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INNOVATIVE RESEARCH ON THE PRODUCTION OF TUBEROSE BULBILS FOLLOWING ARTIFICIAL LED LIGHTING

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Abstract

Flowers have long held economic, cultural, and ornamental importance, while several species are also valued as raw materials for the cosmetic and pharmaceutical industries. In Romania, tuberose is appreciated particularly for its decorative qualities and intensely fragrant flowers. This study aimed to evaluate the influence of supplemental light treatments applied to tuberose bulbs before planting on plant development and bulbil production. The experiment was conducted using the ‘Avatea’ cultivar in a vertical greenhouse at the Vegetable Research and Development Station Buzău, Romania. Before planting, the bulbs were exposed to supplemental lighting provided by high-power light-emitting diode panels emitting monochromatic blue, red, or white light. An untreated variant was included as the control. During the vegetation period, biometric measurements were performed to assess the plants' response to the different pre-planting light treatments. At the end of the experiment, bulbil production was determined separately for each experimental variant and compared with that of the control. The results indicated that pre-planting exposure to light-emitting diode treatments influenced the reproductive performance of tuberose plants. The red-light treatment, V2, produced the highest bulbil weight and total bulb-plus-bulbil biomass, whereas the white-light treatment, V4, produced the highest mean number of bulbils. Both treatments showed distinct advantages compared with the untreated control. These findings suggest that supplemental lighting of tuberose bulbs before planting may represent a useful technological approach for improving the production of propagation material under protected cultivation conditions.

Keywords: pre-planting light treatment; LED irradiation; bulbil production; propagation material; protected cultivation; ornamental geophytes

1. Introduction

Tuberose is an ornamental species of considerable horticultural interest due to the decorative value and intense fragrance of its flowers. In addition to its use in landscape design and cut-flower production, the species is also valued as a potential raw material for the cosmetic and pharmaceutical industries. Under Romanian cultivation conditions, tuberose is appreciated by both growers and consumers, and the development of efficient propagation and production technologies remains important to ensure high-quality planting material (Iancu & Stanciu, 2017).

The quality of planting and propagation material represents an essential component of successful crop establishment, as its genetic identity, physiological condition, and phytosanitary status may directly affect subsequent plant development and productive performance. Although certification systems primarily concern seeds and officially marketed plant material, the same general principle is relevant to ornamental geophytes: technological treatments intended to improve bulb performance should preserve material health, uniformity, and biological quality. Consequently, the evaluation of pre-planting LED exposure should consider not only the quantity of bulbils obtained, but also their suitability as viable and uniform propagation material for subsequent production cycles (Dincă et al., 2019).

The economic relevance of improving tuberose propagation is also supported by the broader situation of the Romanian floriculture sector. Domestic production of flowers and ornamental plants remains limited in comparison with European production, while the national market is strongly dependent on imports. In this context, the development of efficient local technologies for producing healthy and uniform propagation material could contribute to strengthening domestic ornamental-plant production and reducing some of the disadvantages faced by Romanian growers (Munteanu Pila & Stanciu, 2021).

The commercial multiplication of tuberose relies mainly on bulbs and bulbils. Consequently, the quantity and quality of the propagation material obtained at the end of the growing cycle directly influence the establishment of future crops and the economic efficiency of the production system. Bulbil formation may be affected by several factors, including cultivar characteristics, the physiological condition of the bulbs, environmental conditions, and the cultivation technology applied before and after planting. Improving the biological potential of bulbs prior to planting may therefore represent a practical method for supporting plant development and increasing the production of propagation material.

Controlled-environment cultivation provides the possibility of applying specific technological treatments that are difficult to manage under field conditions. Among these, supplemental lighting may be used not only during active plant growth but also as a pre-planting treatment for vegetative propagation organs. Exposing bulbs to different light spectra before planting may influence their physiological activity and may subsequently affect sprouting, vegetative development, and bulbil formation. However, the effects of such treatments on tuberose have not been sufficiently clarified, particularly under vertical greenhouse conditions.

The research problem addressed in this study concerns the possibility of improving tuberose bulbil production through the application of supplemental light treatments to bulbs before planting. The study focuses on the 'Avatea' cultivar and evaluates whether exposure to blue, red, or white light-emitting diode radiation produces measurable differences in plant growth and propagation performance compared with untreated bulbs.

The main objective of the research was to determine the influence of pre-planting light-emitting diode treatments on selected biometric characteristics and on the production of tuberose bulbils. The study was based on the hypothesis that the spectral composition of the light applied before planting could

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induce different physiological responses and that one or more treatments could increase bulbil production relative to the untreated control.

The manuscript is structured as follows. The next section presents the relevant literature and the theoretical framework concerning light quality, plant responses, and the use of light-emitting diode technology in horticultural production. This is followed by a description of the biological material, experimental design, lighting treatments, and measurement methods. The subsequent sections present and discuss the results, while the final section summarizes the main conclusions, practical implications, and directions for further research.

2. Literature Review and Theoretical Framework

The theoretical basis for using light-emitting diode treatments in horticulture is provided by the understanding that light acts simultaneously as an energy source and as a developmental signal.

Bantis et al. critically synthesized the development of LED applications in horticultural and floricultural production, showing that the main value of this technology lies in the possibility of independently controlling spectral composition, radiation intensity, and photoperiod. These characteristics make LED systems particularly suitable for greenhouses, growth chambers, and vertical cultivation facilities. Nevertheless, the authors also demonstrated that technological efficiency does not automatically imply biological effectiveness, because plant responses depend on species, cultivar, developmental stage, and the interaction between the supplied spectrum and other environmental factors. Their review therefore supports the need for crop-specific experiments rather than the direct transfer of lighting recommendations from one horticultural species to another. This principle is particularly relevant to tuberose, for which the effects of pre-planting spectral treatments remain insufficiently established (Bantis et al., 2018).

The meta-analysis conducted by Ma et al. provides strong evidence that plant responses to LED lighting are heterogeneous and context dependent. By integrating results obtained from multiple plant species and cultivation systems, the authors found that monochromatic and combined spectra can influence biomass accumulation, plant morphology, photosynthetic characteristics, and quality-related traits. However, the magnitude and direction of these effects varied according to taxonomic group, cultivation conditions, and the plant characteristic under evaluation. This variability challenges the assumption that a particular light colour can be considered universally optimal. For the present study, the findings indicate that the response of tuberose bulbs to blue, red, or white light cannot be reliably predicted from experiments conducted on leafy vegetables or other actively photosynthesizing crops. Direct evaluation of the 'Avatea' cultivar is therefore necessary to determine whether pre-planting irradiation produces a measurable effect on subsequent plant growth and bulbil production (Ma et al., 2021).

The research conducted by Dieleman et al. contributes to the conceptual distinction between the photosynthetic and morphogenetic effects of light. Young tomato plants exposed to different spectral environments developed contrasting architectural characteristics, even when the light intensity was controlled. Blue light resulted in shorter plants with smaller, more upward-oriented leaves, whereas other spectra produced different patterns of stem and leaf development. The study demonstrated that spectral quality modifies whole-plant architecture and light interception, rather than merely stimulating or limiting biomass accumulation. Although tomato differs substantially from tuberose, the results support the hypothesis that light treatments may initiate persistent developmental responses.

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At the same time, the use of actively growing tomato plants limits the direct applicability of the findings to non-photosynthetic storage organs. The experiment extends this line of inquiry by testing whether a spectral stimulus applied to bulbs before planting can influence plant characteristics observed later during the vegetation period (Dieleman et al., 2019).

The comprehensive review by Sena et al. expands the analysis of LED effects beyond photosynthesis and plant morphology. The authors emphasized that light quality and quantity may influence enzyme activity, gene expression, cell-wall formation, plant defence mechanisms, metabolism, and postharvest quality. Importantly, they argued that spectral responses are modified by environmental conditions, particularly when supplemental lighting is used in greenhouses where natural and artificial radiation interact. This observation is relevant to the current study because bulbs treated with LEDs may respond not only to light colour, but also to treatment duration, irradiance, temperature, initial physiological status, and subsequent greenhouse conditions. The review also identified insufficient experimental evidence for many horticultural species, reinforcing the need to investigate less-studied crops and alternative moments of treatment, such as the period before planting (Sena et al., 2024).

Solbach et al. showed that the efficiency of supplemental lighting cannot be separated from the natural radiation environment in which plants are cultivated. Their greenhouse experiments with sweet basil compared blue, red, and white plus far-red lighting under seasonal conditions and demonstrated that growth and morphological responses changed with both the supplemental light dose and the amount of available natural light. Biomass-related traits generally increased with light dose, whereas several morphological responses followed nonlinear or saturating patterns.

The study therefore reveals an important methodological issue: plant responses attributed to spectral quality may also reflect differences in total radiation and background environmental conditions. Although the present tuberose experiment applies light before planting rather than throughout active growth, the findings underline the importance of reporting treatment intensity, exposure duration, and greenhouse conditions when interpreting the subsequent production of bulbils (Solbach et al., 2021).

Mitchell and Sheibani placed LED technology within the broader development of plant factories and indoor vertical production. They showed that improvements in diode efficiency, spectral control, fixture design, and heat management have enabled lighting systems to be integrated into multilayer cultivation environments. Their analysis is particularly relevant to experiments conducted in vertical greenhouses, where spatial limitations and the proximity of lamps to biological material require lighting sources that generate limited radiant heat and can be precisely controlled. Nevertheless, much of the plant-factory literature concentrates on crops maintained under artificial lighting during their complete production cycle. The use of a vertical greenhouse for short-term treatment of propagation organs represents a different application. The current study therefore broadens the technological role of LED systems by investigating their use as a pre-planting treatment rather than only as a continuous source of photosynthetic radiation (Mitchell & Sheibani, 2020).

Among the available studies, Kumar et al. provide the most direct theoretical foundation for understanding tuberose propagation. Their systematic review demonstrated that the efficiency of plantlet and bulblet formation is influenced by genotype, explant type, culture medium, growth regulators, physical conditions, and acclimatization procedures. The review confirms that tuberose multiplication is physiologically responsive and can be modified through controlled treatments. However, most of the evaluated evidence concerns in vitro systems, in which tissues are exposed to

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artificial media, plant growth regulators, and highly controlled environmental conditions. These findings cannot be transferred directly to intact bulbs cultivated in a greenhouse. The unresolved question is whether a non-invasive physical treatment applied before planting can influence multiplication under ex vitro conditions. By evaluating intact bulbs and determining final bulbil production, the present study complements the existing in vitro literature with evidence from a protected cultivation system (Kumar et al., 2022).

Yasemin and Beruto examined the broader challenges associated with the micropropagation of bulbous ornamental plants. Their review identified bulb development, dormancy regulation, somatic embryogenesis, rooting, acclimatization, and ex vitro survival as interconnected stages that determine propagation success. A major implication of their analysis is that the production of viable propagation organs depends on the interaction between physiological condition and environmental management. However, the literature reviewed by the authors is strongly centred on tissue-culture techniques and the use of plant growth regulators. Comparatively little attention has been paid to pre-planting physical treatments of mature bulbs.

The present research contributes to this area by examining whether spectral irradiation can be used as a technological stimulus before planting, potentially influencing the later formation of bulbils without relying on in vitro procedures or chemical growth regulators (Yasemin & Beruto, 2024).

Castañeda-Saucedo et al. demonstrated that tuberose performance is highly dependent on cultivation technology. Their study showed that planting date and fertilization regime affected flowering time, floral quality, stem characteristics, and production-related traits. These results indicate that tuberose is responsive to environmental and agronomic interventions and that its productive potential cannot be explained by genotype alone. At the same time, the study focused primarily on nutrient supply, planting time, and commercial flower production rather than on the physiological preparation of bulbs or the generation of propagation material. Distinction is important because treatments that enhance flowering do not necessarily increase bulbil production; resource allocation to flowers, leaves, roots, and storage organs may involve different physiological priorities. The present research addresses this unresolved relationship by using bulbil production as the main productive indicator and biometric characteristics as intermediate measures of plant response (Castañeda-Saucedo et al., 2023).

Saravani et al. provided recent evidence that tuberose growth and development can be modified through targeted technological interventions under greenhouse conditions. Their investigation of mycorrhizal inoculation and biostimulants under water deficit demonstrated that morphological and physiological responses are influenced by the interaction between treatment and environmental stress. The study supports the broader concept that the performance of tuberose bulbs and plants can be improved by modifying their physiological capacity to use resources or tolerate limiting conditions.

Nevertheless, biological treatments and light treatments operate through different mechanisms, and a positive response to a biostimulant cannot be used to predict the effect of spectral irradiation. The relevance of this study lies primarily in confirming the plasticity of tuberose under controlled cultivation and in emphasizing the importance of evaluating treatment effects through several biometric and productive variables rather than through a single growth measurement (Saravani et al., 2025).

Bahadoran et al. showed that modification of the cultivation medium through the addition of poultry litter influenced the vegetative growth and flowering characteristics of tuberose. Their results provide

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further evidence that the species responds to changes in resource availability and cultivation conditions. However, improved vegetative or floral performance following organic fertilization reflects changes in mineral nutrition, substrate properties, and possibly microbial activity, whereas LED exposure represents a physical signal acting before planting. Consequently, the mechanisms involved are not directly comparable. The study remains relevant because it establishes that measurable differences in tuberose growth can result from pre-established technological variants and that biometric determinations are appropriate for evaluating treatment responses.

The present research advances this experimental approach by shifting attention from substrate management to the physiological effects of spectral treatments and from flower production to the formation of bulbils used as propagation material (Bahadoran et al., 2011).

The practical adoption of such treatments also depends on an effective transfer of research results from experimental institutions to commercial growers. Technological modernization in Romanian agriculture requires cooperation between research organizations, producers, and public authorities, together with investment in appropriate infrastructure and technical training. Therefore, the application of pre-planting LED treatments should be accompanied by clear operating protocols, economic assessments, and demonstration activities that allow growers to evaluate the benefits under commercial production conditions (Vlad & Stanciu, 2025).

The present study contributes to current knowledge by transferring the application of controlled spectral lighting from actively growing photosynthetic crops to intact vegetative propagation organs. It evaluates blue, red, and white LED treatments applied before planting to bulbs of the 'Avatea' tuberose cultivar and follows their effects through the vegetation period until bulbil production is determined. The research therefore connects a short-term pre-planting intervention with both intermediate biometric responses and a practically relevant propagation outcome.

The study also provides cultivar- and environment-specific evidence obtained under protected vertical-greenhouse conditions in Romania. By including an untreated control and comparing it with spectrally differentiated treatments, the experiment helps determine whether LED irradiation represents a biologically effective method for improving propagation performance.

Its principal contribution is not the assumption that one spectrum is universally superior, but the empirical identification of whether and under what experimental conditions pre-planting light exposure can influence the production of tuberose bulbils.

3. Materials and Methods

3.1. Study Design and Context

The study was conducted as a comparative experiment to evaluate the influence of pre-planting LED treatments on the vegetative development and propagation performance of tuberose. The biological material consisted of bulbs of the '*Avatea'* cultivar obtained from the plant resources collection of the Laboratory of Physiology, Agrochemistry, and Ecological Crops of the Vegetable Research and Development Station Buzău, Romania.

The experiment was carried out in the vertical greenhouse of the same institution. Before treatment, the bulbs were disinfected with Bordeaux mixture and allowed to air-dry. Four experimental variants

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were established: V1, maintained under natural light and used as the control; V2, exposed to red light at 660 nm; V3, exposed to blue light at 455 nm; and V4, exposed to white light.

The LED treatments were applied for 30 minutes per day over a period of one month, under controlled conditions specific to each experimental light variant. Following the completion of the treatment period, the bulbs were transplanted into larger pots to provide sufficient space for root and shoot development. The pots were then transferred to the greenhouse and placed on a peat bed, where the plants continued their growth under protected cultivation conditions.

3.2. Data, Variables, and Sampling

Data were obtained through direct biometric observations performed during the vegetation period and after harvest. During plant growth, the assessed characteristics included growth habit, leaf shape, leaf colour, number of leaves, plant height, plant diameter, leaf-blade length, and leaf-blade width.

After harvest, the underground organs were evaluated for bulb length, bulb width, main-bulb weight, number of bulblets, total bulb and bulblet weight per plant, and root length. Linear measurements were expressed in centimetres, while weights were expressed in grams.

The individual plants and harvested underground organs represented the observational units.

The experimental codes were retained to distinguish the records associated with each light treatment. Vegetative measurements were available only for variants V1, V2, and V3. Complete vegetative records for the white-light treatment, V4, were not available and were therefore excluded from the comparative analysis of above-ground plant characteristics. Postharvest measurements of bulbs, bulbils, and roots were available for all four experimental variants.

3.3. Analytical Methods

The data were analyzed using a descriptive comparative approach. The recorded values were grouped according to treatment and compared with the control variant to identify differences in vegetative growth, bulb development, bulblet formation, and root growth. The analysis focused on the relative performance of the red-, blue-, and white-light treatments across the measured characteristics. Because the available records did not include the complete replication structure, measures of variability, or raw datasets, inferential statistical tests were not applied. Therefore, the results were interpreted based on numerical and morphological differences among the experimental variants.

4. Results

The biological material consisted of bulbs of the ‘Avatea’ tuberose cultivar from the plant resources collection of the Laboratory of Physiology, Agrochemistry, and Ecological Crops within the Vegetable Research and Development Station Buzău, Romania. Before the establishment of the experiment, the bulbs were subjected to a preventive phytosanitary treatment with Bordeaux mixture and were subsequently allowed to air-dry for several minutes.

This preparatory stage ensured a uniform phytosanitary condition of the biological material prior to planting and exposure to the experimental light treatments, as illustrated in Figure 1.

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Figure 1. Treatment of bulbs with Bordeaux mixture
Source: Authors' experiment

Vegetative characteristics could be compared only among variants V1, V2, and V3 because complete records for the white-light treatment, V4, were not available. Within the three variants for which data were recorded, the qualitative descriptors remained stable, as all plants exhibited a columnar growth habit, linear leaves, and green leaf blades. In contrast, the quantitative measurements showed descriptive differences among the evaluated treatments, as presented in Table 1.

Table 1. Vegetative characteristics of tuberose 'Avatea' under different light treatments

Characteristic	V1 – natural light	V2 – red light (660 nm)	V3 – blue light (455 nm)
Growth habit	Columnar	Columnar	Columnar
Number of leaves	12	15	13
Plant height (cm)	30	35	32
Plant diameter (cm)	25	29	23
Leaf shape	Linear	Linear	Linear
Leaf-blade length (cm)	30	35	29
Leaf-blade width (cm)	1.2	1.6	1.1
Leaf colour intensity	Green	Green	Green

Source: Authors' measurements reconstructed from the experimental records.
Note: V1 = untreated control under natural light; V2 = red LED treatment at 660 nm; V3 = blue LED treatment at 455 nm. Complete vegetative data for the white-light treatment, V4, were not available and are therefore not reported in this table. Values are descriptive, and no inferential statistical tests or p-values are reported.

The red-light treatment, V2, produced the highest values for all evaluated vegetative traits. Compared with the natural-light control, V1, V2 increased the number of leaves from 12 to 15, corresponding to a descriptive increase of 25.0%. Plant height and leaf-blade length both increased from 30 to 35 cm, representing increases of 16.7%, while plant diameter increased from 25 to 29 cm, or 16.0%. The greatest relative difference was observed for leaf-blade width, which increased from 1.2 to 1.6 cm, corresponding to 33.3%.

The blue-light treatment, V3, produced 13 leaves and a plant height of 32 cm, values slightly higher than those of the control. However, plant diameter, leaf-blade length, and leaf-blade width were lower than in V1, indicating a more compact vegetative response under blue light. Overall, the descriptive data suggest that red light at 660 nm was associated with stronger vegetative development, whereas blue light at 455 nm was associated with reduced lateral expansion and smaller leaf dimensions. Because replicate-level measurements, variance estimates, and inferential statistical tests were not

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available, the observed differences should be interpreted as descriptive treatment responses rather than statistically significant effects.

Taken together, the vegetative measurements suggest distinct descriptive response patterns among the evaluated spectral treatments.

These contrasting responses provided the basis for examining whether the observed differences in the above-ground traits were also reflected in bulb development, bulbil production, and root growth after harvest.

Bulb, bulbil, and root response

Postharvest measurements revealed differentiated responses among the lighting treatments, indicating that the spectral conditions did not influence all underground-organ traits in the same manner. As shown in Table 2, the red-light treatment, V2, produced the highest mean total bulb-plus-bulbil weight, reaching 41.53 g compared with 35.90 g in the control. This represents a descriptive increase of approximately 15.7% relative to V1. V2 also recorded the highest mean main-bulb weight, at 27.33 g, the highest mean bulbil weight, at 14.20 g, and the greatest main-bulb width, at 3.47 cm. Mean bulb length was also slightly higher under red light than in the control, with values of 6.72 and 6.67 cm, respectively.

Table 2. Mean postharvest characteristics of bulbs, bulbils, and roots by treatment

Characteristic	V1 control	V2 red	V3 blue	V4 white
Bulb length (cm)	6.67	6.72	5.61	5.58
Bulb width (cm)	5.46	5.22	5.65	4.94
Total bulb + bulbil weight (g)	35.90	41.53	36.94	34.13
Main-bulb length (cm)	4.00	4.33	4.72	4.00
Main-bulb width (cm)	2.39	3.47	2.35	1.98
Main-bulb weight (g)	23.39	27.33	24.38	21.33
Bulbil weight (g)	12.54	14.20	12.56	12.80
Number of bulbils	12.40	11.87	10.67	12.53
Root length (cm)	9.11	9.56	8.18	9.83

Source: Authors' calculations based on the values recorded.

The blue-light treatment, V3, showed a different response pattern. It produced the highest mean bulb width, at 5.65 cm, and the greatest mean main-bulb length, at 4.72 cm, but recorded lower values for bulbil number and root length. The white-light treatment, V4, was associated with the highest mean number of bulbils, at 12.53 per plant, and the greatest mean root length, at 9.83 cm, although it produced the lowest mean total bulb-plus-bulbil weight among the evaluated variants.

Overall, the descriptive data suggest that red light was more strongly associated with increased underground biomass, whereas white light favoured bulbil formation and root development. Blue light appeared to influence bulb shape and longitudinal development rather than total biomass accumulation. Because the available dataset did not include measures of variability, confidence intervals, or inferential statistical tests, these differences should be interpreted as descriptive treatment-related patterns rather than statistically confirmed effects.

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At the level of individual observations, the red-light treatment produced the strongest biomass response. The highest total bulb-plus-bulbil weight was recorded for V2R1R, at 46.50 g, followed by V2R2R, at 40.10 g, and V2R3R, at 38.00 g. V2R1R also exhibited the greatest main-bulb weight within the red-light variant, reaching 31.00 g, together with 14.60 bulbils. By contrast, the white-light treatment was associated with comparatively stronger root development, with V4R1A reaching a root length of 11.50 cm.

These observation-level values reinforce the treatment-level pattern presented in Table 2, suggesting that red light was primarily associated with greater accumulation of underground biomass, whereas white light favoured root development. Representative measurements of the aerial parts and harvested underground organs are presented in Figure 2.

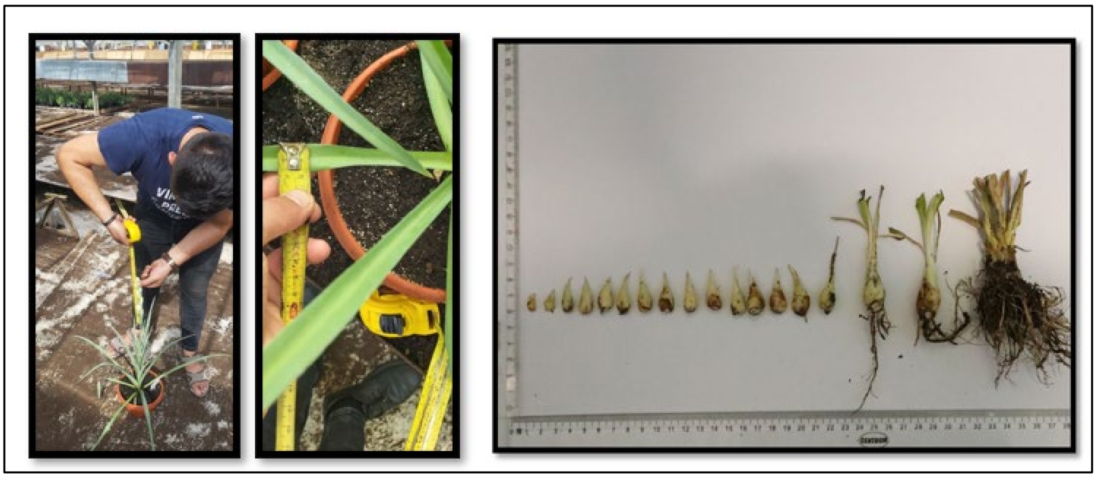

Figure 2. Harvested tuberose bulbs, bulbils, and root systems following the lighting treatments.
Source: Authors' photographic record.

5. Discussion

The present study showed that pre-planting LED exposure was associated with distinct vegetative and postharvest responses in the 'Avatea' tuberose cultivar. The effects were not uniform across all measured traits, indicating that spectral quality influenced different components of plant development.

The red-light treatment produced the most consistent response in terms of vegetative growth and underground biomass. Plants exposed to red light recorded higher values for leaf number, plant height, plant diameter, and leaf dimensions, while the harvested material showed greater main-bulb weight, bulbil weight, and total bulb-plus-bulbil weight. The coordinated increase in both aerial and underground traits suggests that the treatment may have supported a more vigorous developmental pattern throughout the cultivation cycle.

The blue-light treatment was associated with a more compact morphology, reflected by smaller leaf dimensions and reduced plant diameter compared with the red-light treatment. However, this response did not correspond to the highest bulbil production or root development. This difference indicates that compact vegetative growth should not be interpreted automatically as improved propagation performance.

The white-light treatment produced a different response pattern. Although it did not generate the highest total underground biomass, it recorded the greatest average number of bulbils and the longest

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roots. This suggests that white light may have favoured the initiation of propagation organs and root development, whereas red light was more strongly associated with biomass accumulation.

An important aspect of the results is that bulbil number and bulbil weight did not follow the same treatment ranking. Red light produced heavier bulbils and greater total harvested mass, while white light produced a slightly higher number of bulbils. This distinction is relevant because propagation performance may be evaluated either by the number of new organs formed or by their size and weight. The most suitable treatment may therefore depend on whether the production objective is rapid multiplication or the formation of more developed planting material. The observation-level data supported the treatment means, particularly for the red-light variant, where V2R1R recorded the highest total bulb-plus-bulbil weight and the greatest main-bulb weight. At the same time, the strong root development observed in the white-light variant confirmed that the spectral treatments influenced individual plant components differently.

Overall, the discussion of the results indicates that pre-planting LED exposure may represent a useful method for modifying tuberose development, but the response should be assessed using several complementary indicators. The descriptive nature of the available data does not allow definitive statistical confirmation, yet the observed patterns provide a clear basis for further replicated testing of red and white light treatments.

6. Conclusions

The study identified descriptive associations between pre-planting exposure to different LED spectra and the vegetative and postharvest characteristics of ‘Avatea’ tuberose.

Red light at 660 nm was associated with the most consistently favourable response, particularly in terms of vegetative development, main-bulb weight, bulbil weight, and total underground-organ biomass.

Based on the available postharvest data, white light was associated with a higher number of bulbils and stronger root development, whereas complete vegetative measurements for this treatment were not available.

These findings indicate that pre-planting spectral treatments may represent a useful technological approach for modifying tuberose development under protected cultivation conditions.

The main contribution of the study lies in evaluating LED exposure as a short pretreatment applied to bulbs rather than as continuous illumination during plant growth.

Within the limits of the available data, red light appears to be the most promising option when the objective is to increase bulb and bulbil biomass, whereas white light may be more relevant when the production goal is a greater number of propagation organs or improved root development.

6.1. Practical and Policy Implications

Pre-planting LED treatment may be integrated into tuberose propagation systems used in greenhouses, nurseries, research stations, and germplasm collections. The red-light treatment applied at 660 nm for 30 minutes per day over one month represents a potentially practical option for improving the development of propagation material.

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The method is compatible with vertical-greenhouse systems because it can be applied in a limited space and under controlled conditions. However, wider adoption should follow technical standardization of light intensity, exposure distance, treatment duration, energy consumption, and expected production gains.

6.2. Limitations and Future Research

The main limitation of the study is the incomplete documentation of sample size, replication, randomization, variability, and raw data. Consequently, the observed differences were interpreted descriptively and cannot be considered statistically confirmed.

The technical characteristics of the lighting system were also only partially recorded, particularly photon flux density, treatment uniformity, lamp-to-bulb distance, and the spectral composition of the white light. These limitations reduce the reproducibility and generalisability of the findings.

Future studies should use randomized and replicated designs, standardize the initial size and weight of the bulbs, and monitor both environmental and lighting parameters. Further research should also compare different exposure durations, light intensities, and spectral combinations across several tuberose cultivars. Long-term studies should determine whether treated bulbs and bulbils maintain their viability and productive performance in subsequent cultivation cycles.

References

Bahadoran, M., Salehi, H., & Eshghi, S. (2011). Growth and flowering of tuberose (*Polianthes tuberosa* L.) as affected by adding poultry litter to the culture medium. *Spanish Journal of Agricultural Research, 9*(2), 531–536. https://doi.org/10.5424/sjar/20110902-127-10

Bantis, F., Smirnakou, S., Ouzounis, T., Koukounaras, A., Ntagkas, N., & Radoglou, K. (2018). Current status and recent achievements in the field of horticulture with the use of light-emitting diodes. *Scientia Horticulturae, 235*, 437–451. https://doi.org/10.1016/j.scienta.2018.02.058

Castañeda-Saucedo, M. C., Tapia-Campos, E., Ramirez-Anaya, J. del P., Barba-Gonzalez, R., & Pita-Lopez, M. L. (2023). Effect of fertilization and planting date on the production and shelf life of tuberose. *Agronomy, 13*(2), Article 422. https://doi.org/10.3390/agronomy13020422

Dieleman, J. A., de Visser, P. H. B., Meinen, E., Grit, J. G., & Dueck, T. A. (2019). Integrating morphological and physiological responses of tomato plants to light quality to the crop level by 3D modeling. *Frontiers in Plant Science, 10*, Article 839. https://doi.org/10.3389/fpls.2019.00839

Dincă, C., Băcanu (Șerban), C., Ion, I. M., & Stanciu, S. (2019). Aspects regarding the certified seed production in Romania. *Research in Agriculture and Agronomy, 2019*, Article 797526. https://doi.org/10.5171/2019.797526

Iancu, T., & Stanciu, S. (2017). The production of medicinal and aromatic plants—A niche business for Romanian agriculture. In K. S. Soliman (Ed.), *Proceedings of the 30th International Business Information Management Association Conference: Vision 2020: Sustainable economic development, innovation management, and global growth* (pp. 2416–2428). International Business Information Management Association.

Kumar, M., Sirohi, U., Malik, S., Kumar, S., Ahirwar, G. K., Chaudhary, V., Yadav, M. K., Singh, J., Kumar, A., Pal, V., & Prakash, S. (2022). Methods and factors influencing in vitro propagation efficiency of ornamental tuberose (*Polianthes* species): A systematic review of recent developments and future prospects. *Horticulturae, 8*(11), Article 998. https://doi.org/10.3390/horticulturae8110998

Ma, Y., Xu, A., & Cheng, Z.-M. (2021). Effects of light emitting diode lights on plant growth, development and traits: A meta-analysis. *Horticultural Plant Journal, 7*(6), 552–564. https://doi.org/10.1016/j.hpj.2020.05.007

DOI: 10.35219/jards.2026.3.02

Mitchell, C. A., & Sheibani, F. (2020). LED advancements for plant-factory artificial lighting. In T. Kozai, G. Niu, & M. Takagaki (Eds.), *Plant factory: An indoor vertical farming system for efficient quality food production* (2nd ed., pp. 167–184). Academic Press. https://doi.org/10.1016/B978-0-12-816691-8.00010-8

Munteanu Pila, M., & Stanciu, S. (2021). Horticulture in Romania case study: Flowers—A luxury for Romanians. *Communications of International Proceedings, 2021*(35), Article 38144721. https://ibimapublishing.com/p-articles/38AGRI/2021/38144721/

Saravani, M., Boogar, A. R., Aran, M., Ramezan, D., Zargar, M., & Diakite, S. (2025). Optimizing tuberose (*Polianthes tuberosa* L.) production using mycorrhiza and biostimulants to enhance water-deficit tolerance. *Horticulturae, 11*(1), Article 34. https://doi.org/10.3390/horticulturae11010034

Sena, S., Kumari, S., Kumar, V., & Husen, A. (2024). Light emitting diode lights for the improvement of plant performance and production: A comprehensive review. *Current Research in Biotechnology, 7*, Article 100184. https://doi.org/10.1016/j.crbiot.2024.100184

Solbach, J. A., Fricke, A., & Stützel, H. (2021). Seasonal efficiency of supplemental LED lighting on growth and photomorphogenesis of sweet basil. *Frontiers in Plant Science, 12*, Article 609975. https://doi.org/10.3389/fpls.2021.609975

Vlad, C., & Stanciu, S. (2025). Technology transfer in Romania's agro-food sector: An overview. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 25*(3), 893–901.

Yasemin, S., & Beruto, M. (2024). A review on flower bulb micropropagation: Challenges and opportunities. *Horticulturae, 10*(3), Article 284. https://doi.org/10.3390/horticulturae10030284

DOI: 10.35219/jards.2026.3.02