposed to UV-A exhibited reduced hypocotyl length, inhibited root development, and decreased fresh and dry mass. Puntel et al. (2024) reported seedling lengths between 14.25 and 15.16 cm in white oat under UV-B, highlighting that different spectral ranges can elicit highly variable responses, both among species and cultivars (Ferrari et al., 2016).

In this context, UV-A radiation was more detrimental to germination and early seedling development compared to UV-B. Studies indicate that UV-B causes less damage to seed physiological systems and better preserves the embryo (Semenov et al., 2020; Moreira-Rodriguez et al., 2017; Debeaujon et al., 2018). Moreover, UV-B can induce the accumulation of antioxidant molecules and protective compounds in plants (He et al., 2019) and promote isoflavone production (Ma et al., 2019). Although UV-A exerts deleterious effects, it can also stimulate the synthesis of secondary metabolites, such as vitamin C, phenolics, chlorophylls, carotenoids, anthocyanins, and flavonoids, which provide UV protection (Loconsole; Santamaria, 2021). This protective effect has been observed by Veselá et al. (2022), who reported increased thermal UV protection in grasses, such as *Agrostis capillaris* (29%), and in herbaceous plants, such as *Hypericum maculatum* (12%), in response to elevated UV radiation.

5. Conclusions

The results of this study demonstrate that different visible light spectra and ultraviolet (UV-A) radiation significantly influence germination rate, germination speed, and the morphological parameters of Massai grass (*Panicum maximum* × Massai) seedlings grown *in vitro*. Exposure to UV-A radiation had a negative impact, resulting in slower germination, a lower total germination percentage, and reduced seedling development, indicating the sensitivity of forage seeds to this radiation source.

In contrast, green, red, and white light spectra promoted faster and higher germination rates. Although no significant differences were found in the final germination percentage among visible light spectra, the yellow light spectrum showed the greatest positive effect on seedling morphological development, suggesting it as the most suitable light condition for Massai grass seed germination and early growth *in vitro*. Future studies should investigate the effects of other UV radiation sources, including UV-B and UV-C, on germination parameters and morphological traits of Massai grass seedlings, both in vitro and under field conditions.

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7. Authors' Contributions

Selton Sales de Souza: Conceptualization, study design, investigation, data collection, statistical analysis, writing

– original draft, writing – review & editing, and publication. *Marcelo Osmar da Silva*: Project administration, supervision, writing – review & editing, post-review corrections, and publication.

8. Conflicts of Interest

No conflicts of interest.

9. Ethics Approval

Not applicable.

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